Strategic Investment Options

Shaping Subtransmission

East Midlands – June 2020

WESTERN POWER DISTRIBUTION

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Contents

1 – Executive Summary

WPD's East Midlands licence area, as part of a wider trend across Great Britain, has experienced unprecedented growth in the connection of Distributed Generation (DG). There is now around 3.7 GW of generation connected to WPD's East Midlands network, with another 3 GW accepted-not-yet-connected and over 0.5 GW offered-not-yet-accepted. This contrasts against an annual maximum demand of around 4.8 GW and minimum demand of 1.8 GW.

Traditionally, connection costs for generation customers have been kept low by using the capacity inherent in a network designed to support demand. As this capacity was used up, DG connection applications resulted in requirements to reinforce our network. While some customers have agreed to contribute to the cost of reinforcement in order to connect to our network, other customers have sought alternative connection arrangements. The Transmission network has been equally affected by the greater volumes of DG being connected. National Grid's responses to WPD's East Midlands Statement of Works (SoW) submissions highlighted that DG output in some parts of the East Midlands is limited by the capability of transmission network components.

WPD has committed to the rolling out of Active Network Management (ANM) across all its licence areas by 2021 in order to manage the output of generators to reduce reinforcement requirements. With parts of the East Midlands network now under ANM, managing both distribution and transmission constraints, customers who are able to reduce output under certain conditions can directly benefit from quicker and more efficient connections.

Meanwhile, the East Midlands network is showing signs of resurgence in demand growth. Local authorities' plans propose developments that would result in strong growth in domestic, industrial and commercial demand in East Midlands. Several new and expanded demand connections have been made in recent years, and there is further interest from developers and customers. Looking into the future, there exists the potential for widespread electrification of heating and particularly transport in the East Midlands.

This report documents the processes that WPD is following to give visibility to network capacity issues in advance of connection applications. With the assistance of Regen, we have developed scenarios for the growth of demand and DG in the East Midlands from 2019 to 2032.

These scenarios correspond to National Grid's 2018 Future Energy Scenarios (FES): Steady Progression, Consumer Evolution, Two Degrees and Community Renewables. They cover the growth of conventional demand, several types of generation and the electrification of transport and heating.

The scenarios were used as inputs to network studies, analysing the impact of future DG and demand connection. This was applied to the Subtransmission components of the WPD East Midlands network, which consist of Grid Supply Points (GSPs), Bulk Supply Points (BSPs) and the 132 kV networks. In these studies, we have moved away from traditional 'edge-case' modelling, where only the network condition that is deemed most onerous is analysed. Instead, we have analysed network behaviour throughout the day for:

- **Winter Peak Demand**, with minimum coincident generation – an assessment of the network's capability to meet peak demand conditions;
- **Summer Peak Demand** and **Intermediate Warm Peak Demand**, with minimum coincident generation – an assessment of the network's capability to meet maintenance period demand conditions;

- **Summer Peak Generation**, with minimum coincident demand – an assessment of the network's capability to handle generation output.

This methodology highlighted that although many onerous network conditions occur at the expected peaks; this is not always the case. In particular, some thermal constraints are met first in spring or autumn rather than summer or winter. Reactive power constraints are often met when the network is lightly loaded. As WPD's network becomes more variable due to changing consumer behaviour, there will an increasing importance on new roles as a Distribution System Operator (DSO) and this will require more analysis of this type to manage the network in real time.

The studies confirmed the justification for WPD's planned Subtransmission reinforcement projects such as the installation of Berkswell SGT4 and the replanting of Staythorpe B. The studies also identified the requirement for significant further reinforcement by 2022 including new transformers, line reconductoring and cable overlays if the expected growth in both DG and demand occurs. Recommendations are given to investigate particular reinforcement requirements in further detail.

It is expected that some – but not all – generation-driven reinforcement could be alleviated by using ANM or other measures to curtail the output of DG to prevent network overstressing. It is important to note that ANM is not capable of mitigating all types of network constraints; furthermore, it does not have an unlimited ability to mitigate constraints unless significant pre-fault curtailment of output is applied to avoid protection operation or equipment damage prior to the operation of ANM.

WPD is now exploring the use of flexibility to manage network loadings and in 2020 is actively seeking flexibility across 47 Constraint Management Zones (CMZs), with 218MW in contract already. By contracting with industrial and commercial customers who can adjust or shift their electricity consumption at key times, Demand Side Response (DSR) can be used to defer demand-driven reinforcement, or maintain network compliance during reinforcement.

While the projected reinforcement requirements were dominated by the growth of domestic, commercial and industrial demand, the growth of DG and electrification of transport and heating also had a significant impact. The studies are particularly sensitive to electric vehicle (EV) usage patterns, which may change dramatically as EVs are more widely adopted.

2 – Objective of this Report

The overall aim of this report is to:

- Assess the potential growth in Distributed Generation (DG) by:
    - fuel type;
    - general location;
    - year of connection.
- Consider potential demand changes that come from:
    - the electrification of transport;
    - the electrification of heating and cooling;
    - growth in industrial, commercial and domestic demand.
- Identify thermal and voltage constraints that may occur on our 132 kV network, which will limit the ability of those connections to take place.
- Assess options for reinforcement.
- Provide recommendations for 'low regret' investment, noting the Office for Gas and Electricity Markets (Ofgem) consultation on 'quicker and more efficient connections' that raised questions on the role of strategic reinforcement funded by the wider customer base.

Given the uncertainty in the growth of DG and changes in demand, the study has been undertaken using a scenario based approach to seek to identify an envelope of likely outcomes and understand the changes needed within that envelope.

We have used the four background Energy Scenarios developed by National Grid Electricity Transmission (NGET) in their Future Energy Scenarios (FES) for 2018 as a framework to develop detailed scenarios for the growth of demand and DG in the East Midlands. The East Midlands licence area was divided geographically into the areas supplied by distinct sections of our subtransmission network; bespoke scenarios were developed for each area. These scenarios were applied to electrical models of the subtransmission network to assess their impact on the network.

3 – Background

East Midlands Licence Area

Western Power Distribution (WPD) is the Distribution Network Operator (DNO) for the East Midlands. The area covers approximately 16,000 square kilometres and extends from Coventry and Uttoxeter in the west, to the Wash on the East Coast and from the outskirts of Sheffield in the north to Milton Keynes in the south. The area is not dominated by major conurbations; however, it has many medium-sized cities and towns including Nottingham, Derby, Leicester, Coventry, Northampton and Milton Keynes. The geography of the area ranges from low-lying farmland in Lincolnshire to the Peak District National Park in Derbyshire. This area serves approximately 2.6 million customers.

There is a high concentration of manufacturing and industrial activities in the East Midlands, with many automotive manufacturers based in the region. The business activity is generally situated along the M1 and M40 corridors; as a result, there are many distribution and logistics industries in the area. In the more rural areas, agriculture is an important part of the local economy.

Current Network

Western Power Distribution receives 132 kV supplies from National Grid at 15 Grid Supply Points (GSP) in the East Midlands:

- Berkswell
- Bicker Fen
- Chesterfield
- Coventry
- Drakelow
- East Claydon
- Enderby
- Grendon
- Ratcliffe
- Staythorpe
- Stoke Bardolph
- Walpole
- West Burton
- Willington
- Hams Hall/Lea Marston

These GSPs are, in turn, supplied from the interconnected 275 kV and 400 kV National Grid network in the East Midlands.

Most GSPs in the East Midlands are operated as radial networks, although in a few instances a mesh system is utilised. Most 132 kV networks have the ability to interconnect at 132 kV to adjoining GSPs; however, they are not operated in parallel. Any interconnection has to be controlled to ensure fault levels are kept within equipment ratings.

132 kV and 66 kV are both treated as subtransmission networks. Establishing or reinforcing 132 kV and 66 kV networks is often a protracted and expensive process, making long-term planning a necessity.

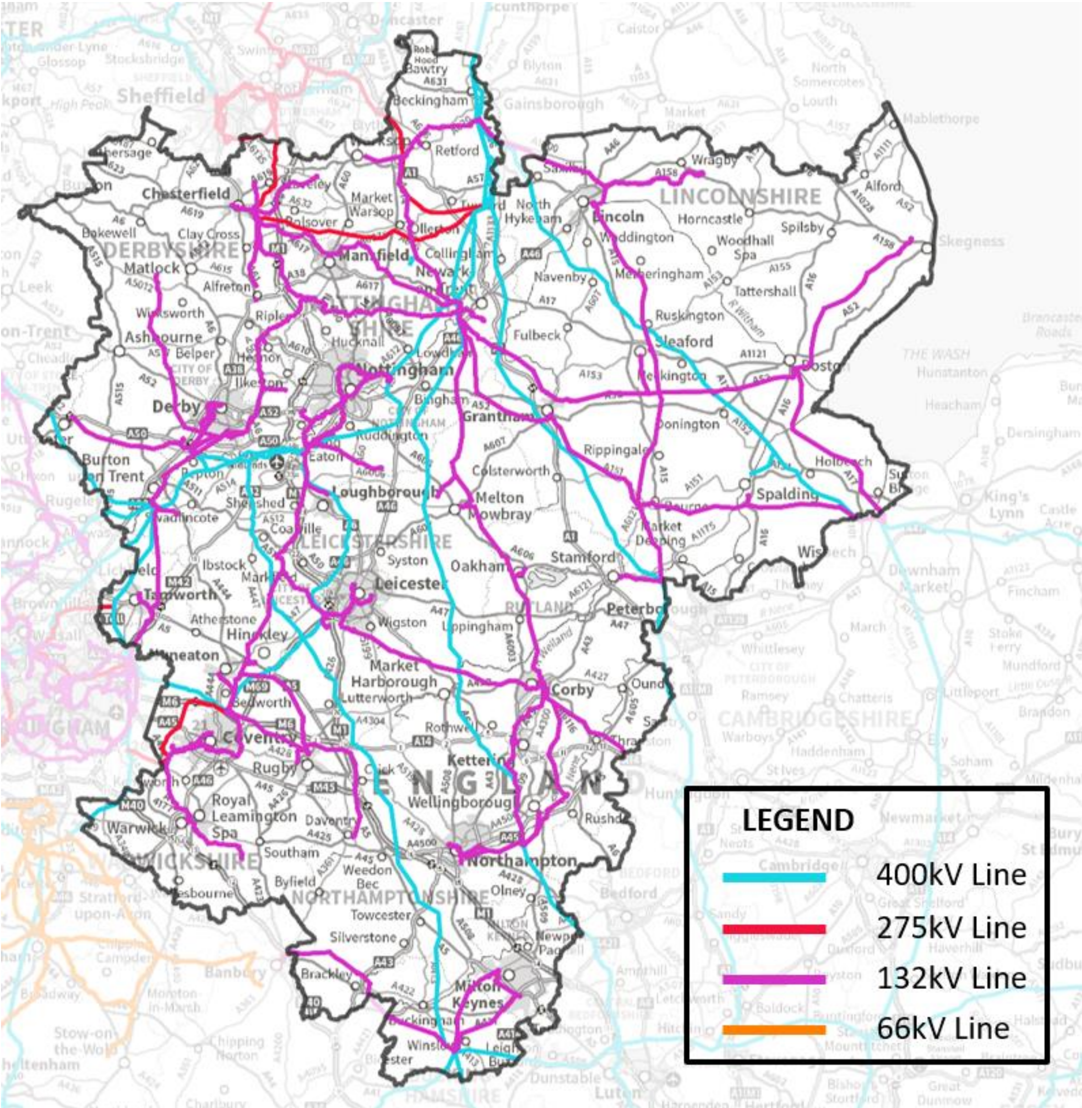

Figure 1: Network in the East Midlands showing 400 kV, 275 kV and 132 kV networks

Demand Usage of the Network

Traditionally, distribution networks were designed for the optimal delivery of power from the transmission network to demand customers. Historic system maximum demands are shown in Figure 2.

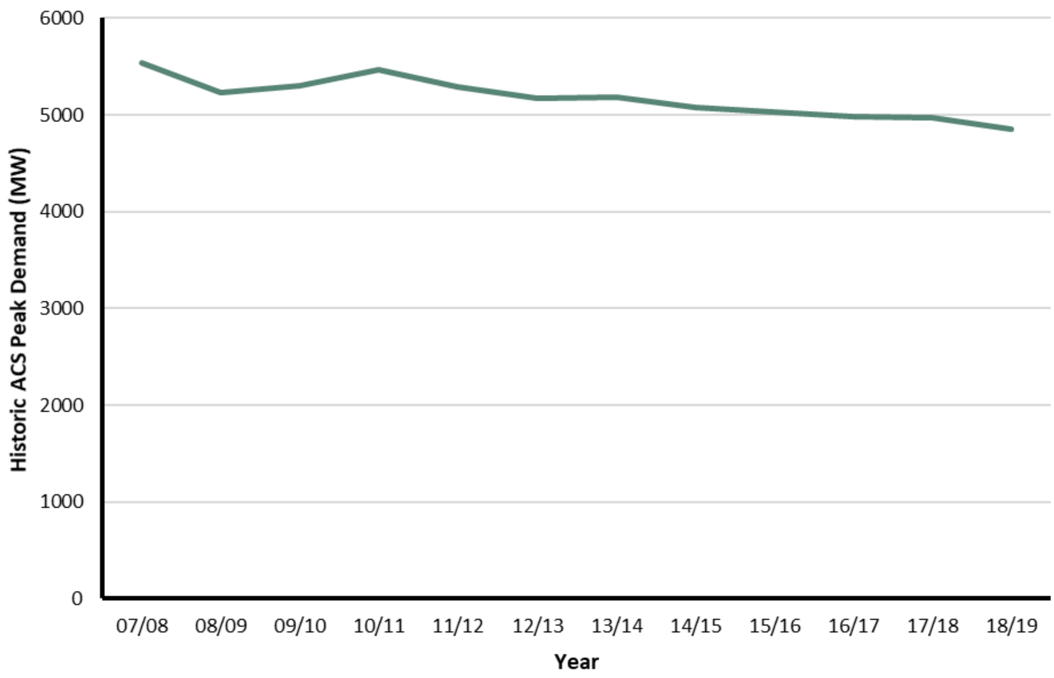

Figure 2: Historic system maximum demand in East Midlands

Flexibility Rollout

With the growth of new electrical demand from technologies such as Electric Vehicles (EVs) and Heat Pumps (HPs), we also expect to see changes to demand profiles. The opportunity to deploy Demand Side Response (DSR) solutions, allowing demand profiles to be modified by network operators and suppliers will be a key solution to managing demand growth in a cost efficient and intelligent manner.

Through its Flexible Power offering, to date WPD has sought to procure DSR across 20% of its network where there are identified constraints and cost benefits from deferred reinforcement. WPD is committed to offering flexibility ahead of traditional solutions and will continue to roll out Flexible Power further across its network, both for reinforcement deferral and capacity sharing.

More information on Flexible Power is available at www.flexiblepower.co.uk

We also acknowledge the requirement to continuously review and improve our DSR offering. As such, we have a range of Innovation projects looking to widen participation. These include our Future Flex project, which is looking to address any barriers for domestic scale providers, and our IntraFlex project, which is looking to understand the impact on our calls on the wider energy market.

For more information on our innovation projects please visit www.westernpower.co.uk/innovation.

Signposting

Facilitating new neutral markets around flexibility is a key objective in WPD's Distribution System Operator (DSO) Strategy. As the energy system becomes more active, an important role for WPD will be to provide the right information to signal the needs of the electricity distribution network to the markets. This will require us to provide a greater level of information on the performance characteristics of our network than ever before and in a format that is understandable and transparent. The information we present will inform the market ahead of us requesting tenders for flexibility and allow flexibility providers to understand our potential requirements for DSR.

WPD's latest signposting information can be found at www.westernpower.co.uk/signposting.

Growth in Distributed Generation

At privatisation, in 1990, there were virtually no generators connected to distribution networks. Those that existed were mainly embedded within customer-owned internal networks and primarily used for standby purposes. Since then there has been a moderate growth of onshore wind generation, supported by various subsidy arrangements, and a few large gas turbine connections.

In addition, NGET have developed various contracted services, which has led to the growth in diesel- and gas-fuelled distribution-connected plant to provide these services, generally being required to operate at or around times of peak national demand.

Since around 2010, there has been a significant growth in solar photovoltaic (PV) connections, both in the volume of small rooftop systems and large, MW-scale, ground-mounted systems.

More recently, battery-based energy storage systems have started to be connected to the distribution network. This has been driven by the falling cost of storage, reduced subsidies for renewable technologies, the growing value of flexibility in timing of import/export to the network and NGET seeking frequency support services.

The current DG position in the East Midlands is shown in Table 1. This shows the breakdown between those connected to the distribution network, those with accepted contracts to connect and those with outstanding offers for connection.

Table 1: Connected, accepted and offered Distributed Generation in WPD East Midlands at the end of May 2020

Generator type	*Connected [MVA]*	*Accepted [MVA]*	*Offered [MVA]*	*Total [MVA]*
Biomass & Energy Crops (not Combined Heat and Power (CHP))	93.9	95.2	15.0	204.1
Hydro	1.8	0.1	0.0	1.9
Landfill Gas, Sewage Gas, Biogas (not CHP)	201.2	67.3	-	268.5
Medium CHP (>5 MW,<50 MW)	64.3	32.0	-	96.3
Micro CHP (Domestic)	0.1	0.0	-	0.2
Mini CHP (<1 MW)	17.4	1.5	0.1	19.0
Mixed	188.7	16.8	0.1	205.5
Offshore Wind	180.0	-	-	180.0
Onshore Wind	403.4	54.0	-	457.4
Other Generation	1,054.1	412.5	161.3	1,627.8
Photovoltaic	1,298.2	1,938.8	373.3	3,610.4
Small CHP (>1 MW, <5 MW)	32.3	4.5	4.5	41.3
Storage (Battery)	45.5	429.0	67.9	542.4
Storage (Pumped)	-	18.0	-	18.0
Tidal Stream & Wave Power	0.0	-	-	0.0
To be confirmed	31.4	4.4	11.5	47.3
Waste Incineration (not CHP)	56.1	-	-	56.1
Total [MVA]	**3,668.5**	**3,074.0**	**633.7**	**7,376.2**

Issues Resulting from the Growth of DG and Demand in East Midlands to 2020

Distribution Network Constraints

Some parts of the East Midlands network are already constrained due to the growth of DG. Several reinforcements that will allow existing assets to be better utilised are planned, and ANM zones have been commissioned for Corby Bulk Supply Point (BSP) and Skegness BSP.

In addition, the installation of Berkswell Super Grid Transformer (SGT) 4, West Burton SGT3 and replanting of Staythorpe B to resolve fault level constraints are planned in response to projected load growth.

Transmission Network Constraints

All changes to demand or generation on the distribution network have some effect on the transmission system. National Grid's Connection and Use of System Code has a requirement in it to seek National Grid's assessment of the impact and any necessary works that they need to undertake where it is deemed that there will be an impact. The initial assessment is carried out via a Statement of Works (SoW), which confirms whether NGET work or connection conditions will be required. Where works are required, a Modification Application is made to NGET. NGET then specifies the precise works or conditions needed before connection can take place.

This process was put in place prior to the substantial growth in DG and while originally designed to address the impact of single large DG plant being connected onto distribution networks, it has been used to assess the cumulative impact of large numbers of smaller DG plant.

Individual SoW applications have been made to NGET for GSPs in East Midlands, which, after subsequent Modification Applications have led to the following conditions being imposed:

- each generator connection must have a reactive capability between 0.95 power factor leading and 0.95 power factor lagging;
- emergency disconnection facility to be provided to allow WPD to de-energise on instruction from National Grid;
- all generation connections in the Bicker Fen, Staythorpe and West Burton GSP areas will be required to participate in an ANM scheme to manage reverse power flow through the Super Grid Transformers.

WPD are currently involved in the SoW Appendix G trial process whereby every month, WPD assess acceptances, connections and withdrawals on a GSP basis. These changes in generation status are documented in the relevant Appendix G parts. In addition, SGT flows and radial fault infeed are amended in the summary table of the Appendix G document to reflect the relevant changes in generation.

The Appendix G trial aims to expedite the assessment process across the transmission and distribution boundary and enables quicker and more efficient connections to customers. All GSPs in the East Midlands area are now included in the Appendix G trial.

WPD, NGET and National Grid Electricity System Operator (NGESO) are collaborating on the Regional Development Programme 4(RDP), which aims to address constraints on the transmission distribution interface. This may be considered as a solution/mitigation for GSP limitations, for both infrastructure and connection asset sites.

4 – Scenarios

National Grid produces Future Energy Scenarios each year, which provide a range of credible energy futures for the United Kingdom (UK). The scenarios are formed of:

- a document covering the model inputs to the scenario analysis, new technologies, social and economic developments, government policies and progress against targets;
- a set of scenarios that can be used to frame discussions and perform stress tests. These scenarios are projected out from the present to 2050. The scenarios form the starting point for all transmission network and investment planning. They are also used in analysis to identify future operability challenges and potential solutions to meet those challenges; and
- a document covering developments in electricity generation and demand, and gas supply and demand.

In order to assess the future challenges facing the East Midlands distribution network, WPD commissioned Regen to produce a set of forecasts for the growth of DG and demand in the East Midlands.

Figure 3: National Grid's Future Energy Scenarios[1]

These scenarios are named after and correspond to those developed by National Grid in the FES 2018. The four scenarios resemble a different level of decentralisation and decarbonisation in the energy mix in the United Kingdom. Each scenario was forecast for each year from baseline in 2018 to 2032.

[1] – From National Grid's Future Energy Scenarios in five minutes, July 2018

Table 2: Key DG, storage and demand technologies, which were assessed by the WPD and Regen forecasts

Electricity Generation Technologies	New Demand Technologies
• Solar PV – ground-mounted • Solar PV – roof-mounted • Onshore wind – large scale • Onshore wind – small scale • Anaerobic digestion (AD) – electricity production • Hydropower • Energy from waste (EfW) • Diesel • Gas • Other generation • Deep geothermal • Floating/offshore wind • Tidal, stream and wave energy	• Electric vehicles • Heat pumps (domestic) • Domestic air conditioning **Conventional Demand Technologies** • Domestic • Industrial and Commercial (I&C) **Energy (electricity) storage** • High Energy Commercial and Industrial • Domestic and community own use • Energy trader • Generation co-location • Reserve service • Response service

Forecasting the long-term growth of any generation or demand technology is complex owing to the multiple variables that can affect the market and determine growth.

Distributed Generation and Storage Forecasting

For each DG technology shown in Table 2, the growth assessment was split into three distinct phases:

1. Baseline – WPD and Regen's databases of connected DG were correlated and confirmed to give a baseline in November 2018 with a high degree of accuracy;

2. Pipeline – WPD's database of Accepted-not-yet-Connected DG was combined with an assessment of the Department for Business, Energy & Industrial Strategy (BEIS) Renewable Energy Planning Database, current market conditions and recent policy changes, to give a forecast shared between all scenarios of what is expected to connect in the next two to four years depending on technology; and

3. Scenario projection – each FES scenario was assessed and interpreted to take into consideration the specific local resources, constraints and opportunities for that technology in WPD's East Midlands licence area under that scenario.

New Demand Technology Forecasting

The new demand technology forecasted consisted of EVs, HPs and domestic air conditioning, all considered to be disruptive technologies with high growth potential. The forecasted data did not include a pipeline section; instead, the forecasts were purely scenario-based from 2018 to 2032.

Conventional Demand Forecasting

One of the key features of recent DFES and Shaping Subtransmission studies was the effects of increasing impact of demand growth as published in local development plans. As a result, this study also included conventional demand growth in domestic, industrial and commercial developments.

For the conventional demand forecasting, Regen used a variety of data sources to identify areas of domestic and non-domestic development out to 2032. A key input was the local development and infrastructure development plans published by local authorities. As part of the East Midlands study, Regen and Western Power Distribution hosted a demand stakeholder engagement event to gain feedback from local authorities and other stakeholders. The forecast data did not include a pipeline; instead, the forecasts were based on two different scenarios from 2018 to 2032. The scenario projections were based on different buildout rates of developments outlined in local development plans, where Community Renewables showed the highest growth, Two Degrees showed a medium level of growth and Consumer Evolution and Steady Progression reflected the lowest levels of growth.

Mapping the Forecasts to our Network

In order to map scenarios for demand and DG growth to the distribution network, the East Midlands licence area was divided into 127 Electricity Supply Areas (ESAs). Each ESA represents a block of demand and generation as visible from the subtransmission network. Each is one of:

- the geographical area supplied by a BSP (or group or part thereof) providing supplies at a voltage below 132 kV; or
- a customer directly supplied at 132 kV or by a dedicated BSP.

ESAs are shown geographically in Figure 4. It should be noted that ESA boundaries do not necessarily follow local authority or other administrative boundaries. Additional ESAs outside the East Midlands licence area have been included to represent areas of neighbouring licence areas that interconnect with the East Midlands subtransmission network. These include:

- Buxton BSP, which is located in Electricity North West Limited's Stalybridge GSP area but supplies a geographic area in the northwest of the East Midlands licence area and the northeast of WPD's West Midlands licence area;
- Banbury BSP in WPD's West Midlands licence area. Banbury is supplied from East Claydon GSP in the East Midlands licence area.

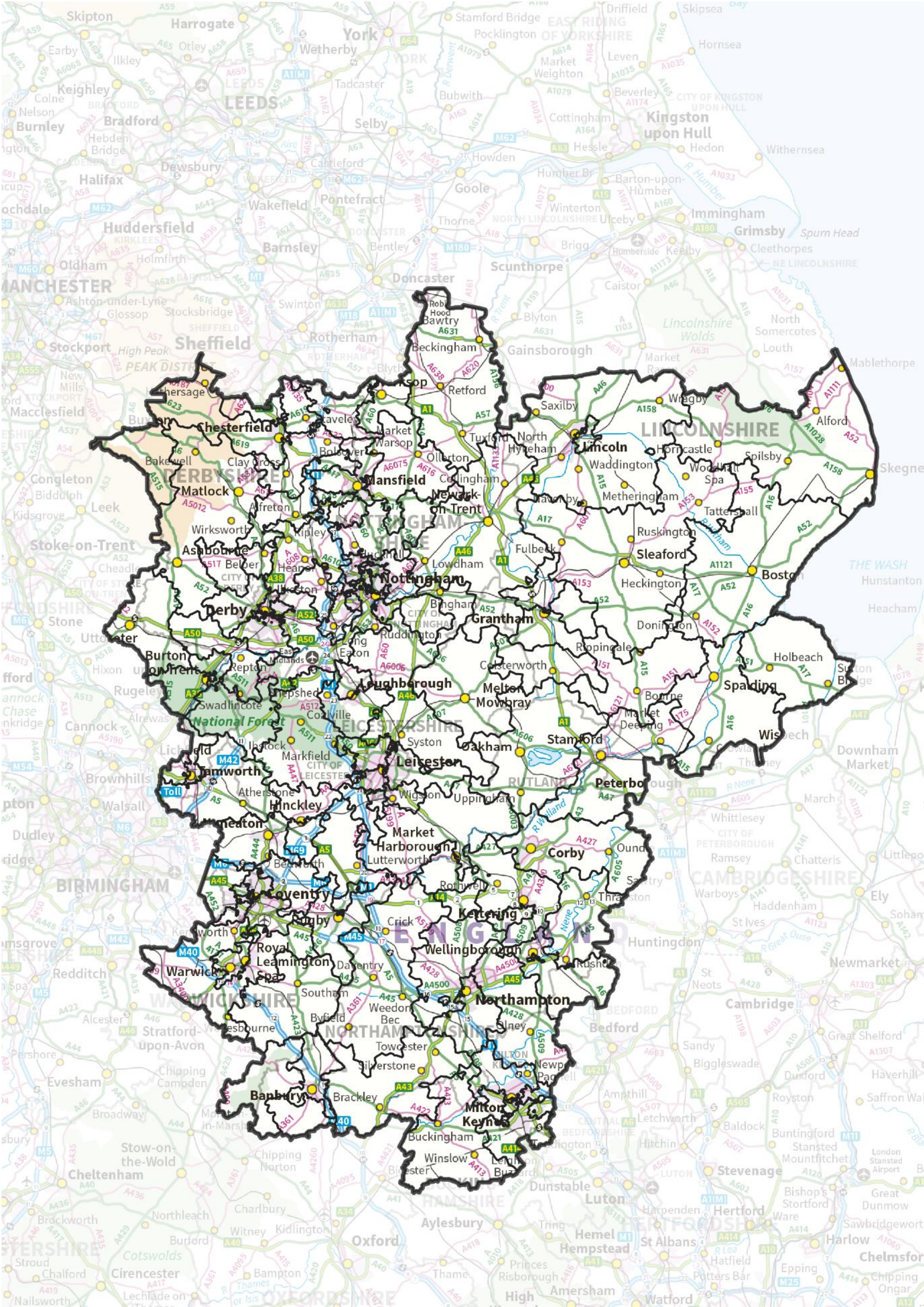

Figure 4: East Midlands geographical ESAs

Scenarios were developed for each ESA, taking into account historic and planned DG developments, local industry, population and natural resources. The results of the assessment are presented in each of the technology chapters in the Regen report and provide a projection of annual capacity deployment, by technology and scenario, for the period from 2018 to 2032. The complete Regen report, *Distribution Future Energy Scenarios -Technology growth scenarios to 2032, East Midlands licence area 2019,* is available from our website at:

www.westernpower.co.uk/distribution-future-energy-scenarios.

A summary of the DG forecasts is shown in Figure 5. From the baseline profiled capacity for a summer peak generation representative day of circa 3.3 GW in November 2018, this grows to 9.4 GW by 2032 under the most ambitious Community Renewables scenario. Growth estimates for the other scenarios are lower overall. However, even under the lowest Steady Progression scenario, there is an expected growth pathway to 5.1 GW of DG capacity by 2032. Figure 6 shows a half-hourly profile of the generation export for the East Midlands licence area for a summer peak generation representative day, which was used in the baseline studies. Figure 7 shows the same breakdown for a Community Renewables scenario in 2032.

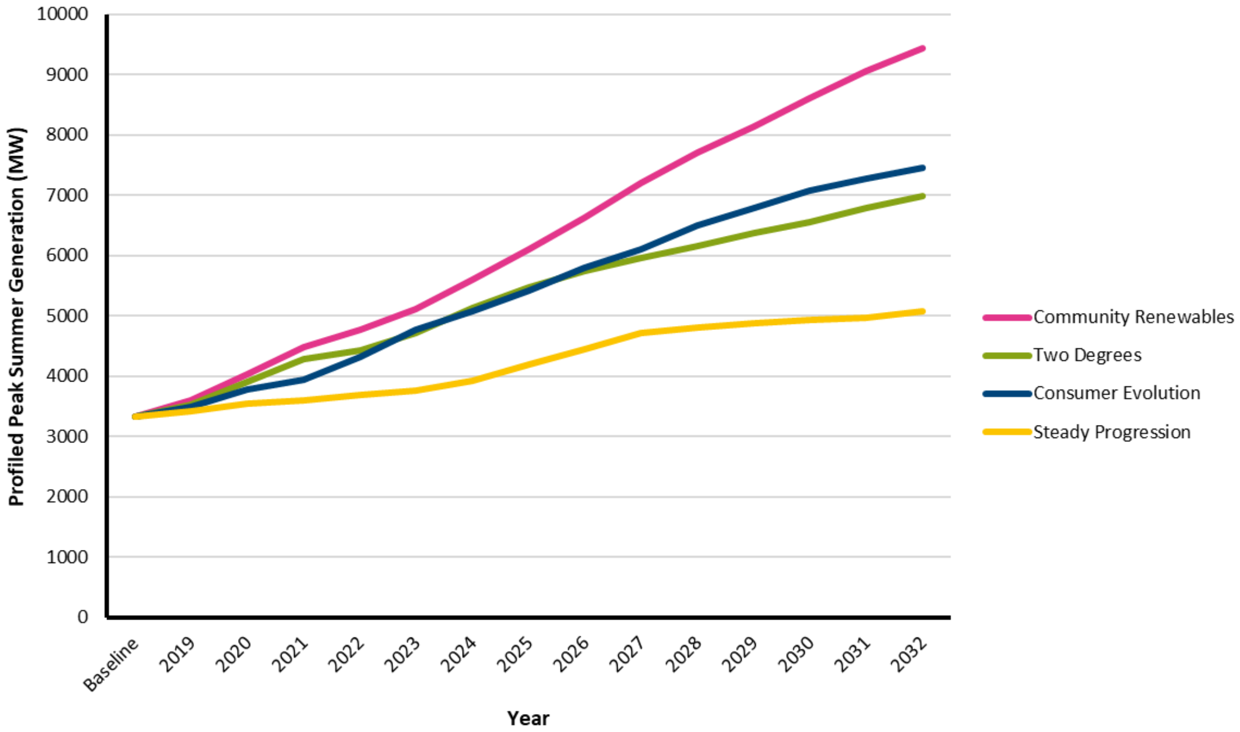

Figure 5: Total Distributed Generation capacity growth in WPD East Midlands licence area from baseline to 2032 under each scenario

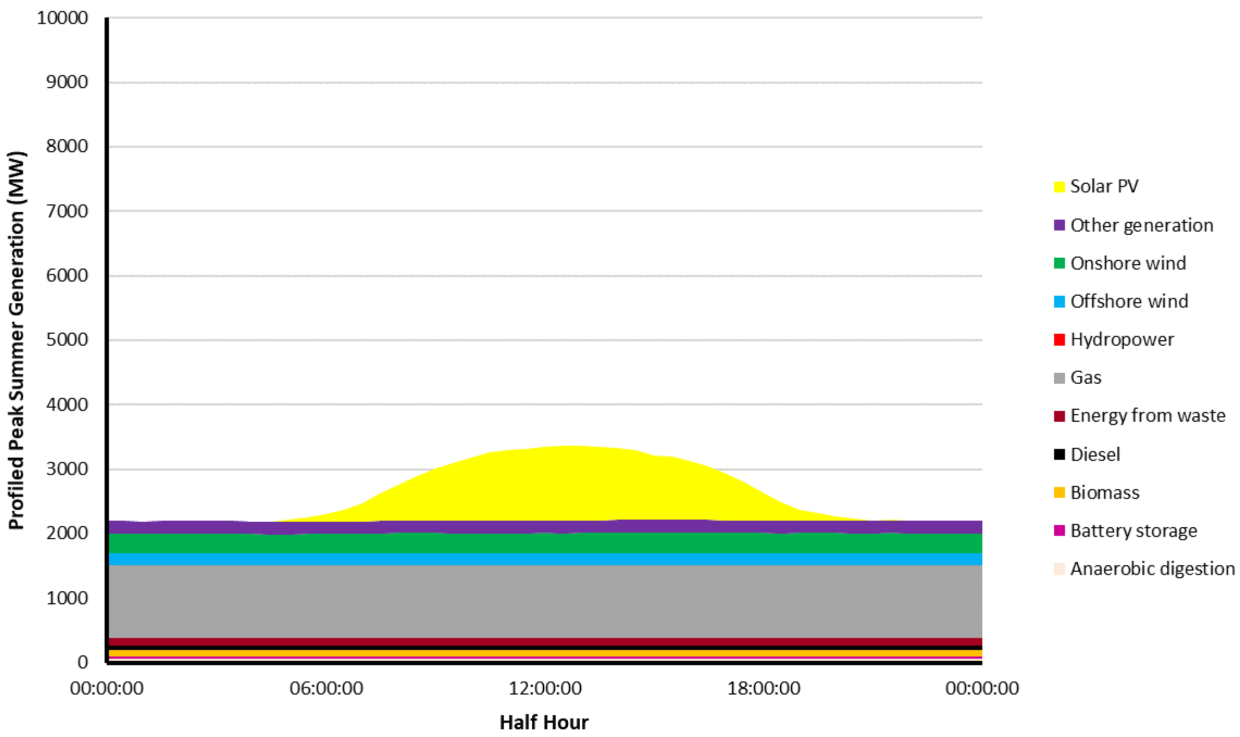

Figure 6: A half-hourly profile of the East Midlands licence area generation export for a summer peak generation representative day, as used in the baseline studies

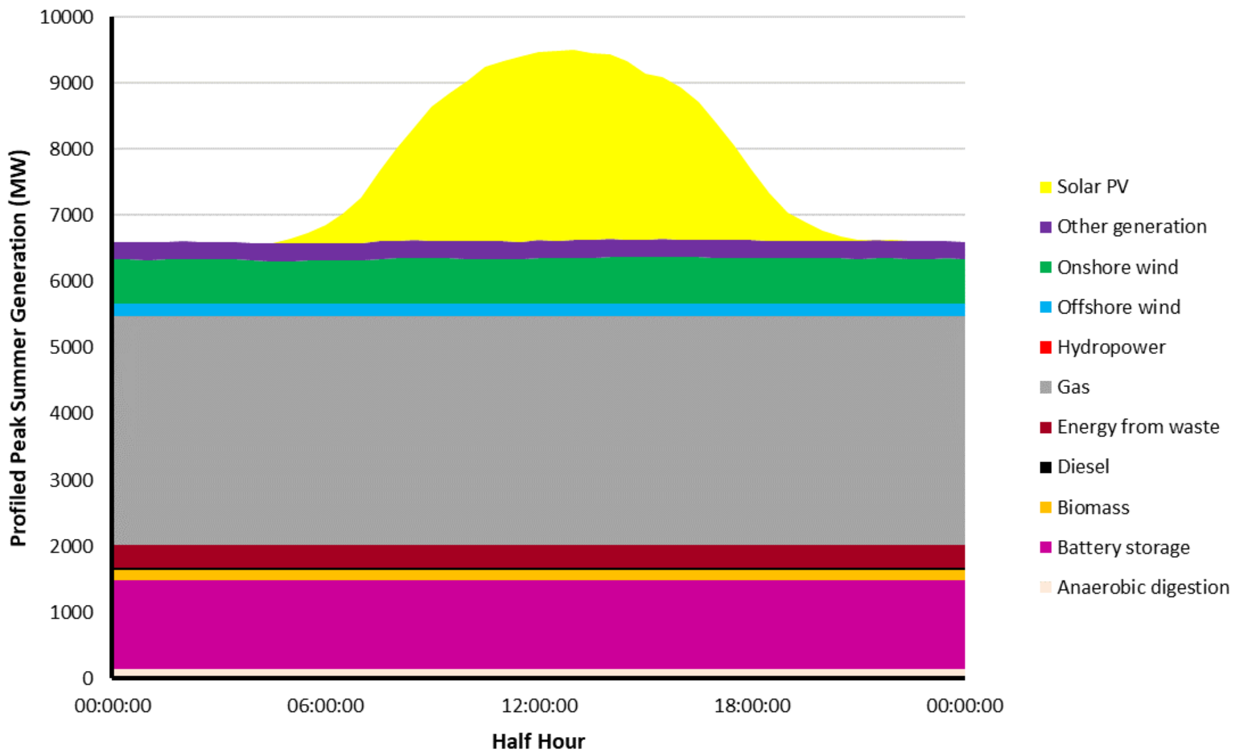

Figure 7: A half-hourly profile of the East Midlands licence area generation export for a summer peak generation representative day, under a Community Renewables scenario in 2032

A summary of peak demand growth across the East Midlands licence area is shown in Figure 8. The demand growth is based on the growth of EVs, HPs and conventional demand growth. The total demand in the baseline studies was approximately 5.0 GW. Demand is expected to increase to as much as 10.1 GW by 2032. Figure 9 shows a half-hourly demand profile for the East Midlands licence area for a winter peak demand representative day, which was used in the baseline studies. Figure 10 shows the same breakdown for a Community Renewables scenario in 2032.

The key factor affecting the growth rate of new developments is the economic environment. In domestic developments, the Community Renewables and Two Degrees scenarios are considered as a high growth scenario while the Consumer Evolution and Steady Progression scenarios are considered as a lower growth scenario. In commercial developments, there are high (Community Renewables), low (Two Degrees) and ultra-low growth (Consumer Evolution and Steady Progression) scenarios to reflect historic growth rates in the licence area. The proportion of the total number of developments outlined in the local authority development plans is scaled depending on the economic growth scenario, in addition to a delay in the build out rate of each individual development.

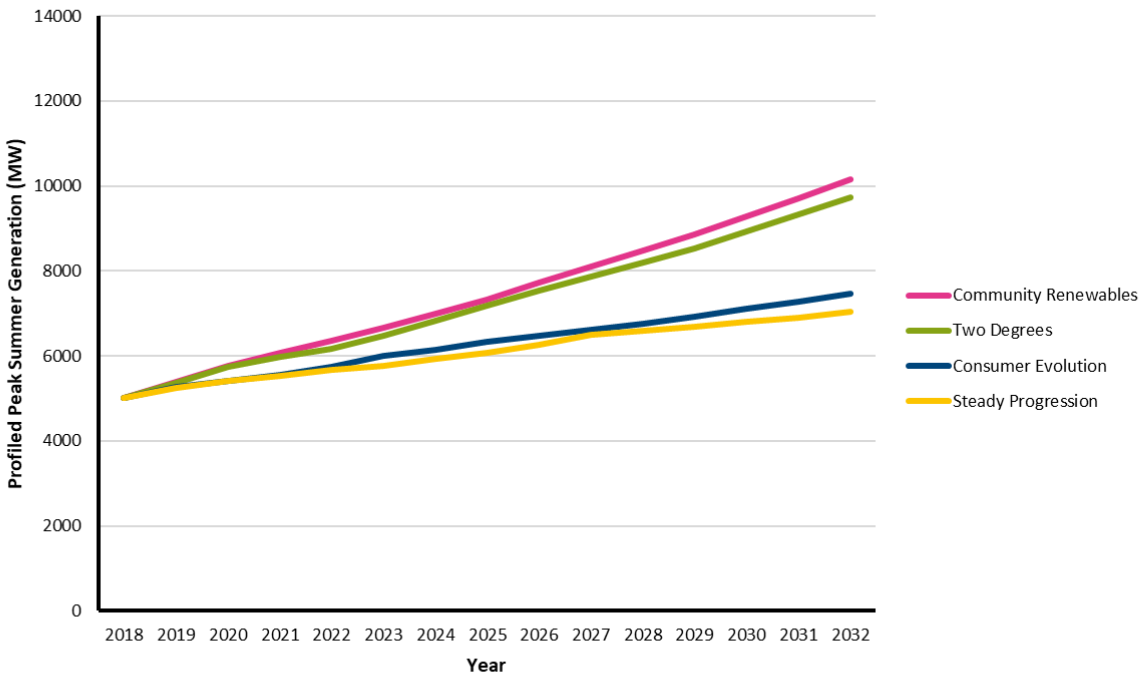

Figure 8: Total peak demand growth in WPD East Midlands licence area from baseline to 2032 under each scenario

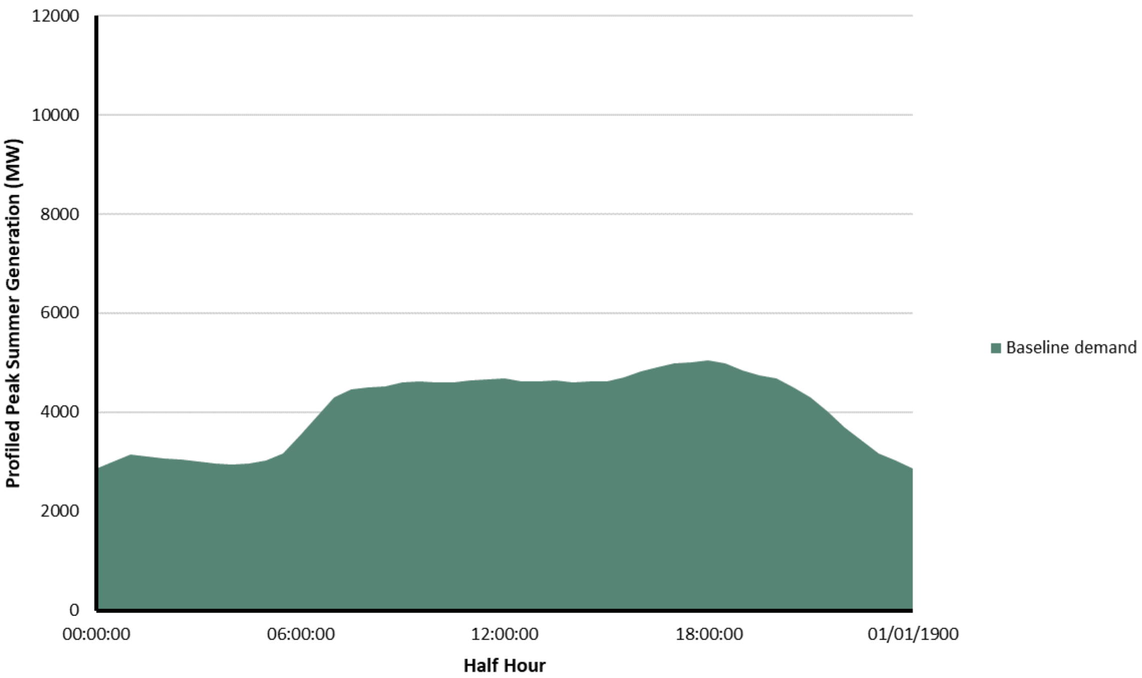

Figure 9: A half-hourly demand profile of the East Midlands licence area for a winter peak demand representative day, as used in the baseline studies

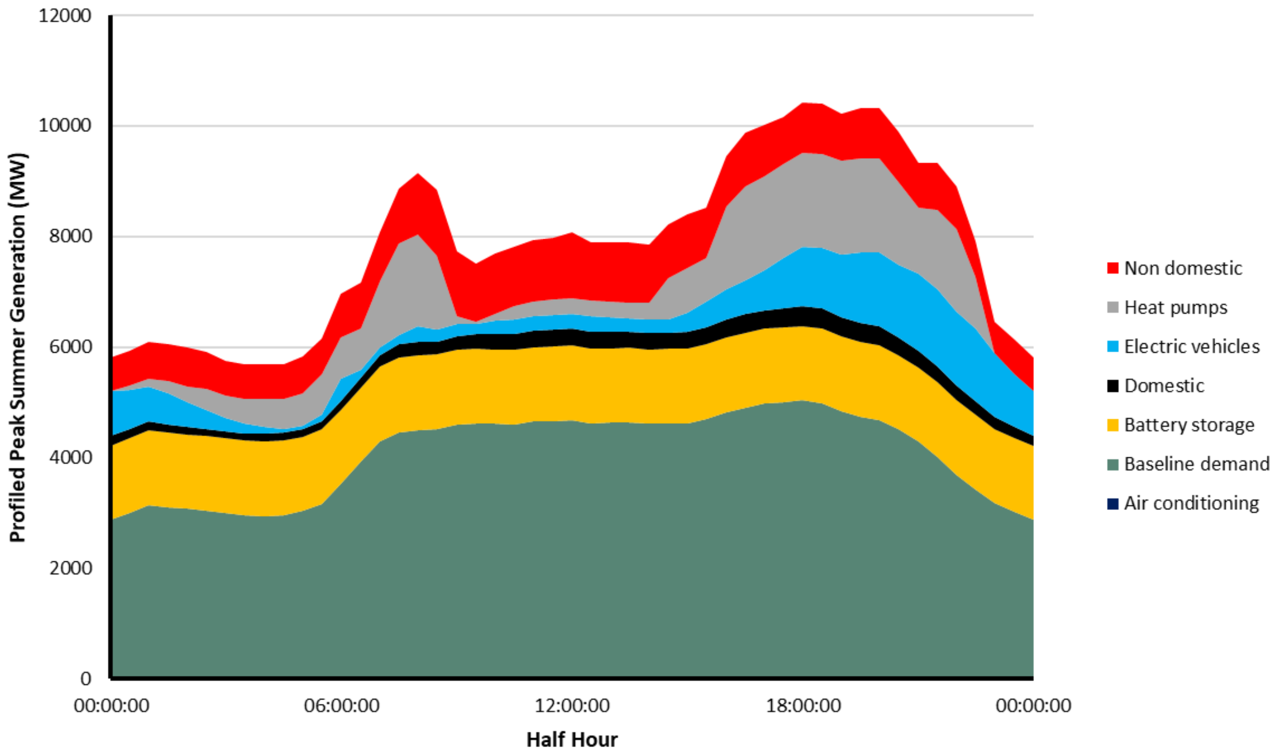

Figure 10: A half-hourly demand profile of the East Midlands licence area for a winter peak demand representative day under a Community Renewables scenario in 2032

It should be noted that since the demand forecasts are derived from local development plans, any further demand growth not captured in these plans will not be included in these studies, which could include new major industrial/commercial developments.

5 – Network Analysis Technique and Inputs

An analysis technique was devised to assess the impact of the four scenarios on WPD East Midlands subtransmission network. The subtransmission network was focussed upon due to the long timescales required to reinforce it.

Traditionally, distribution networks are assessed using 'edge-case' modelling, where only the network condition that is deemed most onerous is analysed. As the installed capacity and behaviour of demand, generation and storage is rapidly changing, it has become difficult to predict what network condition will be most onerous. A detailed overview of modelling methodology can be found in the appendix. For this project, a broader approach was taken. The network was assessed in detail for each of the four scenarios, for baseline, 2022, and 2027.

To cover a range of likely onerous cases, each half-hour of four representative days was analysed for:

- **Winter Peak Demand**, with minimum coincident generation – an assessment of the network's capability to meet peak demand conditions;
- **Summer Peak Demand** and **Intermediate Warm Peak Demand**, with minimum coincident generation – an assessment of the network's capability to meet maintenance period demand conditions;
- **Summer Peak Generation**, with minimum coincident demand – an assessment of the network's capability to handle generation output.

Demand, generation and storage were aggregated by ESA to be modelled at the appropriate node(s) to assess the impact on the subtransmission network.

A half-hourly power profile for each representative day was developed for each demand, generation and storage category. The profiles are described in *Demand, Generation and Storage Profiles* below. The profiles were combined with the forecasts for demand, generation and storage at ESA level.

For each combination of scenario, year, day and half-hour the network was assessed for thermal issues, voltage violations and lost load under intact and credible outage conditions.

Demand, Generation and Storage Profiles

To model the daily and seasonal variation in power flow, it was necessary to develop power profiles for the various categories of demand and DG connected to the network.

Each profile was normalised around the unit of measure used for that type of demand or DG:

- underlying demand is measured in MW of peak demand;
- EVs and heat pumps are measured in number of units installed;
- domestic conventional demand growth is measured as the number of houses installed;
- non-domestic conventional demand growth is measured in m^2 of floor space categorised by development type; and
- each type of DG is measured in MW of installed capacity.

Some profiles were derived from measurements taken on the East Midlands network. Date-stamped readings were reconciled to the representative days using the seasons proposed for a future revision of the Energy Networks Association (ENA) standard for overhead line ratings, Engineering Recommendation (ER) P27:

- **Summer:** June-August;
- **Winter:** December-February;
- **Intermediate Warm:** May, September and October; and
- **Intermediate Cool:** March, April and November.

WPD are currently migrating to these seasons for planning purposes; they will be used for future studies.

Demand Profiles

Profiles for underlying demand were derived from measured power flows at major substations in the East Midlands network. Profiles for HPs, EVs and conventional demand growth were derived from various innovation projects.

Underlying Demand

The underlying demand profiles used to represent a major substation's demand have been derived from real, measured data, obtained from a sample of substations in the East Midlands licence area. A demand profile, made up of 48 data points (48 half-hourly average readings) to represent a 24-hour period, was obtained for each of the representative days and each substation type to be studied. For each of the real power demand profiles produced, a corresponding reactive power demand profile was also produced, so that the reactive power and voltage behaviour of the network could be considered more accurately.

In order to obtain realistic substation demand profiles to impose on the network model, three different substation profile types were produced to represent different levels of population density and are listed below. Each substation was assessed against the population density in the area it supplies electricity to (i.e. its ESA):

- **Urban,** representing BSPs supplying areas with high densities of domestic, commercial and light to medium industrial demand;
- **Rural**, representing BSPs supplying areas with low densities of domestic demand, medium industrial demand and agricultural demand;
- **Mixed**, representing a mix of urban and rural demands;
- **Midday**, representing BSPs that have a midday peak as opposed to an early evening peak. These BSPs are in urban areas and have commercial and industrial demand.

Each substation type was assessed for each representative day to produce twelve real and reactive power demand profiles, which could be applied to the network model.

Figures 11 to 18 show the normalised real and reactive power demand profiles created. As these curves are normalised, as described below in *Demand Profiles – Methodology*, a multiplying factor can be applied to them to represent the actual demand at a particular major substation.

Demand Profiles – Methodology

The major substation demand profiles are based on measured data from 2017/18. For each of the substation categories (urban, rural and mixed), three substations from the East Midlands licence area were selected to form the data sample. The annual measured MW and MVAr demand data for the three substations forming the sample was aggregated by each half-hourly reading. Table 3 shows the substations that were selected to produce the demand profiles.

Table 3: ESA category demand samples

ESA Category	ESAs in sample
Urban	• Nottingham East • Nuneaton • Coventry Central
Rural	• Grantham North • Melton Mowbray • Warwick 132/33
Mixed	• Alfreton • Northampton East • Annesley
Midday	• Derby 132/11 kV • Lincoln 132/11 kV • Whitley

Once the data had been aggregated, the aggregated DG output for generators connected to the respective substations was removed to obtain the true, unmasked, underlying demand. The real and reactive demand profiles were then normalised around the annual real power peak so that the final real power profiles had a peak value of 1pu.

Next, data for the four representative days was selected from the annual demand data in the following way:

- **Winter Peak Demand day:** The 24-hour demand data (48 half-hourly average readings) was selected from the annual demand data for the day where the peak demand occurred. Only data from the months December, January and February was considered. These months align with the seasons proposed for a future revision of the ENA standard for overhead line ratings, ER P27;
- **Summer Peak Demand day:** The 24-hour demand data was selected from the annual demand data for the day where peak demand occurred. Only data from the months June, July and August was considered. These months align with the seasons proposed for a future revision of the ENA standard for overhead line ratings, ER P27;
- **Summer Peak Generation day:** The 24-hour demand data was selected from the annual demand data for the day where the smallest peak demand occurred. Only data from the months June, July and August was considered. These months align with the seasons proposed for a future revision of the ENA standard for overhead line ratings, ER P27;
- **Intermediate Warm Peak Demand day:** The 24-hour demand data was selected from the annual demand data for the day where peak demand occurred. Only data from the months May, September and October was considered. These months align with the seasons proposed for a future revision of the ENA standard for overhead line ratings, ER P27.

Table 4 gives the dates selected for each underlying demand and substation profile type.

