Project FALCON

Blueprint

Revision history

Version	Author	Description
V0.3	EB, OS	First draft
V0.4	OS, MI	Added WPD comments, visualisation
V0.5	EB	Consistency check, added missing parts
V0.7	JW	Draft for consultation
V0.8	EB	Added info about SIM extensibility w. new techniques
0.9	SF	Changes to reflect expert panel comments and header and footer included

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Project FALCON

Scenario Investment Model Design Blueprint

1. Executive Summary

DNOs are entering a period of significant change. The challenges presented by the transition to a low carbon economy will directly impact our network. The widespread connection of distributed generation and the electrification of heat and transport will require new approaches to the design, construction and operation of networks.

To enable DNOs to develop these new approaches, Ofgem have released £500m of funding for DNOs to trial innovative techniques and share the learning with the rest of the industry. Project FALCON (Flexible Approaches to Low Carbon Optimised Networks) is funded via Tier 2 - the competitive bidding element of the Low Carbon Network Fund (LCNF).

Falcon is focused on the 11kV network. The cost and limited flexibility of traditional approaches to 11kV network reinforcement threaten to constrain the uptake of low carbon technologies. It aims to gain an understanding of the dynamic nature of the utilisation and demands placed on this part of the network and to assess a number of alternative solutions to the existing reinforcement methodology currently used. In addition, it aims to obtain telecommunications/ICT insights to identify 'top down' investment needs.

FALCON is a £16.19m project starting 1st December 2011. It has five overlapping phases: mobilisation, solution design, solution build, trials implementation, consolidate and share. Project completion date is 30th September 2015. Organisations providing funding to the project, i.e. Partners, are Alstom, Aston University, University of Bath, Cranfield IVHM Centre, Cisco and Logica.

The key deliverables of Falcon are Knowledge and a new Scenario Investment Model. This document is the first milestone that encapsulates both of these deliverables.

2. Introduction

This document provides a management-level functional description of the Scenario Investment Model (SIM). The SIM is a software tool that is developed as part of the Flexible Approaches for Low Carbon Optimised Networks (FALCON) project, which is a LCNF project with the following broad aims:

- Develop and test a Scenario Investment Model (SIM) - prototype investment planning tool
- Design and trial a telecoms solution of the future
- Assess the effectiveness of industry data for future consumption estimates vs. actual data from monitoring at substations
- Capture knowledge and disseminate learning within Western Power Distribution (WPD), to other Distribution Network Operators (DNO)s and to the industry.

2.1. Intended Audience and Document Overview

This document is intended to be a knowledge dissemination tool for Cranfield University IVHM Centre and Western Power Distribution (WPD). The contents of this document will be made available nationally to all UK Distribution Network Operators (DNOs) and the industry. The document is structured such in a way so as to build up the picture of the SIM. Most sections though can be read in isolation.

Firstly the document covers the High Level Architecture and then it covers some of the technical details of the solution build and the technical elements of the trials, this is important as it is this information that feeds into the SIM.

Some of the sections provide summary information that is further detailed within the Appendices.

2.2. Problem

The cost and limited flexibility of traditional approaches to 11kV network reinforcement threaten to constrain the uptake of low carbon technologies. Current 11kV network modification practices do not evaluate long term consequences of network changes, acting on a short-term horizon. Long term capacity planning is based on historical estimates that assume gradual ramp-up of energy demand.

As part of the project six network intervention techniques are proposed as alternatives to traditional network reinforcements. The technical and commercial benefits of the intervention techniques will be quantified during field trials. The technique description and trials data would be used to create accurate technique models.

The SIM will use the technique models and improved future network load scenarios to plan the network operation for time periods of up to 38 years. Long term planning and use of novel intervention techniques is expected to achieve

significant reduction in network reinforcement costs and facilitate adoption of low carbon technologies.

2.3. Context & focus

The SIM is a planning tool that will be used to model 11kV distribution network for a period of up to 38 years. The software would model a selected future network load scenario to determine the impact the load changes would have on the network, specifically where the network experiences an unacceptable condition such as overloaded conductors or voltages that are outside statutory limits. These are referred to as network constraint violations and they trigger the software to apply intervention techniques to resolve them in the most cost-effective and timely manner. Although the SIM will be a prototype tool, it is expected the approach to be the basis for future commercial network planning tools. The SIM will be operated in a trial area around Milton Keynes having approx. 200 substations.

2.4. Design rationale

The SIM will be used to find the most cost-effective way to run 11kV distribution network over periods of up to 38 years. This time period has been chosen to match the existing load scenarios which are available to 2050. Using the SIM it would be possible to select the best approach to managing network constraints given a range of technical and economic criteria.

For the purposes of the FALCON SIM system development (including the trials) it was necessary to choose a set of initial Techniques and these are built into the development. It is of course always possible to add additional techniques beyond those which have been selected. This would involve further development of the Network Modelling Tool, which while outside the current scope of the SIM design can still be readily supported. The SIM design facilitates possible future addition of new techniques in the following ways:

- The technique models are located in a separate software module with clearly defined interfaces between the module and the rest of the SIM.
- The SIM provides a way to expose generic datasets to its internal search module and thus to the technique models. This enables implementation of techniques that require additional data that is not currently available within the SIM.
- The output of a technique is generalised in the form of a network patch which then feeds back into the SIM.

Thus we have a modular design with generic interface support capability and we thus consider the SIM to be open to future enhancement via formal change request. The nature of future SIM support and development is still being considered.

Furthermore - It is always possible to turn techniques off if they are not applicable.

2.5. Definitions, Acronyms and Abbreviations

The glossary for this project is in the Data dictionary in section 12.

3. High Level Architecture

The aim of the SIM is to find the best sequence of network interventions that will allow a network to operate without network constraints for the period being evaluated.   These network interventions may be traditional reinforcement techniques or the six novel techniques evaluated in Falcon, namely

- Dynamic asset rating
- Automated load transfer
- Meshed networks
- Battery storage
- Demand side management
- Generator support

These techniques are described in more detail in Appendix B Technique Descriptions.

A set of network interventions that enable the network to remain free of constraints is referred to as a RESULT and this will detail the techniques applied, their locations and the years in which they are applied.
A single RUN of the SIM is expected to produce many RESULTs showing different ways to manage the network through the evaluation period.

The SIM is an optimisation tool that automatically searches for the best RESULTs for the 11kV network through the evaluation period. When the SIM needs to resolve a constraint there may be many different techniques which would be successful. These possibilities result in a simulation that could potentially "branch" over and over again. As the number of ways in which the network could be modified is large it will be ill suited to a manual analysis, so an automated tree-based heuristics is selected. This effectively selects the simulation branches that are considered favourable and should be extended from those which are unlikely to provide an optimum result which are "pruned".

Several load scenarios reflecting different assumptions about the uptake of low carbon technologies will be used to predict load for up to 38 years in the future.

To perform this complex process the SIM needs to integrate a number of elements which include;

1) Information about the 11kV Network as it is today
2) Information about known changes to the 11kV Network - contained in "Network Patches"
3) The future loads of distribution substations in the network to be analysed. There will be different values according to the various load scenarios.
4) Technique models that outline how the new interventions and traditional reinforcement techniques affect the network in terms of altering the built assets , the network configuration and the supply and demand at points on the network.

5) The impact of techniques that are applied assessed against a variety of financial and non financial evaluation criteria within a cost model.