Table 4: Dates selected for underlying demand representative days

Representative Day	Dates
Winter Peak Demand	Urban – 28/02/2018 Rural – 06/02/2018 Mixed – 26/01/2018 Midday – 08/01/2018
Summer Peak Demand	Urban – 04/06/2018 Rural – 07/06/2018 Mixed – 28/06/2018 Midday – 23/07/2018
Summer Peak Generation	Urban – 11/08/2017 Rural – 19/08/2017 Mixed – 28/08/2017 Midday – 24/06/2018
Intermediate Warm Peak Demand	Urban – 30/10/2017 Rural – 30/10/2017 Mixed – 30/10/2017 Midday – 30/10/2017

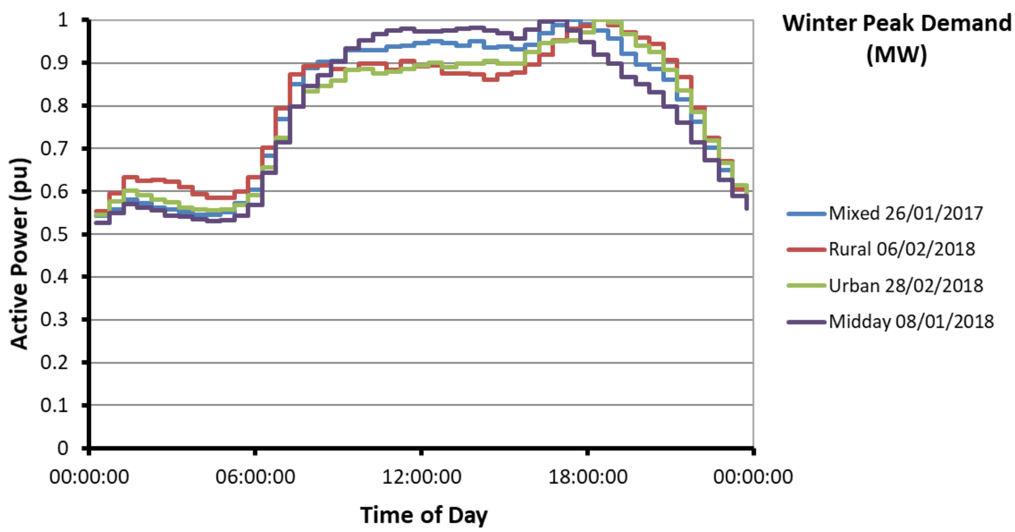

Figure 11: Real power underlying demand profiles for the winter peak demand day, normalised over the peak real power annual demand

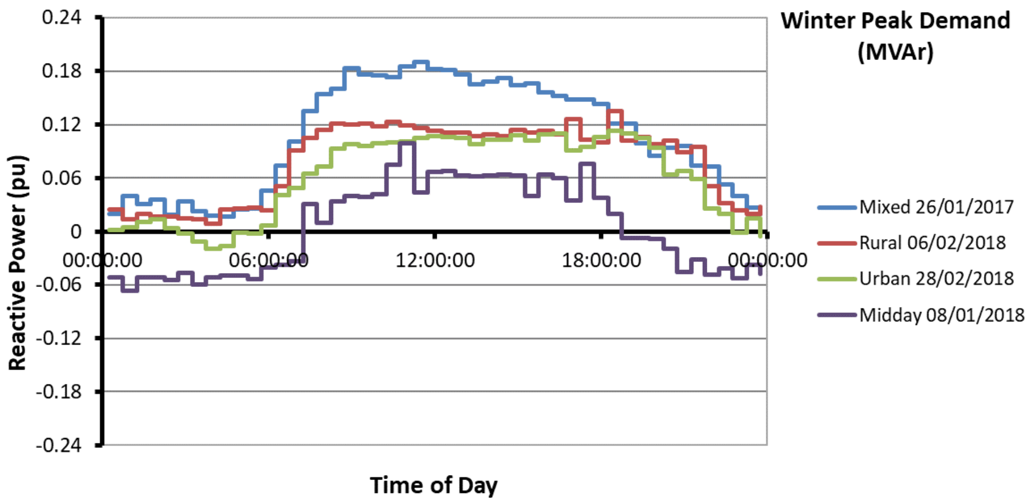

Figure 12: Reactive power underlying demand profiles for the winter Peak Demand day, normalised over the peak real power annual demand (note: reactive power scale is not the same as the active power scale)

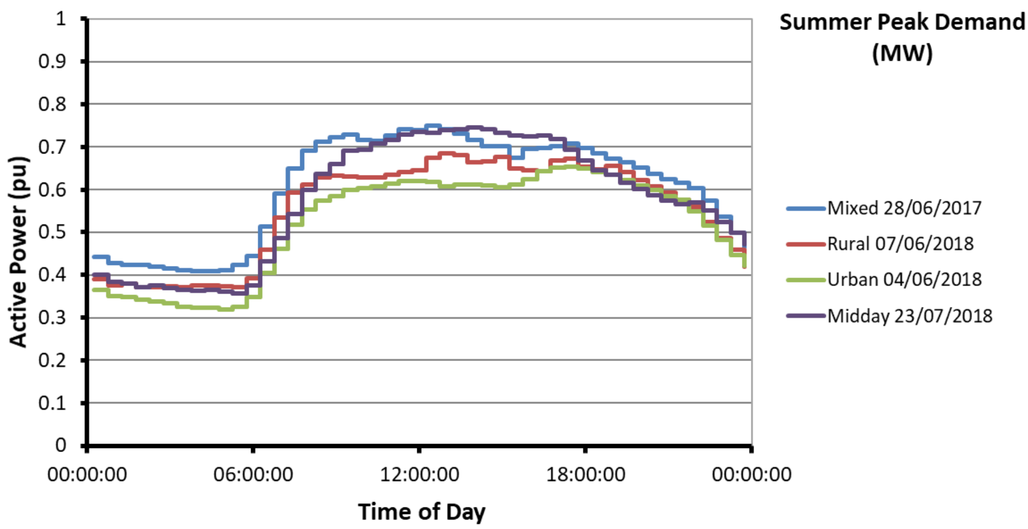

Figure 13: Real power underlying demand profiles for the summer peak demand day, normalised over the peak real power annual demand

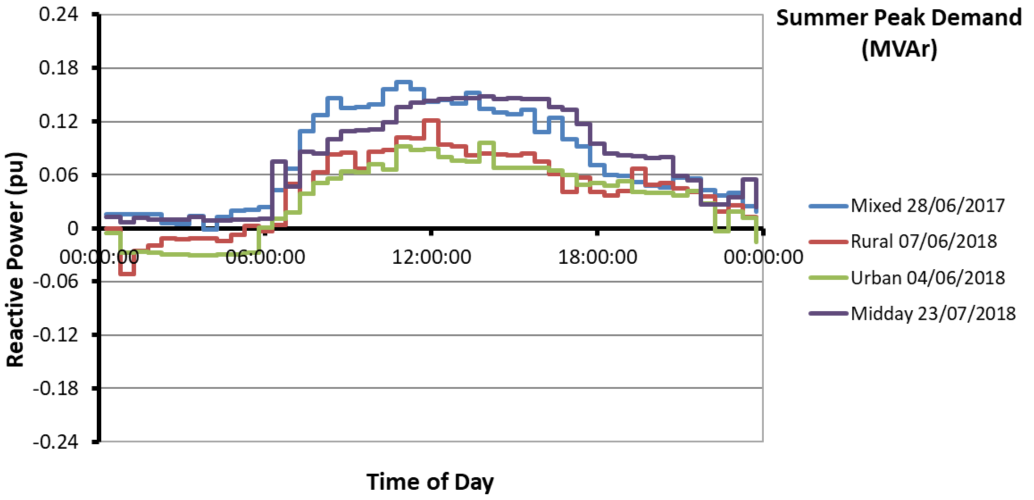

Figure 14: Reactive power underlying demand profiles for the summer peak demand day, normalised over the peak real power annual demand (note: reactive power scale is not the same as the active power scale)

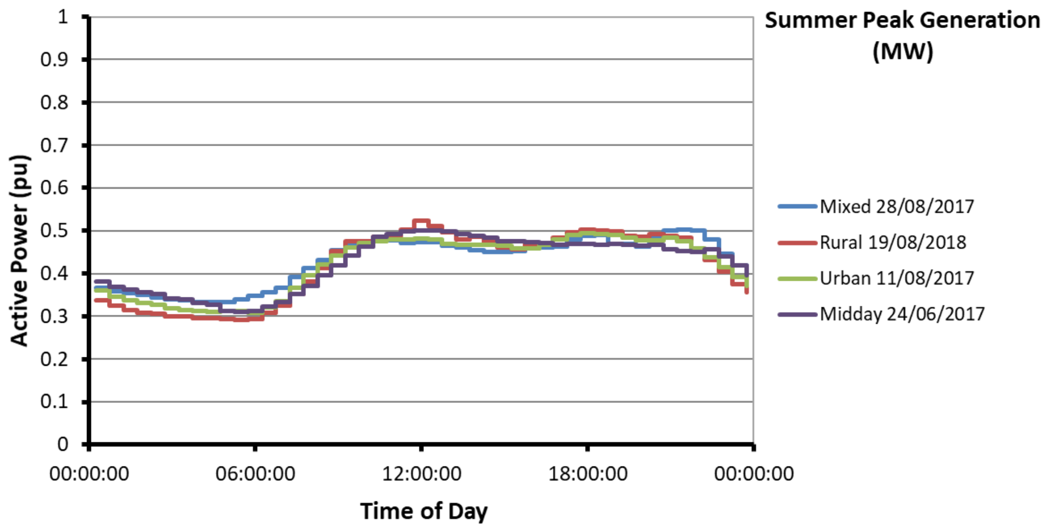

Figure 15: Real power underlying demand profiles for the summer peak Generation day, normalised over the peak real power annual demand

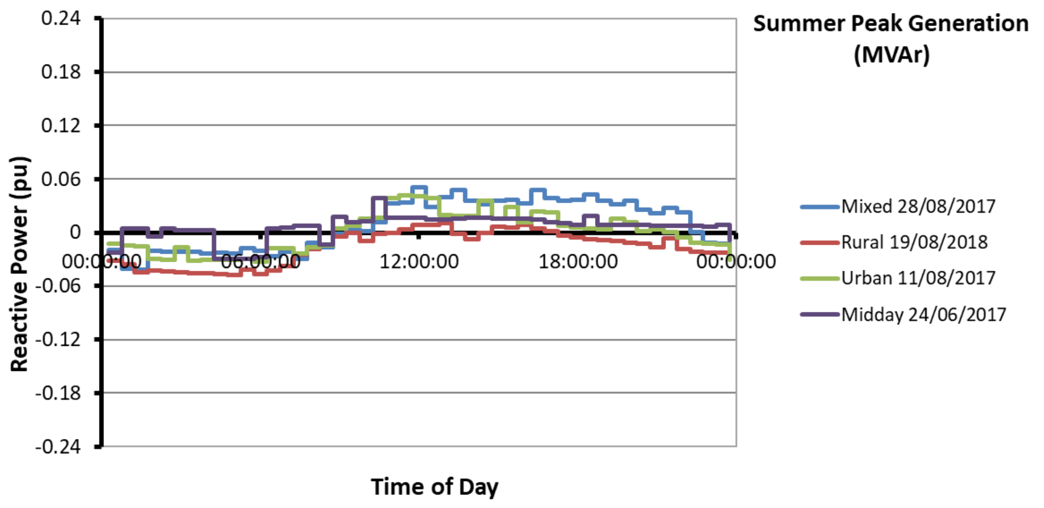

Figure 16: Reactive power underlying demand profiles for the summer peak Generation day, normalised over the peak real power annual demand (note: reactive power scale is not the same as the active power scale)

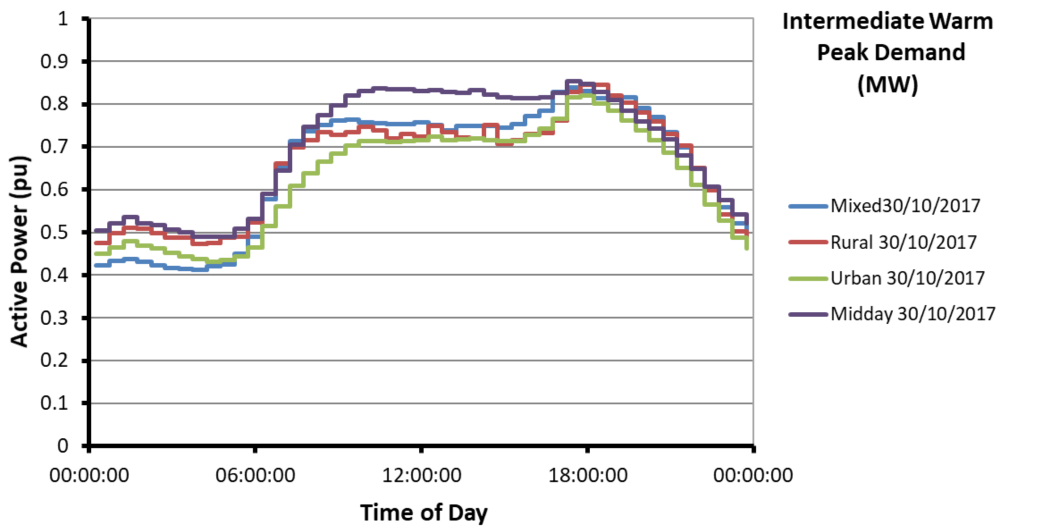

Figure 17: Real power underlying demand profiles for the intermediate warm peak demand day, normalised over the peak real power annual demand

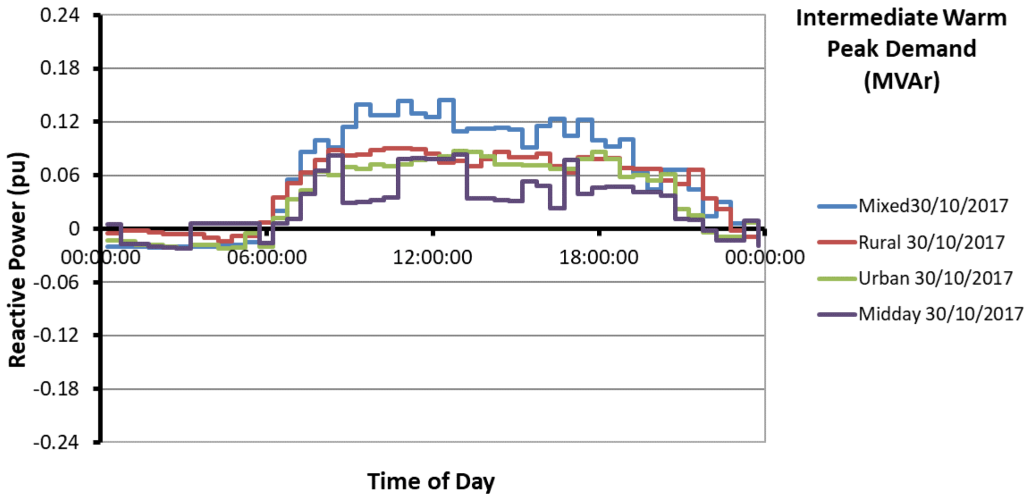

Figure 18: Reactive power underlying demand profiles for the intermediate warm peak demand day, normalised over the peak real power annual demand (note: reactive power scale is not the same as the active power scale)

Heat Pumps

Heat pumps have generally only been installed on off-gas houses, where an electric backup is used at times where the heat pump is not sufficient. Recent developments in hybrid heat pumps, which work with a backup technology (primarily gas), have started to reduce some of the barriers and raise potential for much higher growth in the sector. As well as starting to make it a cost-effective option for an on-gas grid customer, a hybrid system also requires less disruptive change, the higher temperature heat can use existing radiators and the heat pump operates at times when it is most efficient (e.g. low electricity prices or moderate heat requirements), with back up sources taking over when it is not. For this reason, the forecasts differentiate the growth of electric backup and gas backup heat pumps.

The profiles for heat pumps were derived from the Electricity North West Limited (ENWL) Network Innovation Allowance (NIA) funded study: *Managing the Impact of Electrification of Heat,* dated March 2016.

The study considered various types of heat pump as follows:

- Lower temperature Air Source Heat Pump (ASHP):
  - seasonal performance factor of 2.5-3.0;
  - generates flow temperatures of up to 55°C;
  - suitable for well-insulated buildings and new builds.
- Higher temperature ASHP:
  - seasonal performance factor of 2.3-3.0;
  - generates flow temperatures of up to 80°C;
  - suitable for older dwellings with a moderate thermal demand.
- Hybrid ASHP:
  - lower temperature ASHP plus a boiler;
  - switches between fuel sources, based on efficiency/running costs;
  - suitable for older dwellings with a larger thermal demand.

Ground source heat pumps were not considered in the ENWL study. Due to space requirements for the ground source loop, these are expected to be less prevalent.

The profiles for gas and electric backup heat pumps are shown in Figure 19 and Figure 20.

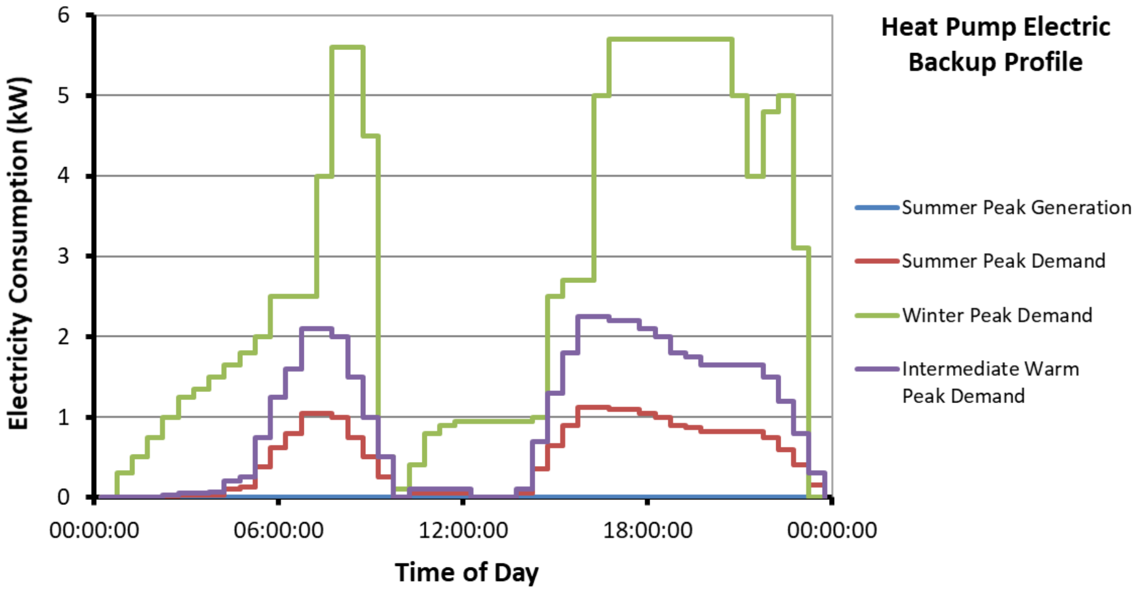

Figure 19: Electric backup heat pump profile

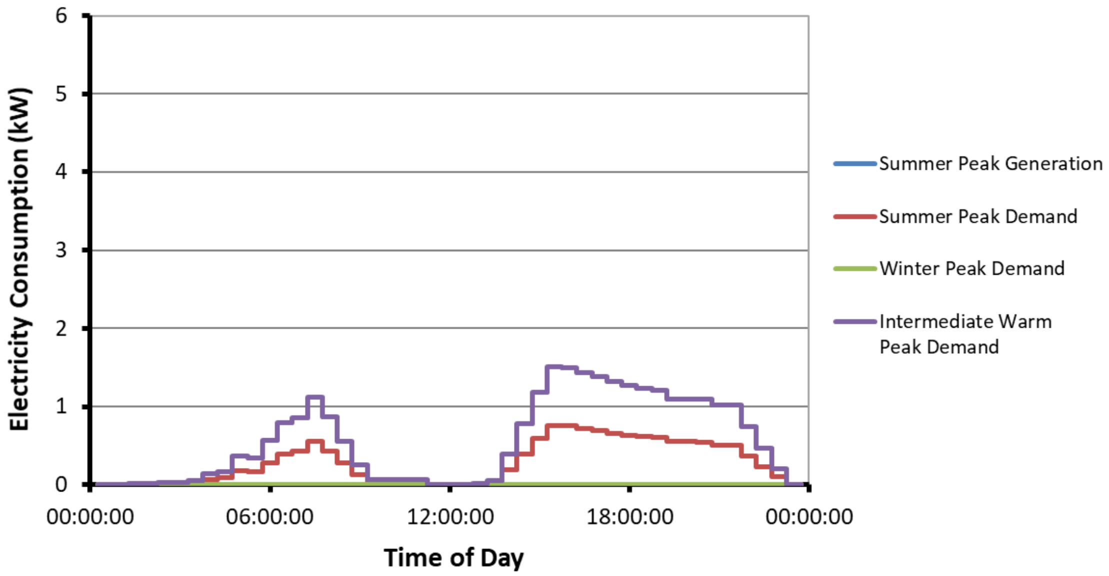

Figure 20: Gas backup heat pump profile

These profiles highlight the impact an electric backup has on the network, compared with a gas backup. The winter peak demand from an electric backup heat pump is 5.7 kW, due to the 3 kW electric backup. The gas backup heat pump at winter peak demand can switch to entirely gas, meaning there is no demand on the network at times of high demand. The profiles assumed there was no demand in summer from heat pumps during the peak generation studies.

Electric Vehicles

The first round of East Midlands Shaping Subtransmission reports forecast the growth of EVs, without differentiating the type of EV. A development in the scenarios for this round was to separate the growth into:

- bus and coach combined;

- HGV combined;
- motorcycle combined;
- pure electric LGV;
- pure electric car;
- hybrid LGV;
- hybrid car.

EV charging profiles were derived from the *Electric Vehicles Insight Report of the Customer-Led Network Revolution* project. This was based on a trial involving 143 domestic EV owners, which took place in 2014. The profile is shown in Figure 21.

WPD hosted the Electric Nation project in partnership with EA Technology; this project was funded by Ofgem. The aim of this project was to determine the impact EVs will have on the network and the effectiveness of demand side management. At the start of this project, there was sufficient data to back up the Customer-Led Network Revolution profiles used. The Electric Nation project also showed the diversified peak of hybrid vehicles was similar to that of pure electric. For the purposes of these studies, we have assumed the same profile for all EV types; this will be reviewed again, once more information is available from the Electric Nation project.

A follow-up project called Electric Nation PoweredUp will implement a bi-directional Vehicle to Grid (V2G) charging platform to test the effects on low voltage networks for future use of this technology by EV users. The project will establish a network of between 90 and 110 V2G chargers within domestic properties. The chargers will be divided into three to five groups of circa 25 units each; these groups will be offered to partner energy suppliers and aggregators who are offering or developing advanced energy services that can utilise battery storage. By utilising the Crowd Charge platform, these partners will be able to easily and quickly experiment with charging and discharging the vehicle batteries to suit their energy trading requirements. The data gathered from the chargers will give a unique insight into possible future demands on the low voltage network driven by energy trading and grid services. This project is due to finish in summer 2022.

The daily profile of weekday charging load averaged across all participants exhibits a significant evening peak of 0.9 kW per EV at around 21:00. The daytime profile is consistent with the EVs being used primarily as commuting vehicles, where the evening peak correlates with household occupancy as commuters return home and plug in their EVs to charge. The evening peak begins to drop after 22:00, indicating that some vehicles are fully charged by this time. A large seasonal variation in EV consumption was found, with the January peak charger demand of 0.9 kW steadily reducing to 0.45 kW by June. This is likely to be due to additional lighting and heating requirements, as well as reduced battery performance in colder weather.

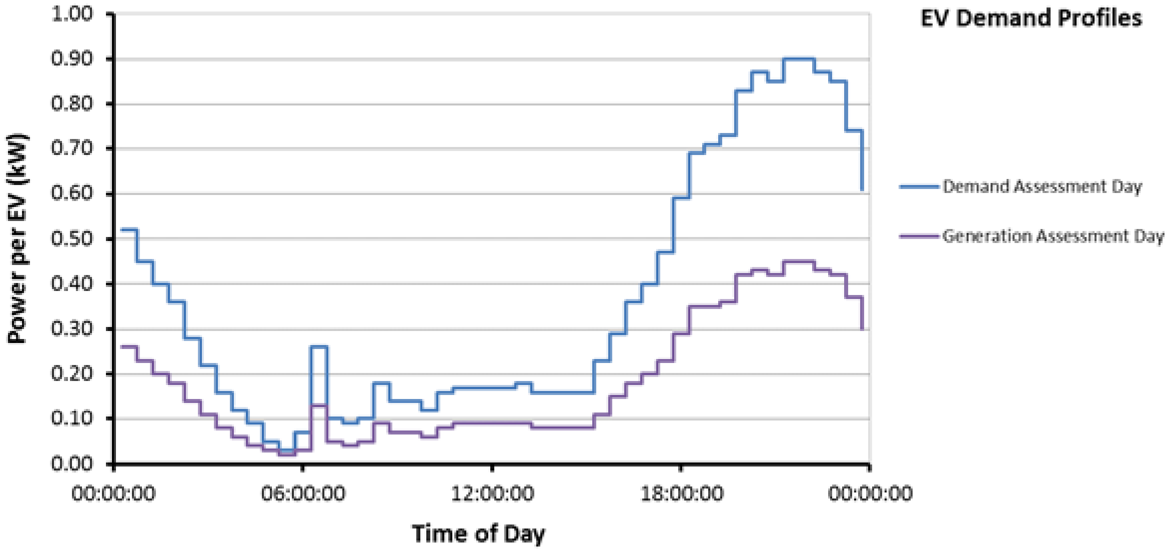

Figure 21: EV profiles

Air Conditioning

The air conditioning profiles were derived from the *Air Conditioning Demand Assessment* report as part of the NIA Demand Scenarios project ran by ENWL. As part of the scenario forecasts, only domestic air conditioning growth was considered. The daily profile for all of the demand representative days was assumed to be zero. The reasoning for this was that the peak demand representative days in winter, intermediate warm and summer all coincide with a cold day where domestic air conditioning was assumed not to be in use. In the East Midlands, the summer peak generation representative day is a solar PV-dominated day. As a result, it was assumed that there would be a demand for domestic air conditioning on a warm sunny day. The half-hourly profile used for the summer peak generation representative day was taken from the domestic air conditioning load on a peak summer day, for a mid-level of cooling degree-days (CDDs).

Conventional Demand Growth

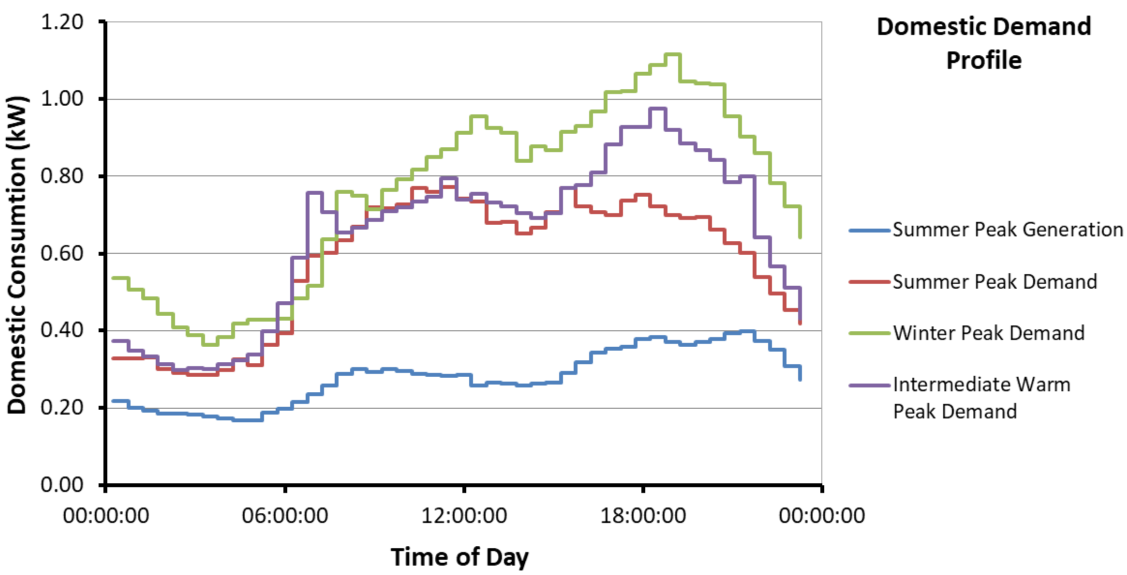

Figure 22: Diversified domestic profile (per house)

The industrial and commercial (I&C) demand growth is measured as a floor space in m^2 expected to be built in the region out to 2032. Regen were provided with a list of 15 different industrial and commercial demand categories, which were derived from the 'Modelling Demand Profiles in the I&C Sector' innovation project run by Western Power Distribution:

- factory and warehouse;
- government;
- hospital;
- hotel;
- hypermarket;
- medical;
- office;
- other;
- police;
- restaurant;
- retail;
- shop;
- school and college;
- sport and leisure;
- university.

The 15 demand categories each have an associated scaling factor to relate the energy consumption in kWh from the development size in m^2. The methodology used for the demand profiles was the same as was used in previous Shaping Subtransmission studies, where aggregated and anonymised half-hourly customer metering data was used to obtain a separate profile for each representative day and industrial/commercial demand category. These individual profiles were scaled around the peak half hour of energy consumption, as derived from the output of the innovation project. Each individual development in the Regen forecast was assigned a profile and overlaid onto the network model.

132 kV Demand Customers

The East Midlands network supplies a number of large demand customers with 132 kV connections or dedicated grid transformers (GTs) at WPD BSPs. Such customers often do not have a regular daily or seasonal demand profile. As a result, the assumed profile for these 132 kV customers is:

- Peak Demand days (summer, intermediate warm and winter): continuous demand at agreed supply capacity; and
- Summer Peak Generation day: zero demand.

Generation Profiles

Solar PV

Real power output data from all solar PV generation sites in the East Midlands licence area was collected and aggregated by each half hour for 2017/18. Only PV sites with an installed capacity greater than or equal to 1 MW were considered. The PV generator data sample comprised 153 sites, with an installed capacity of 1,017 MW. The geographical spread of solar PV sites in the data sample is shown Figure 23.

The generation output profiles are for a 24-hour period and consist of 48 data points (48 half-hourly readings). A generation profile was created for each of the four representative days and only generation data from the respective representative day and season was considered. Once the generation meter data had been aggregated together, an actual day's worth (48 half-hourly readings) of data was selected. The data for each generation profile was selected in the following way:

- **Winter Peak Demand:** Considers data in the months between December and February. The peak power output was found for each day and the day with minimum peak power output was selected;
- **Summer Peak Demand:** Considers data in the months between June and August. The peak power output was found for each day and the day with minimum peak power output was selected;
- **Summer Peak Generation:** Considers data in the months between June and August. The peak power output was found for each day and the day with maximum peak power output was selected;
- **Intermediate Warm Peak Demand:** Considers data in the months of May, September and October. The peak power output was found for each day and the day with minimum peak power output was selected.

Figures 24 and 25 show the PV generation profiles that were imposed on the network models.

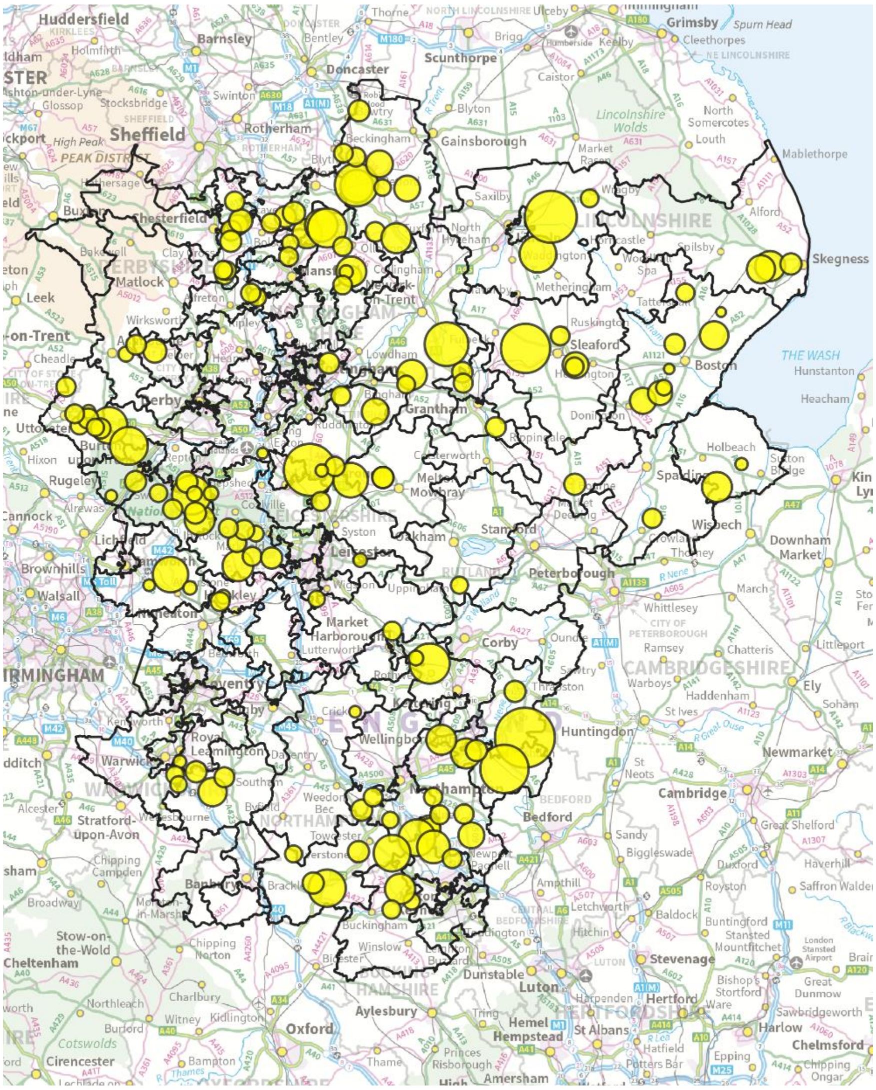

Figure 23: Map of solar PV sites contributing to generation profiles; symbol area proportional to installed capacity [MW]

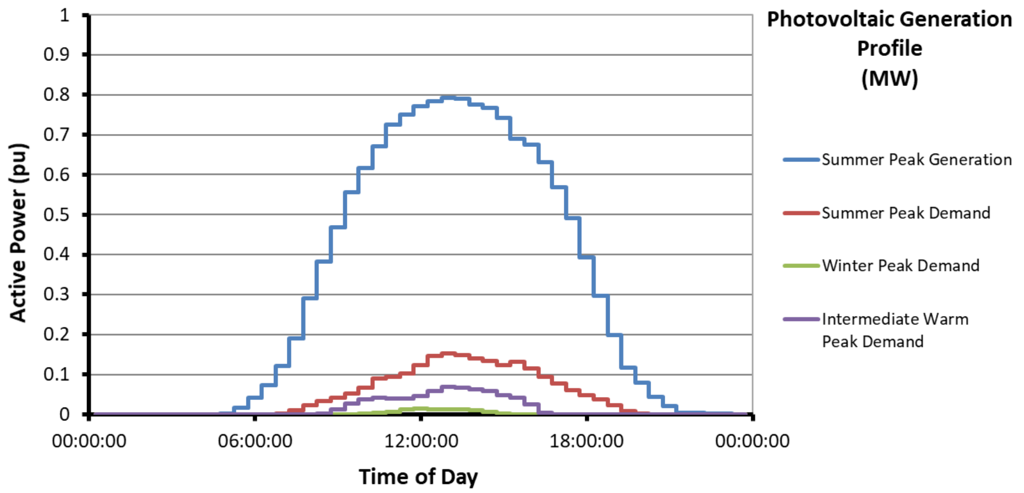

Figure 24: Normalised PV generation profile for each representative day

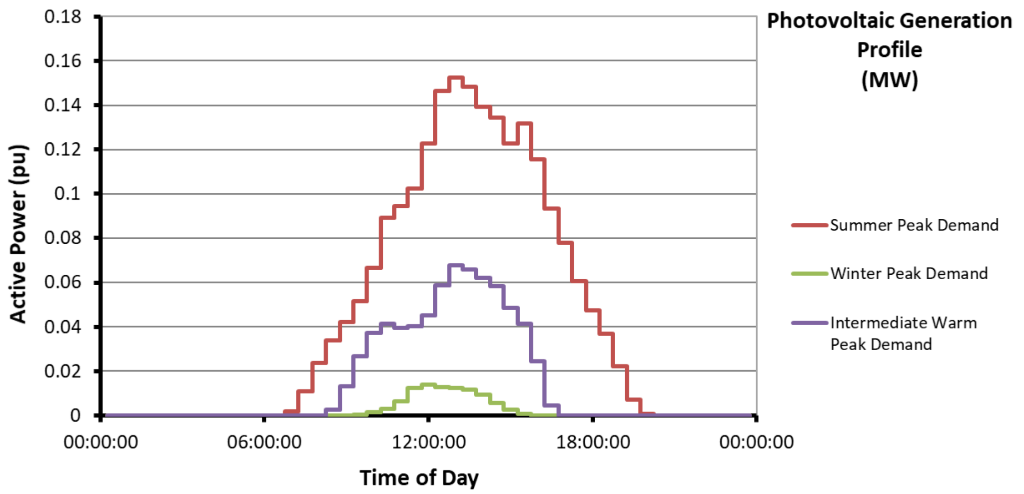

Figure 25: Detailed view of normalised PV generation profiles used for the summer peak, intermediate warm peak and winter peak demand representative days

Onshore and Offshore Wind

A similar process used for the PV generation profiles was used to create the wind profiles. The onshore wind generator data sample comprised 39 sites, with an installed capacity of 389 MW. The offshore wind generator data sample comprised two sites, with an installed capacity of 180 MW. For both technology types, the generation output profiles are for a 24-hour period and consist of 48 data points (48 half-hourly readings). A generation profile was created for each of the four representative days and only generation data from the respective representative day and season was considered. Once the generation meter data had been aggregated together, an actual day's worth (48 half-hourly readings) of data was selected. The data for each generation profile was selected in the following way:

- **Winter Peak Demand:** Considers data in the months between December and February. The peak power output was found for each day and the day with minimum peak power output was selected;
- **Summer Peak Demand:** Considers data in the months between June and August. The peak power output was found for each day and the day with minimum peak power output was selected;

- **Summer Peak Generation:** Considers data in the months between June and August. The peak power output was found for each day and the day with maximum peak power output was selected;
- **Intermediate Warm Peak Demand:** Considers data in the months May, September and October. The peak power output was found for each day and the day with minimum peak power output was selected.

The geographical spread of wind sites in the data sample is shown Figure 26. Figures 27 to 29 show the wind generation profiles that were imposed on the network models.

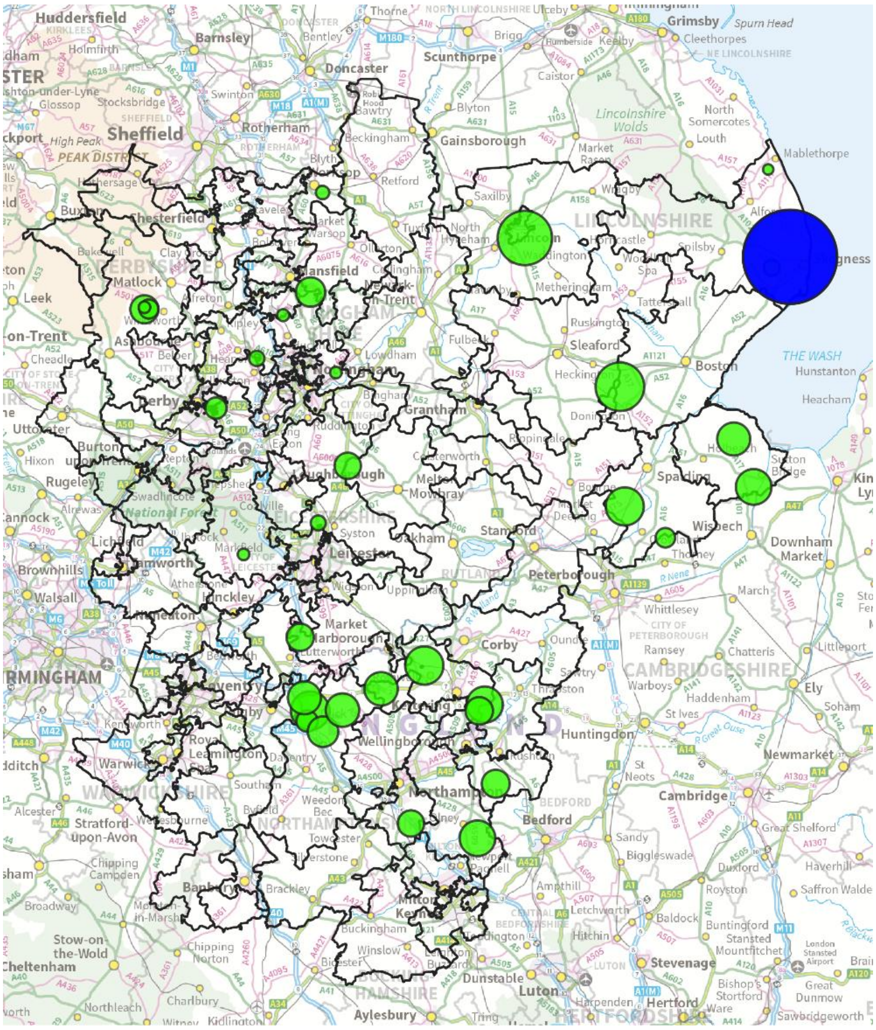

Figure 26: Map of onshore (green) and offshore (blue) wind sites contributing to generation profiles; symbol area proportional to installed capacity [MW]

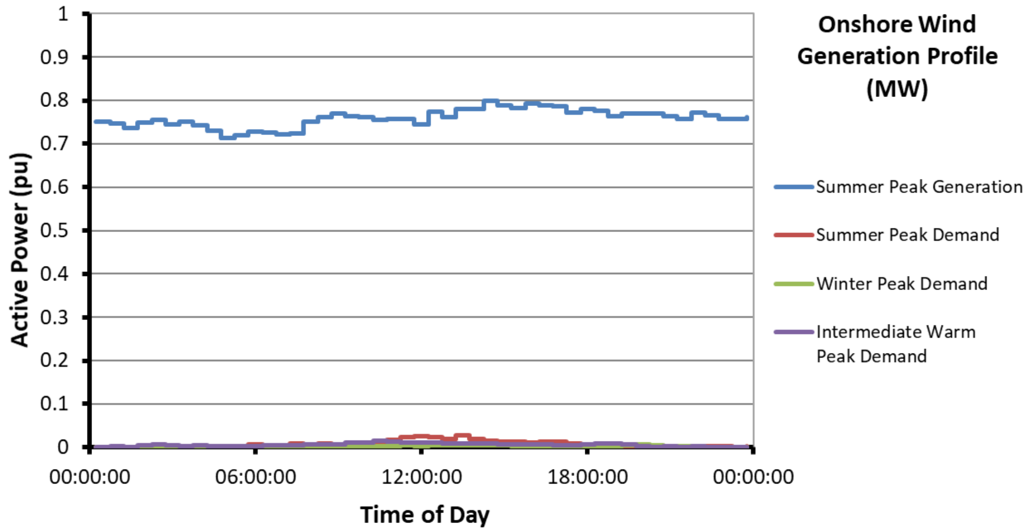

Figure 27: Normalised onshore wind generation profile used for each representative day. Note that due to the scale, the profiles for the demand days are shown near zero.

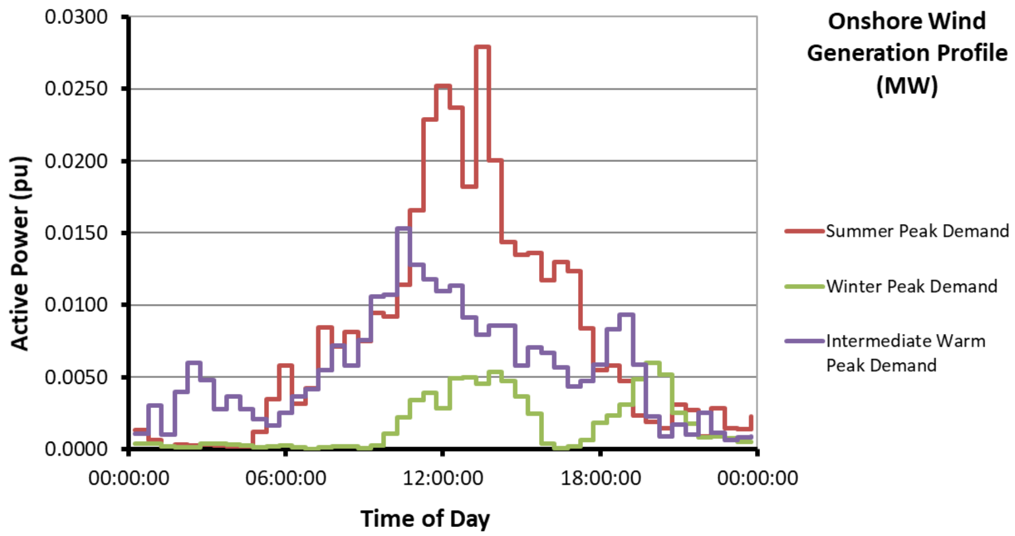

Figure 28: Detailed view of normalised onshore wind generation profiles used for the summer peak, intermediate warm peak and winter peak demand representative days

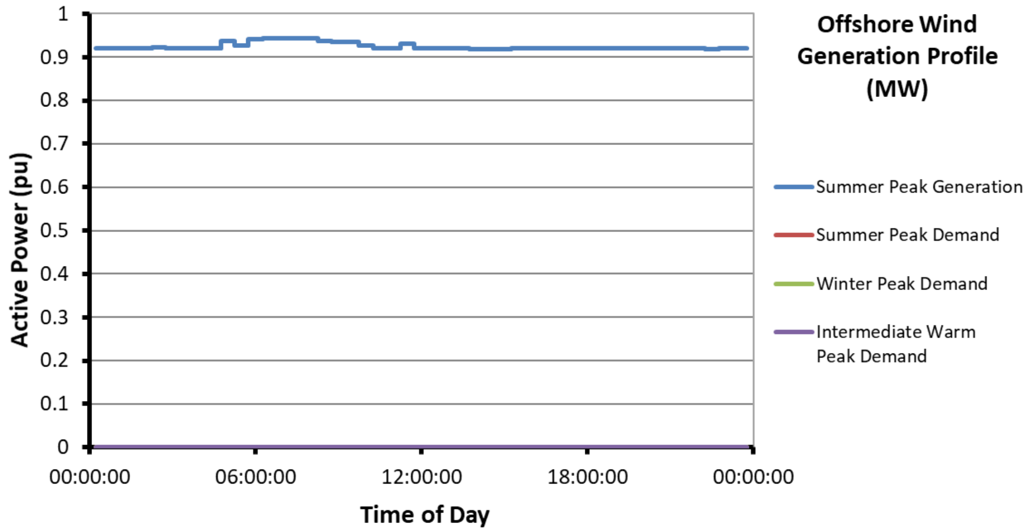

Figure 29: Normalised offshore wind generation profile used for each representative day. Note that due to the scale, the profiles for the demand days are shown near zero.

Other Generation

The remaining DG types modelled were:

- anaerobic digestion;
- deep geothermal;
- wave energy;
- energy from waste;
- hydropower;
- non-renewable Distributed Generation – including diesel and gas.

Insufficient data was available to derive profiles from measured flows for these technologies. In the case of infrequently despatched, non-intermittent generation, measured flows may not reflect the potential network impact. Instead, a flat (continuous output) profile was assumed for each representative day, representing the realistic behaviour that would have the worst impact upon the network. These were assumed as follows:

- Summer Peak Generation day: continuous export at agreed supply capacity; and
- Peak Demand days (summer, intermediate warm and winter): zero export.

Storage Profiles

WPD has been working with Regen to develop an approach to model the growth and operation of storage. As part of this modelling work, a consultation paper was developed and issued, aiming to validate some of the key assumptions used to model energy storage. The results from the consultation paper have been published and can be found on our website at:

www.westernpower.co.uk/energystorage.

The consultation paper proposed different energy storage business models and asked for feedback on the behaviour of energy storage in each of these business models. One noteworthy response to the consultation was that customers expressed a desire to be able to ‘stack’ different business models and revenue streams. Respondents also identified a preference not to commit to a specific operating mode, as the evolving nature of procurement of balancing services by the Great Britain System Operator (GBSO) in the future may change some of the proposed operating modes.

The consultation responses demonstrated that energy storage customers prefer flexibility to operate energy storage without a specific operating profile. As a result, the profile assumptions used in this study are:

- peak demand days (summer, intermediate warm and winter): continuous demand at agreed import capacity; and
- summer peak generation day: continuous generation at agreed export capacity.

This unconstrained mode of operation is onerous for networks. In some cases, it may trigger major reinforcements that would prove unnecessary with relatively minor changes in the behaviour of energy storage connections. The energy storage profiles will be reviewed in future studies, with the expansion of the suite of representative days to assess the energy curtailment impact of measures such as ANM and DSR.

WPD and National Grid have collaborated on the Regional Development Plan 4 (RDP4) to investigate how energy storage or other customers can provide flexibility to the system. This RDP looks to extend the flexibility arrangements given to generation so that they apply to storage demand. This will allow storage projects to become part of the solution to network capacity ussies, rather than capacity planning standards being a potential barrier to them.

6 – Results Overview

Results are given by year, GSP and network area within GSP. The scenarios to which particular results apply are identified with the following logos beside section headings:

CE Consumer Evolution	CR Community Renewables
SP Steady Progression	TD Two Degrees

The severity of a particular network constraint or deficiency often varies between scenarios. Where this variation is material, it is described in the text.

Where a network constraint or deficiency is identified, potential reinforcements or mitigations are identified in bold.

Demand Results at a Glance

Table 5: Summary of demand-driven network deficiencies by year, scenario and GSP group

GSP Group	2022	2027
Berkswell	SP CE TD CR	SP CE TD CR
Coventry	SP CE TD CR	SP CE TD CR
Enderby	SP CE TD CR	SP CE TD CR
Ratcliffe-on-Soar	SP CE TD CR	SP CE TD CR
Stoke Bardolph		SP CE TD CR
Hams Hall/Lea Marston		
Drakelow	CR	TD CR
Grendon	SP CE TD CR	SP CE TD CR
East Claydon	SP CE TD CR	SP CE TD CR
Chesterfield	TD CR	SP CE TD CR
Willington	SP CE TD CR	SP CE TD CR
Staythorpe	SP CE TD CR	SP CE TD CR
Bicker Fen	SP CE TD CR	SP CE TD CR
Walpole	SP CE TD CR	SP CE TD CR
West Burton	SP CE TD CR	SP CE TD CR

Generation Results at a Glance

Table 6: Summary of generation-driven network deficiencies by year, scenario and GSP group

GSP Group	2022	2027
Berkswell		
Coventry		CR
Enderby	TD CR	SP CE TD CR
Ratcliffe-on-Soar		
Stoke Bardolph		TD CR
Hams Hall/Lea Marston		
Drakelow		
Grendon	SP CE TD CR	TD CR
East Claydon	TD CR	SP CE TD CR
Chesterfield	CE CR	SP CE TD CR
Willington		CE TD CR
Staythorpe	CE TD CR	SP CE TD CR
Bicker Fen	SP CE TD CR	CE TD CR
Walpole	SP CE TD CR	
West Burton	TD CR	CE TD CR

Seasonal Ratings

The ratings of most electrical circuits vary with seasonal changes, particularly ambient temperature. Traditionally, distribution networks have only been assessed for 'edge-case' conditions, and so some circuits have only had ratings assigned for the season(s) pertinent to those edge cases.

In order to facilitate the connection of new types of demand, generation and storage economically and efficiently, it is becoming necessary to assess network capacity and utilisation all year round. As we develop new analysis techniques to assess year-round network capability, some limitations in our existing ratings methodologies have been identified.

Overhead Line Ratings

An NIA project to improve the accuracy of overhead line ratings, *Improved Statistical Ratings for Distribution Overhead Lines*, was recently completed. The results of this project are being used to revise the ENA standard for overhead line ratings, ER P27. The project identified that some of the traditional seasons used for ratings do not align well with seasonal changes in network loading and ambient temperature. For example, assessment of autumn peak demand against an autumn rating compares a demand that is likely to be driven by cold weather in late November against a rating that is constrained by warm weather in September. To mitigate this effect, P27/2 will introduce new seasonal definitions, shown in Table 7. These seasons have been chosen to limit the variation in ambient temperature-related demand behaviour during any one season.

Table 7: Changing seasons for overhead line ratings

<table>
<tr><th>Month</th><th>Old season (WPD’s ST:SD8A/2)</th><th>New season (P27/2)</th></tr>
<tr><td>January</td><td rowspan="2">Winter</td><td rowspan="2">Winter</td></tr>
<tr><td>February</td></tr>
<tr><td>March</td><td rowspan="2">Spring</td><td rowspan="2">Intermediate Cool</td></tr>
<tr><td>April</td></tr>
<tr><td>May</td><td rowspan="4">Summer</td><td>Intermediate Warm</td></tr>
<tr><td>June</td><td rowspan="3">Summer</td></tr>
<tr><td>July</td></tr>
<tr><td>August</td></tr>
<tr><td>September</td><td rowspan="3">Autumn</td><td rowspan="2">Intermediate Warm</td></tr>
<tr><td>October</td></tr>
<tr><td>November</td><td>Intermediate Cool</td></tr>
<tr><td>December</td><td>Winter</td><td>Winter</td></tr>
</table>

Western Power Distribution is now adopting overhead line ratings calculated to the P27/2 method.

Transformer Ratings

WPD’s transformer ratings standard includes ratings for summer and winter, but not for intermediate seasons. In order to assess transformers for the intermediate warm Peak Demand representative day, it was necessary to estimate intermediate warm transformer ratings. Summer emergency ratings were used as a proxy to intermediate warm cyclic ratings in the studies.

It is recommended that the new seasons used in the proposed revision to ER P27 are also used to recalculate a wider suite of transformer ratings. The calculation of any cyclic ratings should take into account changing load profiles.

Note that under intact conditions, ONAN ratings have been assigned to transformers fitted with forced cooling. This ensures that transformers are not prematurely aged by prolonged high loading. More detail on the ratings assigned to transformers is given in Chapter 11 – Definitions and References.

Assessing Network Access Requirements

There are two broad classes of network outage:

- **Fault outages:** when a component of the network fails, it is detected by protection relays, which open the circuit breakers enclosing the failed component. This de-energises the network between those circuit breakers, so clearing the fault. By their nature, fault outages cannot be predicted so may be expected to happen at any time;
- **Arranged outages:** each component of the network needs to be accessed for periodic or condition-driven inspection, maintenance and replacement. Similarly, access may be required for reinforcement or to make new connections. The minimum zone to access any particular component is usually defined by the isolators enclosing the component. The scheduling of arranged outages is flexible to some extent, so can take advantage of seasonal variation in network loading.

Since any component of the network could fail, it is necessary to assess the impact of each credible fault outage on the network. Since each component of the network will need to be accessed eventually, it is necessary to assess the impact of each credible arranged outage on the network. These are both types of *First Circuit Outage (FCO)*.

Combining these two requirements, it is also possible that a network component could fail during access to another network component. It is therefore also necessary to assess the impact of each credible fault outage during each credible arranged outage. Each combination is a *Second Circuit Outage (SCO)*.

Case Study: Three-Circuit Group

Some areas of network are operated with three (or more) circuits in parallel, feeding a Group Demand of less than 300 MW. Below that threshold, P2 has no requirement for demand to be supplied immediately following a SCO. This does not mean, however, that the possibility of an SCO can be ignored.

Consider the network shown in Figure 30. Each of the circuits A, B and C has a rating of 90 MVA. The three circuits share load evenly. The seasonal peak demand at the 33 kV busbar of the BSP is:

- summer peak demand: 85 MW;
- Intermediate warm peak demand: 105 MW;
- winter peak demand: 125 MW.

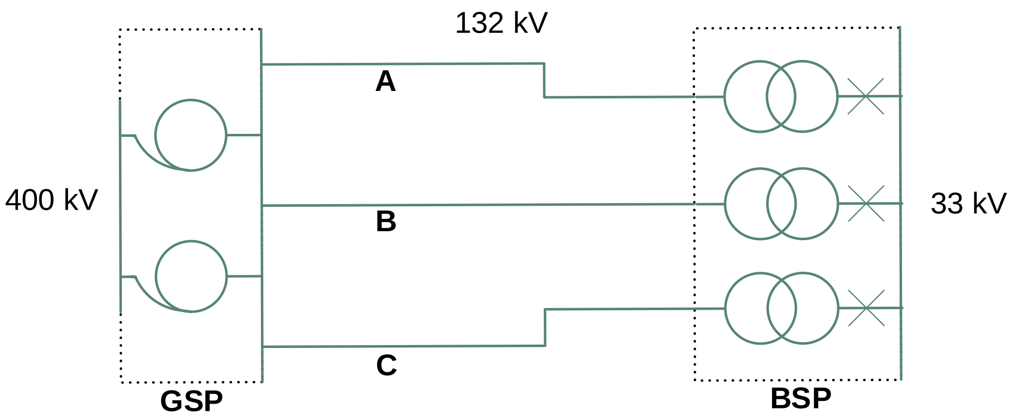

Figure 30: Three-circuit group example network

The Group Demand is the maximum of the seasonal peak demands, 125 MW. This puts the group into class D of P2. This requires that:

1. For a circuit fault from an intact network (FCO fault):
   a. Group Demand minus up to 20 MW (automatically disconnected), i.e. 105 MW, is met immediately; and
   b. Group demand is met within three hours.
2. For a circuit fault during an arranged outage (SCO):
   a. Group Demand minus 100 MW, i.e. 25 MW, is met within three hours; and
   b. Group Demand is met within the time taken to restore the arranged outage.

The FCO of one of the three circuits leaves the prevailing demand of the group fed by the remaining two circuits, which have a total rating of 180 MVA. Since the Group Demand of 125 MW is well within the capability of the circuits, this meets the requirements of P2 without compromising network integrity.

The SCO of any two of the three circuits leaves the prevailing demand of the group fed by the remaining circuit, which has a rating of 90 MVA. While the remaining circuit is sufficient to supply the demand required by P2 (25 MW), the actual impact on the network depends on the prevailing demand:

- in summer, the demand of 85 MW is within the capability of the remaining circuit;
- in Intermediate Warn, the demand of 105 MW overloads the remaining circuit;
- in winter, the demand of 125 MW overloads the remaining circuit.

This overload is unacceptable, so steps should be taken to prevent it. Options include:

1. only taking the arranged outages of the three circuits in summer;
2. reinforcing all three circuits so that any one circuit can support the Group Demand of 125 MW;
3. splitting the 33 kV busbar and downstream network into two sections for the duration of the arranged outage, with each section connected to one of the circuits and a 62.5 MW demand group. If a fault occurs during an arranged outage, half of the demand would be disconnected, but the remaining circuit would not be overloaded;
4. installing intertripping or overload schemes to detect and trip or deload any circuit that is overloaded;
5. contracting with customers within the 33 kV network for flexibility services to operate during arranged outages to reduce the net demand of the group.

Several areas of the East Midlands subtransmission network exhibit similar network constraints to this case study. Some of these areas were found to have an access window that is limited to summer. This may be acceptable for some areas, but if large parts of the network have narrow, coincident access windows, this may conflict with scheduling requirements for specialist staff and equipment.

It is recommended that techniques for assessing the sufficiency of available access windows for distribution circuits are formalised.

Distribution Circuit Access

Traditionally, arranged outages in or near summer have been preferred due to:

- lower loads relative to seasonal ratings;
- longer daylight hours;
- fewer severe weather conditions that could interrupt work or trigger coincident faults.

Recent changes to load behaviour, particularly the adoption of solar generation and air conditioning, have eroded the advantage of lower loads relative to seasonal ratings in many networks. Arranged outages are now commonly taken over a wider portion of the year.

These studies have identified several networks where access is only available in certain seasons. While this is not necessarily a problem, having large areas of network restricted to the same season could conflict with staff and equipment scheduling.

There is currently no industry-wide standard for distribution network operability and access scheduling. The only security of supply standard applicable to distribution networks is P2, which is primarily concerned with Demand Security.

It is recommended that processes for assessing distribution circuit access requirements at planning and operational stages are developed further.

Grid Code SGT Access Periods

SGTs form the interface between transmission and distribution networks, so their arranged outages need to be planned cooperatively by transmission and distribution operators. To ensure that access to SGTs is designed into networks, the Grid Code includes a process (Planning Code A.4.1.4) whereby indicative access windows are scheduled for all SGTs. Actual arranged outages of SGTs are scheduled separately in operational timescales.

Normally, access is scheduled between week 13 (late March) and week 43 (late October), a total of 31 weeks. This period falls across the summer, intermediate warm and Intermediate Cool seasons. Each SGT requires an eight week *Access Period* every three years. GSPs that are interdependent due to interconnection or demand transfer capacity are aggregated into *Access Groups*; each remaining GSP becomes an Access Group in its own right. Following these requirements, each Access Group can have up to nine SGTs without requiring concurrent SGT outages. Larger groups do require concurrent outages.

In exceptional circumstances with mutual agreement, the Grid Code allows Access Periods of as little as four weeks, starting as early as week 10 (early March). These provisions are not currently used in the East Midlands.

Table 8: Grid Code Access Groups in East Midlands for 2020

GSPs	Number of SGTs	Potential Concurrent SGT Outages
Berkswell and Coventry	7	1
Chesterfield	4	1
Bicker Fen, Staythorpe, West Burton, Walpole, Willington and Drakelow	18	3
East Claydon	4	1
Enderby, Ratcliffe-on-Soar and Stoke Bardolph	10	2
Grendon	5	1
Lea Marston	4	1

For these studies, it has been assumed that if access to an SGT is available in summer and intermediate warm seasons, then the requirements of the Grid Code will be met. Concurrent SGT outages have not been assessed.

It is recommended that the Switch-Level Analyser be extended to assess concurrent SGT arranged outages for Grid Code Access Groups. The part of the year that the Grid Code allows Access Periods to fall within should be re-evaluated as seasonal load profiles change.

Security of Supply to Single Customers

The East Midlands 132 kV network has several customers connected either directly at 132 kV or via sole-user grid transformers. Security of supply to individual customers is outside of the scope of P2, which states that:

> *"This document deals with the security of DNO's distribution network. It does not apply to the security of the connection between the DNO's distribution network and an individual customer, which should be agreed between the DNO and that customer."*

As such, the security of supply to these customers varies case-by-case, but has not been directly considered in this report. Where changes to the network surrounding an existing customer are proposed, the existing level of security of supply is maintained.

Where supplies are provided for 25 kV Alternating Current (AC) single-phase railway traction supplies, security of supply is achieved by off-load transfers at 25 kV to:

1. another transformer at the same transforming station (a 132/25 kV BSP in all cases supplied by Western Power Distribution) via 25 kV switchgear at the trackside feeder station;
2. other transforming stations via Network Rail's 25 kV network.

Standard arrangements for these are given in ENA ER P24. The 25 kV AC traction networks are single-phase, and the 132/25 kV GTs are variously supplied from different 132 kV phase pairs to minimise imbalance. This prevents parallel operation on the 25 kV network between points of infeed.