These elements are shown in the high level hierarchy diagram below and explained in more detail in the following sections.
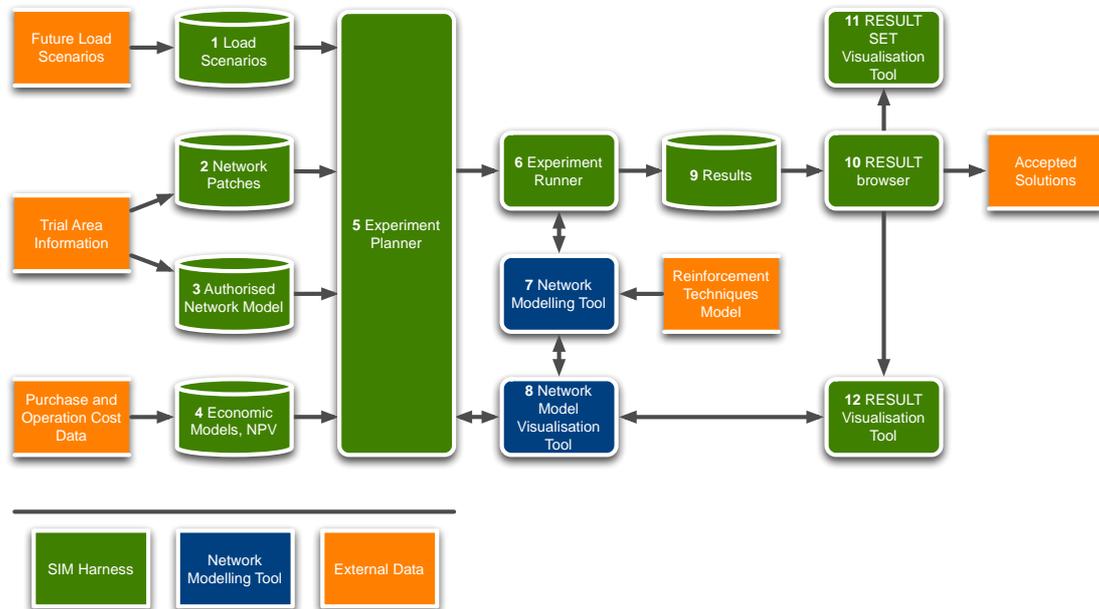
Figure 1. Outline of SIM structure

At the heart of the SIM there is a network modelling tool (NMT) that is used to
- Browse and edit the network model.
- Evaluate the network to determine voltages, powerflows and network performance metrics.
- Apply the intervention techniques

The SIM harness that is built around the NMT is used for a variety of functions that include;
- Planning the "experiments" , which means setting up the SIM to run a set of analysis according user selected parameters.
- Handling the way the network simulation branches where more than one option would resolve a network constraint.
- Select RESULTs for reporting, display or export.

3.1. Functional Descriptions

The SIM is envisaged as having three main types of business users as follows:

1) 11kV Planners who can use the SIM to plan work on a specific area of the network
2) Strategic Planners who would want an overall view of the expected work volumes for large areas of networks
3) Policy users who would be interested in understanding the implications of changing the way the 11kV network is managed

The system will support the following general workflow:

- The authorised network will be imported from an external source.
- The Engineer will create patches, load profiles, costing models needed for their experiment if they do not already exist.
- The Engineer will define the inputs to one or more RUNs of the SIM. For each RUN the SIM will need to know the network area and patches to be applied. The full list of input data is set out in the detail sections below. Some questions will have several RUNs using the same costing model but for different network areas while others will have different costing models on the same network area. The Engineer is expected to define a series of RUNs (RUN SET) that will provide the data to answer the question they are addressing. The SIM will not guide the Engineer in this process.
- The SIM will batch process the RUN SET defined by the Engineer.
- All RESULTs will be saved to a result store.
- The Engineer will select from the store of results, the RUNs and RESULTs to use for reporting.
- The Engineer will be able to perform either an in-depth inspection of a single RESULT or export one or several RESULTs into an external spreadsheet program for analysis.

3.1.1. Load Scenarios

This section gives an introduction to the functionally in block 1 of Figure 1

This is a data store. The load scenarios are used by the SIM to predict future load in the network. The load scenarios will be user-selectable. As the future is uncertain, the load scenarios will differ in their assumptions for the uptakes of various low carbon technologies, energy efficiency measures and other factors such as economic growth.

Load scenarios will contain load estimates for distribution substations for different years. Within each year estimates will be given for different seasons (autumn, winter, spring summer and high summer) and day types (Weekday, Saturday, Sunday) for days when the conditions are expected to be most onerous Winter Peak, Summer Peak, Summer Minimum. For each of these days 48 half hourly load values are given.

Differences in the load profiles may have a significant impact on the recommendations developed through the SIM.

The SIM will provide functionality to browse through existing load scenarios and amend / delete a load scenario.

3.1.2. Patches

This section gives an introduction to the functionally in block 2 of Figure 1.

This is a data store. The SIM needs to be able to model planned work and auto generated changes to the networks. All these changes are referred to as patches. Patches that reflect changes occurring in a single year are referred to Annual patches. Some planned network changes deal with complex projects that have many separate stages. To cater for this we have defined a Multi year patch so that it can include a set of changes that can occur over a number of non-contiguous years.

An annual patch is a set of changes to the network. A change could be:
- Addition of a new network component.
- Removal of a component
- A change in the parameters of a component.

Some patches will be manually created by users editing the network whereas some may be generated automatically using predefined algorithms.

Patches created by the Engineer can result in new distribution substations and/or generators appearing on the network. As these are new entities, these will not be known to the energy model that creates the load profiles. The SIM will be able to create a load profile for a new substation based on the types of customers that are connected to the substation. The Engineer should supply this information at the substation's creation time.

The SIM will provide functionality to browse through existing patches and update them.

3.1.3. Authorised network model

This section gives an introduction to the functionally in block 3 of Figure 1 .

This is a data store. The SIM uses nodal models of the 11kV power networks to determine if they require remedial action. These networks are already represented as nodal models and used in other computer-based tools, e.g., planning tools such as GROND and DINIS or a Control room system. The SIM should be able to import the data required for its modelling from the same master sources for the data, i.e. the asset management and geographic information systems. If this is not practicable, then data will be imported from the nodal models that are used by the planning tools or the control room system.

The SIM will provide functionality to browse the authorised network model.

3.1.4. Costing models

This section gives an introduction to the functionally in block 4 of Figure 1

In order to develop a plan for future investment and to help determine the optimum solutions, the SIM needs to have processes to calculate the probable cost and associated benefits of different types of work at different locations. The processes for calculating probable costs are referred to as costing models and must be developed and managed by the engineers using the SIM. The costs of implementing a patch can only be known by the authority that produced it for example if an 11kV planner designs an extension to the network to accommodate a new connection, then the network planner can estimate the installation cost and any ongoing costs associated with the new assets within the patch. Where patches are automatically generated by the network modelling tool, then the cost modelling values must also be generated. Therefore Patches will be required to store the initial and on-going costs of implementing the patch. There will be a fixed number of these values; each will represent a cost in terms of manpower, equipment or other factor.

Lastly, for reporting purposes, it will be possible for the author of a patch to associate a bill of materials with a patch. This will be at a very high level for example number of transformers or batteries installed, length of overhead line installed etc.

What is a cost model?
A costing model will convert the cost factors associated with patches into a financial indicator, this can include initial as well as ongoing costs. This indicator is then used for the optimisation of the model.
To allow for flexibility in reporting, several cost factors can be defined, for example the DNO may wish to separate out different cost types if these are treated differently for regulatory purposes. In reality these cost factors may not even be financial costs but simply a factor that we wish to include in the evaluation such as impact on customers, for example disruption, or labour hours.

Business requirements to be supported
The cost model needs to support the following business requirements.
Selection between a variety of different cost models. This allows for cost models to differ between regions which may have different installation costs, ongoing costs and different incentive rates for CMLs, CIs and losses. Having the ability to select different cost models also allows for different assumptions to be applied for how costs might vary over time. For example, we could use three different cost models to see the impact of stable, increasing or decreasing costs for batteries.
Separately identify initial and ongoing costs in several user definable categories
Include values for non-cost items specified within the patch for example customer disturbance, safety impact on both an initial and ongoing basis. These will be included as a cost which will reflect their relative weighting
Allow for the inclusion of the impact of items calculated by the network modelling tool that are not held within the patch – i.e. CML, CI, Losses. A weighting factor will be included to convert the values provided by the NMT to a

cost.   For example the weightings could be set to reflect the regulatory financial incentive rates for these items.