7 – Baseline Results

Berkswell GSP

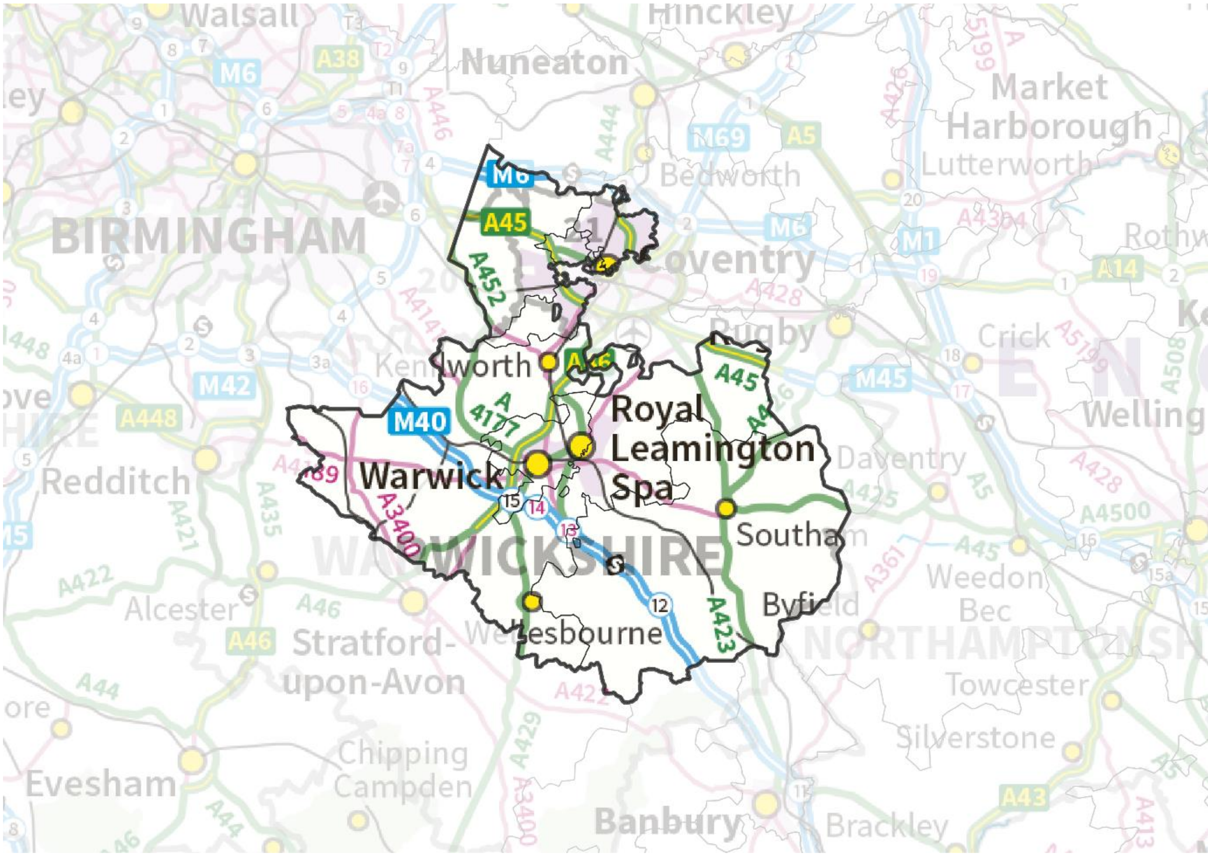

Figure 31: Area supplied by Berkswell GSP

Berkswell GSP has three 275/132 kV 240 MVA SGTs, supplying a 132 kV double busbar. To manage fault level constraints, the 132 kV busbar is normally run split into two nodes, which are remote-coupled and loose-coupled via WPD BSPs.

In the baseline studies, the Group Demand of Berkswell GSP is 312 MW, which falls into Class E of P2. For a summer peak demand case, the demand of the group does not fall below 214 MW.

Load transfers to Coventry GSP are available via normally open 132 kV circuit breakers at Coventry South BSP.

SGT Overloads

Generation **Demand**

The 132 kV busbar at Berkswell GSP is normally split into two nodes, with bus coupler 130 open:

- SGT1 and SGT2 supply main busbar sections 1 and 2;
- SGT3 supplies reserve busbar sections 1 and 2.

These two nodes are remote-coupled by the 132 kV mesh at Warwick BSP, and loose-coupled by the 33 kV and 11 kV busbars of other BSPs supplied from Berkswell. For the arranged outage of any one

SGT, the 132 kV busbar is coupled solid and Coventry South BSP 132/33 kV is transferred to Coventry GSP to de-load Berkswell GSP. As a result of this transfer, Berkswell and Coventry GSPs form a Grid Code Access Group.

For the arranged outage of an SGT followed by the fault of a second SGT, the group load is supplied by the remaining SGT. For this SCO combination in baseline, the remaining SGT in service would overload up to 108% of nameplate rating for a winter peak demand case. This overload does not occur for summer or intermediate warm peak demand cases.

It is still possible to schedule Grid Code SGT Access Periods within the summer and intermediate warm ratings seasons.

A fourth 240 MVA SGT and 132 kV bus coupler 230 that will alleviate the studied overloads and support demand growth is due to be commissioned at Berkswell GSP by September 2022.

Warwick BSP GT Capacity

Generation **Demand**

Warwick BSP has a 132 kV four corner mesh connecting:

- two incoming circuits from Berkswell GSP;
- two outgoing circuits to Harbury BSP;
- three 132/33 kV grid transformers;
- three 132/11 kV grid transformers.

132/11 kV GT Capacity

Warwick BSP has three 15/30 MVA 132/11 kV grid transformers. For the SCO of any two of these GTs, the remaining GT supplies the group load. In baseline, this SCO would overload the remaining GT up to 129% of rating (winter peak demand) or 122% of rating (intermediate warm peak demand). This overload does not occur at summer peak demand.

It is recommended that the sufficiency of the available access window for the 132/11 kV GTs at Warwick is confirmed.

132/33 kV GT Capacity

Warwick has three 132/33 kV grid transformers:

- GT1A: 30/60 MVA;
- GT2A: 45/90 MVA;
- GT3A: 30/60 MVA.

For the SCO of any two of these GTs, the remaining GT supplies the group load. If the remaining GT is GT1A or GT3A (the lower rated units), in baseline, it would overload up to 103% of rating at winter peak demand. This overload does not occur for summer or intermediate warm peak demand case.

It is recommended that the sufficiency of the available access window for the 132/33 kV GTs at Warwick is confirmed.

Warwick and Harbury Lost Load

Generation **Demand**

Warwick (132/11 kV and 132/33 kV) and Harbury (132/33 kV) BSP sites are supplied via two 132 kV circuits from Berkswell GSP. Their combined Group Demand is 140 MW; the SCO of both 132 kV circuits between Berkswell and Warwick interrupts supplies to the group.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of 40 MW is required.

At least 40 MW of 33 kV post-fault transfer capacity into Warwick BSP 33 kV network is available, satisfying the requirements of P2.

Coventry GSP

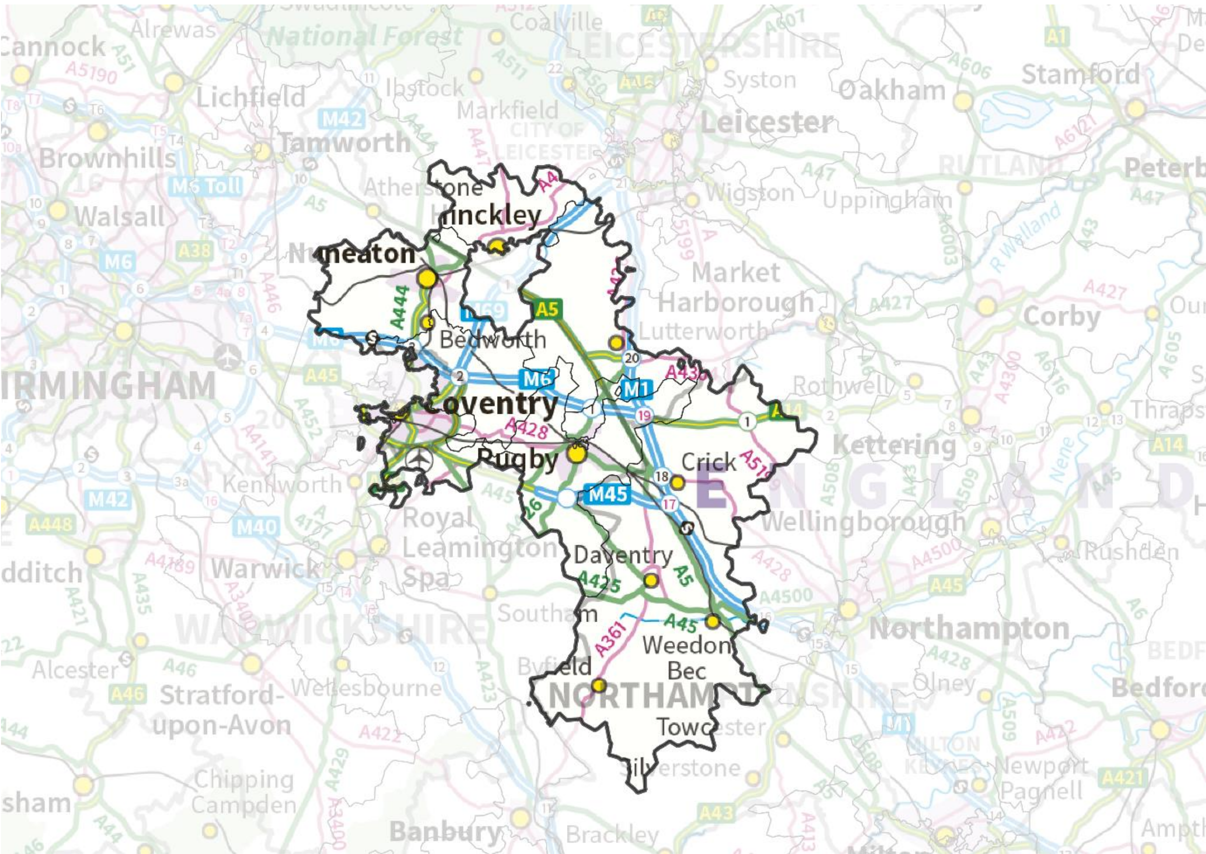

Figure 32: Area supplied by Coventry GSP

Coventry GSP has four 275/132 kV SGTs, supplying a 132 kV double busbar. To manage fault level constraints, the 132 kV busbar is normally split into two nodes, which are remote-coupled and loose-coupled via WPD BSPs.

In the baseline studies, the Group Demand of Coventry GSP is 487 MW, which falls into Class E of P2. For a summer peak demand case, the demand of the group does not fall below 347 MW.

Load transfers are available to:

- Berkswell GSP via normally open 132 kV circuit breakers at Coventry South BSP;
- Enderby GSP via normally open 132 kV circuit breakers at Hinckley BSP.

SGT Overloads

Generation | **Demand**

The 132 kV busbar at Coventry GSP is normally split into two nodes, with bus couplers 130 and 230 open:

1. SGT1 and SGT2 supply main busbar sections 1 and 2;
2. SGT3 and SGT4 supply reserve busbar sections 1 and 2.

These two nodes are remote-coupled by the 132 kV mesh at Rugby GSP, and loose-coupled by the 33 kV and 11 kV busbars of other BSPs supplied from Coventry. The busbars cannot run solid with three or four SGTs in service without exceeding equipment fault level ratings.

SGT SCOs

For the arranged outage of an SGT followed by the fault of a second SGT, the group load is supplied by the remaining SGTs. Depending on the SCO combination in baseline, the remaining SGTs in service can overload up to:

- 143% of nameplate rating at winter peak demand;
- 119% of nameplate rating at intermediate warm demand.

As Coventry 132 kV is split into two nodes, there is poor load share between the two remaining SGTs. These overloads do not occur for the summer peak demand case.

As described above, Berkswell and Coventry GSPs form a Grid Code Access Group.

It is recommended that a further study is undertaken to re-assess the busbar section load distribution at Coventry GSP and confirm that Grid Code SGT Access Periods are available. National Grid may be able to determine short-term ratings for Coventry SGTs, which allow loading to be managed by post-fault transfers and redistribution of load.

Once Berkswell SGT4 is commissioned, it may be possible to transfer Coventry South BSP 132/11 kV onto Berkswell GSP and/or Hinckley BSP 132/33 kV onto Enderby GSP for the duration of Coventry SGT arranged outages.

Reserve Busbar Fault

There is a section circuit breaker 120 between main busbar sections 1 and 2, but no section circuit breaker between reserve busbar sections 1 and 2. This means that a fault on either reserve busbar section results in both being de-energised, with all of Coventry GSP being supplied by SGT1 and SGT2.

At winter peak demand in baseline, this fault would overload SGT1 to 111% of nameplate rating and SGT2 to 107% of nameplate rating.

It is recommended that this fault condition is reviewed with National Grid – it may be possible for National Grid to manage post-fault SGT loading with short-term ratings. If not, the installation of a 132 kV reserve section circuit breaker 160 would mean that only one busbar section and SGT is lost for either reserve busbar fault.

Enderby GSP

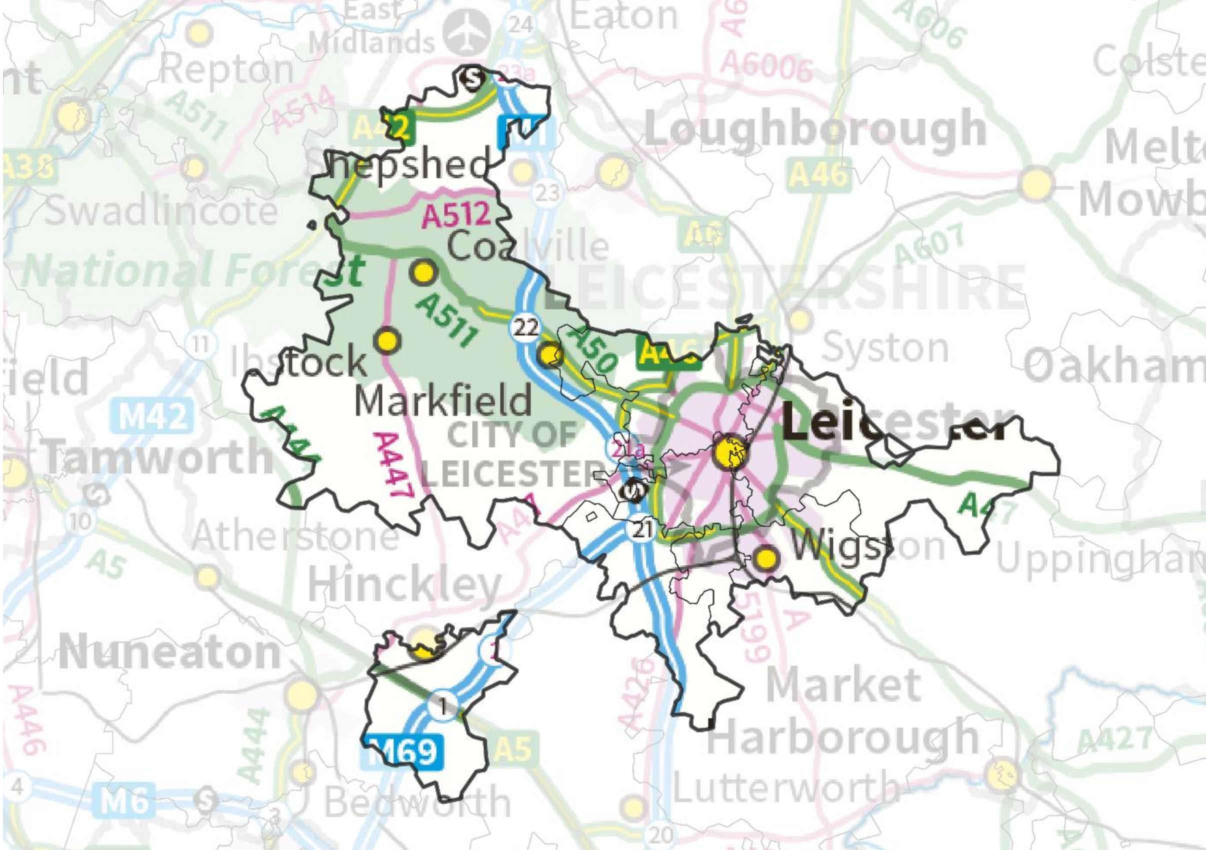

Figure 33: Area supplied by Enderby GSP

Enderby GSP has four 400/132 kV SGTs, supplying a 132 kV double busbar. To manage fault level constraints, the 132 kV busbar is normally run solid with only SGT1, SGT3 and SGT4 on load. SGT2 is held on hot standby, with an automatic switching scheme to close its 132 kV circuit breaker for the loss of any other SGT.

In the baseline studies, the Group Demand of Enderby GSP is 507 MW, which falls into Class E of P2. For a summer peak demand case, the demand of the group does not fall below 345 MW.

SGT Overloads

Generation **Demand**

The arranged outage of an SGT followed by the fault of another leaves Enderby GSP fed by the remaining two SGTs. In baseline, this SCO overloads both remaining SGTs up to 114% of nameplate rating for a winter peak demand case. This overload does not occur for summer or intermediate warm peak demand cases.

It is still possible to schedule Grid Code SGT Access Periods within the summer and intermediate warm ratings seasons.

132 kV Circuit Overloads

Generation | **Demand**

Leicester BSP is supplied by four 132 kV circuits from Enderby GSP. There are two 132/33 kV GTs at Leicester and six outgoing 132 kV circuits to other BSPs. Leicester 132 kV, following recent asset replacement, is now operated as two independent 132 kV nodes, each supplied by two circuits from Enderby GSP, one from each of the CN and CC routes. The two 132 kV busbars are loose-coupled via 33 kV and 11 kV busbars at the local BSP and several other BSPs in the group.

An arranged outage of the Leicester 132 kV Main 2 busbar followed by a fault on the Enderby 405 to Leicester 205 132 kV circuit leaves the Enderby 105 to Leicester 805 (CN route) circuit supplying one of the two independent 132 kV nodes, including all of the 33 kV busbars at each of Leicester and Leicester North BSPs. The other CN route circuit is left supplying the other 132 kV node, but it is relatively lightly loaded.

Similarly, an arranged outage of Leicester 132 kV Main 3 busbar followed by a fault to the Enderby 805 to Leicester 105 132 kV circuit leaves the Enderby 505 to Leicester 505 (CN route) circuit supplying one of the two independent 132 kV nodes, including all of the 33 kV busbars at each of Leicester and Leicester East BSPs. The other CN route circuit is left supplying the other 132 kV node, but it is loaded relatively lightly.

In baseline, these SCOs overload the CN route circuit that carries most of the load up to 117% for a winter peak demand case and up to 106% for an intermediate warm peak demand case.

The existing twin 175mm^2 Aluminium Conductor, Steel Reinforced (ACSR) twin Lynx conductors on each circuit of the CN route are due to be reprofiled for 75°C operation in 2020. Following this work, marginal overloads remain for winter peak demand only. It is recommended that the sufficiency of the available access window for these circuits is confirmed.

The existing twin 175mm^2 ACSR (twin Lynx) conductors on each of the CC route have been reprofiled for 75°C operation. Baseline studies indicate that either circuit that is left to supply one of the two independent 132 kV busbars and all of the 33 kV busbar at Leicester is marginally overloaded up to 102% for winter peak demand only.

It is recommended that the sufficiency of the available access window for these circuits is confirmed. If the arranged outage window is not sufficient, the studied overloads could be alleviated by:

- **reconductoring the CC route with a larger conductor system such as 570mm^2 All Aluminium Alloy Conductor (AAAC) (Sorbus) at 75°C;**
- **transferring Wigston BSP onto Grendon GSP via Kibworth and Corby for planned outages including GTs at Leicester and circuits between Leicester and Enderby. This may constrain the Grendon GSP network;**
- **improving load balance between the Leicester–Enderby circuits by coupling the two Leicester 132 kV busbars, either locally or at remote BSPs;**
- **partially deloading the affected Leicester 132 kV busbar for the duration of the arranged outage by offloading a downstream GT. This would put more demand at single-circuit risk.**

Leicester Lost Load

Generation **Demand**

Leicester 132/33 kV has two grid transformers, one supplied from each of the independent Leicester 132 kV busbars. The Group Demand is 114 MW; the SCO of both grid transformers interrupts supplies to the group.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of 14 MW is required.

Over 40 MW of 33 kV post-fault transfer capacity into Leicester BSP 33 kV network is available, satisfying the requirements of P2.

Ratcliffe-on-Soar GSP

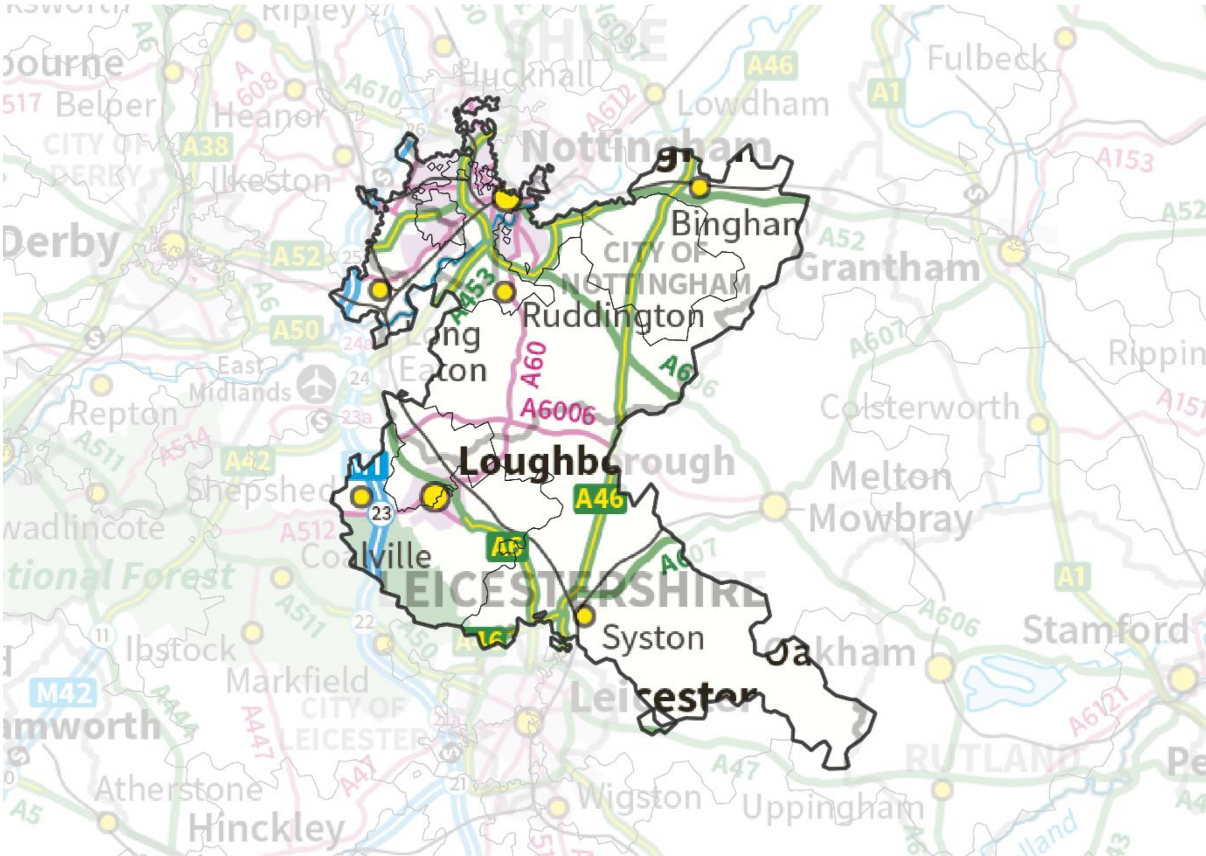

Figure 34: Area supplied by Ratcliffe-on-Soar GSP

Ratcliffe-on-Soar GSP is shared between WPD East Midlands and Ratcliffe-on-Soar Power Station. As such, SGT capacity is National Grid's responsibility. Ratcliffe-on-Soar GSP has four 400/132 kV 240 MVA SGTs supplying:

1. WPD's 132 kV network in Nottingham and the surrounding area, with a Group Demand of 419 MW, which falls into Class E of P2. For a summer peak demand case the demand of the group does not fall below 292 MW;
2. Ratcliffe-on-Soar Power Station's station transformers, modelled at an assumed 14.5 MW demand.

SGT Overloads

Generation **Demand**

To manage fault level constraints, the 132 kV busbar is normally split on bus couplers 130 and 230 into two nodes, which are loose-coupled via WPD BSPs:

1. SGT4 and SGT6 supply main busbar sections 1 and 2;
2. SGT1 and SGT3 supply reserve busbar sections 1 and 2.

The busbars cannot run solid with three or four SGTs in service without exceeding equipment fault level ratings. There is a section circuit breaker 120 between main busbar sections 1 and 2, but no section circuit breaker between reserve busbar sections 1 and 2.

For the arranged outage of an SGT followed by the fault of a second SGT, the group load is supplied by the remaining SGTs. For particular SCO combinations in baseline, the remaining SGTs in service can overload up to:

- 122% of nameplate rating at winter peak demand;
- 107% of nameplate rating at intermediate warm peak demand.

These overloads do not occur for the summer peak demand case.

It is recommended that a further study is undertaken to re-assess the busbar section load distribution at Ratcliffe-on-Soar GSP and confirm that Grid Code SGT Access Periods are available. National Grid may be able to determine short-term ratings for Ratcliffe-on-Soar SGTs, which allow loading to be managed by post-fault transfers and redistribution of load.

It may be possible to transfer Nottingham North BSP 132/11 kV onto Stoke Bardolph GSP for the duration of Ratcliffe-on-Soar SGT arranged outages.

The SCO of both SGTs on a 132 kV node leaves the node back energised by the loose couples at WPD's BSPs. Under these circumstances, a station transformer would be supplied solely via WPD's network. Depending upon the load associated with that station transformer, there may be network integrity implications on WPD's network.

It is recommended that, as part of the ongoing design and operational liaison between WPD and National Grid, detailed joint studies are carried out to assess current and planned running arrangements at Ratcliffe-on-Soar. For arranged outages of SGTs, the station transformers should be reselected at 132 kV or offloaded as necessary so that a station transformer is never supplied from a node with only one SGT. This would ensure that on-load station transformers still have direct 132 kV infeed from at least one SGT for any credible SGT fault.

Loughborough BSP 132/33 kV GT Capacity

Generation **Demand**

Loughborough BSP currently has two 30/60 MVA 132/33 kV GTs that are normally fed from Ratcliffe-on-Soar GSP via the SZ and HT 132 kV circuit routes.

For the fault or arranged outage of either 132/33 kV GT, the remaining GT in service would overload up to 115% of rating at winter peak demand and 107% of rating at intermediate warm peak demand. This overload does not occur for the summer peak demand case.

Ongoing reinforcement work at Loughborough BSP will replace both 132/33 kV GTs with 90 MVA units. This will resolve the studied overloads.

Toton BSP 132/33 kV GT Capacity

Generation | **Demand**

Toton BSP currently has two 30/60 MVA 132/33 kV GTs that are normally fed from Ratcliffe-on-Soar GSP via the AK 132 kV circuit routes.

Toton BSP is loose-coupled across the two 132 kV nodes at Ratcliffe-on-Soar. For the SCO of SGT3 and SGT4, Ratcliffe-on-Soar 132 kV busbar section 2 has no direct SGT infeed. The balance of flows through loose couples overloads Toton GT1 to 83 MVA at winter peak demand, 106% of the seasonal cyclic rating. A similar overload occurs at intermediate warm peak demand.

A winter emergency rating of 84 MVA is available for 30/60 MVA GTs that meet certain criteria. It is recommended that the GTs at Toton are assessed to ensure that emergency ratings can be applied. If this is the case, they could be deloaded post-fault. Flows at Toton should be considered as part of the joint studies with National Grid recommended above.

Planned reinforcement work at Toton BSP will replace both 132/33 kV GTs with 90 MVA units. This will resolve the studied overloads.

Voltage Issues

Generation | **Demand**

All 132 kV circuits in the Ratcliffe-on-Soar network are operated as transformer feeders. The fault outage of a 132 kV busbar at Ratcliffe-on-Soar leaves the downstream 132 kV circuits back energised via the 33 kV or 11 kV busbars of the associated BSPs. These studies have identified a risk of overvoltages under these conditions on 132 kV nodes at Nottingham BSP, Nottingham North BSP, Nottingham East BSP and Toton BSP. The overvoltages occur because the 132 kV circuits are back fed via transformers that were tapped for pre-fault loading but are unloaded post-fault. Depending upon Automatic Voltage Control (AVC) relay stability, the overvoltages may be exacerbated by AVC runaway. Similar overvoltages arise for some SCO conditions.

It is recommended that these overvoltages are studied in further detail. Depending on the magnitude of the overvoltages, options to alleviate them include:

- **intertripping to the LV circuit breakers of the grid transformers at the remote ends of the affected circuits. In some cases, remote end tripping is fitted as part of busbar protection schemes;**
- **operational procedures to open the LV circuit breakers of the grid transformers at the remote ends of the affected circuits promptly.**

Loughborough Tee to Ratcliffe-on-Soar 132 kV SZ Route Circuit Overloads

Generation | **Demand**

For arranged outages of either 132 kV circuit from Enderby GSP to Coalville BSP, Coalville BSP would be left at single-circuit risk. To avoid this, Coalville BSP is typically transferred onto Ratcliffe-on-Soar GSP for the duration of the arranged outage.

The subsequent fault loss of either Ratcliffe-on-Soar/Loughborough/Coalville 132 kV circuit leaves the group load of Loughborough and Coalville BSPs on the remaining circuit. This would overload the section of the remaining circuit between Ratcliffe-on-Soar and Loughborough tee (the SZ route) up to

136% of its rating at winter peak demand and up to 117% of rating at intermediate warm peak demand. This overload does not occur at summer peak demand.

It is recommended that Coalville BSP is only transferred onto Ratcliffe-on-Soar GSP where seasonal loading and ratings allow.

If the transfer is required at other times of year, the studied overloads could be alleviated by reconductoring the existing 175mm² ACSR (Lynx) conductor on the SZ route between the Loughborough tee and Ratcliffe-on-Soar GSP with 300mm² AAAC (Upas) profiled for operation at 75°C.

Stoke Bardolph GSP

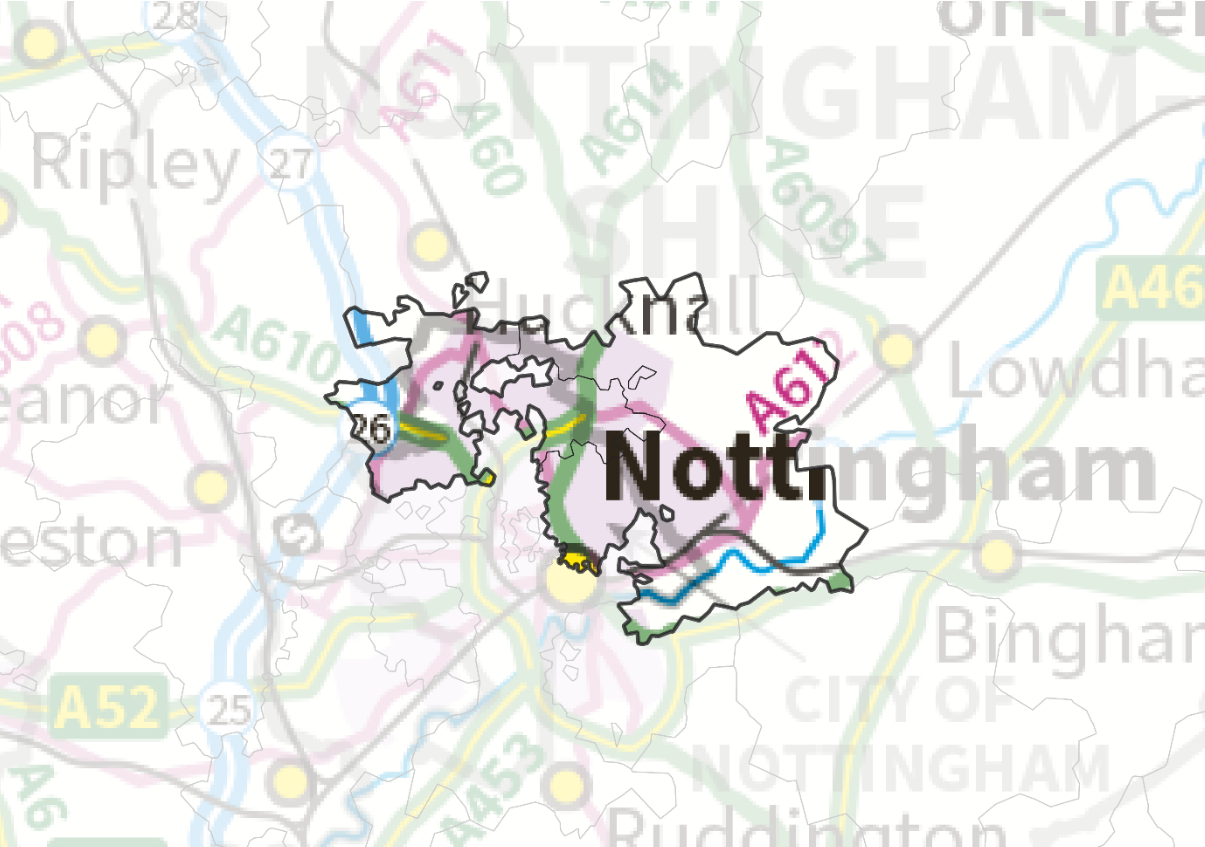

Figure 35: Area supplied by Stoke Bardolph GSP

Stoke Bardolph GSP has two 400/132 kV 240 MVA SGTs, supplying a 132 kV double busbar, which is normally run solid.

The Group Demand of Stoke Bardolph GSP is 149 MW, which falls into Class D of P2. For a summer peak demand case, the demand of the group is 96 MW.

Stoke Bardolph GSP was built to reinforce Ratcliffe-on-Soar GSP and supplies load previously supplied by Ratcliffe-on-Soar 132 kV. Stoke Bardolph 132 kV demand can be transferred back into Ratcliffe-on-Soar 132 kV post fault.

Nottingham East and Nottingham North Lost Load

Generation | **Demand**

Nottingham East (132/33 kV) and Nottingham North (132/33 kV side) BSPs are supplied via two 132 kV circuits from Stoke Bardolph GSP. Their combined Group Demand is 149 MW; the SCO of both 132 kV circuits or both SGTs interrupts supplies to the group.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of 49 MW is required.

Over 150 MW of 132 kV post-fault transfer capacity from Ratcliffe-on-Soar GSP is available, satisfying the requirements of P2.

Hams Hall/Lea Marston GSP

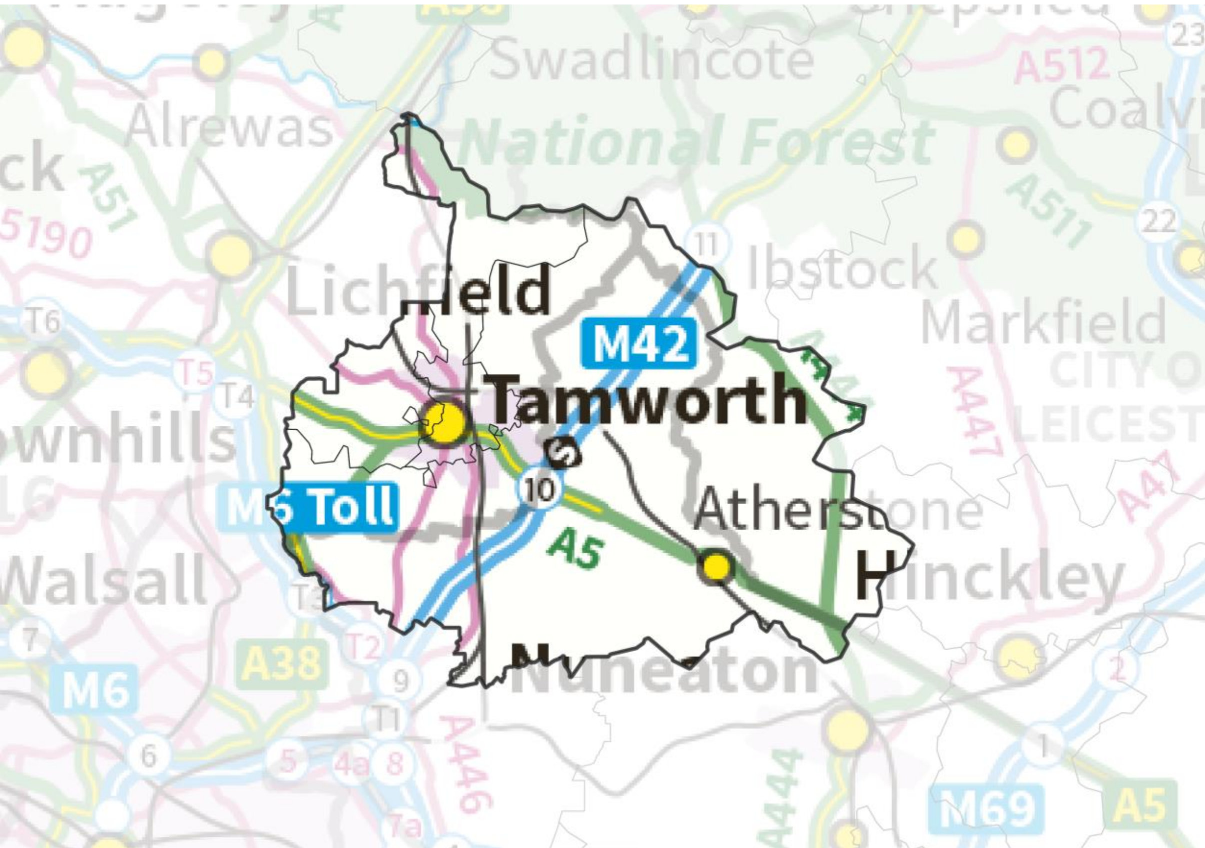

Figure 36: Area supplied by Hams Hall/Lea Marston GSP

Hams Hall GSP is shared between WPD West Midlands and WPD East Midlands licence areas. The 132 kV busbar is on a site adjacent to the GSP called Lea Marston. WPD East Midlands's network supplied from Hams Hall GSP consists of two 132 kV circuits supplying a group of BSPs around Tamworth. The baseline studies did not identify any issues in WPD East Midlands's network supplied from Hams Hall GSP.

The WPD West Midlands network supplied from Hams Hall GSP will be studied in the next issue of *Shaping Subtransmission West Midlands.*

Drakelow GSP

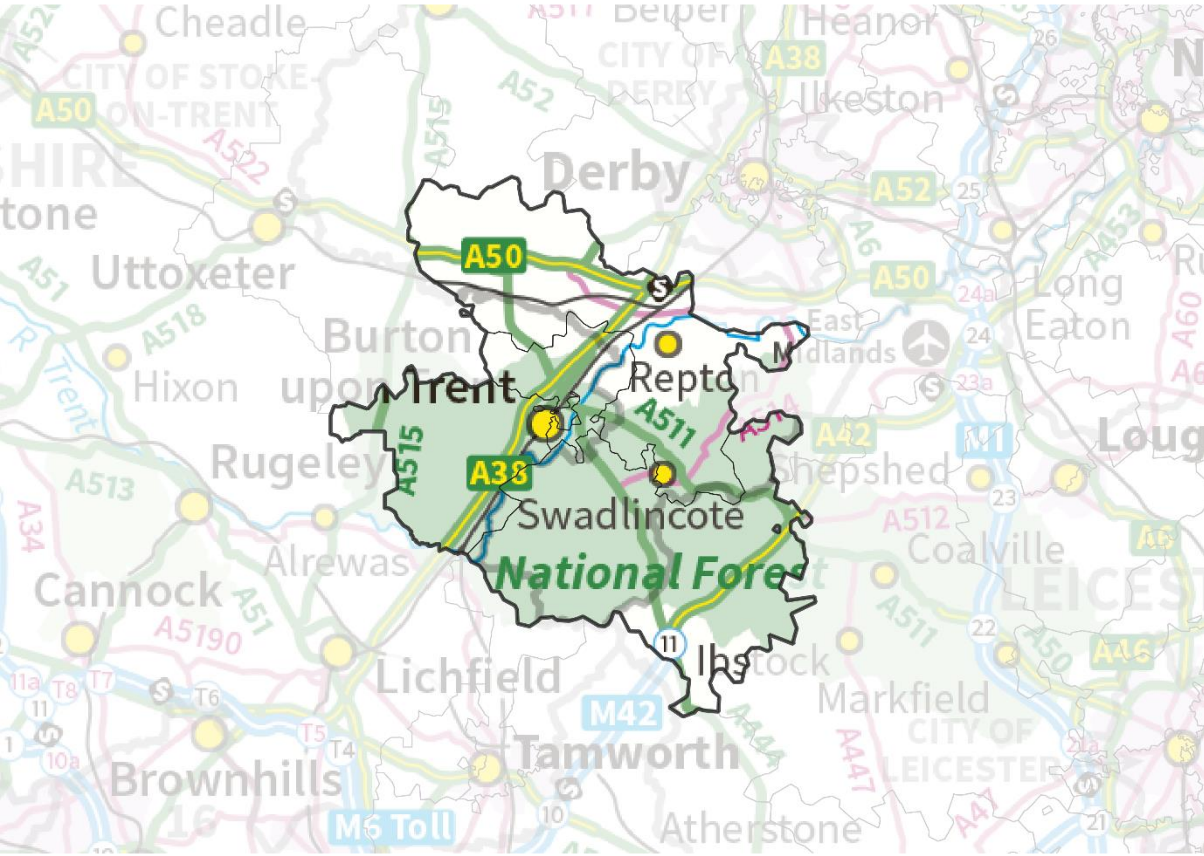

Figure 37: Area supplied by Drakelow GSP

WPD East Midlands’s network supplied from Drakelow GSP consists of six 132 kV circuits supplying Gresley BSP, Burton BSP and Burton South BSP. The baseline studies did not identify any issues in the Drakelow GSP area.

Grendon GSP

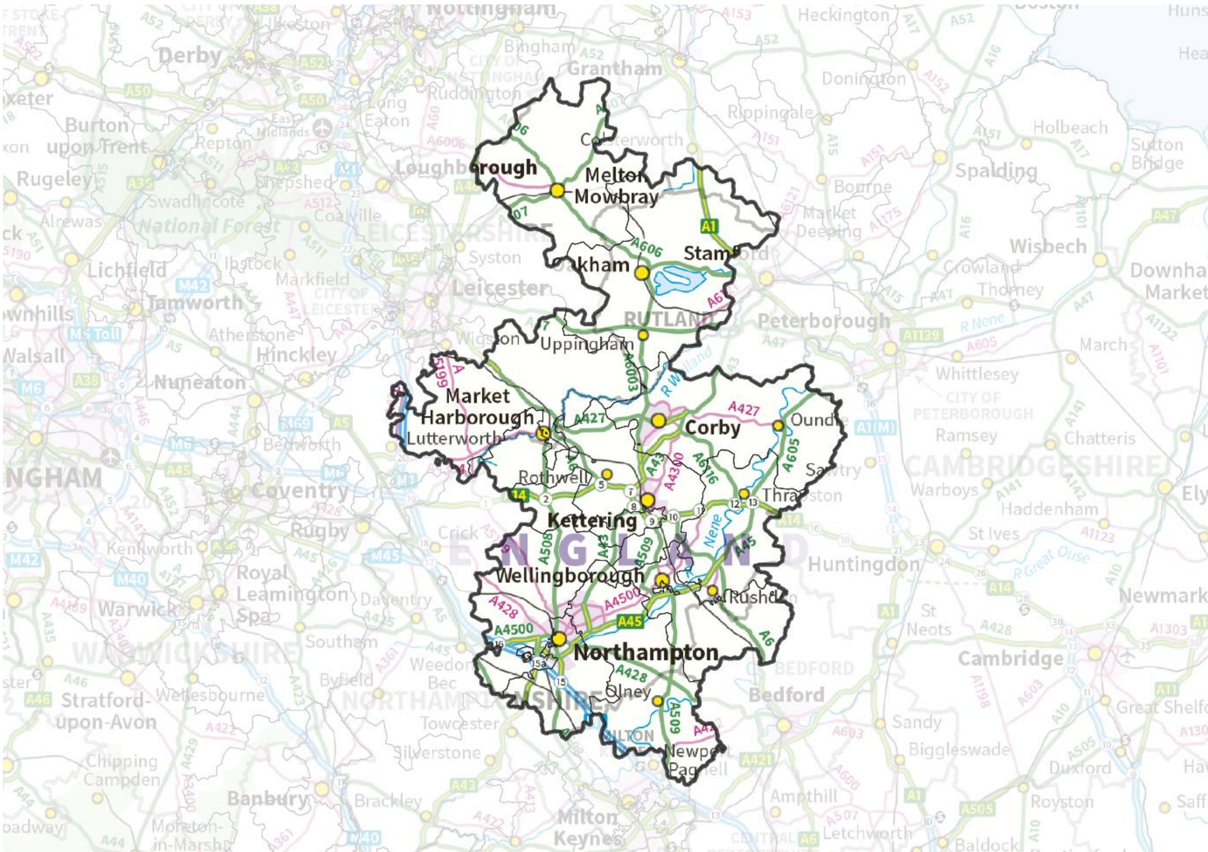

Figure 38: Area supplied by Grendon GSP

Grendon GSP is an infrastructure site supplying:

- WPD East Midlands:
  - three circuits into the Northampton 132 kV network, with three BSPs;
  - four circuits via Kettering and Irthlingborough BSPs to Corby BSP, a 132 kV bussing point that in turn supplies three further BSPs and Corby North, the connection point for Corby Power Station;
  - two circuits to Wellingborough BSP.
- UKPN Eastern:
  - one circuit to ARA and RAE BSPs;
  - two circuits via WPD's Corby BSP that provide alternative 132 kV infeed to Huntingdon BSP.

Loose Couple Management

Generation | Demand

There is a complex series of loose couples via the 11 kV busbars of primary substations that interconnect the 33 kV networks of several WPD East Midlands BSPs in the Grendon network:

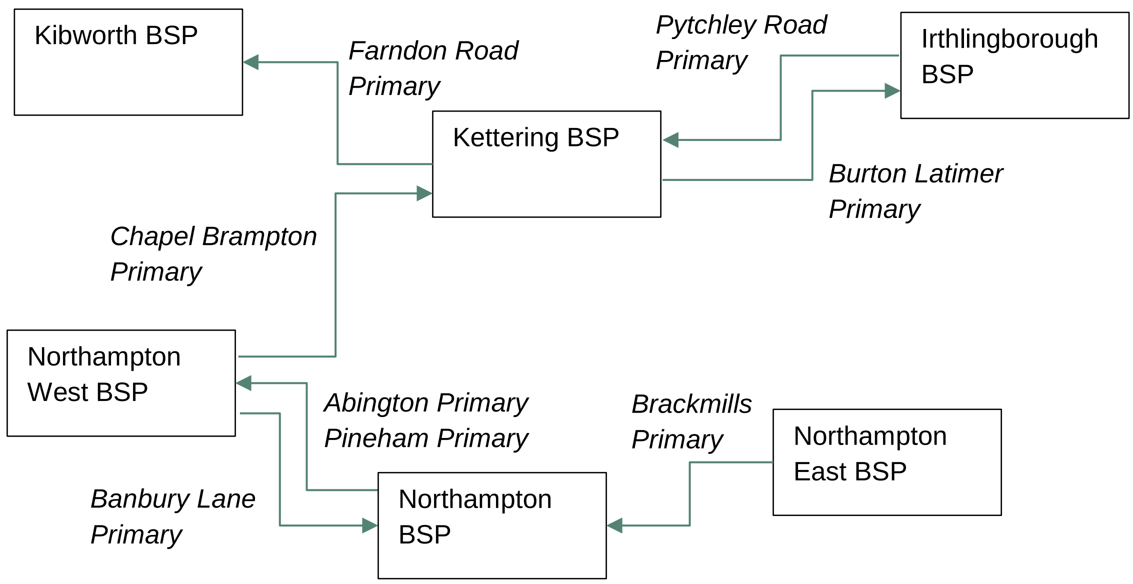

Figure 39: Loose couples between 33 kV networks supplied by Grendon GSP

For any SCO that removes direct GT infeed to one of these 33 kV networks, that 33 kV network will remain back energised via the loose couples. This risks overloads of the loose-coupling primary transformers and their associated 33 kV circuits. Since the 33 kV windings of primary transformers do not have earthed neutrals, this would also create an unearthed network.

For these studies, it was assumed that loose couples would be split as necessary during arranged outages, to avoid placing any 33 kV network at risk of being solely supplied via loose couples for the subsequent fault loss of GT infeed. It has been assumed that each primary would be transferred to whichever BSP it is more strongly associated with; the direction of these transfers is shown by the direction of the arrows in Figure 39.

It is recommended that these splits or equivalent measures are applied operationally to mitigate the risks associated with loose couples.

Northampton 132 kV Network

Generation **Demand**

Northampton West, Northampton and Northampton East BSPs are supplied by three 132 kV circuits from Grendon GSP.

For the SCO of both circuits from Grendon to Northampton, the circuit from Grendon to Northampton East would overload up to 111% of rating at winter peak demand. No overload occurs at summer or intermediate warm peak demand.

For the fault of Grendon 132 kV busbar Main 1, the circuit from Grendon to Northampton GT2 would overload up to 106% of rating at winter peak demand. No overload occurs at summer or intermediate warm peak demand.

Reinforcement is planned to restring both circuits on that route with 500mm² AAAC (Rubus). Although circuit ratings will be partially restricted by the cable sections at each end, the studied overloads will be alleviated. Until reinforcement is complete, outages can be scheduled appropriately to avoid most overloads.

Corby Area 132 kV Network and Grendon SGTs

Generation Demand

Due to the growth of generation across Grendon GSP's network, combined with the existing Corby North Power Station, there are now potential overloads on:

- the 132 kV circuits between Grendon GSP and Corby BSP;
- the 132 kV circuits between Corby BSP and Corby North;
- the Grendon SGTs.

Recently connected generators supplied via these 132 kV circuits are subject to management by ANM, which would resolve the studied overloads. Real world curtailment to date has been zero, in part due to diversity between generator types. If dispatchable generation in the area moves towards baseload operation, real world curtailment may become considerable. This is reflected in the studied network constraints.

Grendon GSP SGTs

Generation Demand

Grendon GSP is shared between WPD East Midlands and UKPN's Eastern network. As such, SGT capacity is National Grid's responsibility. Grendon has five SGTs, and the 132 kV busbars are normally operated split into two sections to keep fault levels within plant ratings:

- SGT2 and SGT3 supply section 1 of the main and reserve busbars;
- SGT1 and SGT4 supply section 2 of the main and reserve busbars;
- SGT5 is a hot standby SGT with two 132 kV circuit breakers, 580 and 585, so that it can be quickly and automatically connected to section 1 or section 2 in the event of a fault disconnecting one of the other SGTs. It does not normally supply load.

For arranged outages of busbars and/or SGTs, a variety of arrangements are used to distribute load amongst SGTs, alongside auto-close schemes available on both the 580/585 SGT5 132 kV circuit breakers and the bus section/coupler circuit breakers.

Various SGT SCOs can also leave overloads on the remaining SGTs in peak demand cases. Careful scheduling of outages, with particular concern to the current operational status of Corby North Power Station (which drives the choice of alternative running arrangement at Grendon GSP due to potential fault level exceedances), and correct selection of the auto-close schemes that are already installed can generally manage the potential overloads.

It is recommended that, as part of the ongoing design and operational liaison between WPD, UKPN and National Grid, detailed joint studies are carried out to assess current and planned running arrangements at Grendon. In particular, the impact on WPD's circuits and the available capacity at Grendon should be considered carefully by both NGET and WPD.

Two of the busbar section faults from normal running will cause the loss of an SGT and the ability to use SGT5 also, leaving a single SGT supplying a large amount of load. Due to the distribution of load across the 132 kV busbars at Grendon, particularly where all of the Northampton load is on busbar 1, a Main 1 fault is far worse than Reserve 2. A Reserve 2 busbar fault causes no overloads outside of reasonable short-term ratings; however, Main 1 faults can cause significant overloads of the remaining SGT2: up to 140% of rating under winter peak load conditions.

A modified normal running arrangement for Grendon 132 kV has been proposed by NGESO and is currently being assessed by WPD. Circuit breaker 580 would be reselected to the

reserve busbar so that an auto-close action is available to mitigate post-fault SGT loading for all credible SGT or busbar faults.

East Claydon GSP

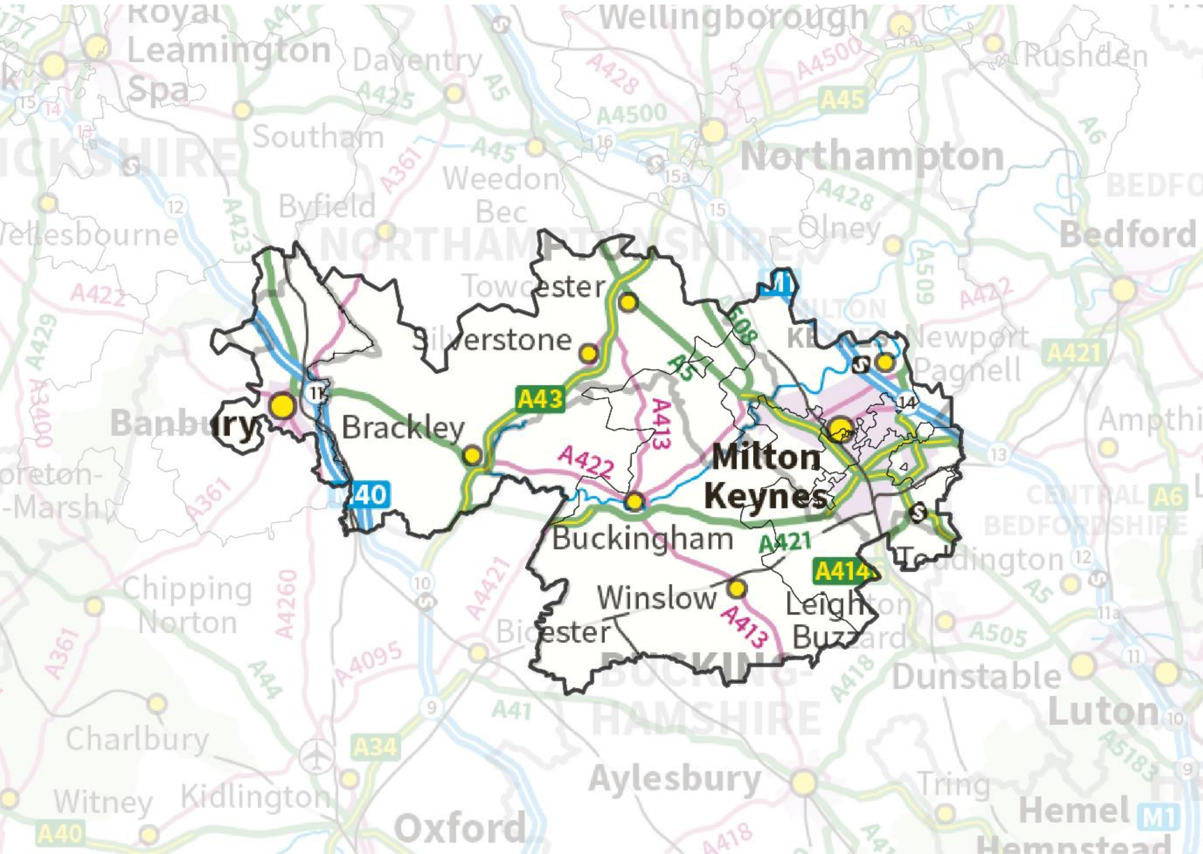

Figure 40: Area supplied by East Claydon GSP. Supplies are also provided to SSEN's Southern licence area

East Claydon GSP is shared between WPD East Midlands, WPD West Midlands and SSEN's Southern network. As such, SGT capacity is National Grid's responsibility. It supplies:

- WPD West Midlands's Banbury BSP;
- WPD East Midlands's:
  - East Claydon BSP;
  - Brackley BSP (teed from WPD West Midlands's tower line to Banbury BSP);
  - Milton Keynes 132 kV network, a four-circuit ring with three BSPs.
- SSEN Southern's new Bicester North BSP via a pair of 132 kV cables.

There are four 400/132 kV 240 MVA SGTs, supplying a 132 kV double busbar. To manage fault level constraints, the 132 kV busbar is normally run split into two nodes, each supplied by two SGTs. These nodes are remote-coupled via Banbury BSP's 132 kV busbar and the Milton Keynes 132 kV network, and loose-coupled via other BSPs in the network.

The Group Demand is 354 MW, with a summer peak demand of 247 MW.

The fault level constraints do not allow three SGTs to run on a single node. For the outage of an SGT, the 132 kV busbar remains split into two nodes, with two SGTs on one node and one SGT on the other node. The subsequent fault loss of the single SGT leaves a node solely supplied via WPD and SSEN remote and loose couples.

Loose Couple Management

Generation **Demand**

There are a complex series of loose couples via the 11 kV busbars of primary substations that interconnect the 33 kV networks of several WPD East Midlands BSPs in the East Claydon network:

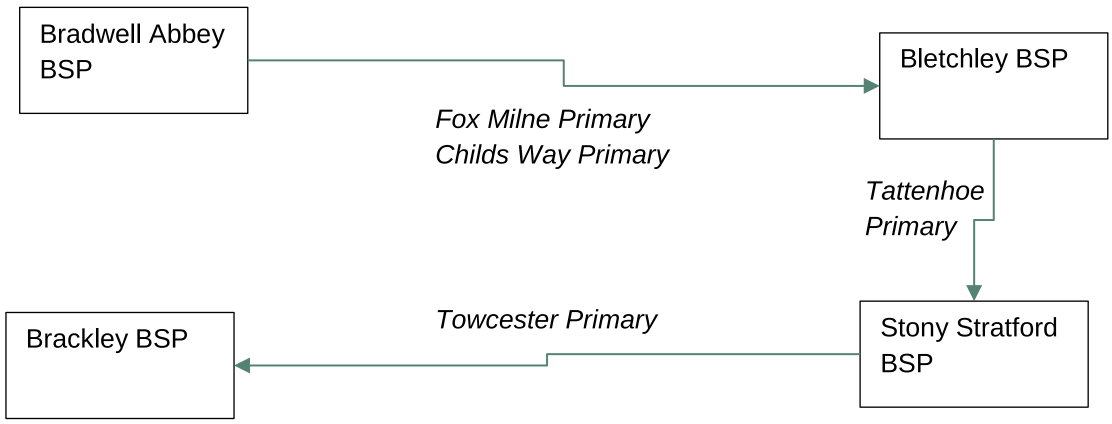

Figure 41: Loose couples between 33 kV networks supplied by East Claydon GSP

For any SCO that removes direct GT infeed to one of these 33 kV networks, the network will remain back energised via the loose couples. This risks overloads of the loose coupling primary transformers and their associated 33 kV circuits. Since the 33 kV windings of primary transformers do not have earthed neutrals, this would also create an unearthed network.