Allow for changes in all these values over time. For example users might want to model the impact of expected changes in labour cost or materials cost, or assume an efficiency improvement in labour hours. Similarly users may wish to predict changes in the incentive rates for CML,CI and Losses

Allow for a calculation of net present value by allowing the same cost to have a different impact on the total according to the year in which it occurs.

Ongoing costs are simplified to a single value which is applied every year. In reality ongoing costs are likely to be different each year reflecting the cyclic costs of inspection and maintenance of different components which may have different cycle periods. The complex functionality to support cyclic ongoing costs is not supported.

The SIM cost model is not expected to anticipate expenditure that is triggered by network investment but not modelled directly within the patch. Therefore while it is possible to associate incremental telecommunications costs with a technique any central or one off costs for setting up new data processing systems etc. would need to be calculated and added to the results outside the SIM.

In any year the following factors will be present:

Factor	Value
Up to 10 factors relating to work performed via patches in that year	The initial values will be used.
The same 10 factors relating to work performed via patches in previous years.	The on-going values will be used
Each of these 10 factors will be summed	The losses, CMLs and CIs predicted by the NMT in that year.

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The costing model will have a costing for each of the 10 factors in each year of the evaluation. Thus allowing a total cost to be calculated. The cost for each factor in each year should be built up by combining the expectation of equipment and staff costs in that year and any allowances that the user wishes to make for net present value.

For example let us imagine the cost model table below represents application of automatic load transfer. X1 represents the material installation cost in 2012, X2 will be the cost in 2012 modified to reflect the combined impact of expected increases in materials costs but also modified to reflect the discount factor to bring this in to alignment with 2012 prices,

Similarly step changes in incentive rates can be modelled as the CML rate changes from A to B

Cost model identifier	Example use	2012	2013	2014	……	2050
Initial cost factor 1	Materials	X1	X2	X3		Xn
Initial cost factor 2	labour (or alternatively labour hours)	Y1	Y2	Y3		Yn
Initial cost factor 3	Contractors costs					
Initial cost factor 4	pensions costs					
Initial cost factor 5	Telecommunications costs					
Initial cost factor 6	DSM payments					
Initial cost factor 7	Road closures					
Initial cost factor 8	Customer disturbance factor					
Initial cost factor 9	Risk / Safety impact					
Initial cost factor 10	Load index metric					
Ongoing cost factor 1	Materials					
Ongoing cost factor 2	labour (or alternatively labour hours)					
Ongoing cost factor 3	Contractors costs					
Ongoing cost factor 4	pensions costs					
Ongoing cost factor 5	Telecommunications costs					
Ongoing cost factor 6	DSM payments					
Ongoing cost factor 7	Road closures					
Ongoing cost factor 8	Customer disturbance factor					
Ongoing cost factor 9	Risk / Safety impact					
Ongoing cost factor 10	Load index metric					
CML		A	A	B	B	
CI						
Losses						

 Differences in the costing model may have a significant impact on the recommendations developed through the SIM. There may be a large number of different costing models, driven by different predictions for future technology costs and economic factors.

The SIM will provide functionality to browse through and update the existing costing models and create new costing models.

3.1.5. Experiment planner

This section gives an introduction to the functionally in block 5 of Figure 1

To plan an experiment, the engineer should be able to select the following parameters
- Costing models,
- Network area to analyse,
- Patches,
- Load profiles,
- Other run parameters, such as the evaluation period

Selecting the cost models
The SIM should provide the functionality to browse the costing models. It should be possible to select models for:
- The whole area under analysis
- A sub area of the analysis
- Everything except a sub area of the analysis
- A class of equipment.
It should be possible to select several cost models and to have them applied in the order they were selected. So for example it should be possible to:
- Select cost model 1 for the whole network.
- Select cost model 2, but only for transformers in range x-xx.
- Select cost model 3, but only for equipment connected to feeder y.
Thus a transformer connected to feeder y would be under cost model 3.
The selections for cost model should be for a single run of the SIM. It should be possible to save and recall the selections so that they can be re-applied or modified for further runs.

Selecting the Network Area
Using an interface consistent with the network/patch editor and the network viewer, the SIM needs to enable the Engineer to select a sub area of the network to analyse.