For these studies, it was assumed that loose couples would be split as necessary during arranged outages, to avoid placing any 33 kV network at risk of being solely supplied via loose couples for the subsequent fault loss of GT infeed. It has been assumed that each primary would be transferred to whichever BSP it is more strongly associated with; the direction of these transfers is shown by the direction of the arrows in Figure 41.

It is recommended that these splits or equivalent measures are applied operationally to mitigate the risks associated with loose couples.

Bletchley GT3

Bletchley BSP has three GTs:

- GT1 (60/120 MVA);
- GT2 (60/120 MVA);
- GT3 (60/90 MVA).

The 33 kV board is normally operated as two separate nodes, which are loose-coupled via the 11 kV busbars of several primary substations:

- Node A supplied by GT1 and GT2;
- Node B supplied by GT3.

This makes Bletchley 33 kV node B an unusual case: the fault loss of GT3 removes direct infeed to its 33 kV network without any underlying arranged outage. This has the same risks described above for loss of direct infeed due to an SCO.

It is recommended that an auto-close scheme is commissioned to close the normally open 33 kV bus section circuit breaker 91 at Bletchley BSP for the fault loss of GT3. This would couple the 33 kV busbars solid on GT1 and GT2. It should be possible to disable the scheme for the duration of arranged outages where its operation would be unhelpful.

Chesterfield GSP

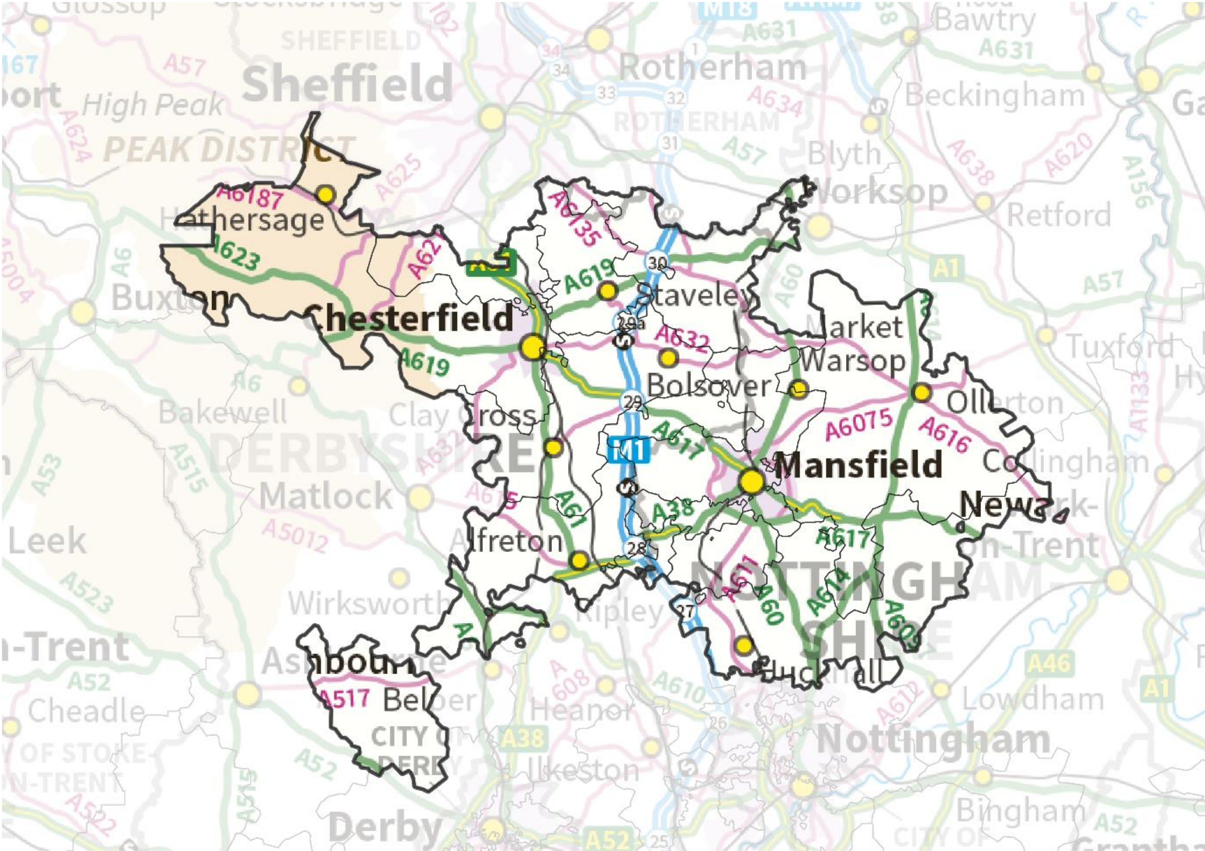

Figure 42: Area supplied by Chesterfield GSP

Mansfield and Clipstone BSP Transfer

Generation | **Demand**

Mansfield and Clipstone BSPs are 132/33 kV sites normally supplied via two 132 kV circuits from Chesterfield GSP. They transfer onto Staythorpe C GSP, via two 132 kV interconnectors, for various planned outages at Chesterfield. In the winter season and during such transfers, a circuit fault on either of the 132 kV circuits from Staythorpe C may potentially overload the other.

These constraints could be managed by:

- **restricting arranged outages to summer and intermediate warm periods only; or**
- **transferring sufficient load out of Mansfield and/or Clipstone (at 11 kV or 33 kV) prior to the arranged outage; or**
- **uprating the 132 kV circuits between Staythorpe C and Clipstone.**

Willington GSP

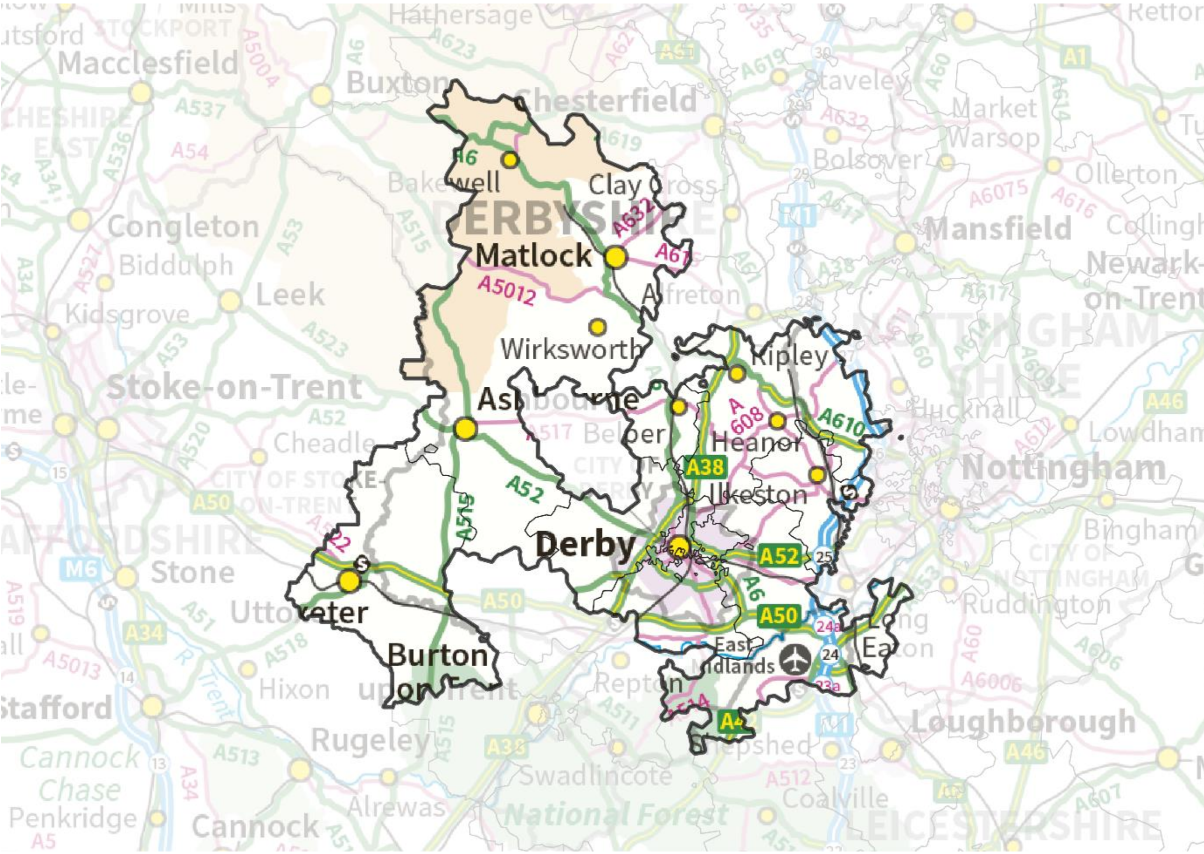

Figure 43: Area supplied by Willington GSP

Winster, Burnaston and Uttoxeter Group

Generation | **Demand**

Winster, Burnaston, and Uttoxeter BSPs are fed via two 132 kV circuits from Willington GSP. Their combined Group Demand is 113 MW; the SCO of both 132 kV circuits interrupts supplies to the group.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of 13 MW is required.

Considerably more than 13 MW of 33 kV post-fault transfer capacity is available, satisfying the requirements of P2.

Willington–Spondon 132 kV Circuits

Generation | **Demand**

Spondon 132 kV is a double busbar site, normally run solid. It is fed via three circuits from Willington GSP, and primarily supplies a large embedded generator, Derby South (GT1 and GT2), Spondon B, Stanton and Heanor BSPs. The circuits are:

- Willington main 1–Burton tee–Spondon main 1;
- Willington main 1–Derby South GT1–Spondon main 1; and
- Willington reserve 1–Derby South GT2–Spondon main 1.

Stanton and Heanor BSPs have two 132 kV interconnectors to Staythorpe C (via Loscoe switching site) and are transferred across for various arranged first circuit outages.

During certain busbar and SCOs, various overloads can be observed across the 132 kV network.

Some of these restrictions are managed via load transfers and post-fault ratings. It is recommended that ongoing review is maintained and load management schemes commissioned to mitigate high-impact, low-probability faults. Depending on how the network develops, more conventional reinforcement options may need to be considered.

Stanton and Heanor BSP Transfers

Generation **Demand**

Stanton and Heanor BSPs are 132/33 kV sites fed via two 132 kV circuits from Spondon. They transfer on to Staythorpe C, via two 132 kV interconnectors through Loscoe 132 kV switching site, for various arranged outages between Willington GSP and Spondon 132 kV.

During such transfers (in the winter and intermediate warm seasons), the 132 kV network between Loscoe and Stanton potentially sees low volts during a fault on either of the Staythorpe C–Loscoe–Heanor circuits.

These constraints could be managed by:

- **restricting the relevant arranged outage to the summer months; or**
- **transferring sufficient load at 33 kV or 11 kV from Stanton to Toton prior to the arranged outage; or**
- **carrying out an assessment to determine the feasibility of raising the target volts at Staythorpe C.**

SGT Capacity

Generation **Demand**

Willington GSP is fed via five SGTs (SGT1, SGT6, and SGT7 are 240 MVA 400/132 kV transformers, whereas SGT4 and SGT5 are 120 MVA 275/132 kV transformers). These are run 3+2 split with SGT1, SGT4 and SGT6 in parallel with each other, and SGT5 and SGT7 in parallel with each other.

Busbar Fault

Generation **Demand**

A busbar fault on Willington reserve 1 during the winter potentially overloads SGT4 and a busbar fault on Willington main 1 potentially overloads SGT5 and SGT7.

These constraints could be managed by:

- **utilising SGT post-fault ratings and transferring load post-fault; or**
- **replacing SGT4 (or SGT5) with a 400/132 kV lower impedance 240 MVA unit and transferring sufficient load permanently to the network it feeds. Further 33 kV or 11 kV interconnections may need to be established to enable this.**

Circuit Outage

Generation | **Demand**

An arranged winter outage on the Willington–Derby GT2A/2B circuit followed by:

- a fault on SGT1 will potentially overload SGT6;
- a fault on SGT6 will potentially overload SGT1;
- a fault on either of the Derby South/Spondon circuits will potentially overload SGT4.

Similarly, an arranged winter outage on the Willington–Derby GT1A/1B circuit followed by a fault on SGT7 will potentially overload SGT5.

These constraints could be managed by:

- **restricting the arranged outages to summer and intermediate warm periods only; or**
- **relying on the SGTs' post-fault ratings and transferring load post-fault; or**
- **replacing SGT4 with a 400/132 kV lower impedance 240 MVA unit.**

Staythorpe GSP

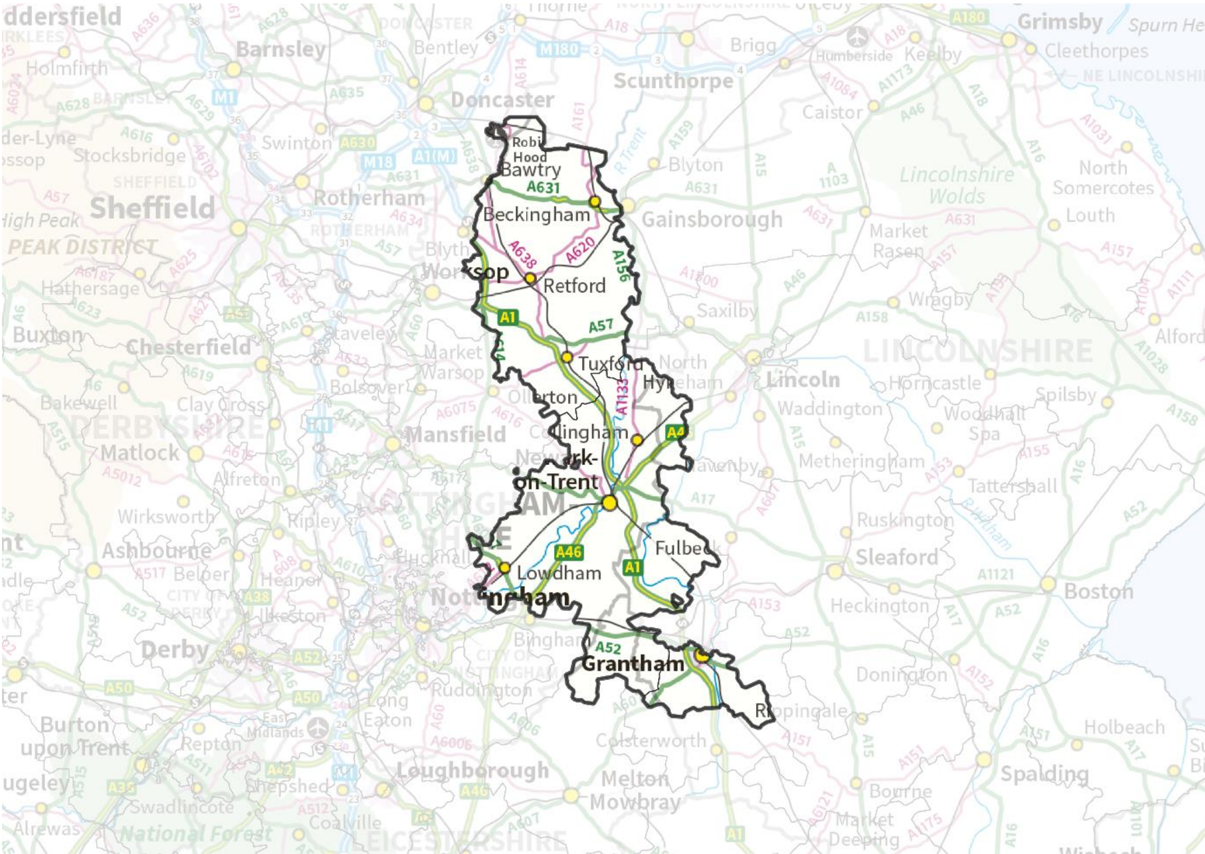

Figure 44: Area supplied by Staythorpe GSP

Staythorpe GSP is comprised of two adjacent substations: Staythorpe C and Staythorpe B, with two 132 kV interconnecting circuits between them. Staythorpe C has two SGTs and six 132 kV outgoing feeders; Staythorpe B has seven outgoing 132 kV feeders only (six WPD feeders and one National Grid feeder). Due to fault level limitations on the switchgear at Staythorpe B, the main and reserve busbars at the two substations are operated split, with the 132 kV bus couplers at both substations run normally open. There is one SGT supplying each 132 kV node. There are loose couples at

Checkerhouse and Hawton BSPs (at 33 kV) and at Grantham North and Grantham South BSPs (at 11 kV).

Checkerhouse/Hawton/Grantham North/Grantham South Transformer Overloads

Generation **Demand**

An arranged outage of one of the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuits or one of the Staythorpe–Checkerhouse 132 kV circuits causes the loose couple at Hawton BSP or Checkerhouse BSP, respectively, to be broken. A subsequent fault on one of the SGTs at Staythorpe GSP, or on one of the Staythorpe C–Staythorpe B interconnectors, can cause overloads on any or all of the transformers at Grantham North, Grantham South, Checkerhouse or Hawton BSPs. Similar overloads occur when there is an arranged busbar outage at Staythorpe B or Staythorpe C followed by one of the faults described above.

These overloads are caused by load back fed via the loose couples on the Staythorpe network and occur in all seasons. In some cases, the overloads can be over 130% of the relevant transformer rating and Directional Over Current (DOC) protection has been shown not to be effective at preventing these overloads in all cases.

A project is planned to replace the 132 kV switchgear at Staythorpe B substation, which would allow Staythorpe to be run solid and thus alleviate the issues identified. This scheme is currently expected to be completed by 2024.

In the meantime, when an outage is taken on one of the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuits or on one of the Staythorpe–Checkerhouse circuits, it is recommended that an SGT at Staythorpe GSP be taken off load and the 132 kV bus couplers at Staythorpe C and Staythorpe B substations be closed. Alternatively, when one of these outages is taken, the bus sections at Hawton, Checkerhouse, Grantham North and Grantham South BSPs could be opened (as appropriate) and any downstream loose couples broken.

Staythorpe/Grantham South/Bourne Low Voltage

Generation **Demand**

There are two 132 kV feeders from Staythorpe B that feed Grantham South BSP and then onwards to open points at Bourne BSP (Bourne BSP itself is normally fed from Walpole GSP). The No2 feeder (circuit breaker 105 at Staythorpe B) also feeds one transformer at Bourne West BSP.

An arranged outage of one of these circuits followed by a fault on one of the Staythorpe C–Staythorpe B interconnectors can cause the 132 kV voltage at Bourne, Grantham South, Grantham North and Staythorpe to drop below 90% of nominal. The voltage dips occur as the remaining Staythorpe–Grantham South/Bourne West/Bourne 132 kV circuit is being fed via the loose couples at Checkerhouse and Grantham North BSPs.

The worst undervoltages occur at winter peak demand, when the voltage can drop to 12% below nominal voltage, but undervoltages can also occur at intermediate warm peak demand. However, none of the 132 kV nodes at which undervoltages occur have any 132 kV-metered customers connected, so the statutory limit of –10% does not apply to these nodes; voltages are within statutory limits on the 33 kV and 11 kV sides of grid transformers at the affected BSPs.

The impact of the undervoltages is minimal as no 132 kV-metered customers are connected to any of the affected 132 kV nodes and statutory voltages are maintained on the 33 kV and 11 kV

busbars at the affected BSPs. Furthermore, the planned Staythorpe 132 kV switchgear replacement scheme previously described will resolve the identified issue.

In the meantime, it is recommended that arranged outages of either of the Staythorpe–Grantham South/Bourne West/Bourne 132 kV circuits are undertaken during the summer period only. If arranged outages are undertaken outside of the summer period, it is recommended that an SGT at Staythorpe GSP be switched out and the 132 kV bus couplers at Staythorpe C and Staythorpe B substations be opened.

GSP Lost Load

Generation **Demand**

Staythorpe GSP has a Group Demand of 189 MW. The SCO of both SGTs at Staythorpe GSP interrupts supplies to the group. As described above, it is also necessary to offload one SGT as part of the management of certain other arranged outages.

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand is restored within three hours of an SCO. In this case, restoration of 63 MW is required.

Considerably more than 63 MW of 132 kV post-fault transfer capacity into the Staythorpe 132 kV network is available, satisfying the requirements of P2. In the situations where an SGT has been offloaded as part of the management of another outage, it can be brought back on load to restore the group.

Staythorpe/Hawton/Asfordby Low Voltage

Generation **Demand**

Staythorpe C circuit breakers 105 and 505 feed the two 132 kV circuits to Hawton/Asfordby/Melton Mowbray. Under an arranged outage of either circuit breaker, Hawton and Asfordby BSPs can be back fed from Grendon GSP via Melton Mowbray BSP, to maintain double circuit security.

If there is a subsequent fault on one of the Staythorpe–Hawton/Asfordby/Melton Mowbray circuits, the 132 kV voltage at Staythorpe and Hawton drops up to 17% below nominal voltage (the statutory limit is –10%). This occurs under winter and intermediate warm loadings. There are no 132 kV-metered customers connected to this part of the circuit and the 33 kV voltage at Hawton BSP is within statutory limits. However, under winter loadings, the 132 kV voltage at Asfordby BSP can drop to 12% below nominal voltage and Asfordby BSP is a 132 kV-metered connection.

It is recommended that Hawton and Asfordby BSPs are only transferred onto Grendon GSP in summer. If outages are taken outside of the summer period, they should be left on the remaining circuit from Staythorpe GSP.

Corby–Corby North 132 kV Circuit Outage

Generation Demand

Corby North Power Station is normally fed from Grendon GSP via Corby BSP. When there is an outage of one of the Corby–Corby North 132 kV circuits, one of the three generating units at Corby North Power Station can be transferred to Staythorpe GSP via Melton Mowbray BSP.

Staythorpe–Hawton/Asfordby/Melton Mowbray Circuit Overload

Generation Demand

When the above running arrangement is in place, a subsequent fault on one of the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuits causes an overload on the other circuit up to 106% of rating. The overload only occurs in the summer peak generation studies.

It is recommended that arranged outages are scheduled around the seasonal output of generators in this area. This may prevent arranged outages in summer.

If access is required at times of high generator output, sufficient generation should be curtailed to prevent this overload. Curtailment could be applied pre-fault during the arranged outage, or an intertripping scheme could be commissioned to apply it post-fault.

Bourne/Spalding Transfer into Staythorpe

Generation **Demand**

Under certain outage scenarios on the Walpole network, Bourne and Spalding BSPs can be transferred into Staythorpe GSP.

Staythorpe SGT Overloads

Generation **Demand**

An arranged outage causing Bourne and Spalding BSPs to be transferred to Staythorpe GSP, followed by a fault on one of the SGTs at Staythorpe, can cause considerable overloads on the remaining SGT. The overloads occur with both winter and intermediate warm loadings and can be up to 142% of rating. National Grid has confirmed that the SGTs at Staythorpe have a 20-minute rating of 342 MVA (143% of rating), meaning that the overloads seen are just within the short-term ratings.

It is recommended that Bourne and Spalding BSPs be transferred to Staythorpe GSP during the summer period only if possible. For transfers outside of this period, prompt action will be required by WPD control to de-load the remaining SGT to within its continuous rating in the event of a subsequent SGT fault. If it is not practicable to rely on the 20-minute SGT rating then it is recommended that sufficient demand be transferred away from Staythorpe GSP to accept the incoming BSPs and/or an additional SGT be installed at Staythorpe GSP.

Annesley Transfer to Staythorpe

Generation **Demand**

Under certain outage scenarios of the 132 kV switchgear/busbars at Annesley BSP, Annesley can be transferred to Staythorpe GSP.

Annesley Low Voltage

Generation **Demand**

If Annesley BSP is transferred to Staythorpe GSP, a subsequent SGT fault at Staythorpe GSP can cause low volts on the 132 kV busbars at Annesley BSP. The undervoltage occurs under winter loadings only and can be as low as 12% below nominal voltage (the statutory limit is –10%). However, there are no 132 kV-metered customers connected to the Staythorpe–Annesley 132 kV circuits and the voltage is within statutory limits on the 33 kV busbars at Annesley BSP.

The impact of the undervoltages is minimal as no 132 kV-metered customers are connected to any of the affected 132 kV nodes and statutory voltages are maintained on the 33 kV and 11 kV busbars at the affected BSPs. Furthermore, the planned Staythorpe 132 kV switchgear replacement scheme previously described will resolve the identified issue. In the meantime, it is recommended that this transfer is not made in winter.

Bicker Fen GSP

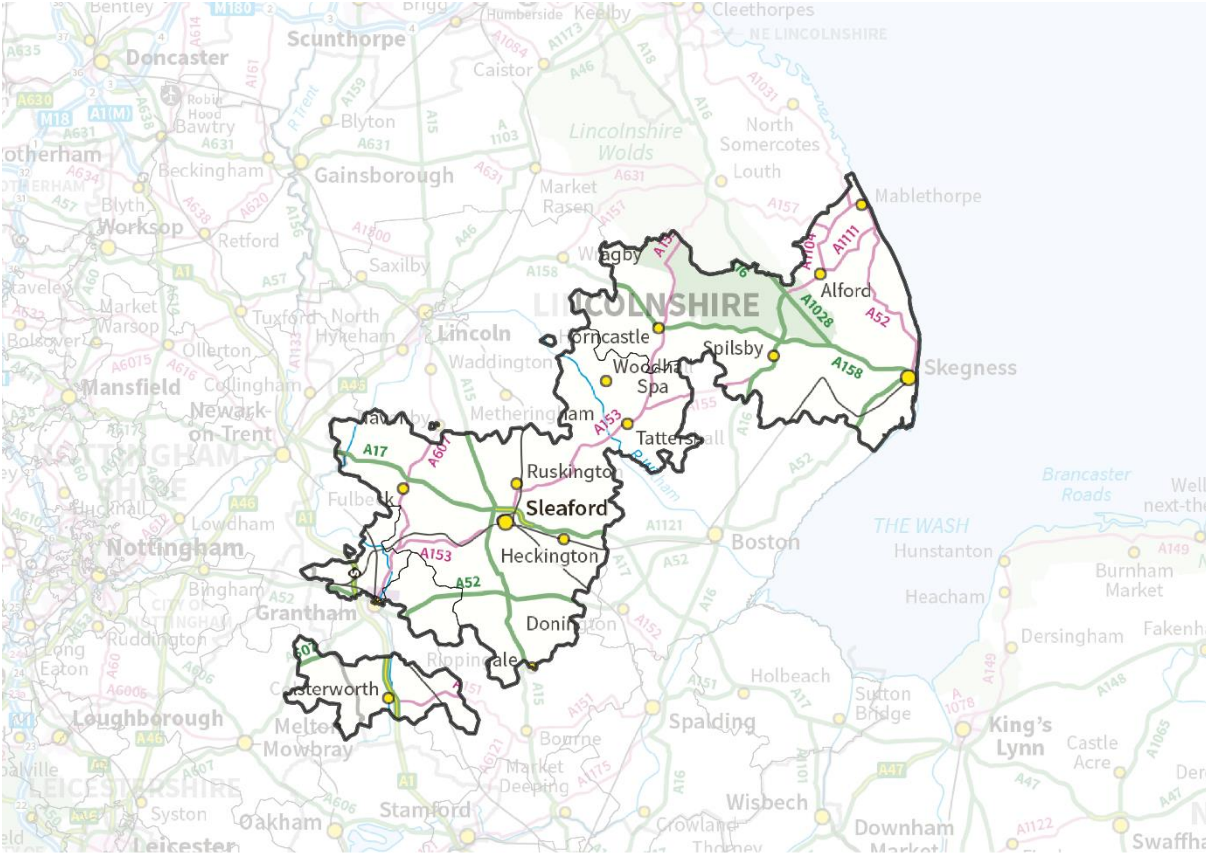

Figure 45: Area supplied by Bicker Fen GSP

Bicker Fen SGT Outages

Generation **Demand**

Bicker Fen GSP comprises two SGTs and has four outgoing 132 kV feeders. Under an arranged outage of one of the SGTs at Bicker Fen GSP, Skegness and Middlemarsh BSPs are transferred to Walpole GSP to maintain double circuit security.

Grantham and Sleaford Lost Load

Generation **Demand**

Sleaford BSP, Grantham BSP and the 132/25 kV GTs at Grantham North BSP are supplied by two 132 kV circuits from Bicker Fen. Their combined Group Demand is 117 MW; the SCO of both 132 kV circuits interrupts supplies to the group.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of 17 MW is required.

Considerably more than 17 MW of 132 kV transfer capacity into the group is available from Staythorpe GSP at Grantham North BSP, satisfying the requirements of P2.

Middlemarsh Wind Farm Connections

Generation Demand

Middlemarsh substation is the 132 kV exit point for two offshore wind farms. Each wind farm is tee-connected to one of the transformer feeders from Boston BSP to Skegness BSP.

Inner Dowsing Wind Farm

Generation Demand

Inner Dowsing Wind Farm is supplied by the 132 kV Boston–Skegness/Middlemarsh number 1 circuit. An intertrip scheme is in place to ensure that the wind farm is disconnected automatically in the event of a fault on this circuit.

This circuit is in turn supplied at Boston by a 132 kV circuit from Bicker Fen GSP, or for certain arranged outages, a 132 kV circuit from Walpole GSP. The fault loss of the upstream circuit or associated 132 kV busbar at the upstream GSP removes direct 132 kV infeed from the 132 kV Boston–Skegness/Middlemarsh number 1 circuit. That would leave Inner Dowsing Wind Farm in service, back energised via the 33 kV busbar and GTs at Skegness BSP (and Boston BSP if it is selected to the same 132 kV circuits). This risks overloading those GTs and 33 kV busbars.

It is recommended that the intertrip be cascaded so that Inner Dowsing Wind Farm is also tripped for the fault loss of the upstream circuit or associated 132 kV busbar at the upstream GSP. The intertrip should be automatically selected to whichever circuit and busbar is currently upstream.

Lynn Wind Farm

Generation Demand

Lynn Wind Farm is supplied by the 132 kV Boston–Skegness/Middlemarsh number 2 circuit. An intertrip scheme is in place to ensure that the wind farm is disconnected automatically in the event of a fault on this circuit.

This circuit is in turn supplied at Boston by a 132 kV circuit from Bicker Fen GSP, or for certain arranged outages, a 132 kV circuit from Walpole GSP. The fault loss of the upstream circuit or associated 132 kV busbar at the upstream GSP removes direct 132 kV infeed from the 132 kV Boston–Skegness/Middlemarsh number 2 circuit. That would leave Lynn Wind Farm in service, back energised via the 33 kV busbar and GTs at Skegness BSP (and Boston BSP if it is selected to the same 132 kV circuits). This risks overloading those GTs and 33 kV busbars.

It is recommended that the intertrip be cascaded so that Lynn Wind Farm is also tripped for the fault loss of the upstream circuit or associated 132 kV busbar at the upstream GSP. The intertrip should be automatically selected to whichever circuit and busbar is currently upstream.

Sleaford/Grantham Transfer to Staythorpe

Generation **Demand**

For certain arranged outages at Bicker Fen GSP, Sleaford and/or Grantham BSPs are transferred to Staythorpe GSP, usually to maintain double circuit security.

Staythorpe–Grantham North 132 kV Circuit Overload

Generation Demand

If Sleaford and/or Grantham BSPs are back fed from Staythorpe GSP and there is a subsequent fault on one of the Staythorpe C–Staythorpe B interconnectors, or a fault on one of the Staythorpe–Grantham North 132 kV circuits, this causes an overload on the other Staythorpe–Grantham North 132 kV circuit. Overloads occur for all seasonal loadings and can be up to 123% of circuit rating.

It is recommended to avoid transferring Sleaford and Grantham BSPs to Staythorpe GSP where possible, as the transfer is not necessary to comply with P2, or transfer Grantham BSP only. If both Sleaford and Grantham BSPs are transferred then it is recommended that the 33 kV bus sections at Sleaford and Grantham BSPs be opened. Any downstream loose couples would also need to be broken.

Grantham/Sleaford/Skegness Loose Couples

Generation Demand

The 33 kV interconnectors between Grantham, Sleaford and Skegness BSPs are run normally open so that none of these BSPs operate in parallel. There are, however, two primary substations that straddle different BSPs and run with their 11 kV bus sections normally closed: Billingborough (between Grantham and Sleaford BSPs) and Horncastle (between Sleaford and Skegness BSPs).

For an arranged outage of a grid transformer at Grantham, Sleaford or Skegness BSPs, a subsequent fault on the remaining grid transformer at the same BSP will result in the entire BSP demand being supplied via the above loose couples. This causes considerable overloads under all seasonal loading conditions and DOC protection has been shown not to prevent such overloads in all outage/fault scenarios. Since the 33 kV windings of primary transformers do not have earthed neutrals, this would also create an unearthed network.

It is recommended that the 11 kV bus section at Billingborough PSS be opened when there is a grid transformer outage at Grantham or Sleaford BSPs and the 11 kV bus section at Horncastle PSS should be opened when there is a grid transformer outage at Sleaford or Skegness BSPs. This should be done anyway if the arranged outage results in two coupled BSPs being supplied by different GSPs i.e. where the loose couple forms a grid parallel.

Boston Transfer into Bicker Fen

Generation Demand

Under certain outages at Walpole GSP or an outage of one of the Walpole–Boston 132 kV circuits, Boston BSP is transferred into Bicker Fen GSP, usually to maintain double circuit security.

Bicker Fen–Boston 132 kV Circuit Overloads

Generation Demand

When Boston BSP is back fed from Bicker Fen GSP and there is a subsequent fault on one of the Bicker Fen–Boston 132 kV circuits, this can cause an overload on the remaining circuit. Overloads only occur with summer loadings and are caused due to the amount of generation on this part of the network. Such overloads can be up to 115% of circuit rating.

It is recommended that planned outages be undertaken outside of the summer period where possible. If outages are taken during the summer, it is advisable to open the 33 kV bus

sections at Boston and Skegness BSPs and break any downstream loose couples. Consideration should also be given to constraining 33 kV and 11 kV generation connected to Boston BSP when Boston is back fed from Bicker Fen GSP.

Bicker Fen SGT Overloads

Generation | **Demand**

When Boston BSP is back fed from Bicker Fen GSP and there is a subsequent fault on one of the SGTs at Bicker Fen GSP, this can cause an overload on the remaining SGT. Overloads occur both in summer (due to generation) and in winter (due to demand). Overloads can be up to 107% of rating in the summer and up to 106% of rating in winter. National Grid has advised that the SGTs at Bicker Fen GSP have a 20-minute rating of 274 MVA (114% of rating); however, the short-term ratings cannot be applied when there is reverse power flow.

It is suggested that planned outages involving the transfer of Boston BSP to Bicker Fen GSP take place under intermediate warm loadings only, where possible. For outages taken in the winter period, potential overloads on the SGTs under the outage/fault scenario above are within the 20-minute SGT rating. However, in the event of a fault, WPD control will need to de-load the remaining SGT promptly to within its continuous rating.

For outages taken during the summer period, the short-term SGT ratings cannot be used. A TANM scheme is planned for Bicker Fen GSP to manage reverse power flow through the SGTs. Consideration should also be given to constraining 33 kV and 11 kV generation connected to Boston BSP when Boston is back fed from Bicker Fen GSP.

If the affected outages are required at a time of year where there is a risk of overload, it is recommended that the 33 kV bus sections at Sleaford and Grantham BSPs and the 132 kV bus coupler at Bicker Fen (CB230) be opened when Boston BSP is transferred to Bicker Fen GSP. This is in addition to opening bus sections at Boston and Skegness BSPs, as described above, to avoid overloading the Bicker Fen–Boston 132 kV circuits. Any other loose couples will also need to be opened. These actions should also be applied if it is not practicable to use the short-term SGT ratings.

Walpole GSP

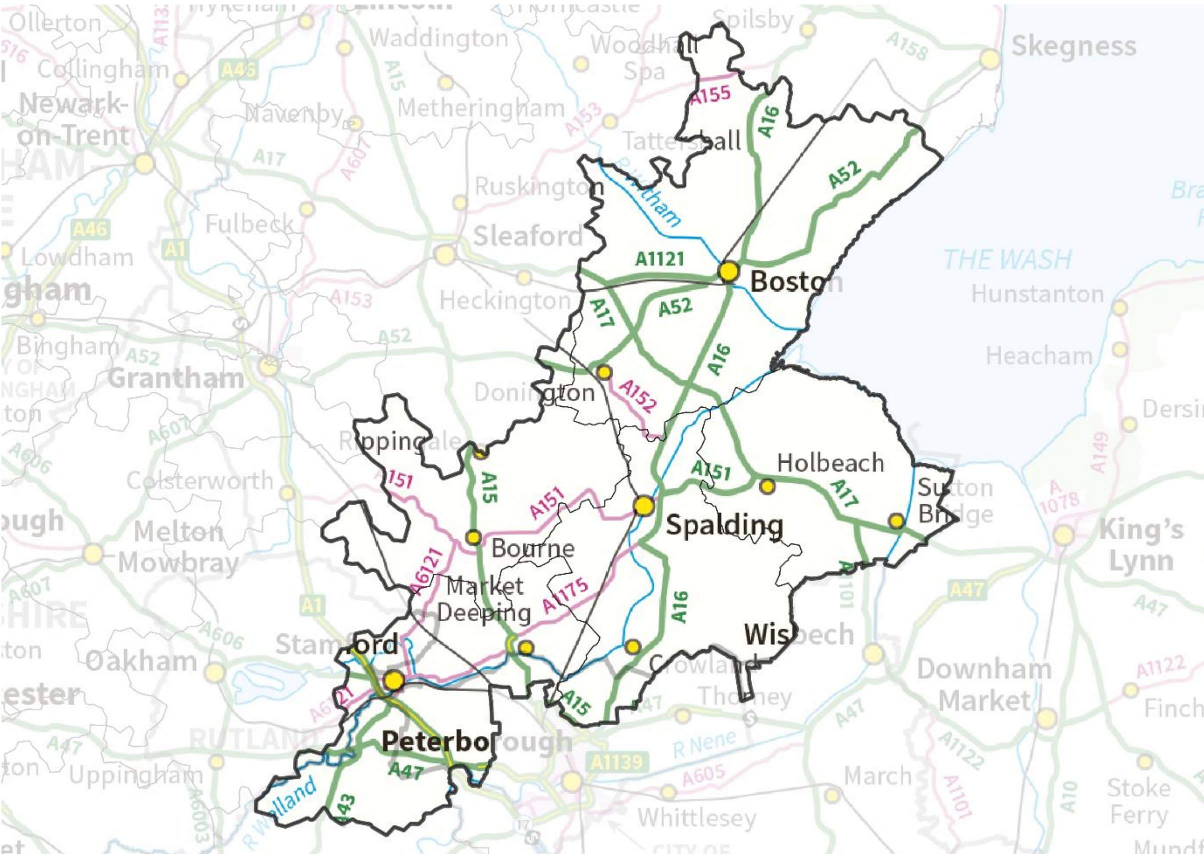

Figure 46: Area supplied by Walpole GSP. Supplies are also provided to UKPN's Eastern licence area

Walpole GSP is shared between WPD East Midlands and UKPN's Eastern network. As such, SGT capacity is National Grid's responsibility. WPD's Bourne area network is supplied from Walpole by two 132 kV circuits, and UKPN's Peterborough area network is supplied by four 132 kV circuits. A 132 kV circuit between WPD's Stamford BSP and UKPN's Peterborough North BSP interconnects these two networks, and is operated normally closed. A further two 132 kV circuits from Walpole supply WPD's Boston BSP. No issues have been identified for the WPD-only baseline studies on Walpole GSP.

It is recommended that the impact of these scenarios on the interdependent Peterborough and Bourne area 132 kV networks is studied in more detail in conjunction with UKPN to inform their future development.

Bourne BSP

Bourne BSP is a complex substation with two 132/33 kV transformers and a complex 132 kV switchgear arrangement. There are two incoming feeders from Walpole GSP via South Holland and Spalding BSPs and outgoing feeders to Stamford BSP and to Lincoln BSP (via Bourne West and Sleaford REP). There are also two 132 kV circuits to Staythorpe/Grantham South/Bourne West, although these are normally open.

At the time of writing, Bourne BSP is undergoing a project to replace the 132 kV switchgear. All studies have been based on the post-rebuild layout at Bourne BSP.

West Burton GSP

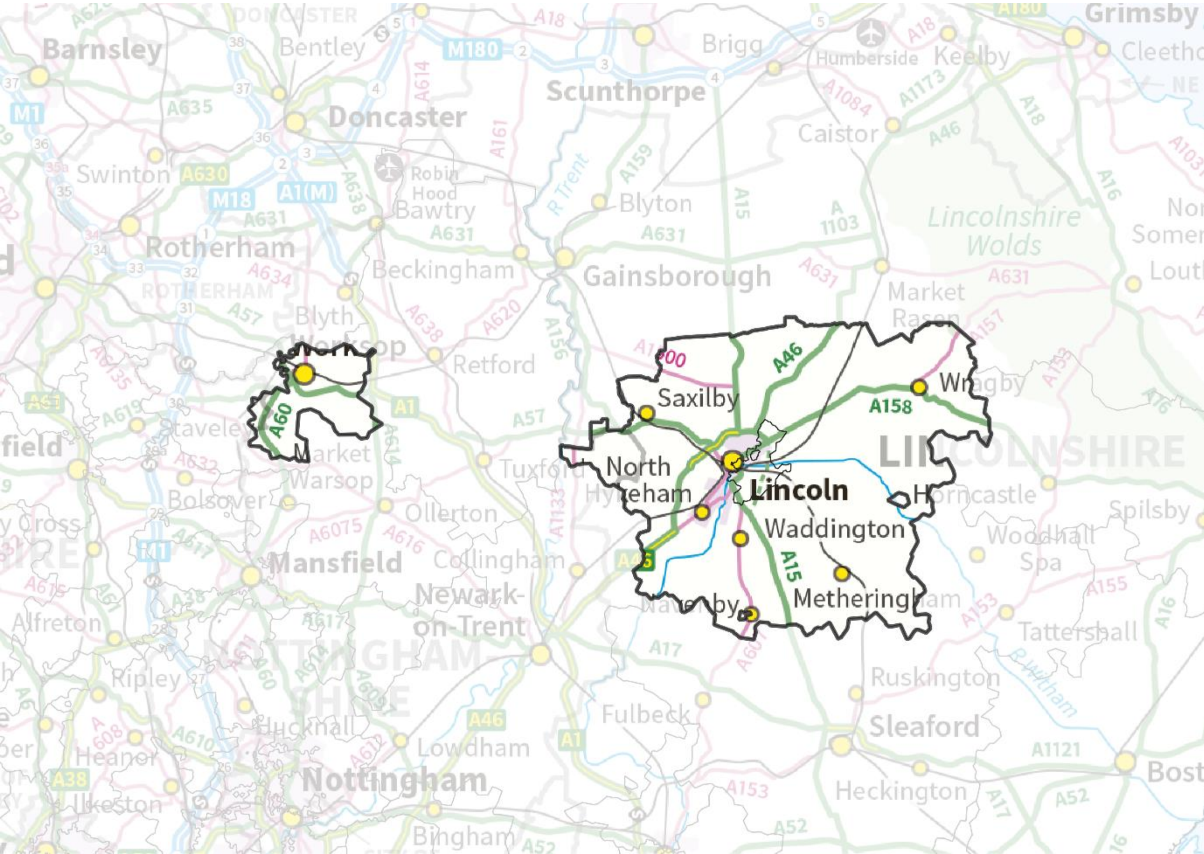

Figure 47: Area supplied by West Burton GSP. Supplies are also provided to West Burton Power Station

West Burton Power Station

Generation **Demand**

West Burton GSP is shared between WPD East Midlands and West Burton Power Station. As such, SGT capacity is National Grid's responsibility. West Burton GSP has two 400/132 kV 240 MVA SGTs supplying:

- two WPD circuits towards Retford/Checkerhouse/Worksop;
- two WPD circuits towards Lincoln/North Greetwell; and
- two third-party station transformers for West Burton Power Station.

The 132 kV switchboard at West Burton GSP runs split due to fault level limitations, with one SGT and one of each pair of circuits on each node. The two nodes are remote-coupled through Lincoln BSP 132 kV busbar, and loose-coupled through the 33 kV busbar at Worksop BSP.

As West Burton Power Station is a National Grid customer, WPD has limited visibility of the power station's load and internal network. For the purposes of these studies, it has been assumed that the power station operates with a normal open point on its 11 kV busbar, to prevent loose coupling the two 132 kV nodes through the power station's 11 kV busbar. An estimated 30 MVA demand was assigned to each of the two 11 kV busbars. Initial studies based upon these assumptions have indicated that certain outage scenarios could cause considerable overloads on WPD's network.

It is recommended that more detailed studies on the interaction between networks supplied by West Burton 132 kV are carried out in conjunction with National Grid.

West Burton SGT Outages

Generation **Demand**

The two SGTs at West Burton GSP are rated at 240 MVA each. National Grid has provided a 20-minute SGT rating of 315 MVA (131% of nameplate rating), meaning that demand can exceed the nameplate rating for a short period.

West Burton SGT Overloads

Generation **Demand**

An outage of one of the SGTs at West Burton GSP, or a 132 kV busbar fault at West Burton GSP can cause an SGT overload of up to 119% of rating. Overloads occur during the winter and intermediate warm periods but are within the short-term SGT rating.

A project is currently being delivered to install a third SGT at West Burton GSP, which was triggered due to the issue identified. This scheme is currently expected to be completed by October 2020. Until the third SGT scheme is completed, it is suggested that SGT outages at West Burton GSP take place during the summer period where possible. For outages outside of the summer period, it is recommended that demand be moved to adjacent GSPs to ensure that the SGT rating is not exceeded. In the case of a fault outage, this will require prompt action by WPD control to de-load the remaining SGT to within its continuous rating.

West Burton–Retford/Checkerhouse/Worksop 132 kV Circuit Outages

Generation **Demand**

There are two 132 kV feeders out of West Burton GSP towards Retford, Checkerhouse and Worksop BSPs. Checkerhouse BSP itself is normally fed from Staythorpe GSP via two 132 kV circuits, which, together with the feeders from West Burton GSP, provide transfer capacity between Staythorpe and West Burton GSPs.

An arranged outage of one of the West Burton–Retford/Checkerhouse/Worksop 132 kV circuits followed by the fault loss of the SGT supplying the other 132 kV node leaves most load in the network supplied via the 132 kV busbars at Lincoln BSP.

Lincoln Voltage Collapse

Generation **Demand**

Supplying much of the group via Lincoln 132 kV under this SCO puts considerable impedance between the GSP and the load. At winter peak demand, loading on the circuit between the remaining SGT and Lincoln exceeds its transfer capacity. This causes voltage collapse at Lincoln 132 kV and all downstream buses.

The voltage collapse overloads the remaining SGT up to 231% of nameplate rating, and the circuit from that SGT to Lincoln up to 172% of rating. No voltage collapse was observed at other times of year.

Retford Low Voltage

Generation | **Demand**

Some variations of this SCO do not cause voltage collapse, but do cause low volts on the 25 kV busbar at Retford BSP. The undervoltage only occurs under winter peak loading and the voltage can drop to 8% below nominal (the statutory limit is –6%). No undervoltage occurs at other times of year.

Reinforcement Strategy

The aforementioned scheme to install a third SGT at West Burton GSP will resolve both identified issues.

Until this scheme is delivered, it is recommended to avoid taking an outage of the West Burton–Retford/Checkerhouse/Worksop 132 kV circuits during winter, where possible. For outages taken during the winter period, it is recommended that an SGT at West Burton GSP be switched out and the 132 kV bus couplers at West Burton be closed when the arranged outage is taken.

West Burton–Lincoln 132 kV Circuit Outages

Generation | **Demand**

Lincoln BSP is normally fed via two 132 kV circuits from West Burton GSP. There is a third 132 kV circuit from Walpole GSP via Bourne BSP, but this is operated normally open and is only used under the SCO of both circuits from West Burton. The circuit from Walpole GSP is limited to 97 MVA by volt drop and usually requires other BSPs to be switched away if the circuit is to be used to feed Lincoln BSP.

Lincoln Lost Load

Generation | **Demand**

Lincoln BSP has a Group Demand of 188 MW. The SCO of both 132 kV circuits from West Burton GSP interrupts supplies to the group.

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand is restored within three hours of an SCO. In this case, restoration of 63 MW is required.

The alternate 132 kV circuit from Walpole GSP satisfies the requirements of P2. If further restoration were required, it may be possible to improve this circuit's transfer capacity using reactive compensation at Lincoln BSP.

Worksop Transformer Overloads

Generation | **Demand**

When there is an arranged outage on one of the West Burton–Lincoln 132 kV circuits, or an arranged 132 kV busbar outage at Lincoln BSP, a subsequent fault on one of the SGTs at West Burton GSP can cause an overload on the transformers at Worksop BSP. Overloads can occur both under summer and winter loadings and can be up to 125% of the transformer rating. DOC protection has been shown not to be effective at preventing overloads in all scenarios.

When the third SGT at West Burton GSP is installed, the issue identified will no longer exist. In the meantime, it is recommended that an SGT at West Burton GSP be taken off load and the 132 kV bus couplers at West Burton be closed when the arranged outage is taken.

Lincoln 132 kV Busbar Outages

Generation **Demand**

There are three main sections of 132 kV busbar at Lincoln BSP, each section having one of the three 132 kV infeeds. This means that any busbar outages at Lincoln cause one of the 132 kV infeeds to be lost, and thus cause similar results to those described above when there is a 132 kV circuit outage.

West Burton SGT Overload

Generation **Demand**

An arranged or fault outage of 132 kV busbar section 1 or 2 at Lincoln BSP leaves all of the BSP supplied by one of the two circuits from West Burton. Lincoln 132 kV is an integral part of the load balancing between the two nodes of the split 132 kV busbar at West Burton GSP, so at winter peak demand this would cause an overload of one of the SGTs. The SGT overload can be up to 103% of rating. National Grid has provided a 20-minute SGT rating of 315 MVA (131% of nameplate rating) so the overload in this case is well within the short-term SGT rating.

It is recommended that the use of a solid running arrangement at West Burton GSP be investigated, so that under the above-arranged outage, the demand can be shared more evenly between the SGTs at West Burton. Once the third SGT at West Burton GSP is installed, this could take the form of a ‘2+1’ arrangement. This running arrangement may trigger third-party fault level reinforcement works at West Burton GSP.

Whilst West Burton GSP operates with a split running arrangement, it is recommended that planned 132 kV busbar outages at Lincoln BSP be taken outside of the winter period where possible. For planned outages taken during the winter period, it will be necessary to move demand off West Burton GSP to bring the SGT loading to within its continuous rating. In the case of a fault outage, this will require rapid intervention by WPD control.

GSP Lost Load

Generation **Demand**

West Burton GSP has a Group Demand of 224 MW. The SCO of both SGTs at West Burton GSP interrupts supplies to the group. As described above, it is also necessary to offload one SGT as part of the management of certain other arranged outages.

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand is restored within three hours of an SCO. In this case, restoration of 75 MW is required.

Considerably more than 75 MW of 132 kV post-fault transfer capacity into the West Burton 132 kV network is available, satisfying the requirements of P2. In the situations where an SGT has been offloaded as part of the management of another outage, it can be brought back on load to restore the group.

Checkerhouse Transfer into West Burton

Generation **Demand**

Under certain 132 kV busbar outages at Staythorpe or an outage of one of the Staythorpe–Checkerhouse 132 kV circuits, Checkerhouse BSP is transferred to West Burton GSP, usually to maintain double circuit security.

West Burton SGT Overload

Generation | **Demand**

When Checkerhouse BSP is transferred into West Burton GSP under an arranged outage, a subsequent fault on one of the SGTs at West Burton GSP can cause an overload on the other SGT. Overloads occur under winter and intermediate warm loadings and can be up to 142% of the SGT rating. National Grid has provided a 20-minute SGT rating of 315 MVA (131% of nameplate rating), but winter loadings cause even this rating to be exceeded.

The previously mentioned installation of SGT3 at West Burton GSP will resolve the overload identified. Until then, it is advisable to restrict transfers of Checkerhouse BSP to West Burton GSP to the summer period only if possible. For outages taken during the intermediate warm period, the SGT loading can reach 118% of rating under the fault/outage scenario described above, but this is within the 20-minute SGT rating. Rapid intervention will be required by WPD control in the event of a fault, in order to de-load the SGT to within its continuous rating.

For outages taken during the winter period, it is recommended that the 33 kV bus sections at Checkerhouse and Worksop BSPs and the 33 kV and 11 kV bus sections at Lincoln BSP be opened, in order to avoid causing an overload in excess of the SGT short-term rating. Any downstream loose couples will also need to be broken. These actions should also be applied for outages during the intermediate warm period if it is not practicable to apply the short-term SGT rating.

8 – 2022 Results

Berkswell GSP

Network Changes Modelled

The fourth SGT and associated bus coupler 230 that are due to be commissioned by 2022 have been included in the model under all scenarios. The running arrangement has been modelled as three SGTs in parallel onto a solid 132 kV busbar and one SGT on hot standby. This option can only be utilised if Berkswell GSP substation fault rating can be increased following a survey and any subsequent works being carried out. This running arrangement is the preferred option for Berkswell GSP. For the purpose of these studies, it has been assumed that any subsequent work to uprate the fault rating of the substation will have been completed by 2022, and this preferred running arrangement will be in place. Additionally, an auto-close scheme on the hot standby SGT4 has been assumed, to be brought on-load for the fault loss of another Berkswell SGT.

By 2022, Group Demand is projected to grow from 312 MW in baseline to the figures shown in Table 9.

Table 9: Projected Group Demand on Berkswell GSP in 2022

Scenario	Group Demand
SP	344 MW
CE	345 MW
TD	364 MW
CR	390 MW

SGT Overloads

Generation **Demand**

Following the installation of SGT4 and the associated bus coupler 230, the SGT overloads identified in baseline studies have all been alleviated.

Warwick BSP GT Capacity

132/33 kV GT Capacity

Generation **Demand** SP CE TD CR

The overloads described in the baseline results increase under all scenarios in the 2022 studies. For the SCO of any two of these GTs, the remaining GT supplies the group load. If the remaining GT is GT1A or GT3A (the lower rated units), this SCO combination would overload the Warwick 132/33 kV GT to between 111% and 127% for winter peak demand, and between 104% and 118% for intermediate warm peak demand. This overload does not occur at summer peak demand.

It is recommended that the sufficiency of the available access window for the 132/33 kV GTs at Warwick be confirmed.

If the arranged outage is required outside of summer, the overloads could be alleviated by methods such as:

- **load management schemes, for example flexibility services;**
- **transferring sufficient demand from Warwick 132/33 kV BSP for the duration of the arranged outage;**
- **replacing Warwick 132/33 kV GT1A and GT3A with 60/90 MVA units.**

For the purposes of these studies, it was assumed that the transformers would be replaced with 60/90 MVA units. It may be possible to defer this reinforcement through access scheduling.

132/11 kV GT Capacity

Generation **Demand** SP CE TD CR

The overloads described in the baseline results increase under all scenarios in the 2022 studies. For the SCO of any two of these GTs, the remaining GT supplies the group load. These SCO combinations would overload the Warwick 132/11 kV GTs to between 136% (Steady Progression) and 145% (Community Renewables) for a winter peak demand case, and to between 128% and 136% for an intermediate warm peak demand case. The overload would also be as much as 103% and 109% for summer peak demand.

Changing the 11 kV running arrangements at Warwick to disconnect some load for the SCO of two GTs would alleviate the studied overloads without affecting the P2 compliance of this network.

Warwick and Harbury Lost Load

Generation **Demand** SP CE TD CR

The lost loads described in the baseline results increase under all scenarios in the 2022 studies. Warwick (132/11 kV and 132/33 kV) and Harbury (132/33 kV) BSP sites are supplied via two 132 kV circuits from Berkswell GSP. Their combined Group Demand exceeds 100 MW and under various second circuit outages, the entire demand is lost.

Demand growth to 2022 increases the combined Group Demand of Warwick and Harbury BSPs to between 159 MW (Steady Progression) and 192 MW (Community Renewables). As described in baseline, the group load is interrupted for the SCO of both 132 kV circuits between Berkswell and Warwick.

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand be restored within three hours of an SCO. In this case, restoration of between 53 MW (Steady Progression) and 64 MW (Community Renewables) would be necessary. At least 40 MW of transfer capacity is available into this group via 33 kV circuits.

It is recommended that:

- **a reinforcement scheme to bring additional SCO infeed to the Warwick and Harbury group is developed. Further demand growth in the scenarios to 2027 triggers a third 132 kV circuit from Berkswell to Warwick;**
- **flexibility services are procured as necessary to maintain SCO compliance until reinforcement is complete.**

Coventry GSP

Network Changes Modelled

For the 2022 studies, it has been assumed that Rugby 25 kV British Rail has been disconnected from the network. A section circuit breaker 160 has also been modelled between reserve busbar sections 1 and 2 at Coventry GSP.

By 2022, Group Demand is projected to grow from 487 MW in baseline to the figures shown in Table 10.

Table 10: Projected Group Demand of Coventry GSP in 2022

Scenario	Group Demand
SP	528 MW
CE	529 MW
TD	552 MW
CR	570 MW

SGT Overloads

Generation Demand SP CE TD CR

The overloads described in the baseline results increase further under all scenarios in the 2022 studies. The arranged outage of an SGT followed by the fault of a second SGT leaves the group load supplied by the remaining SGTs. Depending on the SCO combination, the remaining SGTs in service can overload up to:

- 174% of nameplate rating at winter peak demand;
- 142% of nameplate rating at intermediate warm peak demand;
- 119% of nameplate rating at summer peak demand.

The studied Coventry SGT overloads could be alleviated for intermediate warm/summer peak seasons by:

- **transferring Hinckley 33 kV onto Enderby GSP for an arranged SGT outage at Coventry GSP; and**
- **implementing an auto-close scheme on the Coventry 132 kV bus couplers to operate following an SCO SGT fault, to balance the loading across the remaining SGTs.**

With these mitigations, it is still possible to schedule Grid Code SGT Access Periods within the summer and intermediate warm rating seasons.

Daventry Tee to Rugby Main 1 132 kV (AB Route)

Generation Demand SP CE TD CR

The arranged outage of Coventry GSP circuit breaker 405 leaves the HZ route towards Hinckley BSP (33 kV) and the tee to Pailton BSP in service. The subsequent fault of the Coventry GSP circuit breaker 505 circuit leaves all of Hinckley 33 kV, Pailton and Daventry supplied via the Daventry tee to Rugby Main 1 132 kV circuit (AB route). This SCO condition overloads the Daventry tee to Rugby

Main 1 132 kV circuit to as much as 116% at winter peak demand for all scenarios and 101% at intermediate warm peak demand for Community Renewables only.

This overload does not occur for the arranged outage of Coventry circuit breaker 505 (feeding the other HZ route), as Pailton is only fed from one side of the HZ route. This means Hinckley and Pailton are fed on separate circuits following the subsequent fault of the Coventry–Hinckley/Daventry/Rugby Main 3 circuit outage.

It is recommended that the adequacy of the available access window for Coventry circuit breaker 405 be confirmed.

If a wider access window is required, it is recommended that when an outage of circuit breaker 405 at Coventry GSP is taken either:

- **the Hinckley/Pailton circuit fed from circuit breaker 405 is switched out to mitigate the next fault risk. This leaves Hinckley 33 kV at next fault risk, but remains P2 compliant as the Hinckley demand can be resupplied via the normally open interconnectors with Enderby; or**
- **Hinckley is transferred into Enderby for the arranged outage, to maintain double circuit security and remove the overload identified.**

Coventry to Hinckley Tee 132 kV (HZ Route)

Generation **Demand** SP CE TD CR

For an arranged busbar outage of Rugby BSP Main 1, followed by a fault of the Coventry–Hinckley 1/Daventry 2 132 kV circuit, the Coventry to Hinckley tee 132 kV HZ circuit (feeder 405) overloads by as much as 113% at winter peak demand. This condition leaves all of Hinckley 33 kV, Pailton and Daventry BSPs fed via Coventry circuit breaker 405. No overloads are seen at intermediate warm or summer peak demand under any scenario.

Furthermore, for an arranged busbar outage of Rugby BSP main 4, followed by an SGT1 fault at Coventry GSP, the Coventry to Hinckley tee 132 kV HZ route (505 feeder) overloads. This overload only occurs under the Two Degrees and Community Renewables scenarios and only at winter peak demand.

In Two Degrees and Community Renewables, the Coventry to Hinckley tee 132 kV HZ route circuit (505 feeder) also overloads up to 105% at winter peak demand.

It is recommended that the sufficiency of the available access window for the arranged outage be confirmed.

If the arranged outage window is not sufficient, the studied overloads could be alleviated by reconductoring the existing 175mm^2 ACSR (Lynx) conductor on the HZ route between Coventry GSP and the Hinckley tee with 300mm^2 AAAC (Upas), profiled for operation at 75°C. For the purpose of these studies, it has been assumed that the reconductoring would be carried out; it may be possible to defer this reinforcement through access scheduling.

Coventry to Rugby Main 2 and 4 132 kV (CP Route)

Generation **Demand** SP CE TD CR

At Coventry GSP, there is a section circuit breaker 120 between main busbar sections 1 and 2, but there is not currently a section circuit breaker between reserve busbar sections 1 and 2. This means that a fault on either reserve busbar section results in both being de-energised, with all of Coventry

GSP being supplied by SGT1 and SGT2. This busbar fault overloads the Coventry circuit breaker 705 to Rugby circuit breaker 405 circuit to between 100% (Steady Progression) and 108% (Community Renewables) at winter peak demand. This overload occurs because two of the four infeeds to the Rugby ring are lost for this busbar fault.

A reserve section circuit breaker 160 between reserve busbar sections 1 and 2 at Coventry GSP would alleviate these overloads. As described above, the installation of circuit breaker 160 was also recommended in baseline to resolve SGT overloads for the same busbar faults.

The arranged outage of SGT3 followed by the fault outage of SGT4 leaves Coventry reserve busbar remotely coupled via Rugby BSP 132 kV. This overloads the Coventry circuit breaker 705 to Rugby Main 2 circuit (CP route) to between 124% (Steady Progression) and 136% (Community Renewables) at winter peak demand. Overloads are also seen for intermediate warm demand by as much as 114%.

Implementing an auto-close scheme on the Coventry 132 kV bus couplers, to operate following an SCO SGT fault to balance the loading across the remaining SGTs alleviates these overloads.

The arranged outage of Coventry Main 2, followed by the fault of the Coventry circuit breaker 405 to Hinckley/Pailton circuit, overloads the Coventry circuit breaker 705 to Rugby Main 2 (CP route) circuit to between 107% (Steady Progression) and 114% (Community Renewables) for winter peak demand only. This overload is caused by poor load share between the Main 1 and the reserve busbars. The CP route circuit that is fed from Main 1 picks up the majority of the Rugby ring demand. This is because all of Coventry North and Whitley BSPs are fed from the reserve busbars for the Coventry Main 2 outage. Coventry North BSP can be reselected to Main 1, but this effectively creates a loose couple across the split busbars. The HK route that feeds Whitley and provides interconnection with Berkswell are both connected onto section 2, so for the arranged outage of Main 2 there is no ability to feed one circuit from section 1.

It is recommended that the sufficiency of the available access window for the arranged outage be confirmed.

It is also recommended that a further study be undertaken to re-assess the busbar section load distribution at Coventry GSP. If the overloads cannot be mitigated by improving the load share, then increasing the rating of the CP route circuits would resolve the overloads identified.

The overhead sections of these circuits are 300mm² AAAC (Upas); the circuit ratings are constrained by the cable sections at either end. If the arranged outage window is not sufficient, the studied overloads could be alleviated by overlaying these cables with a larger cable type such as 1000mm² copper Cross Linked Poly-Ethylene (XLPE), to allow full use of the overhead section ratings. For the purpose of these studies, it has been assumed that the overlaying would be carried out; it may be possible to defer this reinforcement through access scheduling.

Coventry to Whitley 132 kV Circuit Overloads

Generation **Demand** SP CE TD CR

For an arranged outage of a Berkswell–Coventry West/Coventry South 132 kV circuit, Coventry South 33 kV is routinely transferred into Coventry GSP to maintain double circuit security. The subsequent 132 kV circuit fault of either side of the HK route overloads the remaining circuit on the HK route between Coventry GSP and Whitley BSP.

These SCO combinations overload the remaining Coventry to Whitley 132 kV circuit to between 110% (Steady Progression) and 120% (Community Renewables) for a winter peak demand case, and to between 100% (Consumer Evolution) and 108% (Community Renewables) for an intermediate warm peak demand case. This overload does not occur for a summer peak demand case.

It is recommended that Coventry South 33 kV be transferred onto Coventry GSP only where seasonal loading and ratings allow.

If the transfer is required at other times of year, the studied overloads could be alleviated by reconductoring the existing 175mm² ACSR (Lynx) conductor on the HK route between Coventry GSP and Whitley BSP with 300mm² AAAC (Upas), profiled for operation at 75°C. For the purpose of these studies, it has been assumed that the reconductoring would be carried out; it may be possible to defer this reinforcement through a review of the Coventry South 33 kV transfer.

Nuneaton (132/33 kV) Lost Load

Generation **Demand** CR

Nuneaton (132/33 kV) BSP site is supplied via two 132 kV circuits from Coventry GSP. In Community Renewables, the Group Demand increases to 103 MW. For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW be restored within three hours of an SCO. In this case, restoration of 3 MW is required.

Sufficient transfer capability is available between Nuneaton and Coventry North BSPs to satisfy the requirements of P2.

Enderby GSP

Network Changes Modelled

For the 2022 studies, Enderby GSP has been modelled with all four SGTs operating in parallel, as this is the planned running arrangement following the replant of Leicester BSP 132 kV.

The existing twin 175mm² ACSR (twin Lynx) conductors on each circuit of the CN route will be reprofiled to 75°C by 2022.

By 2022, Group Demand is projected to grow from 507 MW in baseline to the figures shown in Table 11.

Table 11: Projected Group Demand of Enderby GSP in 2022

Scenario	Group Demand
SP	568 MW
CE	574 MW
TD	596 MW
CR	613 MW

SGT overloads

Generation | **Demand**

SP CE TD CR

In 2022, the 132 kV busbar at Enderby GSP is modelled with all four SGTs running in parallel, supplying main and reserve busbar sections 1 and 2.

The overloads described in the baseline results increase further under all scenarios in the 2022 studies. The arranged outage of an SGT followed by the fault of another leaves Enderby GSP fed by the remaining two SGTs and causes overloads up to:

- 143% of nameplate rating at winter peak demand;
- 119% of nameplate rating at intermediate warm peak demand.

These overloads do not occur for the summer peak demand condition.

If the available access window is insufficient, National Grid may be able to determine short-term ratings for the Enderby SGTs, which would allow loading to be managed by post-fault transfers.

If short-term ratings are not available, then the access window could be extended by transferring Coalville 132/33 kV onto Ratcliffe-on-Soar GSP for any SGT arranged outage at Enderby GSP. This transfer would trigger 132 kV circuit reinforcement between Ratcliffe-on-Soar GSP and Loughborough tee. With the transfer, it is still possible to schedule Grid Code SGT Access Periods within the summer and intermediate warm ratings seasons.

Enderby to Leicester 132 kV (CC and CN) Circuits

Generation | **Demand**

SP CE TD CR

The overloads described in the baseline results increase under all scenarios in the 2022 studies. For an arranged outage of one CC route circuit, followed by the loss of the 132/33 kV GT at Leicester fed from the other 132 kV busbar or vice versa, this leaves a CN route circuit feeding all of one 132 kV busbar and the 33 kV busbar at Leicester.

Furthermore, an arranged outage followed by a fault (in either order) of one CN route circuit and the 132/33 kV GT at Leicester fed from the other 132 kV busbar leaves a CC route circuit feeding all of one 132 kV busbar and the 33 kV busbar at Leicester.

The 2022 studies now indicate that any of the four CC or CN route 132 kV circuits, depending on the outage, can overload up to 121% for a winter peak demand case (Community Renewables), and up to 107% for an intermediate warm demand case (Community Renewables).

It is recommended that the sufficiency of the available access window for the arranged outage be confirmed.

If the arranged outage window is not sufficient, the studied overloads could be alleviated by improving the load balance between the Leicester to Enderby 132 kV circuits. This can be achieved by coupling the two Leicester 132 kV busbars, either locally or at remote BSPs.

Wigston 132/33 kV Transformers

Generation | **Demand**

CR

There are a number of first circuit fault conditions that can cause the Wigston 132/33 kV grid transformers to overload. For a fault of Leicester Main busbars 1 or 4, or for a circuit fault on either of the Leicester–Wigston/Kibworth 132 kV circuits, the remaining in-service Wigston 132/33 kV grid transformer will overload up to 103% for a winter peak demand case. This only occurs for the Community Renewables scenario.

It is recommended that existing Wigston 132/33 kV GT1B and GT2B be replaced with 60/90 MVA units. For the purpose of these studies, it has been assumed that these transformers would be replaced.

Wigston Tee to Leicester 132 kV (AZ Route)

Generation **Demand** SP CE TD CR

For arranged circuit/busbar outages at Corby BSP, Kibworth BSP is transferred into Enderby GSP. For a subsequent SCO circuit fault to one of the Leicester–Wigston/Kibworth 132 kV circuits, the remaining Leicester to Wigston tee 132 kV circuit (AZ route) can overload. These overloads occur during the winter peak demand, intermediate warm peak demand and summer peak demand cases.

The Leicester to Wigston tee 132 kV circuits (AZ route) can overload by up to:

- 122% of circuit rating at winter peak demand;
- 110% of circuit rating at intermediate warm peak demand;
- 106% of circuit rating at summer peak demand.

Kibworth is only transferred into Enderby for an arranged outage that leaves Kibworth at single circuit risk. There are no P2 or network integrity requirements to transfer Kibworth for an arranged outage. Leaving Kibworth at single circuit risk remains P2-compliant, as the Group Demand does not go above 40 MW under any scenario. Following the fault, the majority of the demand could still be resupplied via Enderby GSP.

If the ability to transfer Kibworth was required, the studied overloads could be alleviated by reconductoring the existing 175mm² ACSR (Lynx) conductor on the HZ route between Leicester and Wigston tee with 300mm² AAAC (Upas), profiled for operation at 75°C. For the purpose of these studies, it has been assumed that the reconductoring would be carried out; it may be possible to defer this reinforcement through a review of the Kibworth transfer.

Hinckley BSP 132/11 kV GT Capacity

Generation **Demand** SP CE TD CR

Hinckley BSP 132/11 kV currently has two 15/30 MVA, 132/11 kV GTs that are normally fed from Enderby GSP via the 132 kV double circuit AP route.

For the outage of either 132/11 kV GT, the remaining GT in service would overload up to 123% of rating at winter peak demand, and up to 119% of rating at intermediate warm peak demand. The overload would also occur up to 108% for a summer peak demand case.

A 15/30 MVA transformer is the largest two-winding transformer WPD currently install as standard for a 132/11 kV transformation, which means the transformers cannot be replaced with larger units.

The Hinckley BSP 132/11 kV GT overloads could be alleviated by transferring demand to Hinckley BSP 132/33 kV, potentially with a new 33/11 kV primary substation. As the 132/33 kV GTs are normally supplied from Coventry GSP, the impact of the transfer on the wider network would have to be studied in detail.

Coalville 132/33 kV GT Capacities

Generation | **Demand**

TD CR

Coalville 132/33 kV currently has two 45/90 MVA, 132/33 kV GTs that are normally fed from Enderby GSP via the 132 kV HE route.

A circuit fault of one of the Enderby to Coalville/Hinckley 132 kV circuits (HE Route), leaving Coalville with one grid transformer in service, results in an overload of 102% at winter peak demand for the Community Renewables scenario only. Busbar faults at Enderby GSP during winter peak demand periods can overload the remaining Coalville GT up to 107% (Two Degrees and Community Renewables), and during intermediate warm periods up to 102% (Community Renewables only).

These studied Coalville 132/33 kV BSP overloads can be alleviated by installation of a third 132/33 kV 90 MVA grid transformer at Coalville BSP, or by permanently transferring load away from Coalville to other BSPs.

Enderby 132 kV Busbar Faults

Generation | **Demand**

TD CR

The fault outage of a 132 kV busbar at Enderby supplying a Hinckley/Coalville circuit leaves the downstream 132 kV circuits back fed via the 33 kV or 11 kV busbars of the associated BSPs. This leaves part of the Hinckley 11 kV demand fed via the Coalville 33 kV busbar. This busbar fault marginally increases the overload seen on the Coalville GT for the fault outage of the other GT.

These busbar faults should be taken into account when designing the recommended reinforcements for Coalville and Hinckley BSPs. It may prove appropriate to intertrip from Enderby to the GT LV circuit breakers for these busbar faults.

These busbar faults would also leave new 132 kV generators on these circuits back energised via the 33 kV busbar at Coalville and the 11 kV busbar at Hinckley. This risks overloading the GTs at those BSPs.

It is recommended that the loss-of-mains intertripping to these new generators covers the condition where a busbar fault at Enderby leaves the generator back energised.

Leicester Lost Load

Generation | **Demand**

SP CE TD CR

Leicester 132/33 kV BSP is supplied via two 132 kV circuits, one from each of the independent Leicester 132 kV busbars. By 2022, the Group Demand of Leicester increases to as much as 129 MW (Community Renewables) and for certain SCO conditions, the entire group is lost.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW be restored within three hours of an SCO. In this case, restoration of 29 MW is required.

Sufficient 33 kV post-fault transfer capacity into Leicester BSP 33 kV network is available, satisfying the requirements of P2.

Leicester East Lost Load

Generation Demand TD CR

Leicester East 132/33 kV BSP is supplied via two 132 kV circuits, one from each of the independent Leicester 132 kV busbars. The Group Demand increases in 2022 to as much as 107 MW under Community Renewables and Two Degrees; the SCO of both grid transformers interrupts supplies to the group.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW be restored within three hours of an SCO. In this case, restoration of 7 MW is required.

Sufficient 33 kV post-fault transfer capacity is available within the Leicester group, satisfying the requirements of P2.

Leicester North Lost Load

Generation Demand TD CR

Leicester North 132/33 kV BSP is supplied via two 132 kV circuits, one from each of the independent Leicester 132 kV bars. By 2022, the Group Demand increases to as much as 107 MW under Community Renewables and Two Degrees; the SCO of both grid transformers interrupts supplies to the group.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW be restored within three hours of an SCO. In this case, restoration of 7 MW is required.

At least 20 MW of 33 kV post-fault transfer capacity is available within the Leicester group, satisfying the requirements of P2.

Coalville and Hinckley (132/11 kV) Lost Load

Generation Demand SP CE TD CR

Coalville and Hinckley (132/11 kV) BSPs are supplied via two 132 kV circuits from Enderby GSP. The Group Demand increases in 2022 to as much as 152 MW under Community Renewables.

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand is restored within three hours of an SCO. In this case, restoration of up to 52 MW (Community Renewables) would be necessary.

Coalville can be transferred into Ratcliffe-on-Soar and Hinckley can be transferred into Coventry, satisfying the requirements of P2 under all scenarios.

Ratcliffe-on-Soar GSP

Network Changes Modelled

A section circuit breaker 160 has been modelled between reserve busbar sections 1 and 2 at Ratcliffe-on-Soar GSP.

By 2022, Group Demand is projected to grow from 419 MW in baseline to the figures shown in

Table 12.

Table 12: Projected Group Demand of Ratcliffe-on-Soar GSP in 2022

Scenario	Group Demand
SP	472 MW
CE	473 MW
TD	496 MW
CR	511 MW

SGT Overloads

Generation **Demand** SP CE TD CR

The overloads described in the baseline results increase further under all scenarios in the 2022 studies. Under the arranged outage of an SGT followed by the fault of a second SGT, the group load is supplied by the remaining SGTs. Depending on the SCO combination, the remaining SGTs in service can overload up to:

- 144% of nameplate rating at winter peak demand;
- 125% of nameplate rating at intermediate warm demand;
- 105% of nameplate rating at summer peak demand.

The studied Ratcliffe-on-Soar SGT overloads could be alleviated by methods such as:

- **transferring Nottingham North 11 kV onto Stoke Bardolph GSP for an arranged SGT outage at Ratcliffe-on-Soar GSP;**
- **implementing an auto-close scheme on the Ratcliffe-on-Soar 132 kV bus couplers to operate following an SCO SGT fault, to balance the loading across the remaining SGTs.**

With these mitigations, it is still possible to schedule Grid Code SGT Access Periods within the summer and intermediate warm rating seasons.

Reserve Busbar Fault

Generation **Demand** SP CE TD CR

There is a section circuit breaker 120 between main busbar sections 1 and 2, but no section circuit breaker between reserve busbar sections 1 and 2. This means that a fault on either reserve busbar section results in both sections being de-energised, with all of Ratcliffe-on-Soar GSP being supplied by SGT4 and SGT6.

SGT4 and SGT6 can overload to between 101% of nameplate rating (Steady Progression) and up to 111% of nameplate rating (Community Renewables). These overloads occur under the winter peak demand condition only.

It is recommended that this fault condition is reviewed with National Grid – it may be possible for National Grid to manage post-fault SGT loading with short-term ratings. If not, the installation of a 132 kV reserve section circuit breaker 160 would mean that only one busbar section and SGT is lost for either reserve busbar fault.

For the purpose of these studies, a section circuit breaker 160 has been modelled.

Loughborough Tee to Ratcliffe-on-Soar 132 kV SZ Route Overloads

Generation Demand SP CE TD CR

As described in baseline, transferring Coalville BSP into Ratcliffe-on-Soar GSP can trigger overloads of the SZ route between Ratcliffe-on-Soar and Loughborough tee. It was recommended that this transfer be made only where seasonal loading and ratings allow.

Demand growth to 2022 under all scenarios extends this overload to summer peak demand, at up to 127% of rating.

To continue to be able to transfer Coalville BSP onto Ratcliffe-on-Soar GSP pre-fault, it would be necessary to reconductor the existing $175mm^2$ ACSR (Lynx) conductor on the SZ route between the Loughborough tee and Ratcliffe-on-Soar GSP with $300mm^2$ AAAC (Upas), profiled for operation at 75°C. For the purpose of these studies, it has been assumed that the reconductoring would be carried out; it may be possible to defer this reinforcement through a review of the Coalville transfer.

Loughborough 132/11 kV GT Capacity

Generation Demand SP CE TD CR

For the fault outage of either 132/11 kV GT at Loughborough BSP, the remaining 132/11 kV GT in service would overload up to 107% of rating at winter peak demand and 103% of rating at intermediate warm peak demand (Two Degrees and Community Renewables only). These overloads do not occur for a summer peak demand case.

A 15/30 MVA transformer is the largest two-winding transformer WPD currently install as standard for a 132/11 kV transformation, which means the transformers cannot be replaced with larger units.

It is recommended that an 11 kV study be undertaken to determine if permanent load transfers to nearby 33/11 kV primary substations can be made. If this is not possible, a new 33/11 kV primary substation in the vicinity, supplied by the 132/33 kV BSP at Loughborough, would be required.

Nottingham to Nottingham North (HU Route) 132 kV Circuit Overloads

Generation Demand CE TD CR

For arranged outages of either 132 kV circuit from Nottingham East BSP to Nottingham North BSP, Nottingham North 33 kV would be left at single circuit risk. To avoid this, Nottingham North 132/33 kV is typically transferred onto Ratcliffe-on-Soar GSP for the duration of the arranged outage.

The subsequent fault loss of either Nottingham BSP to Nottingham North BSP 132 kV circuit leaves all of Nottingham North 33 kV and 11 kV on the remaining circuit. This overloads the remaining circuit between Nottingham BSP and Nottingham North BSP 132 kV (HU route) to 108% at winter peak demand for all scenarios except Steady Progression. This overload does not occur for the intermediate warm or summer peak demand cases.

It is recommended that Nottingham North 132/33 kV is only transferred onto Ratcliffe-on-Soar GSP where seasonal loading and ratings allow.

Loughborough Lost Load

Generation | **Demand** SP CE TD CR

Loughborough (132/33 kV and 132/11 kV) BSP is supplied via two 132 kV circuits that are normally fed from Ratcliffe-on-Soar GSP via the SZ and HT 132 kV circuit routes. In 2022, the Group Demand of Loughborough (11 kV and 33 kV) increases to between 103 MW (Steady Progression) and 109 MW (Community Renewables).

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW be restored within three hours of an SCO. In this case, restoration of between 3 MW and 9 MW would be necessary.

Sufficient post-fault transfer capacity is available into Willoughby, satisfying the requirements of P2.

Stoke Bardolph GSP

Network Changes Modelled

No network changes were modelled for the Stoke Bardolph 2022 studies.

By 2022, Group Demand is projected to grow from 149 MW in baseline to the figures shown in Table 13.

Table 13: Projected Group Demand of Stoke Bardolph GSP in 2022

Scenario	Group Demand
SP	158 MW
CE	158 MW
TD	166 MW
CR	170 MW

Nottingham East and Nottingham North Lost Load

Generation | **Demand** SP CE TD CR

The lost loads described in the baseline results increase under all scenarios in the 2022 studies. Nottingham East (132/33 kV) and Nottingham North (132/33 kV side) BSPs are supplied via two 132 kV circuits from Stoke Bardolph GSP. Demand growth to 2022 increases the combined Group Demand of Nottingham East and Nottingham North (132/33 kV side) BSPs to between 158 MW (Steady Progression) and 170 MW (Community Renewables).

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand be restored within three hours of an SCO. In this case, restoration of between 58 MW (Steady Progression) and 70 MW (Community Renewables) would be necessary.

Sufficient 132 kV post-fault transfer capacity from Ratcliffe-on-Soar GSP is available, satisfying the requirements of P2.

Hams Hall/Lea Marston GSP

The 2022 studies revealed no additional issues in the Hams Hall/Lea Marston GSP group.

Drakelow GSP

Network Changes Modelled

No reinforcements were modelled for the Drakelow 2022 studies. One new 132 kV connection was included for all scenarios based on accepted-not-yet-connected records.

Drakelow SGT Capacity

Generation **Demand** CR

With the connection of a large 132 kV energy storage site, the level of demand connected to Drakelow GSP can exceed the nameplate rating of a single SGT for the Community Renewables scenario. This overload of up to 108% is currently only present during winter conditions, so Grid Code SGT Access Periods are still readily available. The available interconnection at 132 kV remains adequate to ensure P2 compliance under n-2 conditions.

National Grid may be able to determine short-term ratings for the Drakelow SGTs. If short-term ratings are not available then a third SGT or 33 kV load transfers may be required.

WPD and National Grid have collaborated on the Regional Development Plan 4 (RDP4) to investigate how energy storage or other customers can provide flexibility to the system. The extended flexibility arrangements developed as part of this RDP could be implemented to manage Drakelow SGT loadings in the future.

Grendon GSP

Network Changes Modelled

For the Grendon GSP 2022 studies, the Northampton 132 kV circuit reinforcement and busbar works are modelled as completed. One new 132 kV connection was included for the Two Degrees scenario only, based on accepted-not-yet-connected records.

Grendon GSP SGTs

Generation Demand SP CE TD CR

Under all scenarios, at summer peak demand, there are various overloads of SGTs for SCO conditions; this includes the outage of two SGTs at Grendon GSP. This is due to existing accepted offers for connections in the group. A Modification Application is already in progress with NGET, considering the impact of these connections.

If the Modification Application determines that works are required at Grendon GSP, then these works will need to be designed suitably with consideration of the wider running arrangements at Grendon GSP. There is already a DANM system to manage WPD constraints; this could be integrated with a TANM system to managed SGT constraints.

Corby BSP Load Growth

Generation | **Demand** — SP CE TD CR

Load growth in the Corby BSP group eventually breaches the rating of the single remaining GT under SCO conditions. Loading during intermediate warm peak demand varies between a 103% overload (Steady Progression) and 120% (Community Renewables); loadings are higher in winter, however, the FCO condition could be avoided.

It is recommended that the load growth at the site is monitored and when the load is high enough to cause concern for adequate outage windows, the use of either flexibility, outage load transfers or operational tripping is initially considered to mitigate the exceedance.

132 kV Overloads Caused by Received Load Transfers

Corby to Oakham/Melton Mowbray 132 kV Network

Generation | **Demand** — CR

For specific 132 kV arranged outages in the Staythorpe GSP group, Asfordby BSP and Hawton BSP are transferred into Grendon GSP via the Corby North to Melton Mowbray/Oakham BSP 132 kV network. Under the highest growth scenarios, the subsequent SCO loss of either Oakham to Corby North BSP 132 kV circuit causes overloads the remaining in-service Oakham to Corby North circuit to between 106% at intermediate warm peak demand and 124% at winter peak demand.

Grendon to Irthlingborough 132 kV Network

Generation | **Demand** — CR

Similar to the above issues at Oakham, the transfer of Asfordby BSP and Hawton BSP from Staythorpe GSP can also cause overloads further back into the Grendon GSP network. The SCO loss of either Grendon to Irthlingborough circuit causes overloads on the remaining in-service Grendon to Irthlingborough circuit of between 105% at intermediate warm peak demand and 122% at winter peak demand.

It is recommended that the load growth be monitored at Asfordby and Hawton BSPs. When there is not a sufficient outage window, the use of either flexibility, outage load transfers or operational tripping should be initially considered to mitigate the exceedance.

East Claydon GSP

Network Changes Modelled

No network changes were modelled for the East Claydon 2022 studies. One new 132 kV connection was included for the Two Degrees and Community Renewables scenarios, based on accepted-not-yet-connected records.

By 2022, the Group Demand of East Claydon GSP is projected to grow from baseline’s 354 MW with a summer peak of 247 MW to the figures shown in Table 14.

Table 14: Projected Group Demand of East Claydon GSP in 2022

Scenario	Group Demand	Summer Peak Demand of Group
SP	430 MW	308 MW
CE	460 MW	338 MW
TD	532 MW	406 MW
CR	543 MW	414 MW

The growth includes large battery storage connections and demand transferred by SSEN from Cowley GSP to their new Bicester North BSP.

Reserve Busbar Fault

Generation **Demand** TD CR

East Claydon 132 kV reserve busbar sections 1 and 2 are normally operated solid. There is no section circuit breaker between them, so the fault of either results in disconnection of both busbar sections with the associated circuits and two SGTs. In Two Degrees and Community Renewables, this fault overloads the remaining SGT3 and SGT4 to between 101% and 116% of nameplate rating.

It is recommended that this fault condition is reviewed with National Grid – it may be possible for National Grid to manage post-fault SGT loading with short-term ratings. If not, the installation of a 132 kV reserve section circuit breaker 160 would mean that only one busbar section and SGT is lost for either reserve busbar fault.

SGT Capacity

Generation **Demand** CE

In Consumer Evolution, SGT SCOs would overload SGT2, SGT3 and SGT4 to between 101% and 106% of nameplate rating at winter peak demand. No overload occurs at summer or intermediate warm peak demand.

It is still possible to schedule Grid Code SGT Access Periods within the summer and intermediate warm rating seasons.

SGT and Milton Keynes Ring Capacity

Generation **Demand** TD CR

As described in baseline, East Claydon 132 kV busbar is split into two nodes to manage fault level constraints. As a result of this, East Claydon GSP is heavily dependent upon remote and loose couples via WPD and SSEN networks, to manage loading on SGTs and 132 kV circuits.

As a general principle, East Claydon 132 kV busbar is operated with the following connected to each node:

- two SGTs;
- one Milton Keynes ring circuit via Bletchley;
- one Milton Keynes ring circuit via Stony Stratford;
- one Banbury ring circuit;

- one SSEN Bicester North transformer feeder.

This configuration gives the best load share between interdependent circuits. Unfortunately, the configuration of the busbars and the nature of outages mean that it cannot always be achieved. In particular, both Banbury ring circuits are on section 2 of the busbar, so the arranged outage of Main 2 or Reserve 2 forces both circuits onto the same node. This compromises load share on the Milton Keynes ring.

In Two Degrees and Community Renewables, load growth to 2022 triggers overloads of up to:

- 125% of nameplate rating (winter peak demand) and 108% of nameplate rating (intermediate warm peak demand) on each SGT for the SCO of two other SGTs;
- 118% of rating (winter peak demand) and 106% of rating (intermediate warm peak demand) on the 132 kV circuit between Bradwell Abbey disconnector 203 and Stony Stratford disconnector 403 for the SCO of two other circuits in the Milton Keynes 132 kV ring;
- 115% of rating (winter peak demand) and 106% of rating (intermediate warm peak demand) on the 132 kV circuit between Bradwell Abbey disconnector 303 and Bletchley disconnector 303 for the SCO of two other circuits in the Milton Keynes 132 kV ring;
- 105% of rating (winter peak demand) and 101% of rating (summer peak demand) on the 132 kV circuit between East Claydon disconnector 805 and Stony Stratford disconnector 103 for the SCO of two other circuits in the Milton Keynes 132 kV ring;
- 103% of rating at summer peak generation on the 132 kV circuit between Bradwell Abbey disconnector 103 and Stony Stratford disconnector 303 for the maintenance of East Claydon circuit breaker 120 and the fault loss of SGT4.

Most overloads are marginally lower in Two Degrees than Community Renewables. Due to the interdependence between SGTs and 132 kV circuits, overloads also occur on 132 kV circuits for some outages including SGTs, and vice versa.

Demand growth on this scale would trigger major reinforcement. It is recommended that a reinforcement plan for East Claydon GSP be developed in conjunction with National Grid and SSEN.

Many of the studied overloads could be avoided by operating East Claydon 132 kV busbar as a single node. Due to the fault level constraints previously described, this would require the replacement of much of the 132 kV switchgear at East Claydon. When selecting a reinforcement scheme, the trade-off between circuit reinforcement and fault level reinforcement should be considered carefully. Alleviating fault level constraints would improve operational flexibility, while allowing improved utilisation of the capability of existing circuits.

If circuit reinforcement proves most appropriate, there are further considerations to be made:

- **33 kV constraints are likely to trigger a new BSP to the northeast of Milton Keynes. If this BSP is supplied by a second 132 kV circuit between Bletchley and Bradwell Abbey, constraints on the existing circuit between those two BSPs could be alleviated;**
- **moving one of the Banbury ring circuits to section 1 of the East Claydon 132 kV busbar would improve load share for outages including a section 2 busbar, so reducing or avoiding several overloads. The disposition of Banbury circuits on the East Claydon 132 kV busbar should be included in the joint study of the Banbury area network recommended below;**
- **the 132 kV circuits from East Claydon to Bletchley and Stony Stratford are composed of a mixture of cable and overhead line. The circuit ratings are currently restricted by the design of joints in the twin 175mm² ACSR (twin Lynx) overhead conductor.**

Replacing these joints and reprofiling to 65°C on the circuits between East Claydon and Stony Stratford would increase circuit ratings by around 13%, reducing or alleviating several overloads;

- **if additional SGTs are installed, the 132 kV (and potentially 400 kV) busbars will need to be expanded with additional sections. Connecting more than four SGTs to a two-section double busbar typically results in a suboptimal topology, often with busbar faults that result in the simultaneous loss of multiple SGTs. This could further constrain the Milton Keynes 132 kV ring, triggering widespread reinforcement.**

Banbury/Brackley Lost Load

Generation | **Demand** SP CE TD CR

Banbury and Brackley BSPs are supplied by a double circuit 132 kV tower line. There is no 132 kV transfer capacity, and limited transfer capacity at lower voltages. By 2022, the combined Group Demand of Banbury and Brackley BSPs is projected to grow from 105 MW in baseline to the figures shown in Table 15.

Table 15: Projected Group Demand of Banbury and Brackley BSPs in 2022

Scenario	Group Demand
SP	117 MW
CE	117 MW
TD	122 MW
CR	125 MW

This falls into Class D of P2, with a requirement to restore Group Demand less 100 MW within 3 hours of an SCO, such as the loss of both 132 kV circuits.

Options for reinforcement include:

- **a normally open 132 kV circuit from Banbury BSP to Harbury BSP in the Berkswell GSP network to provide transfer capacity;**
- **a second 132 kV route from East Claydon GSP to Banbury BSP, with one or two circuits, forming a western 132 kV ring from East Claydon GSP;**
- **a 132 kV circuit from SSEN's Bicester North BSP to Banbury BSP, forming a western 132 kV ring from East Claydon GSP.**

A link between Banbury BSP 132 kV and the 66 kV network supplying Epwell and Bloxham BSPs is also being considered. This is primarily intended to reinforce the Feckenham GSP 66 kV network and could transfer further demand into the Banbury/Brackley group.

It is recommended that the reinforcement requirements of WPD West Midlands, WPD East Midlands and SSEN Southern in this area be studied jointly to determine a whole system solution.

Chesterfield GSP

Network Changes Modelled

No network changes were modelled for the Chesterfield 2022 studies.

SGT Capacity

Due to fault level constraints, the 132 kV busbar at Chesterfield GSP is normally split into two nodes, with bus couplers 130 and 230 open:

- SGT1 and SGT3 supply reserve busbar sections 1 and 2;
- SGT2 and SGT4 supply main busbar sections 1 and 2.

FCO Overloads

Generation **Demand** TD CR

The fault of SGT1 or SGT3 overloads the remaining in-service SGT supplying the reserve busbar sections. Similarly, the fault of SGT2 or SGT4 overloads the remaining in-service SGT supplying the main busbar sections. Under Two Degrees and Community Renewables, the remaining SGT in service would overload to between 110% and 113% of nameplate rating at winter peak demand.

SCO Overloads

Generation **Demand** SP CE TD CR

An arranged outage that takes an SGT out-of-service followed by the fault of an SGT increases the overload on the remaining in-service SGT to between 101% (Steady Progression) and 145% (Community Renewables) at winter peak demand. Overloads of up to 122% are also seen at intermediate warm peak demand under Two Degrees and Community Renewables.

To manage the FCO and SCO constraints, it is recommended that:

- **under Steady Progression and Consumer Evolution, the arranged outage window is restricted to summer and intermediate warm periods. This resolves the SCO overload and still gives a full Grid Code SGT Access Period;**
- **under Two Degrees and Community Renewables, it may be possible for National Grid to determine short-term ratings for the Chesterfield SGTs, which would allow loading to be managed by post-fault transfers;**
- **if short-term ratings are not available, flexibility services could be procured at times of high demand in winter to alleviate the overload;**
- **alternatively, it may be possible to move load from Chesterfield to Staythorpe C under intact running. This will likely involve the installation of an additional SGT at Staythorpe C.**

Alfreton BSP

Generation **Demand** TD CR

Alfreton BSP consists of two 132/33 kV transformers, fed via two 132 kV circuits from Chesterfield GSP. The transformers overload to as much as 106% at winter peak demand during load transfers onto Alfreton from Mansfield BSP, followed by a fault on one of the transformers at Alfreton. Under Community Renewables only, an overload of 100% is also seen at intermediate warm peak demand.

It is recommended that the transfers into Alfreton be assessed and, if possible, transfers are limited to summer only, where the Alfreton transformers are not overloaded for a subsequent fault.

If a summer outage window is not sufficient, it is recommended that the grid transformers are uprated to 60/90 MVA units.

Annesley BSP

Generation | **Demand**

CR

Annesley BSP consists of four 132/33 kV transformers: GT1 running in parallel with GT2, and GT3 running in parallel with GT4. For an arranged outage of a Chesterfield SGT, or one of the circuits between Chesterfield and Mansfield/Clipstone, 33 kV demand is transferred into Annesley. A subsequent fault of Annesley GT1 or GT2 would cause an overload to as much as 102% at winter peak demand, under Community Renewables only.

It is recommended that the transfers into Annesley be assessed and if possible, transfers are not taken in winter.

Mansfield and Clipstone BSP Transfer

Generation | **Demand**

SP CE TD CR

Mansfield and Clipstone BSPs are 132/33 kV sites normally supplied via two 132 kV circuits from Chesterfield GSP. They transfer onto Staythorpe C GSP, via two 132 kV interconnectors, for various planned outages at Chesterfield.

Demand Restriction

Generation | **Demand**

SP CE TD CR

During transfers at winter or intermediate warm peak demand, a circuit fault on either of the 132 kV circuits from Staythorpe C and Clipstone overloads the remaining Staythorpe C to Clipstone circuit to between 111% (Steady Progression) and 118% (Community Renewables).

It is recommended that:

- **Mansfield and Clipstone BSPs be transferred into Staythorpe GSP only where seasonal loading and ratings allow;**
- **sufficient load is transferred out of Mansfield and Clipstone (at 11 kV or 33 kV) prior to the planned outage; or**
- **if neither of the above are possible, reconductoring the existing 175mm^2 ACSR (Lynx) conductor on the AU route between Staythorpe C GSP and Mansfield BSP with 300mm^2 AAAC (Upas), profiled for operation at 75°C would resolve the overload.**

Generation Restriction

Generation | Demand

CE CR

The transfer of Mansfield and Clipstone into Staythorpe GSP at summer peak generation, followed by a circuit fault between Staythorpe C and Clipstone will overload the remaining in-service circuit to as much 110%.

It is recommended that:

- **where possible, single circuit connection generators are curtailed prior to the transfer; or**
- **if this is not sufficient, reconductoring the existing 175mm^2 ACSR (Lynx) conductor on the AU route between Staythorpe C GSP and Mansfield BSP with 300mm^2 AAAC (Upas), profiled for operation at 75°C would resolve the overload.**

Willington GSP

Network Changes Modelled

For the 2022 studies, Willington GSP has had the following model changes:

- decommissioning the 275 kV at Willington including SGT4 and SGT5, and installing a new 240 MVA, 400/132 kV SGT (provisionally named SGT8), connected to Willington Main 2;
- running Willington as a 2+2 site (Main 1 in parallel with Reserve 1, and Main 2 in parallel with Reserve 2);
- uprating GT3 at Derby South BSP and running it in parallel with an additional 132/33 kV transformer (provisionally named GT4), supplied via the ex-GT5 132 kV circuit from Willington. Derby South would effectively become two sites (GT1 and GT2 supplying one half of the load and GT3 and GT4 supplying the other half);
- establishing a new feeder bay at Willington and laying a new 132 kV circuit to Burton tee to pick up the circuit to Spondon, effectively resulting in a direct Willington–Spondon circuit and a direct Willington–Burton circuit;
- connecting the direct Willington–Spondon circuit to Willington main 2. [This will result in four 240 MVA SGTs at Willington paralleled via Spondon 132 kV busbars. A fault level study will therefore be necessary at this stage to ensure the assets at Spondon are not overstressed and, if they are, remedial works must be carried out to uprate them. The alternative scheme here is to keep the direct Willington–Spondon circuit connected to Willington main 1 and reconstruct the Willington–Derby South GT2–Spondon 132 kV circuit to significantly uprate it in the event of a busbar fault at Willington main 1 that takes out the other two feeders to Spondon. The cost and implication of both options are to be weighed up to identify the optimum way forward;]
- for the direct Willington–Spondon circuit, uprating the tower line circuit (subject to line surveys), including remote end works to facilitate this, and changing its connectivity at Spondon from main 1 to main 2.

Given the level of works involved with some of the reinforcement options above, an alternative option would be to re-plant Willington 132 kV substation to allow for a solid running arrangement; this will be subject to a cost-benefit analysis.

SGT Capacity

Generation **Demand** SP CE TD CR

Willington GSP is now run as a 2+2 split with main 1 in parallel with reserve 1, and main 2 in parallel with reserve 2.

A fault of SGT6 or SGT8 (or a busbar fault taking out either SGT) at winter peak demand overloads the remaining SGT to between 103% (Steady Progression) and 105% (Community Renewables).

Similarly, a fault during the winter season on SGT1 or SGT7 (or a busbar fault taking an SGT out of service) overloads the remaining SGT to between 103% (Steady Progression) and 105% (Community Renewables).

It is recommended that:

- **if possible, National Grid determines short-term ratings for Willington SGTs, which may allow loading to be managed by post-fault transfers; or**
- **Heanor BSP is transferred permanently to Staythorpe C. This will trigger reinforcement works at Staythorpe C involving the installation of an additional SGT.**

Winster, Burnaston and Uttoxeter Lost Load

Generation | **Demand** SP CE TD CR

Winster, Burnaston and Uttoxeter BSPs are fed via two 132 kV circuits from Willington GSP. The Group Demand increases to 146 MW under Community Renewables. Under certain second circuit outages on the two 132 kV circuits, the entire group is lost.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of 46 MW is required.

Sufficient 33 kV post-fault transfer capacity is available under all scenarios, satisfying the requirements of P2.

Spondon B BSP Lost Load

Generation | **Demand** SP CE TD CR

Spondon B BSP is a 132/33 kV site supplied from Spondon 132 kV. The Spondon B Group Demand increases to between 106 MW under Steady Progression and 114 MW under Community Renewables. This Group Demand is lost under a second circuit outage as the site is supplied via two 132 kV feeders and two grid transformers.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 6 MW and 114 MW is required.

Sufficient 33 kV transfer capability is available to satisfy the requirements of P2.

Derby BSP Lost Load

Generation | **Demand** SP CE TD CR

Derby BSP consists of four transformers (two 132/33 kV and two 132/11/11 kV). These are fed via two 132 kV circuits from Willington GSP; each 132/33 kV transformer is banked with a 132/11/11 kV transformer.

Demand growth to 2022 increases the combined Group Demand of Derby BSP to between 103 MW (Consumer Evolution) and 113 MW (Community Renewables).

The total winter demand at Derby BSP can exceed 100 MW, which is lost under a second circuit outage on the two feeders from Willington GSP.

Sufficient 33 kV transfer capability is available to satisfy the requirements of P2.

Stanton and Heanor BSP Transfers

Generation | **Demand** SP CE TD CR

Stanton and Heanor BSPs are 132/33 kV sites fed via two 132 kV circuits from Spondon. They transfer onto Staythorpe C, via two 132 kV interconnectors, for various planned outages between Willington GSP and Spondon 132 kV.

Voltage Restriction

Generation **Demand** SP CE TD CR

During such transfers in the winter and intermediate warm seasons, the 132 kV network between Loscoe and Stanton sees low volts during a fault on either of the Staythorpe C–Loscoe–Heanor circuits.

Thermal Restriction

Generation **Demand** SP CE TD CR

During such transfers at winter peak demand, a fault on either of the 132 kV circuits from Staythorpe C potentially overloads the other.

It is recommended that the sufficiency of the available access window for the arranged outage be confirmed.

If the arranged outage window is not sufficient, the studied overloads could be alleviated by:

- **moving demand at 33 kV and/or 11 kV prior to making the transfer into Staythorpe C; or**
- **uprating the conductors between Staythorpe C and Loscoe.**

Willington–Spondon 132 kV Circuits

Generation **Demand** SP CE TD CR

Spondon 132 kV is a double busbar site, normally run solid. It is fed via three circuits from Willington GSP, which primarily supply a large embedded generator, Derby South (GT1 and GT2), Spondon B, Stanton and Heanor BSPs. The circuits are:

- Willington main 2–Spondon main 2;
- Willington main 2–Derby South GT1–Spondon reserve 1; and
- Willington reserve 1–Derby South GT2–Spondon main 1.

Stanton and Heanor BSPs have two 132 kV interconnectors to Staythorpe C and can be transferred across for various planned first circuit outages.

Under all scenarios, the 132 kV circuit between Derby South GT2 and Spondon (DN route) overloads at winter peak demand for:

- a busbar fault at Spondon taking out reserve 1 and reserve 2; or
- a fault on the Willington–Derby South GT1–Spondon 132 kV circuit.

Similarly, the 132 kV circuit between Derby South GT1 and Spondon (one circuit of CN route) overloads at winter peak demand following:

- a busbar fault at Spondon main 1; or
- a fault on the Willington–Derby South GT2–Spondon 132 kV circuit.

Both of the above conditions are marginally exacerbated under certain second circuit outage conditions.

It is recommended that the Willington-Derby South GT1-Spondon 132 kV circuits be surveyed to confirm if they can be uprated with a conductor sufficient to resolve the identified overload. If a survey shows that the constraint cannot be resolved, or it is not shown to be the best

option, then transferring Heanor permanently to Staythorpe C would resolve the overload. This, however, will trigger reinforcement works at Staythorpe C involving the installation of an additional SGT.

Staythorpe GSP

Network Changes Modelled

For the 2022 studies, no network changes have been modelled on the Staythorpe network. The planned scheme to replace the 132 kV switchgear at Staythorpe B substation, which would allow solid running of Staythorpe GSP, is not scheduled to be completed until after 2022.

Staythorpe SGT Overloads

Generation Demand SP CE TD CR

The 2022 studies have indicated that there are several outage combinations that cause the SGTs at Staythorpe to become overloaded. These are described in more detail in the sections below.

Staythorpe 132 kV Busbar/SGT Outages

Generation Demand SP CE TD CR

For a fault or arranged outage on the 132 kV busbars at Staythorpe C or Staythorpe B, or an SGT outage at Staythorpe C, this can cause an overload on the remaining SGT. For the Community Renewables scenario, overloads occur for winter and intermediate warm peak demand and can be up to 122% of SGT rating. Under the other three scenarios, overloads only occur during for the winter peak demand case.

For fault outages, this overload is within the short-term SGT rating so can be managed by post-fault switching.

For arranged outages, it is recommended to avoid taking outages during the winter and intermediate warm periods where possible. For outages taken during these periods, it is recommended to transfer sufficient demand away from Staythorpe GSP to ensure that the loading is within the continuous SGT rating. If this is not possible then it is recommended that a third SGT be installed at Staythorpe GSP.

Corby North Power Station Transfers into Staythorpe

Generation Demand SP CE TD CR

An arranged outage of one of the Corby to Corby North 132 kV circuits (causing Corby North Power Station to be transferred into Staythorpe), followed by a fault on one of the SGTs at Staythorpe can cause an overload on the remaining SGT at Staythorpe GSP. Overloads occur under winter, intermediate warm and summer (generation) peak loadings and are significantly above the SGT short-term rating. For the Two Degrees scenario, overloads are seen under winter and summer (generation) peak loadings only. Under the Consumer Evolution and Steady Progression scenarios, overloads only occur for the summer peak generation case.

Heanor Transfer into Staythorpe

Generation **Demand** TD CR

For a 132 kV switchgear outage at Loscoe 132 kV switching station, Heanor BSP is transferred into Staythorpe GSP. A subsequent fault on one of the SGTs at Staythorpe GSP can cause an overload on the remaining SGT at Staythorpe. The high loading is shown to cause voltage collapse at winter peak demand under Two Degrees and Community Renewables.

It is recommended that when Heanor BSP is transferred to Staythorpe GSP, Checkerhouse BSP be transferred to West Burton GSP. In addition, an SGT at Staythorpe GSP should be taken off load and the 132 kV bus couplers at Staythorpe C and Staythorpe B substations be closed. Alternatively, when the transfer of Heanor is made, the bus sections at Hawton, Checkerhouse, Grantham North and Grantham South BSPs could be opened (as appropriate) and any downstream loose couples broken.

A project is planned to replace the 132 kV switchgear at Staythorpe B substation, which would allow Staythorpe to be run solid and thus alleviate the issues identified. This scheme is currently expected to be completed by 2024.

Retford/Worksop Transfer into Staythorpe

Generation **Demand** CR

An arranged outage of circuit breaker 105 or circuit breaker 405 at West Burton GSP (causing Retford and Worksop BSPs to be transferred into Staythorpe), followed by an SGT fault at Staythorpe GSP can cause voltage collapse at winter peak demand under Community Renewables.

Bourne/Spalding Transfer into Staythorpe

Generation **Demand** SP CE TD CR

For a planned outage of circuit breaker 2705 at Walpole GSP (the Walpole–Spalding/Bourne 132 kV feeder) or a Bourne 132 kV switchgear outage, a subsequent fault on one of the SGTs at Staythorpe GSP or one of the Staythorpe C–Staythorpe B interconnectors can cause significant overloads on the remaining in-service SGT. This is due to voltage collapse on the 132 kV network and occurs under all scenarios.

Mansfield/Clipstone Transfers into Staythorpe

Generation **Demand** SP CE TD CR

For a 132 kV busbar outage at Chesterfield GSP, Mansfield and Clipstone BSPs are transferred into Staythorpe GSP. For winter and intermediate warm peak demand, this can cause an overload of the SGTs at Staythorpe GSP. Overloads can be up to 126% of SGT rating. For the Consumer Evolution and Steady Progression scenarios, overloads occur for winter peak demand only.

It is recommended that Mansfield and Clipstone BSPs are only transferred to Staythorpe GSP during the summer period, if possible. For transfers undertaken outside of the summer period, it is recommended that sufficient demand be transferred away from Staythorpe GSP to ensure that the SGTs are loaded within their continuous rating. If this cannot be done then it is suggested that a third SGT be installed at Staythorpe GSP.

Corby North Power Station Transfers into Staythorpe

Generation Demand CE TD CR

As discussed in the baseline results, Corby North Power Station is transferred into Staythorpe GSP for a planned outage of one of the Corby–Corby North circuits. Various other arranged outage scenarios can also cause Corby North Power Station to be transferred to Staythorpe GSP.

Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV Circuit Overloads

Generation Demand CE TD CR

A planned outage of one of the Corby–Corby North 132 kV circuits, followed by a fault on one of the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuits (TZ route), can cause an overload on the section of 132 kV circuit between Hawton tee and Asfordby tee. The overload occurs at summer peak generation and can be up to 114% of rating. Under Two Degrees, Consumer Evolution and Community Renewables, an overload of up to 105% of circuit rating is also observed on the 132 kV circuit between Asfordby tee and Melton Mowbray for the summer peak generation case.

It is recommended that arranged outages are scheduled around the seasonal output of generators in this area. This may prevent arranged outages in summer.

If access is required at times of high generator output, sufficient generation should be curtailed to prevent this overload. Curtailment could be applied pre-fault during the arranged outage, or an intertripping scheme could be commissioned to apply it post-fault.

If it is not possible to curtail sufficient generation to resolve the overload when transferring Corby North Power Station into Staythorpe GSP, it is recommended to alter the current running arrangement that is used when the transfer is made. It is suggested that the remote couple via the 132 kV busbar at Corby North BSP be broken by opening circuit breaker 405 at Corby North BSP. Oakham GT2 and Melton Mowbray GT4 should be switched to hot standby and the 33 kV bus sections at Hawton and Checkerhouse BSPs and the 11 kV bus sections at Grantham North and Grantham South BSPs should be opened. Any other loose couples should also be broken.

Retford/Worksop Transfer into Staythorpe

Generation Demand TD CR

For an arranged outage of circuit breaker 105 or circuit breaker 405 at West Burton (the 132 kV feeders towards Retford/Checkerhouse/Worksop BSPs), Retford and Worksop BSPs are transferred into Staythorpe GSP. These transfers are also made for an SGT outage at West Burton GSP.

Hawton 132 kV Circuit and Transformer Overloads

Generation Demand CR

For an arranged outage of circuit breaker 105 or 405 at West Burton SGT, a subsequent fault on one of the SGTs at Staythorpe GSP can cause voltages below 0.6 p.u. on the Staythorpe 132 kV network and non-convergence. The low voltages and non-convergences are caused by the Staythorpe main and reserve sections, which are run split due to fault level restrictions, being loose coupled at Checkerhouse and Hawton BSPs (at 33 kV) and at Grantham North and Grantham South BSPs (at 11 kV).

Due to the low voltage, the circuits between Hawton tee and Hawton BSP and the grid transformers at Hawton BSP, overload under all seasons and can be up to 208% of the circuit rating and up to 199% of the transformer rating. DOC protection has been shown not to prevent overloads in all loading scenarios. This overload is caused by Hawton becoming the loose couple between the two sections of the split Staythorpe 132 kV busbars.

It is recommended that when Retford and Worksop BSPs are transferred into Staythorpe, an SGT at Staythorpe GSP be taken off load and the 132 kV bus couplers at Staythorpe C and Staythorpe B substations be closed. The completion of the Staythorpe B replant, which is currently expected to be completed by 2024, will mean that the 132 kV busbars at Staythorpe can be run solid, which will resolve the issue identified.

Checkerhouse 132 kV Circuit Overloads

Generation Demand TD

When there is an arranged outage of circuit breaker 105 or 405 at West Burton GSP, followed by a fault on one of the Staythorpe–Checkerhouse 132 kV circuits, this can cause an overload on the other circuit. The overload occurs for summer peak generation. The overload can reach up to 110% of rating.

As the issues identified are caused solely by generation, it is recommended that the overload be managed using an ANM scheme. If predicted levels of constraint are too high, or insufficient ANM generators are available, the 132 kV circuit between Staythorpe and Checkerhouse can be reinforced with $300mm^2$ AAAC (Upas) conductor and $1000mm^2$ copper XLPE as appropriate.

Worksop Circuit/Transformer Overloads

Generation Demand CR

For an arranged outage of an SGT at West Burton GSP, a subsequent fault on one of the SGTs at Staythorpe GSP can cause an overload on the Checkerhouse–Worksop 132 kV circuits and the transformers at Worksop BSP. Overloads occur for winter and intermediate warm peak demand and can reach up to 102% of circuit rating and up to 154% of transformer rating. DOC protection has been proven not to prevent overloads in all cases. The overload occurs as Worksop becomes a loose couple between the two split 132 kV sections at Staythorpe.

It is recommended that when Retford and Worksop BSPs are transferred into Staythorpe, an SGT at Staythorpe GSP be taken off load and the 132 kV bus couplers at Staythorpe C and Staythorpe B substations be closed. The completion of the Staythorpe B replant, which is currently expected to be completed by 2024, will mean that the 132 kV busbars at Staythorpe can be run solid, which will resolve the issue identified.

Bourne/Spalding Transfer into Staythorpe

Generation Demand SP CE TD CR

Under certain outage scenarios on the Walpole network, Bourne and Spalding BSPs are transferred into Staythorpe GSP. Under current practice, when the transfer is made, one transformer at Bourne BSP is fed on one 132 kV circuit and a single transformer at Spalding BSP is fed via the other 132 kV circuit.

Staythorpe–Grantham South/Bourne West/Bourne 132 kV Circuit Overloads

Generation | Demand — SP CE TD CR

For an outage of circuit breaker 2705 at Walpole GSP (the Walpole–Spalding/Bourne 132 kV feeder), Bourne and Spalding BSPs are transferred to Staythorpe GSP. A subsequent fault on one of the SGTs at Staythorpe GSP is shown to cause voltages as low as 0.6 p.u. and non-convergences under the highest scenarios. The low voltages and non-convergences are caused by the Staythorpe main and reserve sections, which are run split due to fault level restrictions, being loose coupled at Checkerhouse and Hawton BSPs (at 33 kV) and at Grantham North and Grantham South BSPs (at 11 kV). As the voltage is so low under this condition, the section between Grantham South tee and Bourne West/Bourne can become loaded to 242% of circuit rating and the section between Staythorpe and Grantham South tee can reach 239% of circuit rating.

Under the Community Renewables and Two Degrees scenarios, overloads occur under summer loadings only. For the Steady Progression and Consumer Evolution scenarios, overloads occur for summer and intermediate warm loadings and can be caused by both demand and generation.

For the same arranged outage or a 132 kV switchgear outage at Bourne BSP, a subsequent fault on one of the Staythorpe C–Staythorpe B interconnectors means that similar magnitudes of low voltages and overloads are seen.

It is recommended that when Bourne and Spalding BSPs are transferred into Staythorpe, an SGT at Staythorpe GSP be taken off load and the 132 kV bus couplers at Staythorpe C and Staythorpe B substations be closed. The completion of the Staythorpe B replant, which is currently expected to be completed by 2024, will mean that the 132 kV busbars at Staythorpe can be run solid, which will resolve the issue identified. Alternatively, when the transfer of Bourne is made, the bus sections at Bourne, Hawton, Checkerhouse, Grantham North and Grantham South BSPs could be opened (as appropriate) and any downstream loose couples broken.

Grantham South BSP

Generation | Demand — SP CE TD CR

Grantham South BSP currently comprises two 132/11 kV transformers and an 11 kV switchboard. The substation is fed via two 132 kV circuits teed off the Staythorpe–Bourne West/Bourne 132 kV circuits.

Grantham South Transformer Overloads

Generation | Demand — SP CE TD CR

Under all scenarios, the demand growth causes the transformers at Grantham South BSP to exceed the GT ONAN rating for intact running, by as much as 138%.

For certain 132 kV switchgear outages at Staythorpe GSP, Bourne BSP or Bourne West BSP, for a Staythorpe–Grantham South/Bourne West/Bourne 132 kV circuit outage or an outage of one of the transformers at Grantham South BSP, this can leave Grantham South supplied by one transformer only. Overloads under these outages are as much as 150% of the transformer seasonal cyclic rating and are seen in all seasons.

Depending on where exactly the future load growth is, it is recommended either to install an additional pair of 132/11 kV transformers at Grantham South BSP, banked onto the existing incoming 132 kV circuits, or to establish a new BSP in the Grantham South area, connected to the existing Staythorpe–Grantham South/Bourne West/Bourne 132 kV circuits.

Staythorpe C–Staythorpe B Interconnectors

Generation **Demand** SP CE TD CR

Under current practice, for arranged outages of either of the Staythorpe C–Staythorpe B interconnectors, Checkerhouse, Grantham North and Grantham South/Bourne West BSPs are transferred to West Burton, Bicker Fen and Walpole GSPs, respectively. The 2022 studies have identified further issues, in spite of these mitigation measures.

Hawton 132 kV Circuit and Transformer Overloads

Generation **Demand** SP CE TD CR

For an arranged outage of one of the Staythorpe C–Staythorpe B interconnectors, a subsequent fault on one of the SGTs at Staythorpe GSP can cause an overload on the 132 kV circuit between Hawton tee and Hawton BSP. Overloads occur in all seasons and can be up to 132% of circuit rating. For the Consumer Evolution and Community Renewables scenarios, overloads occur for summer and intermediate warm peak demand cases only.

This combination of outages can also cause an overload on the 132/33 kV transformers at Hawton BSP. Overloads occur in all seasons and can reach 128% of transformer rating. In the Consumer Evolution and Community Renewables scenarios, overloads occur during summer and intermediate warm periods only.

It is recommended that for an arranged outage of one of the Staythorpe C–Staythorpe B interconnectors, the 33 kV bus section at Hawton BSP be opened, along with any loose couples.

Checkerhouse BSP

Generation Demand TD CR

Checkerhouse BSP consists of two 132/33 kV transformers and a 33 kV switchboard. The 132 kV switchgear at Checkerhouse BSP forms a normal open point between Staythorpe and West Burton GSPs, such that Checkerhouse BSP is normally fed from Staythorpe GSP.

Checkerhouse Transformer Overload

Generation Demand TD CR

Future load studies have identified that the transformers at Checkerhouse can become overloaded for the summer peak generation case. The intact loading is beyond the ONAN rating under Two Degrees and Community Renewables. For a first circuit outage, that takes a transformer out of service, the remaining GT is at 107% under Two Degrees and Community Renewables.

As the issues identified are caused solely by generation, it is recommended that the overload be managed using an ANM scheme. If predicted levels of constraint are too high, it is recommended that additional 132/33 kV transformers be installed at Checkerhouse BSP. If the latter option is undertaken, care will need to be taken to ensure that switchgear does not become overstressed due to increased fault levels.

Staythorpe 132 kV Busbar/SGT Outages

Generation **Demand** SP CE TD CR

For certain planned 132 kV busbar outages at Staythorpe GSP, it is necessary to switch out an SGT in order to allow the remaining sections of busbar to be coupled. A planned outage of an SGT will also leave a single SGT in-service. A 132 kV busbar fault at Staythorpe GSP will also cause a loss of one of the SGTs at Staythorpe due to the split running arrangement.

Hawton 132 kV Circuit and Transformer Overloads

Generation **Demand** SP CE TD CR

A 132 kV busbar fault at Staythorpe C substation, or a fault on one of the SGTs at Staythorpe GSP, can cause an overload on the 132 kV circuit between Hawton tee and Hawton BSP and on the transformers at Hawton BSP itself. For the Community Renewables and Two Degrees scenarios, overloads occur in all seasons and can be up to 118% of the circuit rating and up to 113% of the transformer rating. For the Steady Progression scenario, overloads occur in winter and intermediate warm seasons only. Under the Consumer Evolution scenario, overloads occur in winter only and only appear on the 132 kV circuit between Hawton tee and Hawton BSP.

The completion of the Staythorpe B replant, which is currently expected to be completed by 2024, will mean that the 132 kV busbars at Staythorpe can be run solid, which will resolve the issue identified. One option to manage this overload prior to the replant is to run Hawton 33 kV bus section split or a Hawton GT on hot standby.

Grantham/Grantham North (BR) Transfer into Staythorpe

Generation **Demand** CR

For an arranged outage of one of the Bicker Fen–Sleaford/Grantham 132 kV circuits, Grantham and Grantham North (BR) BSPs are transferred to Staythorpe GSP.

Staythorpe–Grantham North 132 kV Circuit Overloads

Generation **Demand** CR

When Grantham and Grantham North (BR) BSPs are transferred to Staythorpe GSP, a subsequent fault on one of the SGTs at Staythorpe GSP can cause an overload on one of the Staythorpe–Grantham North 132 kV circuits. The overload is only seen under winter loadings and can reach 102% of the circuit rating.

It is recommended that the transfer of Grantham and Grantham North BSPs into Staythorpe GSP be only undertaken during the summer and intermediate warm periods where possible. For transfers taken during the winter period, it is suggested that either:

- **an SGT at Staythorpe GSP be taken off load and the 132 kV bus couplers at Staythorpe C and Staythorpe B substations be closed; or**
- **the 33 kV bus sections at Checkerhouse, Hawton and Grantham BSPs and the 11 kV bus sections at Grantham North and Grantham South BSPs are opened. Any other loose couples will also need to be broken.**

Staythorpe C CB105/CB505 Outage

Generation | **Demand** SP CE TD CR

Under an arranged outage of circuit breaker 105 or circuit breaker 505 at Staythorpe C substation, Hawton BSP is supplied from Grendon GSP via Melton Mowbray BSP.

Staythorpe/Hawton Low Voltage

Generation | **Demand** SP CE TD CR

When the above outage is taken, this can cause low voltage on the 132 kV busbars at Hawton BSP and at Staythorpe C substation. The undervoltage only occurs for winter peak demand and the 132 kV voltage can drop to 13% below nominal voltage. However, no 132 kV customers are connected to this part of the circuit and the 33 kV voltage at Hawton BSP is within statutory limits.

When the above outage is taken and there is a subsequent fault on one of the Grendon–Kettering–Corby 132 kV circuits or on one of the Corby North–Melton Mowbray 132 kV circuits, this can cause an undervoltage under intermediate warm loadings for the Consumer Evolution and Community Renewables scenarios. The 132 kV voltage at Hawton BSP and Staythorpe C substation can dip to 11% below nominal voltage in this case but again, no 132 kV customers are connected to this part of the circuit and the 33 kV voltage at Hawton BSP remains within statutory limits.

It is recommended that outages be taken during summer only, where possible.

Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV Circuit Outages

Generation | **Demand** SP CE TD CR

For an arranged outage of one of the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuits, this leaves Hawton BSP at single circuit risk. One half of Asfordby BSP will be lost due to the split running arrangement.

Hawton/Asfordby Lost Load

Generation | **Demand** SP CE TD CR

The Group Demand of Hawton and Asfordby BSPs increases to as much as 121 MW under Community Renewables. Under the above arranged outage, a fault on the other Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuit will result in the loss of Hawton and Asfordby BSPs.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of 21 MW is required.

It is recommended that the available 33 kV transfer capability at Hawton be confirmed, to ensure it remains P2-compliant with the continued demand growth.

Proposed 2022 Reinforcement Strategy

The majority of the overloads and voltage issues identified in 2022 are due to the current running arrangement at Staythorpe GSP. Due to fault level limitations on the switchgear at Staythorpe B, the main and reserve busbars at Staythorpe C and Staythorpe B substations are operated split, with the 132 kV bus couplers at both substations run normally open.

The completion of the Staythorpe B replant, which is currently expected to be completed by 2024, will resolve the majority of the 132 kV and GT constraints. Until then, it was shown that the majority of issues could be operationally managed by:

- **taking an SGT at Staythorpe GSP off load and closing the 132 kV bus couplers at Staythorpe C and Staythorpe B; or**
- **opening the 33 kV bus sections at Checkerhouse, Hawton and Grantham BSPs and the 11 kV bus sections at Grantham North and Grantham South BSPs. For transfers into the Staythorpe group, such as Bourne and Retford BSPs, the 33 kV bus sections at the incoming BSPs would also need splitting. Any other loose couples will also need to be broken.**

The projected increase in demand and generation on Staythorpe GSP by 2022 causes several issues with SGT loading, as discussed above. Many of the issues identified are caused by BSPs being transferred into Staythorpe GSP. Several of the overloads could be mitigated by limiting transfers to certain times of year, as seasonal ratings and loadings allow, although this reduces the operability of the wider network.

Where seasonal transfer limitations become too restrictive, the identified overloads could be alleviated by any or all of the following:

- **transferring demand/generation away from Staythorpe GSP, in order to accept the incoming BSPs;**
- **use of ANM/flexibility services to control generation/demand as appropriate;**
- **installing a third SGT at Staythorpe GSP. The impact of a third SGT on fault level will need to be considered. Further fault level reinforcement works may be required to allow three SGTs to operate in parallel. Alternatively, a swing arrangement could be used such that the third SGT operates on hot standby with an auto-close scheme to switch in the SGT in the event of a fault on either of the other SGTs.**

The only reinforcements required where a constraint will not be resolved by the 2024 replant, or can be operationally managed are:

- **installation of two additional 132/11 kV transformers at Grantham South BSP, banked onto the existing incoming 132 kV circuits. These transformers have been configured so that each incoming 132 kV circuit feeds two transformers, each of which are connected to opposite sides of the 11 kV switchboard. A 132 kV cross bay has also been installed;**
- **re-conductor of the Staythorpe–Checkerhouse 132 kV circuits with 300mm^2 AAAC conductor and overlay of the cable sections of these circuits with 1000mm^2 copper XLPE.**

Bicker Fen GSP

Network Changes Modelled

For the 2022 studies, a 54 MW accepted-not-yet-connected generator is connected directly into Bicker Fen GSP under all scenarios except Steady Progression. In 2019, the Bicker Fen 400 kV network was converted to a two-section double busbar site to enable the connection of Triton Knoll offshore wind farm. The National Grid changes have not been explicitly modelled due to the way the National Grid network is represented, but have been accounted for when considering reinforcement options.

In baseline, the Bicker Fen GSP Group Demand is 180 MW with total installed generation of 325 MW. In 2022 this increases to the figures shown in Table 16.

Table 16: Projected Group Demand of Bicker Fen GSP in 2022

Scenario	Group Demand	Generation (Installed Capacity Including Battery Export)
SP	196 MW	337 MW
CE	195 MW	431 MW
TD	259 MW	476 MW
CR	263 MW	506 MW

SGT Overloads

Generation Demand SP CE TD CR

In Two Degrees and Community Renewables, a fault of either Bicker Fen SGT overloads the remaining in-service SGT to between 113% and 116% at winter peak demand. A Bicker Fen busbar fault increases these overloads to as much as 125%. No first circuit overloads are seen for Consumer Evolution or Steady Progression.

It is recommended that the short-term ratings are confirmed for both Bicker Fen SGTs. For the purposes of these studies, it is assumed that both SGTs are limited to 274 MVA for their six-hour short-term rating.

It is also recommended that the short-term ratings are confirmed and the impact of a busbar fault is assessed in more detail.

Boston BSP is normally fed out of Walpole GSP, but for any arranged outage that leaves it at single circuit risk, it is normally transferred into the Bicker Fen group to maintain double circuit security. The subsequent fault of a Bicker Fen SGT leaves the remaining in-service SGT loaded between 103% (Steady Progression) and 169% (Community Renewables) at winter peak demand. Overloads are also seen for this SCO condition in the intermediate warm peak demand. An overload is only seen for summer peak demand under Two Degrees and Community Renewables: between 110% and 113%, respectively.

For the peak demand representative days, there is no outage window for intermediate warm and winter peak demand representative days under all scenarios. While there is a demand outage window in summer for Steady Progression and Consumer Evolution, there are generation overloads identified under all scenarios. These generation overloads are discussed below and a reinforcement strategy that accounts for the demand and generation overloads is described.

A first circuit fault of either Bicker Fen SGT overloads the remaining in-service SGT to between 124% (Consumer Evolution) and 160% (Community Renewables) at summer peak generation. This overload is not seen under Steady Progression.

This overload is not seen for any arranged outages as Skegness, Lynn Wind Farm and Inner Dowsing Wind Farm are transferred into Walpole to maintain double circuit security.

Boston BSP is normally fed out of Walpole GSP, but for an arranged outage that leaves the site at single circuit risk, it is normally transferred into Bicker Fen. A subsequent Bicker Fen SGT fault following this arranged outage increases the SGT loadings to between 129% (Steady Progression) and 217% (Community Renewables).

National Grid has confirmed the SGT short-term ratings are not suitable for reverse power flow. The increase in SGT overload caused by transferring Boston into the group can be removed by leaving Boston at single circuit risk, fed out of Walpole during summer and any periods where the level of generation could cause a next fault overload. This operation strategy remains P2 complaint, as the Group Demand of Boston is 90 MW, so there is no SCO requirement. Even though there is no SCO requirement, the majority of the demand can be resupplied via Bicker Fen following the loss of the second Walpole to Boston circuit.

It may be possible to manage the generation overloads through the use of ANM. If it were not possible to manage the generation constraints with ANM, a new SGT will relieve the generation overloads identified and means that less demand is left at single circuit risk to mitigate demand-driven overloads.

For the purposes of these studies, a third Bicker Fen SGT has been added to the model and the Bicker Fen 132 kV has been converted to a two-section double busbar arrangement.

Grantham and Sleaford Lost Load

Generation | **Demand** SP CE TD CR

As described in baseline, an arranged outage of one of the SGTs at Bicker Fen leaves Sleaford and Grantham BSPs at single circuit risk. The Group Demand of Sleaford and Grantham increases from 119 MW in baseline to as much as 160 MW under Community Renewables. However, this remains P2-compliant as both BSPs can be resupplied via Staythorpe GSP interconnection.

Under current loadings, the existing network remains P2-compliant under all scenarios, so no action is required. The proposed SGT at Bicker Fen would resolve this lost load, as Grantham and Sleaford would not be at next fault risk for the arranged outage of one SGT.

AS Route Overloads

Generation | Demand SP CE TD CR

The significant generation growth at Boston causes the reverse power flow limit of both Boston GTs to be exceeded under all scenarios. A detailed write-up of this issue can be found in the Walpole 2022 results. A summary of the reinforcement options proposed for Boston GT overloads are:

- establishing new grid transformers at or near Boston BSP to de-load the existing transformers at Boston BSP;
- future connections in the area fed by Boston BSP being mandated to connect at 132 kV; or
- configuring ANM to manage GT loadings.

For the purposes of these studies, two additional GTs have been connected at Boston, normally fed out of Bicker Fen. The proposed GT3 and GT4 are run independently to the existing GT1 and GT2, with normally open interconnection at 33 kV. Sufficient demand and generation has been transferred onto the new GTs to resolve the Boston GT1 and GT2 overloads.

In baseline, it was identified that when Boston is transferred onto Bicker Fen for an arranged outage, a subsequent fault of either circuit from Bicker Fen to Boston caused an overload up to 115% of rating for the summer generation representative day. It was recommended that either:

- the 33 kV bus sections at Boston BSP, Skegness BSP and any downstream loose couples are broken when Boston is transferred into the group. This means the subsequent fault causes a lost load rather than overloading the AS route between Bicker Fen and Boston;
- alternatively, Boston is left on Walpole at single circuit risk and if the remaining in-service Walpole to Boston circuit was to fault, Boston could be transferred into Bicker Fen to resupply the majority of the demand. This reduces the switching requirement of control for the arranged outage and reduces the switching required to resupply the lost load following the subsequent fault.

Due to the increase of generation at Boston to as much as 140 MW, the transfer of Boston into the group causes an overload on both sides of the AS route between 107% (Steady Progression) and 136% (Community Renewables). The proposed GTs at Boston do not have a material impact on this overload condition, as all of Boston is fed from Bicker Fen pre and post-reinforcement for this SCO condition.

It is recommended that the AS route circuits are reconductored with 300mm^2 AAAC (Upas) at 75°C and the existing cable sections are overlaid with 1000mm^2 copper XLPE cable for all scenarios.

AF Route Overloads

Generation **Demand** TD CR

The Group Demand of Sleaford BSP, Grantham BSP and Grantham North traction supplies increases from 117 MW in baseline to as much as 160 MW (Community Renewables). In Two Degrees and Community Renewables, a fault of either Bicker Fen to Grantham/Sleaford circuit overloads the remaining in-service circuit to as much as 115% at winter peak demand. This overload is only seen on the AF route between Bicker Fen GSP and the tee to Sleaford. This overload is not seen for any arranged outage or SCO condition as Sleaford and Grantham are routinely transferred into Staythorpe to maintain double circuit security.

It is recommended that both AF route circuits between Bicker Fen and the tee point to Sleaford are reconductored with 300mm^2 AAAC (Upas) at 75°C and the existing cable sections are overlaid with 1000mm^2 copper XLPE cable under Two Degrees and Community Renewables.

Walpole GSP

For the 2022 studies in Walpole, the following network reinforcements were modelled:

- the proposed running arrangement for 2022 uses a bus coupler split with an SGT connected to each of the Main 3, Main 4, Reserve 3 and Reserve 4 busbars. SGT3 will remain on hot standby, able to close onto either section for the loss of an SGT normally supplying that section;
- the short cable section that currently limits the rating of the HW route circuit between Walpole and Boston was uprated from 0.65 oil filled cable to 1000mm^2 XLPE copper cable, to match the rating of the cable at the Walpole end of the circuit;
- following the replant of Boston BSP, operational intertrips were modelled for both of the 90 MW offshore wind farms connected to Middlemarsh BSP, to disconnect for the loss of direct 132 kV infeed from either Bicker Fen or Walpole.

Boston BSP GT Overloads

Generation Demand SP CE TD CR

Boston BSP is supplied by two 45/90 MVA transformers that are normally fed from Walpole via the 132 kV HW route double circuit. Following generation growth at Boston BSP, under all scenarios in 2022, both GTs operate into their forced cooling rating under intact network conditions. In addition, under all scenarios, the FCO (arranged or fault) of one GT would overload the remaining GT in service to between 108% (Steady Progression) and 127% (Community Renewables). There are no SCO conditions that exacerbate this overload.

As there is no option to uprate the grid transformers at Boston BSP, there are a range of options that could be utilised to remove any future network constraints. These include:

- **configuring ANM to manage GT loadings;**
- **establishing new grid transformers at or nearby Boston BSP to de-load the existing transformers supplied by Boston BSP; or**
- **future connections in the area fed by Boston BSP being mandated to connect at 132 kV.**

It is recommended that any generation overloads at Boston BSP are studied in conjunction with wider network issues on the 132 kV circuits between Boston and Bicker Fen, in addition to Bicker Fen SGT capacity.

For these studies, two extra grid transformers were installed at Boston BSP as the proposed reinforcement. Both GTs are normally fed from Bicker Fen GSP, with normally open interconnection at 33 kV to the existing GT1/GT2 units fed from Walpole GSP.

Walpole to Boston 132 kV Circuits

Generation Demand SP CE TD CR

For an arranged outage of an SGT at Bicker Fen GSP, or one of the AS route circuits between Bicker Fen GSP and Boston BSP, Skegness and Middlemarsh BSPs are transferred onto Walpole GSP via the HW route 132 kV double circuit. For the 2022 studies, the cable sections at the Boston end of the circuits were overlaid to match the cable sections at the Walpole end of the circuits. Subsequently this circuit is limited by 300mm^2 AAAC (UPAS) conductor profiled for 75-degree operation.

For the above arranged outage followed by a second circuit fault of one of the HW route circuits, the remaining HW route circuit in service would overload to between 104% (Steady Progression) and 149% (Community Renewables). This is in spite of one of the large offshore wind farms connected to Middlemarsh being disconnected through an intertrip signal.

By operating the network radially for the arranged outage, the second circuit fault will disconnect demand at Boston and Skegness. A similar operating arrangement is currently used for outages of a Walpole–Boston circuit, whereby Boston BSP is transferred onto Bicker Fen. This alleviates the projected overloads under all scenarios; however, it does leave half of Boston BSP and Skegness BSP at single circuit risk.

Spalding/South Holland GT Capacity

Generation Demand TD CR

The 132 kV DZ route from Walpole GSP supplies both Spalding BSP and South Holland BSP, which run in parallel at 33 kV. Spalding BSP has two 45/90 MVA GTs and there is a further 45/90 MVA GT at South Holland BSP. For the second circuit outage combination that results in the loss of two out of the three grid transformers in the group, the remaining GT in service would overload up to 104% (Two Degrees) and 106% (Community Renewables) for a winter peak demand representative day.

It is recommended that the sufficiency of the available access window for the 132/33 kV GTs at Spalding and South Holland is confirmed.

DZ Route Overloads

Generation | **Demand** SP CE TD CR

For an arranged outage at Stamford BSP that breaks the 132 kV interconnected ring, the UKPN and WPD areas of network are fed independently from Walpole. When the arranged outage is followed by a fault of either of the Walpole to South Holland/Spalding circuits, this would overload the remaining DZ/HB route in service up to between 109% (Steady Progression) and 120% (Community Renewables) at winter peak demand. The overloads also occur for an intermediate warm peak demand representative day, up to 102% under the Two Degrees and Community Renewables scenarios. These circuits are currently limited by 175mm^2 ACSR (Lynx) conductor profiled for 75°C operation.

It is recommended that the sufficiency of the available access window for these circuits is confirmed.

Stamford to Peterborough North 132 kV Circuits

Generation | **Demand** SP CE TD CR

The 132 kV circuit (PRA and PFG routes) between Stamford BSP (WPD-owned) and Peterborough North BSP (UKPN-owned) forms part of a wider 132 kV interconnected ring fed from Walpole, which encompasses the Spalding/South Holland, Bourne, Stamford and wider Peterborough area networks. The PRA route is currently limited by a short overhead section of 175mm^2 ACSR (Lynx) conductor, rated for 75°C operation on PL16 towers.

For a fault of the DZ route circuit between Walpole and South Holland, the interconnected ring is supplied via the remaining DZ route circuit in service and the Peterborough–Stamford circuit. This first circuit fault would marginally overload the UKPN-owned PFG route circuit under all scenarios for the winter and intermediate warm peak demand cases.

The overloads from the above fault are exacerbated when the fault follows an arranged outage at Staythorpe GSP, whereby Grantham South BSP is transferred onto Walpole GSP via the DZ route. This SCO combination would also overload the WPD-owned PRA route under all scenarios for a winter peak demand case. Under the Two Degrees and Community Renewables scenarios, the overloads only occur under the summer and intermediate warm peak demand cases.

The overloads on the PRA route could be alleviated through a range of options:

- **reconductoring the first two spans of the PRA route from CB220 at Stamford BSP to tower PR61 with 300mm^2 AAAC (UPAS);**
- **for the arranged outage of a Staythorpe B–C interconnector, not transferring Grantham South onto Walpole, instead running Grantham South at single circuit risk from Staythorpe. This would also involve running Bourne West BR 25 kV at single circuit risk;**
- **managing the overloads in summer through flexibility to allow the arranged outage to take place.**

It is recommended that further collaborative studies are undertaken with UKPN to consider the network fed from Walpole GSP as a whole.

West Burton GSP

Network Changes Modelled

For the 2022 studies, the third SGT at West Burton GSP, which is due to be completed by October 2020, has been modelled. The latest running arrangement has been used, meaning that the third SGT can be switched into service onto either busbar by an auto-changeover scheme if one of the other SGTs is lost.

In addition, both of the West Burton–Retford/Checkerhouse 132 kV circuits have been re-strung with 300mm² AAAC (UPAS) conductor, operating at 75°C. The tees to Retford and Worksop BSPs have not been reinforced, nor have the cable sections between West Burton and Checkerhouse.

West Burton SGT Overloads

West Burton SGT Outages

Generation **Demand** SP CE TD CR

For a fault or planned outage of either SGT1 or SGT2 at West Burton GSP, SGT3 is brought into service by an auto-changeover scheme. For planned SGT outages, Retford and Worksop BSPs are transferred to Staythorpe GSP.

Under an arranged outage of one of the SGTs at West Burton GSP, a subsequent fault on a second SGT at West Burton can cause an overload of the third SGT. Overloads occur under winter and intermediate warm peak demand and can be up to 133% of rating.

It is recommended that if possible, National Grid take the outage during the summer period only. For outages taken outside of this period, it will be necessary to transfer up to 19 MVA of demand away from West Burton GSP, by the use of either 33 kV transfers or the Bourne–Lincoln 132 kV circuit, or both. This will ensure that the predicted overload is within the six-hour rating of an SGT at West Burton GSP. In the event of a fault, post-fault transfers can be used to reduce the loading to within the continuous rating within six hours.

West Burton Busbar Outages

Generation **Demand** SP CE TD CR

Once the third SGT is installed at West Burton GSP, the proposed running arrangement is such that SGT3 will be normally selected to the main busbar, but all feeder circuits will be selected to the reserve busbar, which itself will be split due to fault level issues.

For a fault outage of either half of the reserve busbar at West Burton GSP, this can cause an overload of one of the SGTs at West Burton. The overload occurs during the winter and intermediate warm seasons and can be up to 131% of SGT rating.

It is recommended that this fault condition is reviewed with National Grid – it may be possible for National Grid to manage post-fault SGT loading with short-term ratings. If short-term rating are available, post fault action to select some feeders to the main busbar (and thus be fed via SGT3), in order to reduce the demand on the overloaded SGT to within its continuous rating. If sufficient short-term ratings are not available, it is recommended that the fault level

constraints be reinforced, so the bus coupler can be closed and two SGTs can be run in parallel.

For an arranged outage of the main busbar at West Burton GSP, a subsequent fault on one of the SGTs at West Burton GSP can cause an overload on one of the other SGTs. Overloads appear under winter and intermediate warm loadings and can be up to 137% of SGT rating.

It is recommended that the sufficiency of a summer access window be confirmed with National Grid. For outages taken outside of this period, it will be necessary to transfer sufficient demand away from West Burton GSP, by the use of either 33 kV transfers or the Bourne–Lincoln 132 kV circuit, or both.

For both of the above outage/fault combinations, if insufficient SGT short-term ratings or transfer capability is available, it is recommended that fault level reinforcement be carried out in order to allow two SGTs to operate in parallel. This would eliminate the overload seen in the event of a busbar fault.

West Burton–Lincoln 132 kV Circuit Outages/Lincoln 132 kV Switchgear/Busbar Outages

Generation | **Demand**

CE TD CR

For the purpose of the 2022 studies, the recommendations from the baseline results have been followed. For an outage of one of the West Burton–Lincoln 132 kV circuits or a Lincoln 132 kV switchgear/busbar outage, the 33 kV bus sections at Worksop and Lincoln BSPs and the 11 kV bus section at Lincoln BSP have been opened.

Under an outage of one of the West Burton–Lincoln 132 kV circuits or a Lincoln 132 kV switchgear/busbar outage, this can cause an overload on one of the SGTs at West Burton GSP. Overloads occur under winter loading only and can be up to 118% of SGT rating.

It is recommended that outages of the West Burton–Lincoln 132 kV circuits and Lincoln 132 kV switchgear/busbar outages be taken during the summer and intermediate warm periods where possible. For outages taken during the winter period, it is recommended that Retford and Worksop BSPs be transferred to Staythorpe GSP, and some of the demand at Lincoln BSP be picked up via the Bourne–Lincoln 132 kV circuit.

Worksop Lost Load

Generation | Demand

TD CR

For a fault on either half of the reserve 132 kV busbar at West Burton GSP, this results in the loss of one of the West Burton–Retford/Checkerhouse/Worksop 132 kV circuits, and thus the loss of a transformer at Worksop BSP. Due to the forecast increase in the level of generation on Worksop BSP under Two Degrees and Community Renewables, the loss of a transformer at Worksop BSP causes the DOC protection to trip on the remaining transformer, resulting in the total loss of Worksop BSP. This issue only occurs under summer loading and can result in the loss of up to 15 MVA of demand.

It is recommended that the directional overcurrent settings are reviewed at Worksop BSP to ensure correct operation with increased levels of generation in the group. If the settings cannot be sufficiently increased to handle the level of generation on Worksop BSP, then it is recommended that the DOC relays be replaced by a load-blinded type.

Lincoln GT6 Outage

Generation | **Demand** TD CR

Lincoln GT6 is one of three 132/33 kV transformers installed at Lincoln BSP, but is rated lower than the other two transformers (90 MVA vs 120 MVA). For an outage of GT6 at Lincoln BSP, the 33 kV demand is picked up by the other two 132/33 kV transformers.

Lincoln Transformer Overloads

Generation | **Demand** TD CR

For an arranged outage of GT6 at Lincoln BSP, a subsequent fault on one of the 132 kV busbars at Lincoln BSP, or on one of the West Burton–Lincoln 132 kV circuits, causing the loss of a second 132/33 kV transformer, can cause an overload on the remaining 132/33 kV transformer. The overload occurs in winter only and can be up to 103% of transformer rating.

It is recommended that outages of GT6 at Lincoln be restricted to the summer and intermediate warm periods only. For outages taken during the winter period, it is recommended that the 33 kV bus section between GT1 and GT2 at Lincoln be opened. Any loose couples will also need to be broken.

9 – 2027 Results

Berkswell GSP

By 2027, Group Demand is projected to grow from 2022 to the figures shown in Table 17.

Table 17: Projected Group Demand of Berkswell GSP in 2027

Scenario	2022 Group Demand	2027 Group Demand
SP	344 MW	371 MW
CE	345 MW	382 MW
TD	364 MW	456 MW
CR	390 MW	490 MW

SGT Overloads

Generation **Demand** CR

In the 2027 studies, the 132 kV busbar at Berkswell GSP is modelled with SGT1, SGT2 and SGT3 supplying main and reserve busbar sections 1 and 2, and SGT4 on hot standby.

SGT overloads occur under the Community Renewables scenario only. For the arranged outage of an SGT followed by a fault to a second SGT, the group load is supplied by the remaining SGTs. Depending on the SCO combination, the remaining SGTs in service can overload up to 105% of nameplate rating at winter peak demand. These overloads do not occur for the intermediate warm or summer peak demand conditions.

It is still possible to schedule Grid Code SGT Access Periods within the summer and intermediate warm ratings seasons.

Reserve Busbar Fault

Generation **Demand** CR

There is a section circuit breaker 120 between main busbar sections 1 and 2, but no section circuit breaker between reserve busbar sections 1 and 2. This means that a fault on either reserve busbar section results in both being de-energised, with all of Berkswell GSP being supplied by SGT1 and SGT2.

Although an auto-close scheme on the hot standby SGT4 has been assumed, SGT4 and SGT3 are both selected to the reserve busbars, so neither would be available for this fault.

This condition results in SGT overloads under the Community Renewables scenario and only at winter peak demand. This fault will overload SGT1 and SGT2 up to 108% of nameplate rating.

It is recommended that this fault condition be reviewed with National Grid: it may be possible for National Grid to manage post-fault SGT loading with short-term ratings. If not, the installation of a 132 kV reserve section circuit breaker 160 would mean that only one busbar section and SGT is lost for either reserve busbar fault.

Warwick and Harbury Group

Generation **Demand** SP CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Warwick and Harbury area.

Berkswell GSP to Warwick BSP 132 kV (CX Route)

Generation **Demand** TD CR

An outage (arranged or fault) resulting in one of the Berkswell to Warwick 132 kV circuits (CX route) being out of service causes an overload to the remaining 132kV circuit in service. These overloads can be up to 119% under winter peak demand (Two Degrees and Community Renewables); up to 108% under intermediate warm demand and up to 106% under summer peak demand (Community Renewables only).

The studied overloads could be alleviated by replacing the existing 175mm² ACSR (Lynx) conductor on the CX route between Berkswell GSP and Warwick BSP with 300mm² AAAC (Upas), profiled for operation at 75°C, and overlaying associated cable sections accordingly.

A proposal for a third 132 kV circuit between Berkswell GSP and Warwick BSP, discussed in the combined reinforcement strategy below, may supersede the option above.

Warwick and Harbury Lost Load

Generation **Demand** SP CE TD CR

The lost loads described in the 2022 results increase under all scenarios in the 2027 studies. Warwick (132/11 kV and 132/33 kV) and Harbury (132/33 kV) BSP sites are each supplied via two 132 kV circuits from Berkswell GSP. The group load is interrupted for the SCO of both 132 kV circuits between Berkswell GSP and Warwick BSP.

Demand growth to 2027 increases the combined Group Demand of Warwick and Harbury BSPs to between 176 MW (Steady Progression) and 253 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits between Berkswell and Warwick.

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand is restored within three hours of an SCO. In this case, restoration of between 59 MW (Steady Progression) and 85 MW (Community Renewables) would be necessary.

Warwick 132/11 kV BSP Grid Transformer Capacity

Generation **Demand** SP CE TD CR

The Group Demand of Warwick BSP 132/11 kV grows to between 49 MW (Steady Progression) and 60 MW (Community Renewables) by 2027. This exacerbates the overloads described in the 2022 results under all scenarios.

For the SCO of any two of these GTs, the remaining GT supplies the group load. These SCO combinations would overload the remaining Warwick 132/11 kV GT during winter peak demand (up to 182%), intermediate warm demand (up to 162%) and summer peak demand (up to 127%) under all scenarios.

Changing the 11 kV running arrangements at Warwick to disconnect some load for the SCO of two GTs would alleviate the studied overloads, without affecting the P2 compliance of this network.

Warwick 132/33 kV BSP Grid Transformer Capacity

Generation **Demand** TD CR

SCO combinations would also overload the remaining Warwick 132/33 kV GT under winter peak demand (up to 112%) and intermediate warm demand (up to 102%) for the Two Degrees and Community Renewables scenarios only. Warwick 132/33 kV GT overloads do not occur during a summer peak demand case.

It is recommended that the sufficiency of the available access window for the 132/33 kV GTs at Warwick is confirmed. It the access window is insufficient, a new BSP between Coventry and Warwick could be established to alleviate the studied Warwick 132/33 kV and 132/11 kV overloads.

Combined Reinforcement Strategy

In view of the increase in Group Demand for the Warwick and Harbury group, it is worth considering a wider reinforcement strategy to ensure that additional infeed is available to supply the group. A combined reinforcement option could be to construct a third 132 kV circuit from Berkswell GSP to Warwick BSP. This would alleviate the Berkswell to Warwick 132 kV circuit (CX route) overloads identified as well as ensuring P2 compliance for lost load.

When deciding a route for this circuit, any future requirement for a new BSP between Coventry and Warwick should be taken into account.

Coventry West and Coventry South Group

Generation **Demand** SP CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Coventry West and Coventry South areas.

Coventry West and Coventry South Lost Load

Generation **Demand** SP CE TD CR

Demand growth to 2027 increases the combined Group Demand of Coventry West (132/33 kV) and Coventry South (132/33 kV side) BSPs to between 116 MW (Steady Progression) and 138 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits between Berkswell and Coventry.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 16 MW (Steady Progression) and 38 MW (Community Renewables) would be necessary.

Sufficient 132 kV and 33 kV post-fault transfer capacity into the Coventry West/Coventry South 33 kV networks would be available, satisfying the requirements of P2.

Coventry GSP

By 2027, Group Demand is projected to grow from 2022 to the figures shown in Table 18.

Table 18: Projected Group Demand of Coventry GSP by 2027

Scenario	2022 Group Demand	2027 Group Demand
SP	528 MW	589 MW
CE	529 MW	605 MW
TD	552 MW	707 MW
CR	570 MW	741 MW

SGT Overloads

Generation **Demand** SP CE TD CR

Despite proposed reinforcement, alleviating the SGT overloads described in the 2022 studies, demand growth to 2027 causes further SGT overloads at Coventry GSP. For 132 kV busbar or SGT faults at Coventry, the remaining SGTs left in service (2+1 arrangement post fault) overload up to 155% for winter peak demand (under all scenarios), up to 124% for intermediate warm demand (Two Degrees and Community Renewables) and up to 104% for summer peak demand conditions (Community Renewables only).

Furthermore, for the arranged outage of an SGT followed by a fault to a second SGT, the remaining SGTs in service can overload up to 160% of nameplate rating at winter peak demand, up to 129% at intermediate warm demand (under all scenarios) and up to 113% at summer peak demand (Two Degrees and Community Renewables only).

Proposed Reinforcement Strategy

To alleviate the projected overloads at Coventry GSP, a reinforcement strategy will be required with consideration given to Coventry and the nature of the surrounding 132 kV networks. Coventry is a large GSP with four SGTs and ten outgoing circuits. Given the geographic area supplied and the distribution of future demand growth, it is proposed that one of the following options is considered in order to alleviate the 2027 projected overloads:

- **establishment of a fifth SGT at Coventry GSP. This is likely to require considerable 275 and 132 kV switchgear installation and busbar extension works to facilitate this additional SGT unit;**
- **replacing the existing SGTs with units of a higher rating. In view of the extensive and wide scale load growth up to 2027, it could be that whilst progressing this strategy with National Grid, a more economical solution for these projected overloads could be for larger SGTs (in the order of 360MVA) to be made available;**
- **transferring load away from Coventry GSP by establishing a new GSP, north of Coventry, instead of expanding Coventry GSP further.**

Detailed network design will be required to assess the proposed reinforcement strategies against the projected demand and generation growth, including but not limited to:

- **running arrangements for outage management, particularly for transmission network outages;**
- **protection and fault level studies.**

Whitley Area

Generation | **Demand** TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Whitley area.

Whitley BSP 132/33 kV GT Capacity

Generation | **Demand** TD CR

An outage (arranged or fault) of a GT at Whitley BSP will overload the remaining GT in service. This overload can be up to 119% for a winter peak demand and up to 118% for both intermediate warm and summer peak demand conditions. These overloads occur for the Two Degrees and Community Renewables scenarios only.

Whitley BSP to Coventry GSP 132 kV HK Circuit Overload

Generation | **Demand** TD CR

Despite proposed reinforcement of the HK route (described in the 2022 studies and required only if the Coventry South 33 kV transfer onto Coventry GSP is deemed necessary for all seasonal periods), demand growth to 2027 causes further circuit overloads under the Two Degrees and Community Renewables scenarios.

Following the same SCO outage conditions as described in the baseline report, these conditions in the 2027 studies can overload the remaining Whitley to Coventry 132 kV circuit up to 117% for a winter peak demand case and up to 103% for an intermediate warm peak demand case. This overload does not occur for a summer peak demand case.

Whitley BSP 132/33 kV Lost Load

Generation | **Demand** TD CR

Demand growth to 2027 increases the Group Demand of Whitley (132/33 kV) BSP to between 117 MW (Two Degrees) and 127 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits between Coventry and Nuneaton.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 17 MW (Two Degrees) and 27 MW (Community Renewables) would be necessary.

Combined Reinforcement Strategy

To alleviate the projected overloads between Whitley BSP and Coventry GSP, a reinforcement strategy will be required with consideration given to Whitley and the nature of the surrounding 132 kV networks. Given the geographic area supplied and the distribution of future demand growth, it is proposed that the following strategy is considered in order to alleviate the 2027 projected overloads, as well as ensuring P2 compliance for lost load:

- **establish a pair of 132/11 kV 15/30 MVA GTs at Whitley BSP and transfer the load of the existing on-site 33/11 kV primary substation to the new GTs. It may be necessary to install 132 kV bus section circuit breakers between the 132/33 kV and 132/11 kV GTs to provide SCO compliance and operational flexibility;**
- **re-assess the transfer requirements of Coventry South 132/33 kV into Coventry GSP;**

- **establish additional 33 kV interconnectors at Coventry South BSP to transfer demand away if the transfer into Coventry GSP remains necessary.**

Nuneaton BSP

Generation | **Demand** SP CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Nuneaton area.

Nuneaton BSP 132/33 kV GT Capacity

Generation | **Demand** CE TD CR

Nuneaton BSP has two 132/33 kV 45/90 MVA GTs. Following demand growth to 2027, an outage (arranged or fault) of a GT at Nuneaton BSP will overload the remaining GT in service.

This overload can be up to 130% for winter peak demand, up to 122% for intermediate warm demand conditions (Consumer Evolution, Two Degrees and Community Renewables) and up to 106% for summer peak demand (Two Degrees and Community Renewables only).

Nuneaton (132/33 kV) Lost Load

Generation | **Demand** SP CE TD CR

Demand growth to 2027 increases the Group Demand of Nuneaton (132/33 kV) BSP to between 107 MW (Steady Progression) and 137 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits between Coventry and Nuneaton.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 7 MW (Steady Progression) and 37 MW (Community Renewables) would be necessary.

Combined Reinforcement Strategy

It is proposed that one of the following options is considered in order to alleviate the 2027 projected overloads, as well as ensuring P2 compliance for lost load:

- **establishing a pair of 132/11 kV 15/30 MVA GTs at Nuneaton BSP or a third 132/33 kV GT at Nuneaton BSP;**
- **partially de-load Nuneaton BSP, either by establishing additional 33 kV interconnectors to transfer load away permanently, or by transferring load to the proposed GSP, which is outlined as an option in the proposed reinforcement strategy for Coventry GSP.**

Rugby, Daventry and Pailton 132 kV Network

Generation | **Demand** SP CE TD CR

Following extensive demand and generation growth to 2027, the following overloads have been projected in the area.

Rugby BSP 132/11 kV GT Capacity

Generation | **Demand** SP CE TD CR

Rugby BSP has two 132/11 kV 15/30 MVA GTs: GT2A and GT3A. Following extensive demand growth to 2027, an outage (arranged or fault) of either GT overloads the remaining GT in service. This can be up to 119% for winter peak demand and up to 114% for intermediate warm demand conditions. These overloads occur under all scenarios, however, not under the summer peak demand period.

It may be possible to alleviate the projected overload by transferring demand at 11 kV onto existing primary substations supplied by 132/33 kV GT1 and GT4 at Rugby. If sufficient transfers are not available, a new 33/11 kV primary substation in the vicinity may prove more appropriate.

A proposal for a new BSP, discussed in the combined reinforcement strategy below, may supersede this option above.

Daventry BSP 132/33kV GT Capacity

Generation | **Demand** CR

Daventry BSP has two 132/33 kV 45/90 MVA GTs. Following extensive demand growth to 2027, an outage of either GT overloads the remaining GT in service. This can be up to 106% for winter peak demand and the overload is marginal for both intermediate warm and summer peak demand conditions. These overloads occur under the Community Renewables scenario only.

Further to this, following extensive generation growth to 2027, an outage of either Daventry GT under the summer generation case is also projecting a marginal overload to the remaining GT in service. This overload occurs under the Community Renewables scenario only.

Additional 33 kV interconnectors could be established at Daventry BSP to transfer demand and generation away from Daventry BSP permanently.

A proposal for a new BSP, discussed in the combined reinforcement strategy below, may supersede the option above.

Daventry (132/33 kV) Lost Load

Generation | **Demand** TD CR

Demand growth to 2027 increases the Group Demand of Daventry (132/33 kV) BSP to between 104 MW (Two Degrees) and 111 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits supplying Daventry.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 4 MW (Two Degrees) and 11 MW (Community Renewables) would be necessary.

Pailton 132/33 kV GT Capacity

Generation Demand CR

Pailton BSP has two 132/33 kV 60/90 MVA GTs. Following generation growth to 2027, an outage of either GT overloads the remaining GT in service. This can be up to 110% for summer generation under the Community Renewables scenario only.

Additional 33 kV interconnectors could be established at Pailton BSP to transfer generation away from Pailton BSP permanently.

A proposal for a new BSP, discussed in the combined reinforcement strategy below, may supersede the option above.

Combined Reinforcement Strategy

To alleviate the projected overloads identified in the Rugby, Daventry and Pailton area, a reinforcement strategy will be required with consideration given to the area and the nature of the surrounding 132 kV networks. Given the geographic area supplied and the distribution of future demand and generation growth, it is proposed that in order to alleviate the 2027 projected overloads and ensure P2 compliance. A new BSP be established to the south of Rugby on the CP route between Rugby BSP and Coventry GSP, to partially deload the Rugby, Daventry and Pailton group.

Enderby GSP

By 2027, Group Demand is projected to grow from 2022 to the figures shown in Table 19.

Table 19: Projected Group Demand of Enderby GSP in 2027

Scenario	2022 Projected Group Demand	2027 Projected Group Demand
SP	568 MW	607 MW
CE	574 MW	623 MW
TD	596 MW	719 MW
CR	613 MW	744 MW

SGT Overloads

Generation **Demand** SP CE TD CR

Further demand growth to 2027 causes further SGT overloads for 132 kV busbar or SGT faults, which overload the remaining SGTs in service at Enderby GSP up to 120% for winter peak demand conditions (Two Degrees and Community Renewables only).

Furthermore, for the arranged outage of an SGT followed by the fault of a second SGT, the group load is supplied by the remaining SGTs. Depending on the SCO combination, the remaining SGTs in service can overload up to 180% of nameplate rating at winter peak demand, 144% at intermediate warm demand (under all scenarios) and 115% at summer peak demand (Two Degrees and Community Renewables only).

Proposed Reinforcement Strategy

To alleviate the projected overloads at Enderby GSP, a reinforcement strategy will be required with consideration given to Enderby and the nature of the surrounding 132 kV networks. Given

the geographic area supplied and the distribution of future demand growth, it is proposed that the following strategy is considered in order to alleviate the 2027 projected overloads:

- **transferring load away from Enderby GSP. Given the size of Grendon and Enderby GSPs and the associated overloads seen by both, a new GSP to partially deload both Grendon and Enderby would be an appropriate reinforcement. Please see the 2027 results for Grendon GSP for further information regarding this proposed GSP;**
- **Enderby GSP could be partially deloaded by permanently transferring the 132/33 kV side of Wigston BSP onto this proposed GSP. This could be achieved by moving the Kibworth 132 kV open points to Wigston BSP and teeing Wigston 132/33 kV BSP side into the existing AZ route, Kibworth side. Kibworth BSP has also been proposed to transfer onto this GSP.**

Leicester and Wigston Group

Generation **Demand** SP CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Leicester and Wigston areas.

Enderby to Leicester 132 kV (CC and CN) Circuits

Generation **Demand** TD CR

Despite alleviating the overloads in the 2022 studies by improving the load balance between the Enderby to Leicester 132 kV circuits, extra demand growth results in further overloads in the 2027 studies. Following the same SCO outage conditions as described in the baseline report, overloads are present during the Two Degrees and Community Renewables scenarios.

The proposal of permanently transferring the 132/33 kV side of Wigston BSP onto the proposed GSP between Enderby and Grendon will alleviate the projected 2027 studied overloads.

Leicester North BSP 132/33 kV GT Capacity

Generation **Demand** TD CR

An outage (arranged or fault) resulting in either Leicester North 132/33 kV GT being out of service results in an overload to the remaining GT in service. These overloads can be up to 127% at winter peak demand, up to 119% for intermediate warm and up to 103% for summer peak demand conditions. These overloads occur for the Two Degrees and Community Renewables scenarios only.

Leicester BSP 132/33 kV GT Capacity

Generation **Demand** TD CR

An outage (arranged or fault) resulting in either Leicester 132/33 kV GT being out of service results in an overload to the remaining GT in service. These overloads can be up to 106% for a winter peak demand case only. These overloads occur for the Two Degrees and Community Renewables scenarios only.

Leicester Lost Load

Generation **Demand** SP CE TD CR

Demand growth to 2027 increases the Group Demand of Leicester BSP to between 128 MW (Steady Progression) and 150 MW (Community Renewables). The group load is interrupted for the SCO of both 132/33 kV GTs at Leicester BSP.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 28 MW (Steady Progression) and 50 MW (Community Renewables) would be necessary.

Leicester East Lost Load

Generation **Demand** SP CE TD CR

Demand growth to 2027 increases the Group Demand of Leicester East BSP to between 105 MW (Steady Progression) and 135 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits between Leicester 132 kV and Leicester East 132/33 kV.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 5 MW (Steady Progression) and 35 MW (Community Renewables) would be necessary.

Leicester North Lost Load

Generation **Demand** SP CE TD CR

Demand growth to 2027 increases the Group Demand of Leicester North BSP to between 105 MW (Steady Progression) and 135 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits between Leicester 132 kV and Leicester North 132/33 kV.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 5 MW (Steady Progression) and 35 MW (Community Renewables) would be necessary.

Wigston BSP to Wigston Tee (AZT Route) 132 kV Circuit

Generation **Demand** TD CR

For an outage (arranged or fault) of one of the tee-off AZT route circuits between Wigston BSP and the AZ route circuits, this will overload the remaining AZT route circuit in service. This overload can be up to 110% for winter peak demand. These overloads occur under the Two Degrees and Community Renewables scenarios only.

The proposal of permanently transferring the 132/33 kV side of Wigston BSP onto the proposed GSP will alleviate these 2027 studied overloads.

Wigston BSP Lost Load

Generation **Demand** SP CE TD CR

Demand growth to 2027 increases the Group Demand of Wigston BSP to between 101 MW (Steady Progression) and 124 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits supplying Wigston BSP.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 1 MW (Steady Progression) and 24 MW (Community Renewables) would be necessary.

Combined Reinforcement Strategy

To alleviate the projected overloads in the Leicester area, a reinforcement strategy will be required with consideration given to Leicester BSP and the nature of the surrounding 132 kV and 33 kV networks. Given the geographic area supplied and the distribution of future demand growth, it is proposed that the following strategy is considered in order to alleviate the 2027 projected overloads, as well as ensuring P2 compliance for lost load:

- **establishing a new BSP to the west of Leicester between Enderby GSP and Leicester BSP to partially deload the Leicester group;**
- **partially deload Wigston BSP by permanently transferring the 132/33 kV side of Wigston onto the proposed GSP between Grendon and Enderby. This could be achieved by moving the Kibworth 132 kV open points to Wigston BSP and teeing Wigston 132/33 kV BSP side into the existing AZ route, Kibworth side. Kibworth BSP has also been proposed to transfer onto this GSP.**

Coalville and Hinckley Group

Generation Demand SP CE TD CR

Following extensive demand and generation growth to 2027, the following overloads have been projected in the Coalville and Hinckley areas.

Coalville 132/33 kV BSP

Generation Demand SP CE TD CR

The installation of a third 132/33 kV 90 MVA grid transformer at Coalville BSP, as proposed in the 2022 studies, avoids any GT overloads from occurring in the 2027 studies. However, continuing to transfer Coalville BSP into Ratcliffe-on-Soar GSP results in overloads of the SZ route between Ratcliffe-on-Soar GSP and Coalville BSP. Please see the Ratcliffe-on-Soar 2027 section for further information on these overloads.

Hinckley 132/11 kV BSP

Generation Demand SP CE TD CR

To alleviate the Hinckley 132/11 kV GT overloads observed in the 2022 studies, a proposal was to partially deload Hinckley 11 kV onto the 132/33 kV side, potentially with a new 33/11 kV primary substation. Extensive demand growth under all scenarios has been observed in the 2027 studies and as such, greater load transfers would be required to mitigate any potential overloads in 2027. Please see the combined reinforcement strategy below for further information.

Combined Reinforcement Strategy

To alleviate the projected overloads identified in the Coalville and Hinckley area, a reinforcement strategy will be required with consideration given to the area and the nature of the surrounding 132 kV networks. Given the geographic area supplied and the distribution of future load growth, it is proposed that the following options are considered in order to alleviate the 2027 projected overloads:

- **partially deloading both Coalville and Hinckley BSPs either onto the proposed GSP outlined as an option within the Coventry 2027 reinforcement strategy, or by establishing a new BSP to the south of Coalville between the Coalville tee (AP route) and Hinckley BSP;**
- **re-assessing the transfer requirements of Coalville BSP into Ratcliffe-on-Soar GSP;**

- **partially deloading Coalville BSP either by establishing additional 33 kV interconnectors, or by one of the methods listed above to transfer load away from Coalville BSP permanently if the transfer into Ratcliffe-on-Soar GSP remains necessary.**

Detailed network design will be required to assess the proposed reinforcement strategies against the projected demand and generation growth, including but not limited to:

- **running arrangements for outage management, particularly for transmission network outages;**
- **protection and fault level studies.**

Ratcliffe-on-Soar GSP

By 2027, Group Demand is projected to grow from 2022 to the figures shown in Table 20.

Table 20: Projected demand on Ratcliffe-on-Soar GSP in 2027

Scenario	2022 Group Demand	2027 Group Demand
SP	472 MW	521 MW
CE	473 MW	536 MW
TD	496 MW	622 MW
CR	511 MW	653 MW

SGT Overloads

Generation **Demand** SP CE TD CR

Despite proposed reinforcement to alleviate Ratcliffe-on-Soar SGT overloads described in the 2022 studies, demand growth to 2027 causes further SGT overloads under all scenarios.

For the arranged outage of an SGT followed by a fault to a second SGT, the group load is supplied by the remaining SGTs. Depending on the SCO combination, the remaining SGTs in service can overload up to 146% of nameplate rating at winter peak demand. Overloads are also seen up to 121% at intermediate warm demand (under all scenarios) and up to 104% at summer peak demand (Community Renewables only).

Furthermore, 132 kV busbar and SGT faults under the Two Degrees and Community Renewables scenarios are causing the remaining SGTs in service at Ratcliffe-on-Soar GSP to overload up to 113% for the winter peak demand condition only.

Proposed Reinforcement Strategy

To alleviate the projected overloads at Ratcliffe-on-Soar GSP, a reinforcement strategy will be required with consideration given to Ratcliffe-on-Soar and the nature of the surrounding 132 kV networks. Ratcliffe-on-Soar is already a large GSP with four SGTs, ten outgoing circuits and two station transformer infeeds. Given the geographic area supplied and the distribution of future demand growth, it is proposed that one of the following options is considered in order to alleviate the 2027 projected overloads:

- **establishing a fifth SGT at Ratcliffe-on-Soar GSP. This is likely to require considerable 400/132 kV switchgear installation and busbar extension works to facilitate this additional SGT unit;**

- **replacing the existing SGTs with units of a higher rating. In view of the extensive and wide scale load growth up to 2027, during the progression of a strategy with National Grid, a more economical solution for these projected overloads could be for larger SGTs (in the order of 360MVA) to be made available;**
- **transferring load away from Ratcliffe-on-Soar GSP by reinforcing Stoke Bardolph GSP. Stoke Bardolph GSP was originally built to reinforce Ratcliffe-on-Soar GSP and it may prove appropriate to reinforce Stoke Bardolph instead of expanding Ratcliffe-on-Soar further. This could be achieved by installing a third SGT at Stoke Bardolph GSP and new 132 kV infrastructure in the area. This option is discussed in both the Nottingham 2027 results below and the 2027 report for Stoke Bardolph.**

Detailed network design will be required to assess the proposed reinforcement strategies against the projected demand and generation growth, including but not limited to:

- **running arrangements for outage management, particularly for transmission network outages;**
- **protection and fault level studies**

Loughborough Group

Generation | **Demand** | SP CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Loughborough area.

Loughborough 132/11 kV GT Capacity

Generation | **Demand** | SP CE TD CR

The overloads described in the 2022 results increase under all scenarios in the 2027 studies. For a first circuit outage (arranged or fault) of either Loughborough 132/11 kV GT, the remaining GT supplies the group load. The remaining Loughborough 132/11 kV GT can overload up to 140% during winter peak demand, up to 136% during intermediate warm demand and up to 117% during summer peak demand. These overloads occur under all scenarios.

Loughborough 132/33 kV GT Capacity

Generation | **Demand** | TD CR

A first circuit outage (arranged or fault) of either Loughborough 132/33 kV GT will cause an overload to the remaining GT that is left in service. Overloads can be up to 115% during winter peak demand and up to 108% during intermediate warm demand. These overloads occur under the Two Degrees and Community Renewables scenario only.

Loughborough BSP to Loughborough Tee Circuit Overloads

Generation | **Demand** | TD CR

For an outage (first circuit fault or as a result of an SCO condition) that results in only one of the two HT route circuits supplying Loughborough BSP, this will overload the remaining 132 kV circuit supplied from Loughborough BSP. This overload can be up to 108% for the winter peak demand. These overloads occur under the Two Degrees and Community Renewables scenarios only.

Loughborough Lost Load

Generation | **Demand** SP CE TD CR

Demand growth to 2027 increases the Group Demand of Loughborough (132/33 kV and 132/11 kV) BSP to between 115 MW (Steady Progression) and 138 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits supplying Loughborough BSP.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 15 MW (Steady Progression) and 38 MW (Community Renewables) would be necessary.

Loughborough Tee to Ratcliffe-on-Soar GSP Circuit Overloads

Generation | **Demand** SP CE TD CR

Continuing to transfer Coalville BSP into Ratcliffe-on-Soar GSP as part of the 2027 studies causes further overloads of the SZ route between Ratcliffe-on-Soar GSP and Loughborough tee. These 2027 projected overloads are based on the reconductored SZ route between Ratcliffe-on-Soar GSP and Loughborough tee (300mm² AAAC Upas profiled for operation at 75°C), proposed as part of the 2022 studies.

Following the same SCO outage conditions as described in the baseline report, 2027 studies project that the section of the remaining SZ route circuit between Ratcliffe-on-Soar and Loughborough tee overloads up to 143% of its rating at winter peak demand, up to 124% at intermediate warm demand and up to 109% for summer peak demand.

This SCO combination also overloads the SZ route circuit between Coalville and Loughborough tee up to 103% of its rating at winter peak demand (Two Degrees and Community Renewables only). This overload does not occur at intermediate warm or summer peak demand periods.

Combined Reinforcement Strategy

To alleviate the projected overloads identified in the Loughborough area, a reinforcement strategy will be required with consideration given to the Loughborough area and the nature of the surrounding 132 kV networks. Given the geographic area supplied and the distribution of future demand growth, it is proposed that the following options are considered in order to alleviate the 2027 projected overloads, as well as ensuring P2 compliance for lost load:

- **establishing a new BSP to the south of Loughborough between the Loughborough tee (HT route) and Coalville BSP to partially deload the Loughborough group;**
- **partially deloading Coalville BSP and re-assessing the transfer requirements into Ratcliffe-on-Soar GSP (please see the Enderby GSP 2027 results for further information regarding this reinforcement strategy).**

Willoughby Group

Generation | **Demand** CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Willoughby area.

Willoughby 132/33 kV GT Capacity and CZ Route Overloads

Generation **Demand** TD CR

Willoughby BSP currently has two 132/33 kV GTs (45/90 MVA and 60/90 MVA) that are normally fed from Ratcliffe-on-Soar GSP via the CZ route 132 kV circuit.

A first circuit outage (arranged or fault) of either 132 kV circuit (Ratcliffe-on-Soar 132kV to Willoughby BSP) will overload the remaining Willoughby grid transformer in service. This overload can be up to 119% for winter peak demand (Two Degrees and Community Renewables), up to 117% for intermediate warm demand (Two Degrees and Community Renewables) and up to 106% for summer peak demand (Community Renewables only).

For the same outage condition described above, the remaining Ratcliffe-on-Soar GSP to Willoughby BSP CZ route 132 kV circuit in service can overload up to 113% for winter peak demand (Two Degrees and Community Renewables) and up to 105% for intermediate warm and summer demand conditions (Community Renewables only).

Willoughby BSP (132/33 kV) Lost Load

Generation **Demand** CE TD CR

Demand growth to 2027 increases the Group Demand of Willoughby (132/33 kV) BSP to between 101 MW (Consumer Evolution) and 131 MW (Community Renewables). The group load is interrupted for the SCO of both 132 kV circuits supplying Willoughby BSP.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 1 MW (Consumer Evolution) and 31 MW (Community Renewables) would be necessary.

Combined Reinforcement Strategy

To alleviate the projected overloads identified in the Willoughby area, a reinforcement strategy will be required with consideration given to the Willoughby area and the nature of the surrounding 132 kV networks. Given the geographic area supplied and the distribution of future demand growth, it is proposed that the following options are considered in order to alleviate the 2027 projected overloads, as well as ensuring P2 compliance for lost load:

- **establishing a pair of 132/11 kV 15/30 MVA GTs at Willoughby BSP and transferring the load of the existing on-site 33/11 kV primary substation to the new GTs;**
- **reprofiling the existing 175mm² ACSR (Lynx) conductors on the CZ route for 75°C operation. If reprofiling is not practical then the circuits could be reconductored to 300mm² AAAC (Upas), profiled for operation at 75°C;**
- **installing additional 33 kV interconnectors to transfer demand away from Willoughby BSP permanently if necessary.**

Nottingham Area

Generation | **Demand** — SP CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Nottingham area.

Nottingham to Nottingham North Circuit Overloads

Generation | **Demand** — SP CE TD CR

Following an arranged outage of either 132 kV circuit from Nottingham East BSP to Nottingham North BSP, Nottingham North 33 kV would be left at single circuit risk. To avoid this, Nottingham North 132/33 kV is typically transferred onto Ratcliffe-on-Soar GSP for the duration of the arranged outage.

The subsequent fault loss of either Nottingham North BSP to Nottingham BSP 132 kV circuit leaves the group load of Nottingham North on the remaining circuit. This would overload the remaining circuit between Nottingham North BSP and Nottingham BSP 132 kV (HU route) up to 134% of its rating at winter peak demand (all scenarios) and up to 108% at intermediate warm demand (Two Degrees and Community Renewables only). This overload does not occur for the summer peak demand case.

Nottingham North BSP 132/11 kV GT Capacity

Generation | **Demand** — TD CR

Nottingham North BSP 132/11 kV currently has two 15/30 MVA 132/11 kV GTs (GT3 and GT4) that are normally fed from Ratcliffe-on-Soar GSP via the HU 132 kV circuit routes.

For a first circuit outage (fault or arranged) of either 132/11 kV GT, the remaining GT in service can overload up to 118% of its rating at winter peak demand and 108% of its rating at intermediate warm demand (Two Degrees and Community Renewables only). This overload does not occur for a summer peak demand case.

The Nottingham North BSP 132/11 kV GT overloads could be alleviated by transferring demand to Nottingham North BSP 132/33 kV side, potentially with a new 33/11 kV primary substation.

A proposal for a new BSP, discussed in the combined reinforcement strategy below, may supersede this option above.

Nottingham BSP 132/33 kV GT Capacity

Generation | **Demand** — SP CE TD CR

An arranged outage followed by a circuit fault can leave Nottingham 132/33 kV BSP with only two GTs left in service. This can overload the remaining Nottingham 132/33 kV GTs up to 132% for winter peak demand (all scenarios), up to 126% for intermediate warm demand (Consumer Evolution, Two Degrees and Community Renewables) and up to 109% for summer peak demand (Two Degrees and Community Renewables only).

Combined Reinforcement Strategy

To alleviate the projected overloads identified in the Nottingham area, a reinforcement strategy will be required with consideration given to the Nottingham area and the nature of the surrounding 132 kV networks. Given the geographic area supplied and the distribution of

future demand growth, as discussed earlier as one option under the 'Proposed Reinforcement Strategy', it may deem necessary to reinforce Stoke Bardolph GSP instead of expanding Ratcliffe-on-Soar GSP further.

It is proposed that the following strategy is considered in order to alleviate the 2027 projected overloads within both the Ratcliffe-on-Soar and Stoke Bardolph groups:

- **establishment of a third SGT at Stoke Bardolph GSP;**
- **establishment of a third 132 kV circuit from Stoke Bardolph GSP to Nottingham East BSP. Additional 400/132 kV switchgear installation and busbar extension works at Stoke Bardolph GSP and Nottingham East BSP would be required to facilitate this reinforcement strategy;**
- **establishment of a new BSP between Nottingham and Stoke Bardolph to partially deload Nottingham North BSP and Nottingham East BSP;**
- **partially deload Nottingham BSP from Ratcliffe-on-Soar GSP, either by supplying two 132/33 kV GTs via Stoke Bardolph GSP or transferring load to the proposed BSP.**

Detailed network design will be required to assess the proposed reinforcement strategies against the projected demand and generation growth, including but not limited to:

- **running arrangements for outage management, particularly for transmission network outages;**
- **protection and fault level studies.**

Stoke Bardolph GSP

By 2027, Group Demand is projected to grow from 2022 to the figures shown in Table 21.

Table 21: Projected demand on Stoke Bardolph GSP in 2027

Scenario	2022 Group Demand	2027 Group Demand
SP	158 MW	167 MW
CE	158 MW	173 MW
TD	166 MW	210 MW
CR	170 MW	216 MW

SGT Overloads

Generation **Demand** TD CR

The 132 kV busbars at Stoke Bardolph GSP are normally run solid, with bus coupler 130 closed. SGT1 and SGT3 supply main and reserve busbar section 1, respectively.

SGT overloads occur under the Two Degrees and Community Renewables scenarios only. For an arranged outage leaving Nottingham North 132/11 kV at single circuit risk, Nottingham North 11 kV demand can be transferred across onto Stoke Bardolph. A subsequent SGT fault at Stoke Bardolph can result in the remaining SGT overloading up to 112% of nameplate rating at winter peak demand.

These overloads do not occur for the intermediate warm or summer peak demand conditions.

It is recommended that the sufficiency of the available access window for the arranged outage be confirmed. It is still possible to schedule Grid Code SGT Access Periods within the summer

and intermediate warm ratings seasons. Please see below the combined reinforcement strategy proposed for Stoke Bardolph GSP.

Nottingham East and Nottingham North Group

Generation | **Demand** SP CE TD CR

Following extensive demand growth to 2027, the following demand overloads have been projected in the Nottingham East and Nottingham North areas.

Nottingham East 132/33 kV GT Capacity

Generation | **Demand** TD CR

A first circuit outage (arranged or fault) of a GT at Nottingham East BSP will result in an overload to the remaining Nottingham East GT in service. This overload can be up to 109% for a winter peak demand case and occurs under the Two Degrees and Community Renewables scenarios only.

A pair of 132/11 kV 15/30 MVA GTs at Nottingham East BSP could be established. It may be necessary to install 132 kV bus section circuit breakers between the 132/33 kV and 132/11 kV GTs to provide SCO compliance and operational flexibility.

A proposal for a new BSP, discussed in the combined reinforcement strategy below, may supersede this option above.

Nottingham East and Nottingham North Lost Load

Generation | **Demand** SP CE TD CR

Demand growth to 2027 increases the combined Group Demand of Nottingham East and Nottingham North (132/33 kV side) BSPs to between 167 MW (Steady Progression) and 216 MW (Community Renewables).

For demand groups between 150 MW and 300 MW, P2 requires that one third of Group Demand is restored within three hours of an SCO. In this case, restoration of between 56 MW (Steady Progression) and 72 MW (Community Renewables) would be necessary.

Nottingham East Lost Load

Generation | **Demand** TD CR

Demand growth to 2027 increases the Group Demand of Nottingham East (132/33 kV) BSP to between 117 MW (Two Degrees) and 120 MW (Community Renewables).

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 17 MW (Two Degrees) and 20 MW (Community Renewables) would be necessary.

Combined Reinforcement Strategy

To alleviate the projected overloads identified in both the Ratcliffe-on-Soar and Stoke Bardolph areas, a reinforcement strategy will be required with consideration given to the area and the nature of the surrounding 132 kV networks. Given the geographic area supplied and the distribution of future demand growth, it may deem necessary to reinforce Stoke Bardolph GSP instead of expanding Ratcliffe-on-Soar GSP further.

It is proposed that the following strategy is considered in order to alleviate the 2027 projected overloads within the Ratcliffe-on-Soar and Stoke Bardolph groups, as well as ensuring P2 compliance for lost load:

- **establishment of a third SGT at Stoke Bardolph GSP;**
- **establishment of a third 132 kV circuit from Stoke Bardolph GSP to Nottingham East BSP. Additional 132 kV switchgear installation and busbar extension works at Stoke Bardolph GSP and Nottingham East BSP would be required to facilitate this reinforcement strategy;**
- **establishment of a new BSP between Nottingham and Stoke Bardolph to partially deload Nottingham North BSP and Nottingham East BSP;**
- **partially deload Nottingham BSP from Ratcliffe-on-Soar GSP, either by supplying two 132/33 kV GTs via Stoke Bardolph GSP or transferring load to the proposed BSP.**

Detailed network design will be required to assess the proposed reinforcement strategies against the projected demand and generation growth, including but not limited to:

- **running arrangements for outage management, particularly for transmission network outages;**
- **protection and fault level studies.**

Hams Hall/Lea Marston GSP

The 2027 studies revealed no additional issues in the Hams Hall/Lea Marston GSP group for the East Midlands network.

Drakelow GSP

By 2027, the Group Demand of Drakelow GSP is projected to grow to the figures shown in Table 22.

Table 22: Projected Group Demand of Drakelow GSP in 2027

Scenario	Group Demand	Summer Peak Demand of Group
SP	249 MW	186 MW
CE	255 MW	188 MW
TD	293 MW	215 MW
CR	304 MW	222 MW

Drakelow SGT Capacity

Generation **Demand** TD CR

Further load growth to 2027 results in increasing utilisation of the short-term ratings of the SGTs for first circuit outages that result in the loss of an SGT. For the 2027 Two Degrees and Community Renewables scenarios, this will exceed plausible short-term ratings for typical SGTs.

The Group Demand of Drakelow GSP will exceed 300 MW under a Community Renewables scenario, which pushes the group into Class E of P2. This means that for an SCO of both SGTs, the prevailing demand of the group has to continue to be supplied without interruption.

As all 132 kV connections into the group are single circuits, there are no obvious BSP transfers out of the group at 132 kV. It is recommended that post-fault ratings for the SGTs are

agreed with NGET. Once this limit, or 300MW, is due to be exceeded, it is recommended to plan the installation of a third SGT at the site.

Burton South GT Capacity

Generation | **Demand** CR

For a first circuit outage that results in the loss of a grid transformer at Burton South BSP, the remaining GT in service would overload up to 129% for a summer peak generation case under a Community Renewables scenario.

It is recommended that any large generation connections would connect at 132 kV and would reduce grid transformer loadings. If the increase in connected generation is the sum of a large number of smaller generators, the overloads could be alleviated through ANM or by installation of a third grid transformer.

Grendon GSP

Assumed Works Completed Prior to 2027

For the 2027 studies in Grendon, it is assumed that load transfers towards Grendon via Melton Mowbray 132 kV network will be managed as necessary to ensure 132 kV circuit rating exceedances are avoided in the Grendon GSP group.

As per the 2022 reinforcement strategy, it has been assumed for the 2027 studies that a TANM system has been installed at Grendon GSP, monitoring flows on SGTs, providing signals to the DANM system and consequently enforcing additional constraints on the downstream generation, such that the SGT overloads can be avoided for generation flows.

Corby BSP Grid Transformers

Generation | **Demand** SP CE TD CR

Continuing load growth will cause the exceedances during SCO conditions at Corby to become problematic. Under the 2027 scenarios, SCO transformer outages during intermediate warm conditions produce loadings between 137% (Steady Progression) and 181% (Community Renewables) on the remaining unit.

It is recommended that the nearby 132 kV substation at Corby North is developed with a pair of 132/33 kV GTs and a new 33 kV GIS board. Nearby 33 kV cables could be connected to the new BSP to transfer load from Corby BSP.

Melton Mowbray BSP Grid Transformers

Generation | **Demand** SP CE TD CR

Future load growth will cause exceedances during FCO conditions at Melton Mowbray. Under the 2027 scenarios, FCO transformer outages during winter conditions produce loadings between 104% (Steady Progression) and 136% (Community Renewables) on the remaining unit.

It is recommended that the GTs be replaced by suitably sized units when the growth exceeds the current ratings.

Irthlingborough/Kettering Growth

Irthlingborough BSP

Generation | **Demand** TD CR

In higher growth scenarios, the Group Demand of Irthlingborough BSP exceeds 100MW. The level of reverse power flow during summer peak generation conditions also exceeds 90 MW.

Kettering BSP

Generation | **Demand** CE TD CR

For the Consumer Evolution scenario, the demand at Kettering exceeds 100 MW; under Two Degrees and Community Renewables, the rating of the grid transformers is also exceeded.

Combined Reinforcement Strategy

Given the limited magnitude of overloads at both Kettering and Irthlingborough BSPs, and the availability of 33 kV transfer capacity between them, the reinforcement of one BSP with some load transferred from the other BSP would solve the problems at both.

Given the relative proximity of its 132 kV circuits, Irthlingborough BSP has greater likelihood of being suitable for installing additional 132 kV switchgear and grid transformers. A pair of 132/11 kV transformers installed at Irthlingborough BSP to transfer the local primary, followed by load transfers towards Irthlingborough 33 kV BSP should be able to alleviate the demand growth constraints at both sites. If generation growth is not, or cannot be, managed by making large new connections at 132 kV, then 132/33 kV transformers and a new 33 kV GIS board to divide Irthlingborough BSP may be more appropriate instead.

SCO demand transfer capacity between these sites will need to be considered and maintained at an adequate level to preserve the P2 compliance of both.

Northampton-Area BSPs

Generation | **Demand** TD CR

Under the higher growth scenarios, the demand at all three BSPs in Northampton exceeds the ratings of their respective grid transformers. Grid transformer ratings aside, 132 kV circuit rating limitations are also encountered, despite the ongoing reinforcement.

A new 132 kV site in the Northampton area is recommended, potentially to the north/east of the town, in the vicinity of Boothville primary. Considering the medium distance to Grendon GSP, 132 kV cable circuits will likely be most economic, so site choice should be controllable and unconstrained by proximity to existing 132 kV linear assets. A new primary substation at the

new BSP and several 33 kV cable circuits into the northeast of the town to transfer whole primaries onto the new 33kV board will create adequate new capacity. Load transfers will be needed to balance the loadings between the new site and the existing three sites as required, which will involve further 33 kV works around the town.

Grendon/Corby/Corby North and Connected BSPs

Generation | **Demand** — CE TD CR

The BSPs downstream of Grendon in the Corby area network (Kettering, Irthlingborough, Corby, Kibworth, Melton Mowbray and Oakham) form an interdependent group with linked design concerns. In the higher growth scenarios to 2027, there are developing issues that are not specifically linked to any particular load increase but the summation of them all. Broadly, the issues are caused by too much current flowing across the Grendon–Corby circuits under outages of elements of these circuits. These high currents also cause significant voltage drop, which becomes problematic by the edges of this network.

Many of the below issues in the interdependent network between Grendon, Corby and Corby North are exacerbated by load transfers into the group, however, these issues are also present without the incoming transfers under higher growth scenarios, so the recommendations remain even if all load transfers were to be avoided.

Voltage Issues

Generation | **Demand** — CE TD CR

Voltages are low in the Kettering area of the 132 kV network following an arranged outage of Grendon circuit breaker 505 or 705, followed by the SCO loss of the other of the two circuits, leaving Kettering supplied on a single circuit from Corby.

Voltages are low in the Melton Mowbray and Oakham area of the 132 kV network following FCO faults on either of the Oakham BSP 132kV circuits. This leaves Melton Mowbray and Oakham BSPs supplied on a single circuit from Corby North and low voltages are observed at 132 kV.

Thermal Issues

Generation | **Demand** — TD CR

For Two Degrees and Community Renewables to 2027, there are a large number of similar conditions that lead to various overloads on the Grendon to Corby 132 kV circuits to a greater or lesser extent, under winter, intermediate warm and summer demand conditions (in the most extreme scenarios):

- SCO losses of any of the four 132 kV circuits between Grendon GSP and Corby BSP during the arranged outage of any other of those circuits;
- SCO losses of any of the four 132 kV circuits between Grendon GSP and Corby BSP following most busbar outages at Corby or Grendon GSP;
- SCO losses of SGTs at Grendon following any 132 kV circuit outage between Grendon and Corby;
- Most FCO busbar faults at Grendon or Corby.

Combined Reinforcement Strategy

The ultimate cause of these problems is the growth of too much demand. Grendon GSP under 2027 Community Renewables has grown to 1181 MW. Further expansion of Grendon GSP is impractical; there are already five SGTs operating on four 400 kV and four 132 kV busbar sections, resulting in complex operational and protection arrangements to maintain compliance. The fault level at Grendon GSP is already a significant constraint also, preventing more than two SGTs operating in parallel when Corby Power Station is operating and more than three when it is not.

It is recommended that a new 400/132 kV GSP is constructed near Market Harborough, at the point of 400 kV/132 kV (AZ route) crossing. This new GSP, with some 132 kV rearrangement within WPD substations, could remove both Kibworth BSP and Corby's BSP (or BSPs, following growth and reinforcement) from the group. Further, Melton Mowbray BSP could also be removed from the group by transferring Hawton BSP onto dedicated circuits out of Staythorpe GSP to release capacity on the TZ route.

East Claydon GSP

By 2027, the Group Demand of East Claydon GSP is projected to grow from baseline's 354 MW with a summer peak of 247 MW to the figures shown in Table 23.

Table 23: Projected demand of East Claydon GSP in 2027

Scenario	Group Demand	Summer peak demand of group
SP	547 MW	422 MW
CE	559 MW	428 MW
TD	631 MW	478 MW
CR	648 MW	487 MW

SGT Capacity

Demand-driven Overloads

Generation **Demand** SP CE TD CR

Demand growth causes SGT overloads for first and second circuit outages under all scenarios. The worst studied overload is 154% of nameplate rating on SGT3 in Community Renewables, for the SCO of SGT2 and SGT4.

Overloads occur in winter and intermediate warm periods in all scenarios. In Two Degrees and Community Renewables, they also occur in summer. It is no longer possible to schedule Grid Code Access Periods for the SGTs.

Generation-driven Overloads

Generation Demand CE CR

At summer peak generation, the SCO of two SGTs overloads one or both of the remaining SGTs up to 121% of nameplate rating (Community Renewables) or 106% of nameplate rating (Consumer Evolution).

Combined Reinforcement Strategy

Load growth on the scale seen in these scenarios would trigger extensive reinforcement of East Claydon GSP. Options include:

- **installing extra 240 MVA SGTs at East Claydon. Assuming that fault level constraints allow good load share, expanding to six SGTs would resolve the studied overloads. As**

described in the 2022 results, this would require additional sections of 132 kV and 400 kV busbar;

- **replacing all four existing 240 MVA SGTs with larger units. 360 MVA and 480 MVA SGTs are already used at 275/132 kV and 400/132 kV by the Scottish Transmission Operators, but National Grid only uses 240 MVA units currently. Depending on existing switchgear ratings, four 360 MVA SGTs at East Claydon could be a less complex and disruptive solution;**
- **establishing a new GSP in the area and transferring some load from East Claydon. This option would require extensive new overhead lines and/or cables at 400 kV and/or 132 kV.**

It is recommended that detailed reinforcement plans are developed for the area in conjunction with National Grid and SSEN. Potential load transfers from Feckenham GSP in the West Midlands would increase the load on East Claydon GSP, and should be taken into account.

Milton Keynes Network

132 kV Ring

Generation | Demand   SP CE TD CR

Demand and generation growth to 2027 triggers SCO overloads across the Milton Keynes 132 kV ring at all times of year. The overloads seen in Steady Progression and Consumer Evolution are similar to those seen in 2022 in Two Degrees and Community Renewables.

The overloads in Two Degrees and Community Renewables are more extreme, including:

- 140% (winter peak demand), 122% (intermediate warm peak demand) and 112% (summer peak demand) on the 132 kV overhead line between Bradwell Abbey disconnector 203 and Stony Stratford disconnector 403
- 137% (winter peak demand), 124% (intermediate warm peak demand) and 113% (summer peak demand) on the 132 kV cable between Bradwell Abbey disconnector 303 and Bletchley disconnector 303

Bletchley BSP

Bletchley BSP has three GTs:

- GT1, 60/120 MVA;
- GT2, 60/120 MVA;
- GT3, 60/90 MVA.

The 33 kV board is normally operated as two separate nodes, which are loose-coupled via the 11 kV busbars of several primary substations:

- Node A supplied by GT1 and GT2;
- Node B supplied by GT3.

The two nodes are loose-coupled to each other and other BSPs in the East Claydon network via the 11 kV busbars of several primary substations.

GT1 or GT2 Arranged Outage SCO Lost Load

Generation **Demand** SP CE TD CR

For the arranged outage of GT1 or GT2, the loose couples are split and some load is transferred onto GT3. This means that the subsequent fault loss of a GT disconnects load to avoid overloading the remaining GT.

Following demand growth to 2027, the SCO of GT1 and GT2 causes Group Demand of between 108 MW (Steady Progression) and 128 MW (Community Renewables) to be disconnected.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of up to 28 MW (Community Renewables) is required.

Sufficient demand can be restored from GT3 post-fault to meet the requirements of P2. There are also 33 kV transfers available to the other Milton Keynes BSPs.

GT3 Arranged Outage SCO Overloads

Generation **Demand** TD CR

For the arranged outage of GT3, the 33 kV board is coupled as a single node, transferring all load onto GT1 and GT2. The subsequent fault loss of GT1 or GT2 leaves the remaining GT carrying the group load.

Following demand growth to 2027 in Two Degrees and Community Renewables, this overloads the remaining GT up to 118% of winter rating and 108% of intermediate warm rating. No overload occurs at summer peak demand.

This overload could be avoided by adopting a split running arrangement for arranged outages of GT3, similar to those used for GT1 and GT2 described above.

Bradwell Abbey BSP SCO Lost Load

Generation **Demand** TD CR

Bradwell Abbey BSP has two 45/90 MVA GTs. In some scenarios, Group Demand grows to more than 100 MW by 2027:

- 104 MW in Two Degrees;
- 107 MW in Community Renewables.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of up to 7 MW (Community Renewables) is required.

Sufficient demand could be restored at 33 kV post-fault to meet the requirements of P2.

Demand and generation growth to 2027 at Bradwell Abbey and other substations also triggers some GT overloads at Bradwell Abbey for SCOs around the Milton Keynes 132 kV ring. The loading is due in part to the loose couples between BSPs in the area, but the studied results are of limited accuracy due to the 132 kV focus of this project.

It is recommended that the interdependence between BSPs caused by loose couples in the East Claydon network is studied in further detail, with load modelled at primary substations and 33 kV outages considered.

Stony Stratford BSP SCO Lost Load

Generation | Demand   CE TD CR

Stony Stratford BSP has two 45/90 MVA GTs. In some scenarios, Group Demand grows to more than 100 MW by 2027, introducing SCO requirements under P2:

- 113 MW in Two Degrees;
- 110 MW in Community Renewables.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of up to 13 MW (Community Renewables) is required.

Sufficient demand could be restored at 33 kV post-fault to meet the requirements of P2.

Demand and generation growth to 2027 at Stony Stratford and other substations also triggers some GT overloads at Stony Stratford for SCOs around the Milton Keynes 132 kV ring. The loading is due in part to the loose couples between BSPs in the area, but the studied results are of limited accuracy due to the 132 kV focus of this project.

It is recommended that the interdependence between BSPs caused by loose couples in the East Claydon network is studied in further detail, with load modelled at primary substations and 33 kV outages considered.

Combined Reinforcement Strategy

It is proposed that a detailed reinforcement plan for Milton Keynes is developed including:

- **reconductoring existing overhead lines and overlaying cable sections to maximise the capacity of existing routes, including:**
  - **300mm² AAAC (Upas) at 75°C on the AH route;**
  - **570mm² AAAC (Sorbus) at 75°C on the CJ and DF routes.**
- **a second 132 kV circuit from Bradwell Abbey to Bletchley, with additional switchgear at both ends to improve operational flexibility and avoid through-flow issues;**
- **a new BSP in north-east Milton Keynes to partially deload the three existing BSPs – the new 132 kV circuit could be routed to supply the new BSP;**
- **an additional GT at one or more of the three existing BSPs;**
- **33 kV reinforcement to remove loose couples.**

As an alternative to some of the circuit works, new 132 kV circuits into Milton Keynes could be established from East Claydon or a new GSP in the area.

Banbury/Brackley Network

Banbury/Brackley Lost Load

Generation | Demand   SP CE TD CR

By 2027, the combined Group Demand of Banbury and Brackley BSPs is projected to grow further from 105 MW in baseline to the figures shown in Table 24.

Table 24: Projected Group Demand of Banbury and Brackley BSPs in 2027

Scenario	Group Demand
SP	127 MW
CE	131 MW
TD	154 MW
CR	158 MW

Under P2, there is a requirement to restore part of the Group Demand within three hours of an SCO such as the loss of both 132kV circuits:

- for demand groups between 100 MW and 150 MW, restoration of Group Demand less 100 MW is required;
- for demand groups between 150 MW and 300 MW, restoration of one third of Group Demand is required.

The demand growth increases the restoration requirement to between 27 MW (Steady Progression) and 53 MW (Community Renewables).

Brackley BSP GTs

Generation Demand CE CR

Brackley BSP has two 60/90 MVA GTs. Following the growth of generation to 2027, the arranged or fault outage of either GT at summer peak generation would overload the remaining GT up to 139% of rating (Community Renewables) or 127% of rating (Consumer Evolution).

If this loading cannot be managed by ANM, additional GTs would be required. Given the large rural area supplied from Brackley BSP, it may be appropriate to establish a new BSP in the area to minimise 33 kV reinforcement requirements.

Combined Reinforcement Strategy

It is recommended that routes are investigated for a third (and potentially fourth) 132 kV circuit to Banbury BSP. Options include:

1. **circuits from East Claydon GSP. These could be routed north of the existing circuits to supply a potential BSP to partially deload Brackley BSP and support load growth in the area between the M1 and M40;**
2. **interconnection with SSEN at Bicester North BSP. A new BSP along this route could also support load growth along the M40 corridor south of Banbury;**
3. **a normally open interconnector to Harbury BSP. This would also help with the Warwick/Harbury SCO lost load constraint. This route would bridge East Claydon and Berkswell GSPs, so if a new BSP were required along this route to support load growth north of Banbury, a pair of circuits back to Banbury or Harbury would be required for satisfactory demand security;**
4. **a new transmission route across the area with a new GSP or GSPs to enable much shorter 132 kV routes.**

Whichever option is chosen would require a major new circuit route at 132 kV or 400 kV.

Chesterfield GSP

By 2027, the Group Demand of Chesterfield GSP is projected to grow from baseline's 495 MW to the figures shown in Table 25.

Table 25: Projected Group Demand of Chesterfield GSP in 2027

Scenario	Group Demand
SP	623 MW
CE	640 MW
TD	743 MW
CR	770 MW

Network Changes Modelled

No network changes were modelled for the Chesterfield 2027 studies.

SGT Capacity

Generation **Demand** SP CE TD CR

Chesterfield GSP is fed via four 240 MVA SGTs, which are run split due to fault level limitations. SGT1 and SGT3 supply the main busbars; SGT2 and SGT4 supply the reserve busbars at 132 kV. The two nodes are loose-coupled via all downstream BSPs.

SGT3 and SGT4 Restriction

Generation **Demand** SP CE TD CR

For a circuit fault that results in the loss of SGT1, the remaining SGT3 in service would overload up to 105% (Steady Progression) and 134% (Community Renewables) for a winter peak demand case under all scenarios. This overload also occurs for busbar faults of Main 1, which results in the loss of SGT4. The reason for this is impedance mismatch between SGTs, which results in an unequal load share between SGT3 and SGT1. The overloads also occur for an intermediate warm peak demand case; however, only in the Community Renewables scenario, up to 110%. Similar overloads are seen on SGT4 for faults that result in the loss of SGT2 or the Reserve 1 busbar.

These overloads are exacerbated for second circuit outages that result in the loss of two of the four SGTs at Chesterfield. The overloads are present under all scenarios for a winter peak demand case (up to 146%), and in the Two Degrees and Community Renewables scenarios for an intermediate warm peak demand case, up to 119%.

SGT1 and SGT2 Restriction

Generation **Demand** SP CE TD CR

For a fault that results in the loss of SGT3, the remaining SGT1 in service would overload to between 116% (Steady Progression) and 121% (Community Renewables) for a winter peak demand case. Similar overloads are seen on SGT2 for faults that result in the loss of SGT4 or the Reserve 1 busbar.

These overloads are exacerbated for second circuit outages that result in the loss of two of the four SGTs at Chesterfield. The overloads are present under all scenarios for a winter peak demand case (up to 147%), and in the Two Degrees and Community Renewables scenarios for an intermediate warm peak demand case, up to 118%.

It is recommended that further work is undertaken with National Grid to determine short-term ratings for Chesterfield GSP, which allow loading to be managed by post-fault transfers and redistribution of load. Alternatively, permanent transfers of demand from Chesterfield GSP to Staythorpe GSP could alleviate the projected overloads; however, this is likely to involve reinforcement works at Staythorpe GSP.

Clipstone BSP

Generation Demand SP CE CR

Clipstone is a 132/33 kV site fed via two 45/90 MVA grid transformers and two 132 kV circuits from Chesterfield GSP (via Mansfield BSP). For the Steady Progression, Consumer Evolution and Community Renewables scenarios, an outage (arranged or fault) on either of the two Clipstone grid transformers will potentially overload the remaining GT in service up to 111% for a summer peak generation case.

It is recommended that the following options are considered to alleviate the generation-driven constraints at Clipstone:

1. **introduce ANM to new schemes to manage GT loadings;**
2. **establish further 33 kV interconnection to other BSPs to permanently move generation out of Clipstone;**
3. **convert the 132 kV connectivity at Clipstone from a double tee to a double loop by installing cable sealing end platforms on the two towers on site and bus section circuit breakers. It would then be possible to install two additional 132/33 kV transformers, possibly fed from Staythorpe C (subject to further assessment). The LV side of the new transformers would be connected to a new 33 kV board that can pick up load and generation off the existing transformers.**

Alfreton BSP

Alfreton BSP consists of two 30/60 MVA 132/33 kV transformers fed via two 132 kV circuits from Chesterfield GSP.

Demand-driven Overloads

Generation **Demand** SP CE TD CR

An outage (arranged or fault) on either of the two Alfreton grid transformers will potentially overload the other for a winter and intermediate warm peak demand case under all scenarios, up to 129%. Under the Two Degrees and Community Renewables scenarios, the overloads would also occur for a summer peak demand case up to 104%.

The demand overloads can be managed by uprating both grid transformers to 90 MVA units. Alternatively, additional 33 kV interconnection could be established to transfer demand out of the Alfreton group permanently.

Generation-driven Overloads

Generation Demand CE CR

Similarly, an outage (arranged or fault) on either of the two Alfreton grid transformers will potentially overload the other for a summer peak generation case up to 157% in the Consumer Evolution and Community Renewables scenarios.

The generation-driven overloads can also be alleviated by uprating the grid transformers and permanent transfers out of group; however, ANM could be utilised for new connections in the Alfreton group to manage GT loadings. Alternatively, larger generation connections may be offered at 132 kV if it is more economic to do so, which will also reduce GT loadings.

Mansfield BSP

Mansfield BSP consists of two 45/90 MVA 132/33 kV transformers fed via two 132 kV circuits from Chesterfield GSP.

Demand-driven Overloads

Generation **Demand** CR

Under the Community Renewables scenario, a fault of either grid transformer at Mansfield would marginally overload the remaining GT in service up to 100.4% for a winter peak demand case.

The demand overloads can be managed by permanent transfers of demand onto nearby Clipstone BSP; however, this is dependent on reinforcements at Clipstone BSP being carried out as outlined above.

Generation-driven Overloads

Generation **Demand** CR

Similarly, under the Community Renewables scenario, a fault of either grid transformer at Mansfield would overload the remaining GT in service up to 106% for a summer peak generation case.

The generation driven overloads can also be alleviated by permanent transfers onto Clipstone BSP; however, ANM could be utilised for new connections in the Mansfield group to manage GT loadings. Alternatively, larger generation connections may be offered at 132 kV if it more economic to do so, which will also reduce GT loadings.

Chesterfield BSP

Generation **Demand** TD CR

Chesterfield BSP is a 132/33 kV site fed via two 45/90 MVA grid transformers and two 132 kV circuits from Chesterfield GSP. In the 2027 studies, the Group Demand is projected to increase to the figures shown in Table 26.

Table 26: Projected Group Demand of Chesterfield BSP in 2027

Scenario	Group Demand
SP	93 MW
CE	96 MW
TD	108 MW
CR	114 MW

Lost Load

Generation **Demand** TD CR

The Group Demand at Chesterfield BSP, which exceeds 100 MW under the Two Degrees and Community Renewables scenarios, would be lost for various second circuit outage combinations.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 8 MW (Two Degrees) and 14 MW (Community Renewables) would be necessary.

Recommended solutions:

- **carry out 33 kV and 11 kV post-fault transfers. This may involve the installation of additional interconnectors; or**
- **install an additional 132 kV circuit from Chesterfield GSP to Chesterfield BSP and a third 132/33 kV transformer at Chesterfield BSP to pick up some of the existing demand.**

Transformer Restriction

Generation **Demand** TD CR

For an arranged outage of the Main 2 busbar at Chesterfield GSP, the bus section circuit breaker 160 is opened to run with a three-way split, with an SGT feeding each section of busbar. When this arranged outage is followed by a fault of SGT3, this leaves the Reserve 1 busbar at Chesterfield GSP back energised via the 33 kV busbar at the nearby Chesterfield BSP. This condition would overload GT1 at Chesterfield BSP up to 109% for a winter and intermediate warm peak demand case. Similarly, when the arranged outage is followed by a fault of SGT4, this would overload GT2 at Chesterfield BSP. These overloads occur only in the Two Degrees and Community Renewables scenarios.

It is recommended that the Directional Overcurrent protection at Chesterfield BSP is reviewed to ensure appropriate operation for this SCO combination. Alternatively, the 33 kV bus section at Chesterfield BSP should be opened as part of the arranged outage.

Annesley BSP (GT1 and GT2)

Generation **Demand** SP CE TD CR

Annesley BSP consists of four 132/33 kV transformers: GT1 running in parallel with GT2 (both 22.5/45 MVA units) and GT3 running in parallel with GT4 (both 30/60 MVA units). The two sets of GTs are loose-coupled via several downstream primary substations.

A first circuit outage on the infeed to GT1 would potentially overload GT2, and vice versa. This is observed under the scenarios Consumer Evolution (3% overload), Two Degrees (19% overload) and Community Renewables (24% overload).

A second circuit outage on the two transformers GT3 and GT4 (or their infeeds) would potentially overload GT1 and GT2. This is observed across all four scenarios: Steady Progression (1% overload), Consumer Evolution (4% overload), Two Degrees (22% overload) and Community Renewables (24% overload).

Recommended solutions:

- **transfer load away from Annesley 1&2 permanently (for the SCO conditions only, split the loose couples or transfer load away from Annesley 1&2 prior to the arranged outage); or**
- **reconfigure Annesley BSP (including transformer changes) to add further load capacity.**

Mansfield and Clipstone BSP Transfers

Mansfield and Clipstone BSPs are 132/33 kV sites normally supplied via two 132 kV circuits from Chesterfield GSP. They transfer onto Staythorpe GSP for various planned outages at Chesterfield GSP.

Demand Restriction

Generation | **Demand** SP CE TD CR

During such transfers in the winter and intermediate warm seasons, a circuit fault between Staythorpe C and Clipstone will potentially overload the other circuit by up to 61%. For Community Renewables and Two Degrees scenarios, overloads (by up to 15%) may be seen during the summer months too.

Recommended solutions:

- **carry out surveys to investigate the possibility of uprating the conductors (or rebuilding the line where necessary) between Staythorpe C and Clipstone; or**
- **introduce additional 33 kV interconnection to move load away permanently.**

Voltage Restriction

Generation | **Demand** TD CR

During such transfers in the winter season, and at periods of high demand and low generation, a fault on one of the circuits from Staythorpe C will potentially lead to low volts on the busbars connected to the other circuit.

Recommended solutions:

- **restrict planned outages to summer and intermediate warm seasons; or**
- **carry out surveys to investigate the possibility of uprating the conductors (or rebuilding the line where necessary) between Staythorpe C and Clipstone.**

Generation Restriction

Generation Demand SP CE TD CR

During such transfers, and at times of low demand and high generation, a circuit fault between Staythorpe C and Clipstone will potentially overload the other circuit by up to 74%.

Recommended solutions:

- **introduce ANM to new schemes; or**
- **curtail single circuit connection generators prior to the transfer; or**
- **carry out surveys to investigate the possibility of uprating the conductors (or rebuilding the line where necessary) between Staythorpe C and Clipstone.**

Willington GSP

For the purposes of this report only, the following works have been included in the study prior to the 2027 analysis:

- uprating the two 132 kV circuits between Staythorpe C and Loscoe to 300AAAC at 75ºC;
- introducing normal open points at Loscoe to effectively supply Heanor from Staythorpe C under normal running arrangements. Installation of an additional SGT (or other reinforcement works) would need to be carried out at Staythorpe C;
- establishing two new 132 kV bays at Willington GSP and installing two cable circuits (a few hundred metres each) to pick up Winster BSP only, taking it off the Winster/Burnaston/Uttoxeter group.

SGT Capacity

Generation **Demand** SP CE TD CR

The modelled running arrangement for Willington GSP in the 2027 studies is a bus section split. SGT1 and SGT7 supply the Main 1 and Reserve 1 busbars; SGT6 and SGT8 supply the Main 2 and Reserve 2 busbars.

A fault on SGT1 (or a busbar fault affecting SGT1) potentially overloads SGT7, and vice versa. This is observed under the scenarios Two Degrees (102% overload) and Community Renewables (107% overload).

Under a second circuit outage, where the arranged outage leads to more load being put on to the affected SGT, the overload worsens and extends to Steady Progression and Consumer Evolution scenarios as follows:

- Steady Progression: 109% overload;
- Consumer Evolution: 112% overload;
- Two Degrees: 131% overload;
- Community Renewables: 138% overload.

Similarly, a fault on SGT6 (or a busbar fault affecting SGT6) potentially overloads SGT8, and vice versa. This is observed under the scenarios Two Degrees (110% overload) and Community Renewables (115% overload).

Under a second circuit outage, where the arranged outage leads to more load being put on to the affected SGT, the overload worsens and extends to Steady Progression and Consumer Evolution scenarios as follows:

- Steady Progression: 108% overload;
- Consumer Evolution: 110% overload;
- Two Degrees: 129% overload;
- Community Renewables: 135% overload.

It is recommended that either:

- **The Willington 132 kV is replanted to upgrade the site's fault level rating, and run all four SGTs in parallel. A circuit breaker between Reserve 1 and Reserve 2 will be necessary to prevent losing both under a busbar fault. Upgrade works at Spondon may also be necessary; or**
- **Stanton BSP is transferred to Staythorpe C under normal running (subject to further assessment at Staythorpe C). This will limit the overload, which could then allow for the reliance on the SGT's post-fault rating before transferring load away.**

Spondon B BSP

Generation **Demand** SP CE TD CR

Spondon B BSP is a 132/33 kV site supplied via two 132 kV feeders from Spondon 132 kV. In the 2027 studies, the demand at Spondon B BSP, which can exceed 100 MW, is lost under a second circuit outage combination of both 132 kV infeeds.

In addition to the above, a first circuit outage on either of these 132 kV circuits, potentially overloads the other. Furthermore, a first circuit outage on either of the 132/33 kV transformers at Spondon B, potentially overloads the other. Table 27 summarises the constraints on Spondon B BSP.

Table 27: Summary of constraints on Spondon B BSP

	SP	CE	TD	CR
Lost Load	131 MW	132 MW	151 MW	159 MW
Circuit Overload	101%	102%	120%	128%
Transformer Overload	-	-	100.10%	107%

Derby BSP

Generation **Demand** SP CE TD CR

Derby BSP consists of four transformers (two 132/33 kV and two 132/11/11 kV). These are fed via two 132 kV circuits from Willington GSP; each 132/33 kV transformer is banked with a 132/11/11 kV transformer. The total demand at Derby BSP can exceed 100 MW for all four scenarios (Steady Progression: 112 MW, Consumer Evolution: 115 MW, Two Degrees: 137 MW and Community Renewables: 137 MW), and this is lost under a second circuit outage on the two feeders from Willington GSP.

Combined Reinforcement Strategy

Recommended solutions (combined strategies for Spondon B and Derby BSPs):

- **establish a new BSP in a suitable location, consisting of two 132 kV feeders, two 132/33 kV transformers and a new switchboard. This new BSP could then pick up sufficient demand from Spondon B and Derby BSPs such that all three BSPs remain below 100 MW load. The supply to the new BSP would be from Willington GSP; this will**

further relieve some of the load on the existing Derby South–Spondon 132 kV circuits; or

- **establish two additional 132 kV bays at Spondon and two 132/33 kV transformers (provisionally named Spondon C) to pick up sufficient demand from Spondon B and Derby BSPs. This, however, will need to be accompanied by upgrade works on the two 132 kV circuits between Derby South and Spondon; or**
- **install additional 33 kV interconnectors to transfer sufficient load away from both BSPs, post fault.**

Heanor BSP

Generation **Demand** TD CR

Heanor BSP is a 132/33 kV site fed via two 60/90 MVA grid transformers. In the 2027 studies, Heanor BSP is transferred permanently to Staythorpe GSP and the Group Demand is projected to increase to the figures shown in Table 28.

Table 28: Projected Group Demand of Heanor BSP in 2027

Scenario	Group Demand
SP	96 MW
CE	99 MW
TD	116 MW
CR	120 MW

Lost Load

Generation **Demand** TD CR

The Group Demand at Heanor BSP, which exceeds 100 MW under the Two Degrees and Community Renewables scenarios, would be lost for various second circuit outage combinations.

For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW is restored within three hours of an SCO. In this case, restoration of between 16 MW (Two Degrees) and 20 MW (Community Renewables) would be necessary.

Transformer Restriction

Generation **Demand** TD CR

Similarly, a fault that results in the loss of either grid transformer would overload the remaining GT in service for a winter (up to 116%) and intermediate warm (up to 106%) peak demand case. The overloads occur under Two Degrees and Community Renewables.

It is recommended that the following options are considered to alleviate the demand-driven constraints at Heanor:

- **establish further 33 kV interconnection to other BSPs to permanently move demand out of Heanor;**
- **install two additional 132 kV circuits from Loscoe switching station to Heanor BSP, normally fed from Willington GSP (subject to further assessment and dependent on the level of reinforcement works carried out within Willington GSP). Then install two**

additional 132/33 kV transformers at Heanor BSP, with the LV side of the new transformers connected to a new 33 kV board that can deload the existing transformers.

Stanton BSP

Generation | **Demand** CR

Stanton BSP is a 132/33 kV site fed via two grid transformers and two 132 kV circuits from Spondon. A fault of either transformer (or its 132 kV infeed) will potentially overload the other by up to 102% for a winter peak demand case under a Community Renewables scenario.

It is recommended that the viability of permanent transfers out of Stanton BSP is assessed. However, given the similar constraints at nearby BSPs, it would be possible to alleviate the constraints by uprating the grid transformers to 90 MVA units.

Winster BSP

Generation | **Demand** CE TD CR

Winster BSP is a 132/33 kV site fed via two grid transformers and two 132 kV circuits from Willington GSP. A fault of either transformer (or its 132 kV infeed) will potentially overload the other by up to 127% under all peak demand cases under the Consumer Evolution, Two Degrees and Community Renewables scenarios.

It is recommended that the viability of permanent transfers out of Winster BSP is assessed. However, given the similar constraints at nearby BSPs, it would be possible to alleviate the constraints by uprating the grid transformers to 90 MVA units.

Uttoxeter BSP

Generation | **Demand** TD CR

Uttoxeter BSP is a 132/33 kV site fed via two grid transformers and two 132 kV circuits from Willington GSP. A fault in the winter or intermediate warm seasons on either transformer (or its 132 kV infeed) will potentially overload the other by up to 115% under the Two Degrees and Community Renewables scenarios.

It is recommended that the viability of permanent transfers out of Uttoxeter BSP is assessed. However, given the similar constraints at nearby BSPs it would be possible to alleviate the constraints by uprating the grid transformers to 60 MVA units.

Staythorpe C–Loscoe Circuits

Generation | **Demand** TD CR

In the 2027 studies, Heanor BSP is transferred permanently to Staythorpe GSP. Under the Two Degrees and Community Renewables scenarios, a first circuit fault on one of the feeders from Staythorpe C causes low volts on the other circuit for a winter peak demand case. This effect is worsened under second circuit outages, when Stanton is also transferred onto Staythorpe C.

Recommended solutions:

- **carry out an assessment to determine the feasibility of raising the target volts at Staythorpe C; or**
- **carry out surveys to investigate the possibility of uprating the conductors between Staythorpe C and Loscoe (or rebuilding the line where necessary).**

Willington–Spondon 132 kV Circuits

Spondon 132 kV is a double busbar site, normally run solid. It is fed via three circuits from Willington GSP and primarily supplies a large embedded generator, Derby South (GT1 and GT2), Spondon B and Stanton BSPs. In the 2027 studies, Heanor BSP is permanently transferred onto Staythorpe GSP. The circuits are:

- Willington Main 2–Spondon Main 2 (HY route);
- Willington Main 1–Derby South GT1–Spondon Reserve 1 (AW route); and
- Willington Reserve 1–Derby South GT2–Spondon Main 1 (AW route).

Stanton has two 132 kV interconnectors to Staythorpe C (via Loscoe switching site) and can be transferred onto Staythorpe for various planned first circuit outages.

Demand Restriction

Generation **Demand** SP CE TD CR

The SCO combination of an arranged outage on one of the Derby South–Spondon circuits followed by a fault of the direct Willington–Spondon circuit would overload the remaining Derby South–Spondon circuit up to 127% for a winter and intermediate warm peak demand case under all scenarios.

Recommended solutions:

- **install additional 33 kV interconnection to transfer load away from Spondon B prior to the planned outage; or**
- **carry out surveys to investigate the possibility of uprating the conductors (or rebuilding the line where necessary) for the two 132 kV circuits between Derby South and Spondon.**

Generation Restriction

Generation Demand CE TD CR

A fault of a Derby South–Spondon 132 kV circuit would overload the other up to 108% for a summer peak generation case. Similarly, an arranged outage of a Derby South–Spondon 132 kV circuit followed by a fault on the direct Willington–Spondon circuit would overload the remaining Derby South–Spondon 132 kV circuit up to 119%.

Recommended solutions:

- **carry out surveys to investigate the possibility of uprating the conductors (or rebuilding the line where necessary) between:**
  - **Derby South GT1 and Spondon;**
  - **Derby South GT2 and Spondon.**
- **introduce ANM to new generators in that network.**

Staythorpe GSP

Network Changes Modelled

For the 2027 studies, the proposed reinforcement strategy from the 2022 results was modelled. In addition, the 132 kV bus couplers at Staythorpe C and Staythorpe B substations have been closed to reflect the completion of the Staythorpe B 132 kV switchgear replacement scheme. This scheme resolves the fault level issue at Staythorpe B substation, thus allowing a solid running arrangement.

Mansfield/Clipstone/Pinxton/Annesley Transfers into Staythorpe

Generation | Demand — SP CE TD CR

For certain outages of 132 kV switchgear, busbars and SGTs at Chesterfield GSP, any or all of Mansfield, Clipstone, Pinxton and Annesley BSPs are transferred to Staythorpe GSP.

Staythorpe SGT Overloads

Generation | Demand — SP CE TD CR

When the above BSPs are transferred to Staythorpe GSP, this causes an overload on the SGTs at Staythorpe. Overloads occur in all seasons and can be up to 149% of SGT rating. A subsequent fault on one of the SGTs at Staythorpe GSP increases the overload on the remaining SGT up to 419% of rating, this overload is primarily caused by low volts on the 132 kV. For the SCO, overloads are caused by generation as well as demand. For the Steady Progression scenario, overloads occur in winter and intermediate warm periods only and a subsequent SGT fault causes overloads in summer but due to demand only.

The magnitude of the overload means that it is unlikely to be possible to transfer enough demand off Staythorpe GSP to accept the incoming BSPs. Even with summer loadings, the short-term SGT rating is exceeded for a subsequent SGT fault, so it is recommended that a third SGT be installed at Staythorpe GSP. Demand transfers may be required, depending on the seasonal loading, to ensure that a subsequent SGT fault does not cause either of the remaining SGTs to exceed their short-term ratings.

Stanton/Heanor Transfer into Staythorpe

Generation | Demand — TD CR

For certain outages on the Willington/Spondon network, Stanton and Heanor BSPs are transferred to Staythorpe GSP.

Staythorpe SGT Overloads

Generation | Demand — TD CR

For an arranged outage causing Stanton and Heanor BSPs to be transferred into Staythorpe GSP, a subsequent fault on one of the SGTs at Staythorpe can cause an overload on the remaining SGT. The overload is only seen under winter loading and can reach up to 222% of SGT rating, exceeding the short-term SGT rating.

Installing a third SGT at Staythorpe will alleviate this overload. Until the SGT is installed, it is recommended that Stanton and Heanor BSPs be transferred to Staythorpe outside of the winter period where possible.

Sleaford/Grantham/Grantham North (BR) Transfer into Staythorpe

Generation | Demand — SP CE TD CR

For arranged outages of circuit breaker 605 or 805 at Bicker Fen GSP, Sleaford, Grantham and Grantham North (BR) BSPs are transferred to Staythorpe GSP.

Staythorpe SGT Overloads

Generation | **Demand** SP CE TD CR

When Sleaford, Grantham and Grantham North (BR) BSPs are transferred to Staythorpe GSP, a subsequent fault on one of the SGTs at Staythorpe can cause an overload on the other SGT. The overload occurs under winter loading only and can be up to 219% of SGT rating, exceeding the short-term SGT rating.

It is recommended that these BSPs be transferred to Staythorpe GSP outside of the winter period where possible. The option of transferring Grantham North (BR) BSP only or Grantham North (BR) and Grantham BSPs only could also be investigated. Once a third SGT is installed at Staythorpe, this will alleviate the overloads seen.

Staythorpe C–Staythorpe B Interconnector Overloads

Generation | **Demand** SP CE TD CR

When the above BSPs are transferred to Staythorpe GSP, an ensuing fault on one of the Staythorpe C–Staythorpe B 132 kV interconnectors can cause an overload on the remaining Staythorpe C–Staythorpe B interconnector. The overloads occur under all seasons and can be up to 159% of circuit rating.

The magnitude of the overload means that even re-stringing the interconnectors with the largest possible conductor will still not provide sufficient rating. It is therefore recommended to install further interconnecting circuits between Staythorpe C and Staythorpe B substations. This may require additional 132 kV feeder bays to be installed at Staythorpe C and/or Staythorpe B substations.

Alternatively, consideration could be given to connecting the aforementioned third SGT into Staythorpe B substation, rather than Staythorpe C, in order to reduce loading on the Staythorpe C–Staythorpe B interconnectors.

Staythorpe 132 kV Busbar/SGT Outages

Generation | **Demand** SP CE TD CR

For the 2027 studies, it has been assumed that the Staythorpe B 132 kV switchgear replacement scheme will have been completed, meaning that Staythorpe GSP can be run solid. This means that for an arranged 132 kV busbar outage at Staythorpe C or Staythorpe B substation, it will no longer be necessary to switch out an SGT.

Staythorpe SGT Overloads

Generation | **Demand** SP CE TD CR

For a fault outage of one of the 132 kV busbars at Staythorpe C substation, this causes the loss of one of the SGTs at Staythorpe GSP, resulting in an overload on the remaining SGT. An SGT fault at Staythorpe GSP has the same effect. Overloads can be up to 146% of SGT rating. Table 29 shows the seasons in which overloads are seen for the different scenarios.

Table 29: Staythorpe SGT overloads in 2027 by scenario and season

Scenario		Seasonal Overload			
		Winter	Intermediate Warm	Summer (demand)	Summer (generation)
Community Renewables	CR	Yes	Yes	Yes	Yes
Two Degrees	TD	Yes	Yes	Yes	No
Consumer Evolution	CE	Yes	No	No	Yes
Steady Progression	SP	Yes	No	No	No

Installing a third SGT at Staythorpe will resolve the overloads seen.

Corby North Power Station Transfers into Staythorpe

Generation Demand SP CE TD CR

As discussed previously in this report, there are various planned outage scenarios that result in Gen Set 2 at Corby North Power Station (125 MW) being transferred into Staythorpe GSP. For the purposes of the 2027 studies, the proposed running arrangement from the 2022 results has been applied when this transfer is made. This means that circuit breaker 405 at Corby North BSP is opened to break the remote couple, Oakham GT2 and Melton Mowbray GT4 are switched to hot standby and the 33 kV bus sections at Hawton and Checkerhouse BSPs and the 11 kV bus sections at Grantham North and Grantham South BSPs are opened.

Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV Circuit Overloads

Generation Demand SP CE TD CR

When Corby North Power Station is transferred to Staythorpe GSP, this can cause an overload on the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuit. The overload occurs in summer (due to generation) and in winter (due to demand) and can reach up to 139% of circuit rating on the Hawton tee–Asfordby tee section and up to 125% of circuit rating on the Asfordby tee–Melton Mowbray section. For the Consumer Evolution and Steady Progression scenarios, overloads occur in summer only.

It is recommended that Gen Set 2 at Corby North Power Station be transferred to Staythorpe GSP during the intermediate warm period only where possible. For transfers taken during the summer period, consideration could be given to constraining some of the 33 kV and 11 kV-connected generation at Oakham and Melton Mowbray BSPs, if this is contractually possible. If this outage window is too restrictive then it is suggested that the sections of 132 kV circuit between Hawton tee, Asfordby tee and Melton Mowbray be re-strung with 300mm^2 AAAC conductor.

Staythorpe SGT Overloads

Generation Demand SP TD

When Gen Set 2 at Corby North Power Station is transferred to Staythorpe GSP, a subsequent fault on one of the SGTs at Staythorpe can cause an overload on the other SGT. Overloads occur in summer only and are caused by generation. The overload can be up to 132% of SGT rating.

It is recommended that Gen Set 2 at Corby North Power Station be transferred to Staythorpe GSP outside of the summer period if possible. For transfers undertaken during the summer period, it is suggested that following actions be taken in order of preference (as well as the recommendations above):

- **constrain 33 kV and 11 kV-connected generation at Melton Mowbray and Oakham BSPs, if there is a contractual ability to do so;**
- **consult with National Grid to determine whether a short-term SGT rating can be applied, considering that the overload is caused by reverse power flow;**
- **undertake further studies to determine whether sufficient other generation can be transferred away from Staythorpe GSP, in order to accommodate the incoming generation within the continuous SGT rating or any short-term SGT rating that may be applicable;**
- **install a third SGT at Staythorpe GSP.**

Grantham South BSP

Generation **Demand** CR

In the 2022 studies, Grantham South BSP became overloaded, so it was proposed to install additional 132/11 kV transformers at Grantham South BSP and a 132 kV cross-bay circuit breaker. These proposals were modelled for the 2027 studies.

Grantham South Transformer Overloads

Generation **Demand** CR

In the 2027 studies, further load growth at Grantham South BSP has caused the transformers to become overloaded again. For a fault or planned outage causing the loss of two transformers at Grantham South BSP, this can cause an overload on the remaining two transformers. Overloads occur in summer only due to demand and can reach up to 103% of transformer rating.

As the overload seen is marginal, it is recommended that demand be transferred off Grantham South BSP to adjacent primary substations on a permanent basis, by the use of 11 kV transfers if possible (approximately 1 MVA of demand would need to be transferred). In the unlikely event that this is not possible then it is suggested that a new BSP be established in the Grantham South area, depending on where exactly the new load growth is. Alternatively, a new primary substation connected to Grantham 33 kV BSP could be installed.

Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV Circuit Outages

Generation **Demand** SP CE TD CR

For an arranged outage of one of the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuits, this leaves Hawton BSP at single circuit risk. Asfordby BSP is a single circuit connection and has a split running arrangement. This means that when an outage is taken on the Staythorpe–Hawton/Asfordby/Melton Mowbray 1 circuit, all of the demand connected to Asfordby GT1 is lost and similarly for the Staythorpe–Hawton/Asfordby/Melton Mowbray 2 circuit. The 2022 studies identified that over 100 MW of demand could be lost for a subsequent fault on the other Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuit but it may be possible to manage this by using 33 kV transfers.

Hawton/Asfordby Lost Load

Generation **Demand** SP CE TD CR

Under the above arranged outage, up to 153 MW of demand will be lost if there is a subsequent fault on the other Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuit. In accordance with P2, WPD has up to three hours to restore the lesser of (Group Demand – 100 MW) or a third of Group Demand. This means that at least 51 MW of demand must be restored.

When an arranged outage is planned on one of the Staythorpe–Hawton/Asfordby/Melton Mowbray 132 kV circuits, careful consideration must be given to ensuring P2 compliance in the event of a second circuit fault, either by the use of 33 kV transfers or by the emergency restoration of the arranged outage. If the arranged outage cannot be planned such that the ERTS time does not exceed three hours then there will be insufficient 33 kV transfer capacity to comply with P2.

It is recommended that further consideration be given to improving interconnections with the Hawton/Asfordby demand group. Options that could be considered include but are not limited to:

- **reconfiguring the current Hawton tee arrangement so that Hawton BSP has its own 132 kV feeders from Staythorpe GSP;**
- **installing an additional 132 kV circuit from Staythorpe GSP–Hawton BSP;**
- **improving 33 kV interconnection between Hawton BSP and other surrounding BSPs;**
- **establishing a new BSP in the Hawton area and transferring demand from Hawton BSP onto the new BSP.**

Staythorpe C CB105/CB505 Outage

Staythorpe/Hawton/Asfordby Low Voltage

Generation **Demand** SP CE TD CR

Due to forecast load growth, the undervoltage now occurs in all seasons and occurs without a subsequent fault on the network. The undervoltage can be as low as 17% below nominal voltage. However, the voltage on the 33 kV busbar at Hawton BSP remains within limits and the only 132 kV-metered customer whose voltage drops below the statutory limit is Asfordby BSP, which is constrained off under this outage, as per the previous recommendation. In the Consumer Evolution and Steady Progression scenarios, the undervoltage only occurs for winter and intermediate warm loading.

No further action is required as the voltage on the 33 kV busbar at Hawton BSP is within statutory limits and Asfordby BSP, although 132 kV-metered, is constrained off while this outage is taken.

Bourne/Stamford/Spalding Transfers into Staythorpe

Generation Demand CE TD CR

For certain arranged outages on the Walpole network, any or all of Bourne, Stamford and Spalding BSPs are transferred to Staythorpe GSP.

Bourne/Stamford/Spalding Low Voltage

Generation Demand CE TD CR

When the above transfers are made, the 132 kV voltage at Grantham South, Bourne, Stamford and Spalding BSPs can drop below the statutory limit. The undervoltage occurs in winter only and the voltage can dip to 11% below the nominal voltage (the statutory limit is –10%). However, there are no 132 kV-metered customers connected to the affected nodes and the statutory voltage is maintained on the lower voltage busbars at each of the affected BSPs.

No action is required as there are no 132 kV-metered customers whose voltage is outside of the statutory limits and the statutory voltage is maintained on the lower voltage side of each of the affected BSPs.

Bicker Fen GSP

By 2027, demand and generation are projected to grow to the figures shown in Table 30.

Table 30: Projected Group Demand on Bicker Fen GSP in 2027

Scenario	Group Demand	Generation (installed capacity including batteries exporting)
SP	299 MW	477 MW
CE	308 MW	661 MW
TD	367 MW	620 MW
CR	368 MW	735 MW

Bicker Fen SGTs

Generation

Generation Demand CE TD CR

Under Community Renewables, the first circuit outage of any Bicker Fen SGT overloads the remaining two SGTs to 119% at summer peak generation.

Any arranged outage at Walpole GSP that transfers Boston GT1 and GT2 into Bicker Fen, followed by the fault of a Bicker Fen SGT, overloads the remaining SGTs to between 130% (Consumer Evolution) and 150% (Community Renewables) for summer peak generation.

It is recommended that Boston GT1 and GT2 are not transferred into Bicker Fen for an arranged outage at Walpole GSP that leaves them at single circuit risk. This alleviates the overload identified under Consumer Evolution and Two Degrees. Sufficient post-fault transfer capability is available between Walpole and Bicker Fen GSPs to satisfy the requirements of P2.

Alternatively, the Bicker Fen SGT generation loadings could be managed through a TANM system. Consideration would need to be given on how generators connected to Boston are moved between Walpole and Bicker Fen GSPs.

It is recommended that the first circuit overload seen under Community Renewables is managed with use of the TANM system.

Skegness BSP

Lost Load

Generation **Demand** SP CE TD CR

The Group Demand of Skegness BSP and the offshore windfarms increases to between 101 MW (Steady Progression) and 128 MW (Community Renewables). All the projected demand growth is at Skegness BSP, where winter peak demand increases to 123 MW. P2 requires restoration of between 1 MW (Steady Progression) and 28 MW (Community Renewables).

Skegness BSP currently has 33 kV interconnection with Boston and Sleaford BSPs. One of the main load centres is Skegness town, which is primarily fed from Warth Lane primary. It is approximately 30 km from Warth Lane back to Boston BSP and 50 km from Warth Lane to Sleaford BSP.

Under Steady Progression and Consumer Evolution, sufficient 33 kV post-fault transfers into Boston BSP are available to satisfy the requirements of P2.

It is recommended that detailed studies be undertaken to ascertain if sufficient 33 kV transfer capability is available under the high growth scenarios. It is likely that 33 kV voltage constraints would be reached due to the distance from Boston or Sleaford BSPs to Skegness load centres.

Due to Skegness GT, CO route and AS route constraints, it is recommended that a wider reinforcement strategy is considered to maintain P2 compliance of the Skegness group and alleviate the overloads described below.

Demand Overload

Generation **Demand** TD CR

The demand growth at Skegness causes both GTs to overload for the outage of the other GT. This overload only occurs at winter peak demand under Two Degrees and Community Renewables, and is 118% and 116%, respectively.

Skegness BSP GT Overloads

Generation Demand CE TD CR

Under Consumer Evolution and Community Renewables, the first circuit outage of either Skegness GT overloads the remaining in-service GT to between 157% and 194%, respectively. For the same outage condition, a marginal overload of up to 104% would be seen under Two Degrees and no overload would occur under Steady Progression.

This overload occurs due to 200 MW of generation that is projected to connect by 2027 under Community Renewables; similar levels of generation are also seen under Consumer Evolution.

Boston to Skegness Circuit Overloads (CO Route)

Generation Demand CE CR

At summer peak generation, the first circuit outage of either CO route circuit between Boston BSP and Skegness BSP overloads the remaining in-service CO route circuit to between 126% (Consumer Evolution) and 139% (Community Renewables). This overload is caused by the significant generation growth projected at Skegness BSP under Consumer Evolution and Community Renewables.

Bicker Fen to Boston Circuit Overloads (AS Route)

Generation Demand CE TD CR

By 2022, the AS route was identified as overloaded under all scenarios due to generation growth at Boston and Skegness BSPs. A number of options were proposed to manage these overloads, including configuring a TANM system to manage circuit loadings. For the purposes of these studies, it was proposed that the AS route be reconductored with 300mm² AAAC (Upas) at 75°C and the existing cable sections are overlaid with 1000mm² copper XLPE cable for all scenarios.

Following further generation growth to 2027, the proposed AS route overloads again under all scenarios except Steady Progression. The overload is primarily due to the significant generation growth at Skegness BSP. The outage of one AS route circuit overloads the remaining in-service circuit to between 106% (Two Degrees) and 152% (Community Renewables) at summer peak generation.

Grantham, Sleaford and Grantham North (BR) BSPs Lost Load

Generation Demand SP CE TD CR

The Group Demand of Grantham, Sleaford and Grantham North (BR) sites increases from 160 MW in 2022 to 190 MW under Community Renewables in 2027. For Group Demand between 150 MW and 300 MW, P2 requires that one third of Group Demand be restored within three hours of an SCO. In this case, restoration of 63 MW is required.

Sufficient 132 kV post-fault transfer capacity into Staythorpe GSP is available, satisfying the requirements of P2.

Sleaford BSP

Lost Load

Generation Demand TD CR

As described above, the Sleaford and Grantham BSP group remains P2-compliant under the highest growth scenario, due to the ability to transfer sufficient Grantham demand into Staythorpe GSP.

The Group Demand of Sleaford BSP increases to 117 MW under Two Degrees and Community Renewables. For demand groups between 100 MW and 150 MW, P2 requires that Group Demand less 100 MW be restored within three hours of an SCO. In this case, restoration of 17 MW is required.

Sufficient 33 kV transfer capability into Boston and Skegness BSPs is available, satisfying the requirements of P2.

***GT** Generation Overloads*

Generation Demand CR

Following generation growth to 2027, an outage of either Sleaford GT overloads the remaining in-service GT to 120% at summer peak generation under Community Renewables. Both GTs at Sleaford are currently 45/90 MVA units. A 45/90 MVA transformer is the largest two winding transformer WPD currently install as standard for a 132/33 kV transformation, which means the transformers cannot just be replaced with larger units.

The generation overload could be managed by an ANM system to cover GT overloads. As demand-driven overloads have also been identified on Sleaford GTs under Two Degrees and Community Renewables, a conventional reinforcement strategy to resolve the demand and generation constraints is proposed below.

GT Demand Overloads

Generation **Demand** TD CR

Demand growth to 2027 increases the Sleaford GT loading for a first circuit fault of one GT to 110% at winter peak demand, for both Two Degrees and Community Renewables.

Bicker Fen to Grantham Circuit Overloads (AF Route)

Generation **Demand** SP CE

Sleaford BSP, Grantham BSP and Grantham North traction supplies are normally supplied via the AF route from Bicker Fen GSP.

By 2022, a fault of either Bicker Fen to Grantham/Sleaford circuit overloads the remaining in-service circuit to as much as 115% at winter peak demand. This overload is only seen on the AF route between Bicker Fen GSP and the tee to Sleaford.

Under Steady Progression and Consumer Evolution, this overload does not occur by 2022, due to lower levels of demand growth. By 2027, continued demand growth does cause an overload for the same condition to between 120% (Steady Progression) and 124% (Consumer Evolution) at winter peak demand.

The reconductoring proposed in 2022 under the higher growth scenarios remained sufficient.

It is recommended that both AF route circuits between Bicker Fen and the tee point to Sleaford are reconductored with 300mm^2 AAAC (Upas) at 75°C, and the existing cable sections are overlaid with 1000mm^2 copper XLPE cable under Steady Progression and Consumer Evolution.

Sleaford Tee to Sleaford Circuit Overloads (AFA Route)

Generation Overload

Generation Demand CR

The AF route double circuit runs between Bicker Fen GSP and Grantham BSP. The AFA route double circuit is teed off both sides of the AF route and supplies Sleaford BSP.

Under Community Renewables, the generation growth at Sleaford BSP causes an overload on the AFA route to 114% at summer peak generation.

The AFA route is currently 175mm² ACSR (Lynx) conductor, profiled for 50°C operation.

Demand Overload

Generation | **Demand**

TD CR

Under Two Degrees and Community Renewables, the demand growth at Sleaford BSP causes an overload on the AFA route for the loss of the other circuit to 108% at winter peak demand.

The generation and demand overloads identified on the AFA route would be resolved by reprofiling the 175mm² ACSR (Lynx) conductor to an operating temperature of 75°C. Whilst this does resolve the AFA route overload, it does not address the wider network constraints.

Proposed Reinforcement Strategy

To alleviate the projected overloads at Bicker Fen GSP, a reinforcement strategy will be required that considers:

- **the nature of the surrounding 132 kV network;**
- **existing 33 kV interconnection and transfer capability between Sleaford, Boston and Skegness BSPs;**
- **132 kV Interconnection with Staythorpe and Walpole GSP; and**
- **interaction with UKPN.**

Skegness BSP is located approximately 40 km northeast of Bicker Fen GSP with only two 132 kV infeeds: the AS route and the CO route. By 2027, the demand and generation growth at Skegness and Sleaford BSPs is shown to cause constraints on both sets of GTs. Overloads are also seen on the AF, AFA, CO and AS routes.

The 33 kV interconnection with Boston and Sleaford BSPs is likely to be insufficient to maintain P2 compliance at Skegness BSP under Two Degrees or Community Renewables. A large portion of the demand growth is located at Skegness BSP, where there are currently only two 132 kV infeeds. Notable demand and generation growth is also seen at Sleaford BSP.

Given the geographic area supplied and the distribution of future demand growth, it is proposed that to alleviate the 2027 projected overloads, consideration is given to establishing a new BSP located between Sleaford and Skegness BSPs. One potential site for establishing a new BSP is adjacent to Tattershall primary, where five 33 kV circuits currently converge. This site is located approximately 17 km north of Bicker Fen GSP, and is about 17 km from Sleaford and 30 km from Skegness BSP. A new BSP in this area, fed via two direct 132 kV circuits from Bicker Fen, would enable demand and generation to be permanently transferred from Sleaford and Skegness BSPs. The transformers would need to be two 60 MVA or 90 MVA units.

Detailed network design will be required to assess the option of additional 132 kV infeed against alternative reinforcement options. Consideration should be given to, but not limited to:

- **running arrangements for outage management;**
- **if it resolves the identified circuit constraints; and**
- **33 kV transfer capability.**

It is recommended that this area of network is assessed in greater detail in conjunction with UKPN.

The use of a TANM/ANM system to manage the generation overloads should also be considered. Any wider system reinforcement scheme should give consideration on how to manage generation constraints and the amount of new generation capacity it would release.

Walpole GSP

For the 2027 studies in Walpole, the following network reinforcements were modelled:

- two extra grid transformers were installed at Boston BSP, normally fed from Bicker Fen GSP. These GTs included normally open interconnection at 33 kV to the existing GT1/GT2 units fed from Walpole GSP. The underlying demand was apportioned equally between the four 33 kV busbars; the projected growth was split 26% on the new GTs, with 74% on the old GTs – this was to alleviate overloads on the AS route from Bicker Fen to Boston in the 2022 studies;
- as proposed in the 2022 results, the Boston–Skegness networks were radialised for an arranged outage of an SGT at Bicker Fen GSP. This also applied for an arranged outage of an AS route circuit between Bicker Fen and Boston;
- as proposed in the 2022 results, Grantham South is not transferred into Walpole for the arranged outage of a Staythorpe B–Staythorpe C interconnector. Instead it is run out of Staythorpe GSP at single circuit risk. This is with the aim of alleviating overloads seen on the PRA route between Stamford and Peterborough North;
- connection of a 132 kV generator, teed onto the Walpole circuit breaker 2205–Boston isolator 403 circuit. This has been modelled with an operational intertrip to trigger for the loss of direct 132 kV infeed from Walpole.

Walpole SGTs

Generation **Demand** TD CR

A busbar fault of Main 3 at Walpole results in the loss of SGT infeed and two outgoing circuits, which normally supply the Bourne and Peterborough area networks. The modelled running arrangement for an arranged outage or fault of an SGT connected to the Main 3 or Main 4 busbar is to switch in SGT3 (normally on hot standby) onto the Main 3 busbar via circuit breaker 380. However, for the fault of Main 3 at Walpole, SGT3 does not switch in and this overloads the remaining SGT in service (SGT2) up to 118% (Two Degrees) and 121% (Community Renewables) for a winter peak demand case.

Bus coupler circuit breaker 430 can be switched in to alleviate the projected overload and run three SGTs in parallel; however, this is subject to detailed fault level studies to determine if three SGTs can be run in parallel. This can be achieved through the installation of an auto-close scheme or done through control room action, provided that the overload is within short-term ratings of the SGTs.

It should be noted that the UKPN Kings Lynn and Peterborough area networks fed from Walpole GSP have not been considered for future scenario projections; it may be necessary to install an auto-close scheme on bus coupler 330 for a similar busbar fault of Reserve 4 at Walpole.

Boston BSP

Generation Demand CE TD CR

Following further generation growth to 2027, the net generation increases to 153 MW under a Community Renewables scenario. For the arranged or fault outage of a grid transformer at Boston normally fed from Walpole GSP (GT1 and GT2), this would overload the remaining GT in service supplied via Walpole up to between 126% (Consumer Evolution) and 141% (Community Renewables). There are no SCO combinations that exacerbate this overload.

Three in-service grid transformers at Boston should be sufficient to accommodate the generation growth for a first circuit outage in summer. It may require transferring generation and demand between the GTs fed from Walpole and Bicker Fen GSPs

Walpole to Boston 132 kV Circuits

Generation Demand

CE CR

Under the two higher growth scenarios in 2027, an 80 MW generator is teed onto to the Walpole circuit breaker 2205–Boston isolator 403 132 kV circuit. For arranged outages of an SGT at Bicker Fen GSP, the demand from Skegness BSP, Middlemarsh BSP and Boston GT3/GT4 is transferred onto Walpole. As part of this transfer, it is modelled that the 132 kV generator is curtailed to zero for the duration of the arranged outage and all interconnection at Boston/Skegness is opened to run the network radially. This network running arrangement would also occur for an arranged outage of an AS route circuit between Bicker Fen and Boston. For the above arranged outages, this would overload the HW route circuits from Walpole to Boston up to 120% (Consumer Evolution) and 129% (Community Renewables). Due to the network running radially for the arranged outage, there are no SCO combinations that exacerbate this overload.

Spalding/South Holland GT Capacity

Generation

Generation Demand

CR

For the SCO combination that results in the loss of two out of the three GTs in the Spalding/South Holland group, for a summer peak generation case, this would overload the remaining GT in service up to 106% in a Community Renewables scenario only. This uses the assumption that the group would not be split for the arranged outage.

Demand

Generation **Demand**

SP CE TD CR

Following demand growth to 2027, the Group Demand of the Spalding/South Holland group increases to between 110 MW and 144 MW. For the SCO combination that results in the loss of two of the three grid transformers feeding the group, the remaining GT in service overloads for all peak demand representative days. This uses the assumption that the group would not be split for the arranged outage. The SCO combination would overload the remaining GT in service up to 109% (Steady Progression) and 153% (Community Renewables) for a winter peak demand case and up to 104% (Steady Progression) and 145% (Community Renewables) for an intermediate warm peak demand case. Overloads also occur for a summer peak demand case; however, only under the Two Degrees and Community Renewables scenarios.

The overload can be managed operationally by splitting the 33 kV parallel group for arranged outages of a grid transformer, although care should be given to ensure that any subsequent fault cannot result in overloads. Establishing a second GT at South Holland BSP and breaking the 33 kV parallel under normal running would also alleviate the projected overloads. This reinforcement would also improve the flexibility of the Bourne 132 kV network, deferring some demand-related overhead line reinforcement. A more comprehensive reinforcement strategy is outlined below.

132 kV Bourne to Walpole Circuits

Generation **Demand** SP CE TD CR

The DZ and HB routes consist of a double circuit from Walpole GSP to Bourne BSP, where there is 132 kV interconnection to the outgoing HA and PR routes. South Holland BSP is teed onto the northern side of the DZ route with an inline circuit breaker. Spalding BSP is supplied via twin tees on the HBT route.

FCO

Generation **Demand** TD CR

A circuit fault of one of the outgoing DZ/HB route circuits from Walpole to Bourne (via Spalding and South Holland) will overload the remaining DZ route in service up to 106% (intermediate warm) and 119% (winter peak demand case) under a Two Degrees scenario. The overload also occurs up to 108% (intermediate warm) and 123% (winter peak demand) under a Community Renewables scenario.

SCO

Generation **Demand** SP CE TD CR

For an arranged outage at Stamford BSP that breaks the 132 kV interconnected ring, the UKPN and WPD areas of network are fed independently from Walpole. When the arranged outage is followed by a fault of either of the Walpole to South Holland/Spalding circuits, this would overload the remaining DZ/HB route circuit in service. In the Steady Progression and Consumer Evolution scenarios, the overload occurs for the winter and intermediate warm peak demand days on the DZ routes between Walpole and South Holland/Spalding only: between 117% and 126% for winter and between 106% and 112% for an intermediate warm peak demand case. In the Two Degrees and Community Renewables scenarios, the overloads on the DZ routes are exacerbated to between 158% and 162% for winter, 137% and 141% (intermediate warm) and between 124% and 128% for a summer peak demand case. Under Two Degrees and Community Renewables, the overloads also occur on the HBT route circuits towards Spalding BSP up to 133% for winter and 114% for an intermediate warm peak demand case.

Stamford to Peterborough North 132 kV Circuits

Generation **Demand** SP CE TD CR

In the 2027 studies, the arranged outage of a Staythorpe B–Staythorpe C interconnector was modelled with Grantham South fed from Staythorpe at single circuit risk. The normally open isolators at Bourne BSP remain open to retain the South Holland, Spalding, Bourne, Stamford and Peterborough area network 132 kV ring.

First Circuit Outages

Generation **Demand** SP CE TD CR

A fault of the Walpole to South Holland circuit overloads the PFG route circuits for all peak demand representative days under all scenarios: up to as much as 141% for winter, 148% for intermediate warm and 126% for summer peak demand case under a Community Renewables scenario. Under the Two Degrees and Community Renewables scenarios, the PRA route towards Stamford BSP would also overload for all peak demand representative days: between 109% and 112% (summer), 109% and 113% (intermediate warm) and between 121% and 124% (winter peak demand).

Second Circuit Outages

Generation **Demand**

SP CE TD CR

Following demand growth to 2027, the SCO combination that results in the loss of both DZ route circuits from Walpole to South Holland/Spalding would overload the remaining circuit supplying the group from Peterborough North to Stamford, comprising of the PRA and PFG routes. This is despite the modelled running arrangement without Grantham South transferred into group. The PRA route overloads for all scenarios and representative days: up to as much as 135% for winter, 124% for intermediate warm and 121% for a summer peak demand case under a Community Renewables scenario. The PFG route also overloads for all scenarios and representative days: up to as much as 153% for winter, 162% for intermediate warm and 137% for summer peak demand case under a Community Renewables scenario.

Proposed Reinforcement Strategy

To consider the wider network constraints in these studies, a more comprehensive reinforcement strategy is proposed.

To solve the GT capacity issues at Spalding/South Holland, it is recommended to install a second GT at South Holland and to split the group at 33 kV. The existing network is already set up to accommodate this second GT on the existing circuit.

Option 1

Permanently transferring Bourne into Staythorpe would alleviate the thermal overloads on the DZ/HB route circuits for faults on the other circuit. However, due to the 132 kV configuration at Bourne, transferring this onto Staythorpe permanently leaves the network with the following running arrangement (load share for winter peak demand in Community Renewables in brackets):

- **transformer feeder from Walpole circuit breaker 2705, with Spalding GT2, Bourne West GT1 and Sleaford REP 132 kV generator (57 MW);**
- **132 kV ring from Walpole, consisting of South Holland GT1 (also GT2 if it connects), Spalding GT1, Stamford GT1/GT2 and Peterborough area networks (174 MW not including Peterborough demand).**

As a result, any circuit faults that break the 132 kV ring from above will overload the PRA or DZ route circuits. Options to alleviate the overloads include:

- **reconductor both the PRA route and DZ route from Walpole to South Holland with 300mm² AAAC (Upas), profiled for operation at 75°C (circa 12 km on DZ, 7 km for PRA);**
- **install a wraparound circuit breaker at Bourne, connected between Main 1 and Main 2, with a cable to Main 5. This would also involve existing circuit breakers 120 and 520 being turned into line circuit breakers. This will help to address the load share between the two circuits from Walpole to Bourne; however, this will still require the PRA route to be reconductored with 300mm² AAAC (Upas), profiled for operation at 75°C;**
- **install the second GT at South Holland on the southern DZ route circuit (transformer feeder from above) to address the load share; however, the network is not currently configured to accommodate this.**

It should be noted that to enable Bourne to be transferred onto Staythorpe, this will likely trigger extra SGT works at Staythorpe GSP.

Option 2

If Bourne BSP is not permanently transferred onto Staythorpe, first circuit faults of the PRA route or DZ routes would overload the remaining two circuits in service supplying the ring. This would necessitate reconductoring works on the DZ, PRA and HB routes up to the Spalding tee (circa 12 km for DZ, 7 km for PRA and 25 km for DZ/HB).

Option 3

Reconfigure the cable sealing ends on tower PR1 fed out of Bourne to terminate the Stamford–Bretton PR route circuit onto Bourne Main 1 and terminate the Bourne West–Sleaford REP circuit onto Bourne Main 6. This would effectively swap over the HB route circuits from Walpole to Bourne, resulting in the following running arrangement (load share for winter peak demand in Community Renewables in brackets):

- **132 kV ring from Walpole, consisting of Spalding GT2, Bourne GT2, Stamford GT1/GT2 and Peterborough area networks (130 MW + 27 MW Bourne, not including Peterborough area demand);**
- **transformer feeder from Walpole circuit breaker 2605, consisting of South Holland GT1 (also GT2 if it connects), Spalding GT1, Bourne West GT1 and Sleaford REP 132 kV generator (101 MW + 27 MW Bourne).**

Bourne BSP could also be transferred out of group in this arrangement; however, this leaves a transformer feeder with winter peak demands in excess of 100 MW and provides less flexibility to maintain the ring for arranged outages at Bourne BSP.

Stamford BSP

Generation **Demand** CE TD CR

Stamford BSP currently comprises two 30/60 MVA 132/33 kV transformers. The substation is fed as part of a 132 kV interconnected ring from Walpole–South Holland/Spalding–Bourne–Peterborough. Following demand growth to 2027, the demand of Stamford BSP increases to between 62 MW (Steady Progression) and 80 MW (Community Renewables).

A fault of either GT would overload the remaining GT in service up to between 100% (Consumer Evolution) and 107% (Community Renewables) for a winter peak demand case. Overloads also occur for the summer and intermediate warm peak demand cases under the Two Degrees and Community Renewables scenarios. This overload is exacerbated for an arranged outage of a GT, as the 11 kV loose couples between Stamford BSP and the Bourne network are broken for the arranged outage.

Under the higher growth scenarios, it is recommended to replace the existing 30/60 MVA grid transformers with 60/90 MVA units.

West Burton GSP

Network Changes Modelled

For the 2027 studies, the proposed reinforcement strategy from the 2022 results was used. No other network changes were modelled. For the 2027 studies, the same running arrangement has been modelled at West Burton GSP as was used in the 2022 studies i.e. SGT1 and SGT2 are selected to the reserve busbar, along with all of the outgoing 132 kV feeders, and the reserve busbar is split. SGT3 is selected to the main busbar.

West Burton SGT Overloads

Generation Demand

SP CE TD CR

A fault on either half of the reserve busbar at West Burton GSP can cause an SGT overload at West Burton. Due to the busbar fault, the relevant 132 kV bus coupler cannot be closed by the auto-changeover scheme, resulting in the entire West Burton GSP demand being picked up by a single SGT. The overload can be up to 293% of SGT rating, caused by a voltage collapse. In the summer, overloads can also be caused due to the level of generation and the overload in this case can be up to 136% of SGT rating. The overloads seen are clearly well above even the short-term SGT rating, which itself cannot be applied when the overload is caused by reverse power flow. Table 31 summarises the seasons in which overloads occur for the different scenarios.

Table 31: West Burton SGT overloads in 2027 by scenario and season

Scenario	Seasonal Overload			
	Winter	Intermediate Warm	Summer (demand)	Summer (generation)
Community Renewables CR	Yes	Yes	Yes	Yes
Two Degrees TD	Yes	Yes	Yes	No
Consumer Evolution CE	Yes	Yes	No	Yes
Steady Progression SP	Yes	Yes	No	No

Worksop Transformer Overloads

Generation Demand

CE TD CR

A fault on either half of the reserve busbar at West Burton GSP can cause an overload on the grid transformers at Worksop BSP. The overload can be up to 146% of transformer rating and is caused by the 33 kV busbar at Worksop BSP forming a loose couple, resulting in half of the West Burton GSP demand being fed via this loose couple. For the Community Renewables and Two Degrees scenarios, the overload occurs in winter only; for the Consumer Evolution scenario, the overload occurs in summer only and is caused by generation. DOC protection has been shown not to prevent overloads in all cases.

Under an arranged outage of either half of the reserve busbar at West Burton GSP, a subsequent 132 kV busbar fault at Lincoln BSP increases the overload on the transformers at Worksop BSP to 159% of rating. Overloads occur in winter only and only for the Community Renewables scenario. Again, studies have shown that DOC protection is not effective at preventing overloads in all cases.

To avoid the issues identified, it is recommended that the running arrangement at West Burton GSP be reviewed with a view to using a solid running arrangement if possible, at least to feed the WPD circuits.

West Burton–Lincoln 132 kV Circuit Outages/Lincoln 132 kV Switchgear/Busbar Outages

Generation | Demand | SP | CE | TD | CR

For the 2027 studies, the recommendation from the 2022 results has been followed i.e. for an outage of one of the West Burton–Lincoln 132 kV circuits or a Lincoln 132 kV switchgear/busbar outage, Retford and Worksop BSPs are transferred to Staythorpe GSP.

West Burton SGT Overloads

Generation | Demand | SP | CE | TD | CR

Under a planned or unplanned outage of one of the West Burton–Lincoln 132 kV circuits or a Lincoln 132 kV switchgear/busbar outage, this can cause an overload on one of the SGTs at West Burton GSP, due to a voltage collapse. Overloads occur in all seasons and can be up to 250% of SGT rating, which is significantly above even the short-term SGT rating. The overloads seen are caused by the split running arrangement of West Burton GSP, meaning that the entire Lincoln demand is fed from a single SGT. For the Community Renewables and Consumer Evolution scenarios, overloads in summer occur due to generation only. In the Steady Progression scenario, the overload is seen during winter only.

It is recommended that the possibility of using a solid running arrangement at West Burton GSP be investigated.

West Burton–Lincoln 132 kV Circuit Overloads

Generation | Demand | CE | TD | CR

For a planned or unplanned outage of one of the West Burton–Lincoln 132 kV circuits or a Lincoln 132 kV switchgear/busbar outage, this can cause an overload on the other West Burton–Lincoln 132 kV circuit of up to 185% of circuit rating. This is caused by the remaining West Burton–Lincoln 132 kV circuit trying to pick up the entire Lincoln demand (158 MW), resulting in a voltage collapse. For the Community Renewables and Consumer Evolution scenarios, overloads occur in winter (due to demand) and in summer (due to generation). For the Two Degrees scenario, overloads occur in winter and intermediate warm periods only.

The West Burton–Lincoln 132 kV circuits are already 500mm^2 AAAC/550mm^2 ACSR conductor and profiled at 75°C, so cannot be uprated further. Coupled with the complexity of providing further transformer capacity at Lincoln BSP, it is therefore recommended to establish a new BSP in the Lincoln area, supplied by new 132 kV circuits from West Burton GSP. The exact location of the new BSP will be dependent on where the additional load growth is around Lincoln.

Worksop Transformer Overloads

Generation | Demand | CE | TD | CR

For a fault outage of one of the 132 kV busbars at Lincoln BSP, this can cause an overload on the transformers at Worksop BSP. The overload occurs under winter loading only and can be up to 152% of transformer rating. The overload occurs as the fault outage causes the loss of the remote couple at Lincoln BSP, meaning that part of the West Burton GSP demand is picked up via the loose couple at Worksop BSP. Studies have shown that DOC protection does not prevent overloads in all cases.

It is recommended that the use of a solid running arrangement at West Burton GSP be investigated.

Lincoln Transformers

Generation Demand CE TD CR

In the 2022 studies, an overload was seen for an outage of GT6 at Lincoln BSP. The recommendation of opening the 33 kV bus section at Lincoln BSP for this arranged outage has been followed for the 2027 studies.

Lincoln Transformer Overloads

Generation Demand CE TD CR

Under various outages that result in the loss of one or more of the 132/33 kV transformers at Lincoln BSP, this can cause an overload on the remaining transformer(s) at Lincoln. For the Community Renewables and Consumer Evolution scenarios, the overloads occur at winter peak demand and summer peak generation. In the Two Degrees scenario, overloads occur in winter and intermediate warm periods. Overloads can be up to 147% of transformer rating.

There is limited space at Lincoln GSP to install further transformers and consideration would be necessary to ensure the site remains P18-compliant. It is recommended that a separate BSP be established in the Lincoln area, depending on where the new load growth materialises.

West Burton SGT Outages

Generation Demand SP CE TD CR

As per the 2022 studies, the auto-changeover scheme is modelled so that for a fault or planned outage of SGT1 or SGT2 at West Burton GSP, SGT3 is brought into service. For planned SGT outages, Retford and Worksop BSPs are transferred to Staythorpe GSP.

West Burton SGT Overloads

Generation Demand SP CE TD CR

For an arranged outage of one of the SGTs at West Burton GSP, a subsequent fault on a second SGT at West Burton can cause an overload on the third SGT. Overloads occur under winter and intermediate warm loadings and can be up to 232% of the SGT rating in winter and up to 110% of rating in the intermediate warm season. The winter overload exceeds the short-term SGT rating; the intermediate warm overload does not. In the Consumer Evolution and Steady Progression scenarios, overloads are seen in winter only.

It is recommended that SGT outages at West Burton SGTs be taken during the summer period only if possible. Under intermediate warm loadings, prompt action will be required by WPD control in the event of a fault to de-load the remaining SGT to within its continuous rating. If this outage window is too restrictive then it will be necessary to install a fourth SGT at West Burton GSP.

Checkerhouse Transfers into West Burton

Generation | Demand — CE TD CR

For certain arranged outages on the Walpole/Chesterfield networks that cause BSPs to be transferred into Staythorpe GSP, it is necessary to transfer Checkerhouse BSP to West Burton GSP, usually to avoid overloading the SGTs at Staythorpe GSP.

West Burton–South Wheatley PV/Retford/Checkerhouse/Worksop 132kV Circuit Overloads

Generation | Demand — CE TD CR

When Checkerhouse BSP is transferred into West Burton GSP, a subsequent 132 kV busbar fault at Lincoln BSP can cause an overload on the 132 kV circuit between West Burton and South Wheatley PV/Retford tee. The overload occurs in winter (due to demand) and in summer (due to generation) and can be up to 137% of circuit rating. For the Consumer Evolution and Two Degrees scenarios, the overload is seen in summer only. The overload is caused by power flow circulating via the loose couple at Worksop BSP, caused by the split running arrangement at West Burton GSP.

In the Two Degrees scenario, for the same BSP transfer and ensuing fault, this can cause an overload on the 132 kV circuit between Worksop tee and Worksop BSP. The overload occurs in winter only and can reach up to 108% of circuit rating.

It is recommended that transfers of Checkerhouse BSP to West Burton GSP be restricted to the intermediate warm period only where possible. If this outage window is too restrictive then it is suggested that the practicalities of using a solid running arrangement at West Burton GSP be investigated. If this is not possible then it is recommended that the West Burton–South Wheatley PV/Retford tee 132 kV circuit be reinforced. This will require the cable section of this circuit to be overlaid with 1000mm^2 copper XLPE.

The Worksop tee–Worksop BSP 132 kV circuit will need to be reinforced as well. This section of circuit is currently profiled to 50°C so consideration could be given to using a higher profile temperature, if technically feasible. If the profile temperature cannot be increased then it will be necessary to re-string this circuit with 300mm^2 (Upas) AAAC conductor.

Worksop Transformer Overloads

Generation | Demand — CE TD CR

When Checkerhouse BSP is transferred to West Burton, an ensuing fault on the West Burton–South Wheatley PV 132 kV circuit can cause an overload on the transformers at Worksop BSP. The overload occurs in summer (due to generation) and in winter (due to demand) and can be up to 170% of transformer rating. For the Consumer Evolution scenario, the overload is seen in summer only and for the Two Degrees scenario, the overload is present in winter only. The overload is caused by part of the demand at Checkerhouse and Retford BSPs being fed via the loose couple at Worksop BSP. Studies have shown that DOC protection does not prevent overloads in all cases.

It is recommended that transfers of Checkerhouse BSP to West Burton GSP take place during the intermediate warm period only if possible. For transfers made outside of this period, it is suggested that the 33 kV bus sections at Checkerhouse and Worksop BSPs be opened. Any loose couples will also need to be broken.

10 – Next Steps

Baseline Constraints

It is recommended that the operability constraints identified in the baseline studies are assessed in further detail and mitigated where necessary. Constraints involving transmission outages or SGT capacity should be assessed in conjunction with National Grid, and constraints involving equipment owned by adjacent network operators should be subject to further joint studies.

Comparing Investment Options for 2022

This study has identified some areas of the network that would require reinforcement under the forecasted demand, generation and storage scenarios. It is recommended that for each of the reinforcement requirements identified in the 2022 studies, a preferred solution is developed and triggered as necessary. Each preferred investment option could comprise of conventional network build, novel technologies, flexibility services, or a combination of those solutions. Each strategic investment should be chosen through technical and cost-benefit assessment, to ensure the efficient, co-ordinated and economic development of the network. The timing of planned asset replacement should be taken into account when choosing and coordinating options. The affected networks and potential reinforcements are:

- Additional infeed to the Warwick and Harbury group
- Reconductoring the HZ route between Coventry GSP and the Hinckley tee
- A reserve section breaker at Coventry GSP
- Replacing Wigston 132/33 kV with 60//90 MVA units
- Third GT at Coalville BSP or transferring demand out of group
- Reconductoring the existing 175mm² ACSR (Lynx) conductor on the SZ route between the Loughborough tee and Ratcliffe-on-Soar
- A new Primary substation supplied by the 132/33 kV BSP at Loughborough
- East Claydon SGT and 132 kV reinforcement works
- Replace the switchgear at Staythorpe B substation
- Installation of additional transformers at Grantham South or establish a new BSP in the Grantham South area
- Reconductor the Staythorpe–Checkerhouse 132 kV circuits
- Installation of a third SGT at Bicker Fen GSP
- Reconductor the AS route and AF routes
- Additional GTs at Boston BSP

Where additional reinforcement requirements have been identified in the 2027 studies, then these should also be taken into account to minimise the risk of stranded assets.

Further Modelling

It is recommended that the parts of these studies affected by the operation of the transmission network are repeated in cooperation with National Grid. This may form part of a Regional Development Plan in the future.

It is also recommended that additional studies are carried out in cooperation with UKPN to assess WPD and UKPN's interdependent 132 kV networks supplied from Walpole GSP.

EA Technology are currently revising the EV profiles created as part of the Electric Nation innovation project, using a Monte Carlo approach to overcome some of the previous limitations. Once this analysis is completed, it can be used to update the EV charging profiles in future studies. It is also recommended that a review of existing HP and non-domestic profiles is periodically undertaken to ensure the most up-to-date and representative profiles are used in the analysis.

It is intended that these studies and the underlying scenarios will be revisited on a regular basis. The scope of future studies and related work may be broadened to include:

1. Fault level analysis including switchgear stressing,
2. Flexibility services and ANM including energy estimation,
3. Protection,
4. Stability,
5. Power quality.

11 – Definitions and References

References

External Documents

P18

Engineering Recommendation P18 (*Complexity of 132 kV circuits*) sets out the normal limits of complexity of 132 kV circuits. Originally drafted in 1978 there is now a requirement to revise this document in line with modern terminology and the inclusion of power generating modules now in use across the network. A revision to the ER document is currently ongoing.

P2

Engineering Recommendation P2 (*Security of Supply*) is currently in its seventh revision (P2/7). P2/7 gives requirements for security of supply towards demand customers, which form a condition of WPD's licence.

P27

Engineering Recommendation P27 (*Current Rating Guide for High Voltage Overhead Lines Operating in the UK Distribution System*) is currently its second revision (P27/2). WPD's policy ST:SD8A/3 has been updated to reflect the changes in the revised national document.

Electricity Act 1989 as Amended

Section 9 of the Electricity Act (*General duties of licence holders*) states that:

1. *It shall be the duty of an electricity distributor—*
    a. *to develop and maintain an efficient, co-ordinated and economical system of electricity distribution;*
    b. *to facilitate competition in the supply and generation of electricity.*
2. *It shall be the duty of the holder of a licence authorising him to transmit electricity—*
    a. *to develop and maintain an efficient, co-ordinated and economical system of electricity transmission; and*
    b. *to facilitate competition in the supply and generation of electricity.*

Future Energy Scenarios (FES) 2015, 2016, 2017, 2018, 2019

Annual report published by National Grid that sets out possible scenarios for the future development of energy generation and consumption in Great Britain.

National Electricity Transmission System Security and Quality of Supply Standard (SQSS)

Standard by which NGET must comply with in the planning and operation of the National Grid Electricity Transmission System.

Distribution Future Energy Scenarios (DFES) – Technology growth scenarios to 2032, East Midlands licence area 2019

Report written by Regen to forecast the future changes in demand and generation in the East Midlands WPD licence area. Available from our website at: www.westernpower.co.uk/distribution-future-energy-scenarios-regional-information

Insight Report Electric Vehicles

Report published by the Customer-Led Network Revolution project (reference CLNR-L092) in December 2014, describing research into the charging behaviour of electric vehicle users.

Air Conditioning Demand Assessment Report

Report published by the Tyndall Centre as part of the NIA Demand Scenario project (ENWL001) in May 2016, describing research into the behaviour of air conditioning units.

Managing the future network impact of electrification of heat Report

Report published by Delta EE as part of the NIA Demand Scenario project (ENWL001) in May 2016, describing research into the behaviour of heat pumps.

Western Power Distribution Documents

1. ST:SD8A/3 (*Relating to Revision of Overhead Line Ratings*), used in conjunction with ER P27/2 to determine the ratings applicable to overhead lines;
2. ST:SD8C/1 (*Relating to 132 kV, 66 kV and 33 kV Medium Power Transformer Ratings*), used to determine GT ratings;
3. 2015–2023 RIIO-ED1 Business Plan, used for identifying the WPD commitments for the RIIO-ED1 price control period towards network management and connection of renewable generation. Available at: www.westernpower.co.uk/About-us/Stakeholder-information/Our-Future-Business-Plan
4. East Midlands Subtransmission network geographic map and single line diagrams; available from our website at: www.westernpower.co.uk/distribution-future-energy-scenarios-regional-information

Table of Units

Term	Definition
kV	Kilovolt, a unit of Voltage (x10^3)
LV	This refers to voltages up to, but not exceeding 1 kV
HV	Voltages over 1 kV up to, but not exceeding 20 kV
EHV	Voltages over 20 kV (often refers to the common system design principles, applied at 22 kV, 33 kV and 66 kV)
kW	Kilowatt, a unit of Power (x10^3)
MW	Megawatt, a unit of Active Power (x10^6)
GW	Gigawatt, a unit of Active Power (x10^9)
MVA	Mega volt-ampere, a unit of Apparent Power (x10^6)
MVAr	Mega volt-ampere (reactive), a unit of Reactive Power (x10^6)
MWh	Megawatt hour, a unit of energy (x10^6). Equivalent to a constant 1 MW of Active Power delivered for an hour
MVArh	Mega volt-ampere (reactive) hour, the duration or persistence of reactive power flows. Equivalent to a constant 1 MVAr of Reactive Power delivered for an hour

Glossary

Acronym/ Initialism	Term	Definition
AAAC	All Aluminium Alloy Conductor	Family of overhead line conductors, each of which is composed of strands of an aluminium alloy which combines mechanical strength with electrical conductivity. Reconductoring from ACSR to a slightly larger AAAC often allows a significant improvement in circuit capacity without requiring major modifications to towers. AAAC is now commonly used for new build and refurbishment of transmission and Subtransmission lines in Great Britain. Each AAAC conductor is named after a species of tree.
AC	Alternating Current	An electric current which periodically reverses its direction, having a magnitude that varies continuously. The rate at which the current's direction changes is known as the frequency. The frequency for UK power systems is 50Hz.
ACSR	Aluminium Conductor, Steel Reinforced	Family of overhead line conductors, each of which combines steel strands for mechanical strength with aluminium strands for electrical conductivity. ACSR is the conductor traditionally used for transmission and Subtransmission lines in Great Britain. Each ACSR conductor is named after a species of mammal.
AD	Anaerobic Digestion	Ge+C4:F5neration process that utilises energy from waste products to produce biogas for gas generator sets.
ANM	Active Network Management	The ENA Active Network Management Good Practice Guide [22] summarises ANM as: *Using flexible network customers autonomously and in real-time to increase the utilisation of network assets without breaching operational limits, thereby reducing the need for reinforcement, speeding up connections and reducing costs.*
–	Access Window	The period of spring, summer and autumn in which arranged outages are normally taken.
AVC	Automatic Voltage Control	Automatic adjustment of transformer tap position required for transformers on the Primary Distribution and Subtransmission networks to maintain system voltage within limits as the demand changes.
BEIS	Department for Business, Energy & Industrial Strategy	The governmental department responsible for energy and climate change policy. Formed as a merger between the Department for Business, Innovation & Skills (BIS) and the Department for Energy & Climate Change (DECC)
BSP	Bulk Supply Point	A substation comprising one or more Grid Transformers and associated switchgear
CDD	Cooling Degree Days	A measurement to determine how much demand is required to cool a building.
CHP	Combined Heat and Power	Method of utilising the excess heat energy as part of the electricity generation process to produce heat for local customers
–	Demand	The consumption of electrical energy.
DSR	Demand Side Response	Ofgem led tariffs and schemes which incentivise customers to change their electricity usage habits
DG	Distributed Generation	Generation connected to a distribution network. Sometimes known as Embedded Generation.

Acronym/ Initialism	Term	Definition
DNO	Distribution Network Operator	A company licenced by Ofgem to distribute electricity in the United Kingdom who has a defined Distribution Services Area.
DSO	Distribution System Operator	A role which may be established in the future whereby the DNO undertakes some of the roles of the GBSO at a regional level to balance supply and demand.
ENA	Energy Networks Association	The Energy Networks Association is an industry association funded by gas or distribution or transmission licence holders.
ER	Engineering Recommendation	A document published by the Energy Networks Association.
EV	Electric Vehicle	A vehicle which uses electric motors as its method of propulsion
ESA	Electricity Supply Area	Each ESA represents a block of demand and generation as visible from the Subtransmission network. Each is one of: - The geographical area supplied by a Bulk Supply Point (or group or part thereof) providing supplies at a voltage below 66kV; - The geographical area supplied by a Primary Substation supplied at 66kV (or group or part thereof); - A customer directly supplied at 132kV or 66kV (or by a dedicated BSP or 66kV Primary Substation)
FCO	First Circuit Outage	P2/7 defines a First Circuit Outage as: *…a fault or an arranged Circuit outage…* Also referred to as N-1 in some contexts.
FES	Future Energy Scenarios	A set of scenarios developed by Nation Grid to represent credible future paths for the energy development of the United Kingdom.
GB	Great Britain	A geographical, social and economic grouping of countries that contains England, Scotland and Wales.
GBSO	Great Britain System Operator	National Grid is the system operator for the National Electricity Transmission System (NETS) in Great Britain. Responsible for coordinating power station output, system security and managing system frequency.
GSP	Grid Supply Point	A substation comprising one or more Super Grid Transformers and associated switchgear
GT	Grid Transformer	A transformer that steps voltage down from 132kV to 66kV, 33kV or 11kV.
HP (also ASHP)	Heat Pump	Extracts heat from surroundings which can then be used to produce hot water or space heating. There are a number of types of heat pumps; the common air source heat pumps absorb heat from the outside air.
–	National Grid	The Transmission Network Operator in England and Wales.
NGESO	National Grid Electricity System Operator	National Grid Electricity System Operator is the electricity system operator for Great Britain.
NGET	National Grid Electricity Transmission	National Grid Electricity Transmission owns the electricity transmission network in England and Wales.
NIA	Network Innovation Allowance	Funding scheme for innovation projects introduced as part of RIIO-ED1. For the RIIO-ED1 period, WPD requested the minimum 0.5% of total regulated income.

Acronym/ Initialism	Term	Definition
Ofgem	Office for Gas and Electricity Markets	Ofgem is responsible for regulating the gas and electricity markets in the United Kingdom to ensure customers' needs are protected and promotes market competition.
–	Primary Distribution	The sections of an electrical distribution network which provide the interface between transmission and primary or Secondary Distribution. In WPD's network the 33kV circuits and Primary Substations are considered to be Primary Distribution.
–	Primary Substation	A substation comprising one or more primary transformers and associated switchgear
–	Primary Transformer	A transformer that steps voltage down from 66 or 33kV to 11kV or 6.6kV
PV	Photovoltaic	Type of distributed generation which uses solar irradiance to generate electricity.
RAS	Remedial Action Scheme	Add-on module supplied by Siemens for PSS/E power system analysis software that enabled simulation of Corrective Action, control room actions in reaction to specific network conditions
RDP	Regional Development Plan	A joint study between National Grid and WPD on possible 132kV reinforcement options in the South West.
SCO	Second Circuit Outage	P2/6 defines a Second Circuit Outage as: *…a fault following an arranged Circuit outage...* Also referred to as N-1-1 or N-2 in some contexts.
SGT	Super Grid Transformer	A transformer that steps voltage down from 400kV or 275kV to 132kV, 66kV or 33kV
–	Secondary Distribution	The final section of an electrical distribution network which provides the interface between Subtransmission or Primary Distribution and most final customers. In WPD's network the 11kV, 6.6kV and LV circuits and the distribution substations are considered to be Secondary Distribution.
SoW	Statement of Works	The process under which DNOs request that National Grid assesses the potential impact of the connection of DG upon the National Electricity Transmission System.
SQC	Sequential Control	Method of managing the network without the need for manual intervention from a Control Engineer.
UK	United Kingdom	A geographical, social and economic grouping of countries that contains England, Scotland, Wales and Northern Ireland.
V2G	Vehicle to Grid	Where a plug-in EV can export to the power grid.
WPD	Western Power Distribution	A Distribution Network Operator (DNO) company that is licenced by Ofgem to distributed electricity in the East Midlands, West Midlands, South West, and South Wales regions of United Kingdom.
XLPE	Cross Linked Poly-Ethylene	Commonly used name for type of underground cable, which uses cross linked poly-ethylene insulation. They can be different sizes and are used extensively on the distribution network.
–	Subtransmission	The sections of an electrical distribution network which provide the interface between transmission and primary or Secondary Distribution. In WPD's East Midlands network the GSPs, 132kV circuits and BSPs are considered to be Subtransmission.

Transformer Ratings

Transformer Cooling Methods

Term	Acronym	Definition
Oil Forced, Air Forced	OFAF	Transformer cooled by thermosiphon flow of its insulating oil, assisted by oil pumps and external airflow forced by fans.
Oil Forced, Air Natural	OFAN	Transformer cooled by thermosiphon flow of its insulating oil, assisted by oil pumps and natural convection of external air.
Oil Natural, Air Forced	ONAF	Transformer cooled by the natural thermosiphon flow of its insulating oil and external airflow forced by fans.
Oil Natural, Air Natural	ONAN	Transformer cooled by the natural thermosiphon flow of its insulating oil and natural convection of external air.

Rating Categories

Term	Acronym	Definition
Continuous Maximum Rating	CMR	The allowable sustained loading of a transformer for given cooling conditions that leads to a yearly average winding hot-spot temperature of 98°C (and so unity ageing) under the following ambient temperature conditions: • Maximum yearly average 20°C • Maximum monthly average 30°C • Absolute maximum 40°C Also known as the sustained rating.
Cyclic rating	–	The allowable peak loading of a transformer for given cooling conditions and season or ambient conditions that leads to a peak hot-spot temperature of 120°C for a typical daily load curve.
Continuous Emergency Rating	CER	Primary transformer with a nameplate forced rating based on a very high ageing rate during emergency operation – usually 140˚C hotspot temperature. CER transformers cannot be uprated beyond that rating.
Final rating	–	The rating of a transformer for a given set of conditions with all fitted cooling equipment operating.

Applied ratings

Grid Transformers

Nameplate rating [MVA]	Final Forced cooling method	CMR_{ONAN}	CMR_{FINAL}	$Cyclic_{WINTER\ FINAL}$	$CER_{SUMMER\ FINAL}$
15/30	OFAF	15	30	39	34
20/40	OFAF	20	40	52	46
22.5/45	OFAF	22.5	45	58	51
30/60	OFAF	30	60	78	69
37.5/75	OFAF	37.5	75	97	86
40/60	ONAF	40	60	78	69
45/90	OFAF	45	90	117	103
60/90	ONAF	60	90	117	103

CER-type 66/11 kV primary transformers

Nameplate rating [MVA]	Final Forced cooling method	CMR_{ONAN}	$CMR_{FORCED\ TYPICAL}$	$CYCLIC_{SUMMER\ FORCED}$	$CER_{SUMMER\ FORCED}$	$CER_{WINTER\ FORCED}$
7.5/15	OFAF	7.5	**12**	11.2	12.6	14
12/24	OFAF	12	**19**	18	20.5	23
20/40	OFAF	20	**32**	30	34	38

Notes:

1. *No spring, autumn, intermediate warm or intermediate cool ratings are tabulated in ST:SD8C/1, so summer emergency ratings were used as a proxy to intermediate warm cyclic ratings in the studies.*
2. *No ONAN cyclic ratings are tabulated for transformers fitted with forced cooling in ST:SD8C/1, so a notional ONAN cyclic rating was approximated where required by:*

$$Cyclic_{ONAN} = Cyclic_{Forced} \frac{CMR_{ONAN}}{CMR_{Forced}}$$

Appendix

Network Modelling and Analysis

WPD East Midlands Subtransmission network and Primary Distribution network are normally analysed using TNEI's IPSA power system software. The IPSA load flow tool is designed to analyse a snapshot of the network and has the functionality to perform fault level and basic contingency analysis.

Data migration program

For this project, it was decided PSS/E was a more suitable analysis engine, as it has more advanced contingency analysis with corrective action modelling and a more advanced scripting interface. This required the migration of data from the master IPSA models and circuit database into the PSS/E database format. This was achieved by taking a snapshot of the master IPSA models and using an in-house conversion program to convert the network model. The model was automatically validated throughout the conversion process and manual validation was also carried out to ensure the PSS/E model accurately represented the network.

Analysis Program

A bespoke power system analysis program called the Switch-Level Analyser has been written for the studies underlying the Shaping Subtransmission series of reports. The program is written in Python 2.7. It uses PSS/E version 34 as its core analysis engine to perform the actual load-flow calculations, and uses some of PSS/E's built-in contingency analysis tools for efficiency.

To represent network operations throughout a representative day, the custom program was written so each half hour of the representative day could be overlaid with the demand and generation onto the master model. For each half hour, a full intact, first circuit/busbar outage and second circuit outage contingency analysis was run to assess the state of the network.

All the study input data were stored on a centralised server-side database. The following inputs were combined for each half hour, day, year and scenario studied:

- an appropriate network model;
- the underlying demand capacity on each BSP;
- the forecast capacity of each DG and new demand on each BSP;
- half-hourly profiles for each type of demand and DG;
- the appropriate ratings of network components; and
- existing network automation and manual switching schemes ('corrective actions').

For each half hour, day, year and scenario studied, the program returns:

- MVA flow on all branches of interest for all network conditions detailed in 'Contingency Analysis' below;
- voltage exceedances for all nodes of interest for all network conditions detailed in 'Contingency Analysis' below;
- lost load (i.e. the amount of demand disconnected) for all network conditions detailed in 'Contingency Analysis' below;
- group load (i.e. the demand and generation of each GSP, BSP and primary substation group) for all networks; and
- any studies where the program was unable to calculate valid results (non-convergences).

These results are processed within the program and exported to a results database. A separate 'report writer' program was written to summarise the results in tabular and graphical formats for further evaluation.

To significantly decrease the runtime per study, a distributed computing approach was used, where each study was broken into a half hour and representative day. This gave 192 unique tasks for the four representative days studied, which were stored on the centralised database and run on all available pool computers. Each active computer checks if any tasks are available from the server, runs a full intact, first circuit/busbar outage and second circuit outage study for any available task and writes the processed results to the database. To further improve runtime efficiency, the Python multiprocessing module was utilised, which allowed up to six parallel processes to run on each computer, significantly increasing CPU utilisation.

The processes followed by the analysis program are summarised in Figure 48.

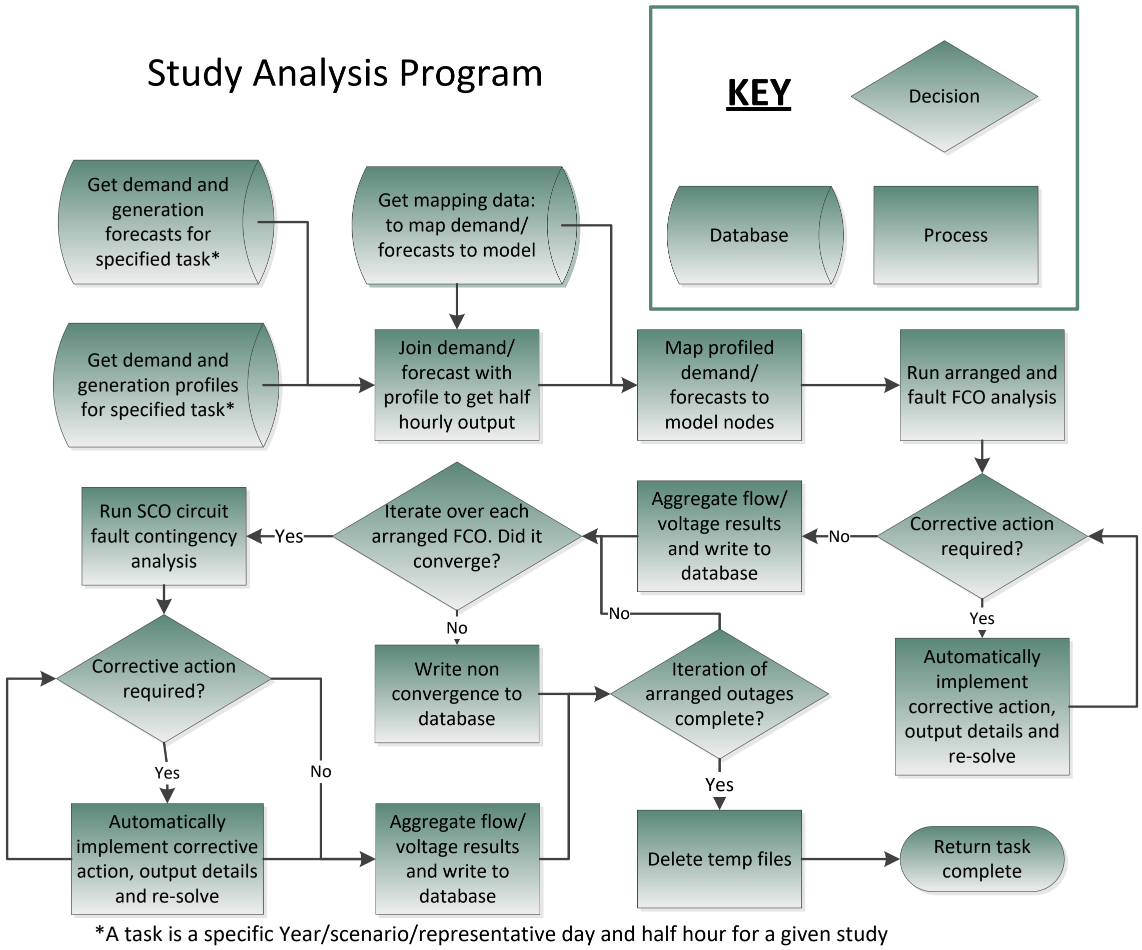

Figure 48: Summary of network analysis process

Modelling Network Automation and Manual Switching Schemes

One of the limitations found with previous versions of PSS/E was the inability to model the behaviour of network automation and manual switching schemes. Networks often rely on such schemes to maintain compliance under outage conditions. Consequently, the results were not always representative of how the network would react to specific outages; extensive manual analysis was required to confirm the impact of these outages. This limitation is avoided in WPD's strategic studies through the use of the PSS/E Advanced Contingency and Remedial Action Scheme (RAS) add-on module. This module takes user-defined conditions and will perform an action dependent on the outcome of the condition. WPD has used this module to model the behaviour of network automation and manual switching schemes including:

- auto-close schemes;
- ANM;
- intertripping;
- sequential control (SQC); and
- load transfers.

Contingency Analysis

The demand and generation capacity of a network is not normally limited by its characteristics under normal running conditions, but by its characteristics under abnormal running conditions. Abnormal running arrangements occur due to faults, maintenance, network construction and other reasons. WPD's network is required to comply with Engineering Recommendation (ER) P2 for demand security, and must safely cope with credible fault conditions beyond the scope of ER P2. There is currently no standard for providing security of supply to DG. Contingency analysis is the analysis of the network under abnormal conditions to confirm that the network complies with these requirements.

Circuit breakers were included in the network model in order to determine the protective zones bounded by circuit breakers, which are de-energised under fault conditions. Isolators were included in the network model to determine the isolatable zones bounded by isolators, which are de-energised to take arranged outages. The following outage types and combinations of outage types were studied:

- the intact (normal running) network;
- each circuit fault;
- each busbar fault;
- each arranged circuit outage;
- each arranged circuit outage followed by each circuit fault;
- each arranged busbar outage;
- each arranged busbar outage followed by each circuit fault.

The outage of each zone that includes at least one 132 kV, 275 kV or 400 kV node was assessed, including all SGTs and GTs. Only those transmission contingencies within the East Midlands area were considered.

Modelling Limitations

1. A minor limitation of the program was that a very small minority of contingencies were unable to converge for the most onerous scenarios. Where this occurred, the condition was evaluated separately to ensure that it did not indicate an issue with the network model or the network itself.
2. Fault outages were modelled by assuming that each area of network enclosed by circuit breakers represents a protective zone. Sectionalising and subsequent auto-reclose operations were not modelled. Circuit breaker failure outages were also not modelled.
3. Arranged outages were modelled by assuming that each area of network enclosed by isolators represents a zone of isolation. The outage required to maintain each isolator was also modelled.
4. Flows on the WPD network can be influenced by the transmission network. Better results are obtained by having accurate data about the transmission network. The current equivalent in the East Midlands model is an equivalent generator connected to the 400 kV or 275 KV side of the SGT transformers for each GSP. With no GSPs run in parallel on the 132 kV, this simplified equivalent is usually sufficient to represent distribution network behaviour. The limitation is where the equivalent of the GSP is oversimplified meaning the model is not

representing the correct load share on the SGTs. This is not a major issue where the 132 kV bars are run solid, but where the bars are run normally split, it is causing incorrect model flows on the 132nkV.

5. In the absence of more detailed models of credible worst-case customer behaviour, battery storage was modelled as:
    a. importing at full capacity when assessing demand security; and
    b. exporting at full capacity when assessing generation security.
6. At present, there is limited data available on the charging behaviour of large populations of fast-charging, high-capacity EVs with a broad range of users. WPD hosted the Electric Nation project in partnership with EA. The aim of this project was to determine the impact EVs will have on the network and the effectiveness of demand side management. When this project was started, there was not sufficient data to derive new profiles from this project, but the available data will be periodically reviewed. For this reason, EV charging profiles were derived from the Electric Vehicles Insight Report of the Customer-Led Network Revolution project. This was based on a trial involving 143 domestic EV owners that took place in 2014. It is possible that increases in power and energy consumption per EV will plateau at some point (despite improvements in charging speed and battery capacity) as EV capabilities come to match the demands of EV users, but it is not known when this will happen or at what level. The EV profiles used in the studies peaked at just 0.9 kW per EV after diversity Future studies will use profiles derived from Electric Nation and other sources. More information on WPD's Electric Nation project is available at www.electricnation.org.uk
7. Only load-flows assessing steady-state voltage and power flows have been undertaken. No power quality, protection or stability studies have been carried out.

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