Selecting the Patches
The SIM should allow the Engineer to browse through a library of previously developed patches and select those that are to be assumed by the run of the SIM. Only those patches that affect the area being analysed should be presented to the Engineer.

Patches are set to a default of either "SELECTED" of "DESELECTED". "SELECTED" patches are automatically applied to the network area that is selected for analysis. The engineer may override the default selection setting for any patch.

The SIM should check that the choices of patches are consistent with each other and the network state. i.e. that they don't add equipment to a location that does not exist etc. Any errors should be reported to the Engineer with an informative error message.

The selections for network area and patches should be for a single run of the SIM. It should be possible to save and recall the selections so that they can be re-applied or modified for further runs.

<u>Technique lives.</u>

The SIM is not intended to be used as a model for age/condition related asset replacement. However the lifetimes of the techniques applied may have an impact on whether they are the optimum solution.

For traditional reinforcement techniques, the assets installed will have a lifetime that is more than the maximum evaluation period in the SIM and therefore the replacement of these assets does not need to be considered. However the new techniques are likely to have shorter lives reflecting the different types of technology involved. Similarly, commercial agreements would be unlikely to made on a long term basis, so it would be more realistic to model these as a series of short term agreements.

The preferred option is that at the end of a techniques assumed lifespan it would expire by removal of the patch that applied it. This expiry could result in the emergence of network constraints which would then either result in a fresh version of the same technique being applied or, other suitable techniques being applied if they were preferable at that time.   While this is the best solution in terms of ensuring all potential options are considered it may introduce an additional burden in terms of complexity that may not be supportable.

A simpler approach may be to assume that a Technique, once applied, is assumed to be continually replaced after its normal lifetime. E.g. If a battery is expected to last 10 years it is replaced every 10 years with no further decision making. Thus replacement costs should be factored in to the ongoing cost element of the cost model. This does not result in the right profile of capex spend but is simple to apply.

Another variant would be as above but with the facility to repeat capex spend at certain intervals and exclude assessment of replacement capex from the ongoing costs. This would require modifying the mechanism of the cost model.

<u>Selecting the Load Profiles</u>

It should be possible to select Load Profiles for:
- The whole area under analysis
- A sub area of the analysis
- Everything except a sub area of the analysis

It should be possible to select several load profiles and to have them applied in the order they were selected. So for example it should be possible to:
- Select load profiles 1 for the whole network.
- Select load profiles 2, but only for substations in range x-xx.

The selections for load profiles should be for a single run of the SIM. It should be possible to save and recall the selections so that they can be re-applied or modified for further runs.

Other Run Parameters

Technique availability
Another run parameter that the user may wish to change would be the availability of each technique. The user may wish to completely exclude some techniques from the analysis or to allow for a technique to become available at a certain time.

For example a planner in 2012 may reflect the fact that meshed networks require considerable time for planning and implementation by suggesting that meshed networks are not an option for solving network constraints until 2015. Similarly a user might reflect their assumptions about when a technique may be a viable proposition by suggesting that substation batteries should not be available until 2020. By allowing availability to be defined by year then the user can effectively switch off techniques by making them unavailable for each year of the evaluation period. In this way the investment for a network using traditional reinforcement alone can be compared with a combination of traditional and smart techniques.

There was no identified business case for making a technique unavailable following a certain date, If required this could be "forced " using the cost model to make a technique prohibitively expensive.

It will also be possible for the Engineer to set any other run parameters such as the evaluation period.

3.1.6. Experiment runner
This section gives an introduction to the functionally in block 6 of *Figure 1*.

The SIM run will be to evaluate a section of network against a selection of load profiles/patches/costing model for a number of years. The SIM must find a number of plausible ways of addressing network issues through the years under evaluation so that as the load increases the network remains operational under regular (ie. intact network) and all N-1 failure modes.

This block of functionality represents the core of the SIM and has several components. These are detailed in later sections of this document. In over view, the SIM must.
- Evaluate the network for each year through the evaluation period until a regular or an N-1 failure mode results in a network constraint violation. A network constraint violation could be a thermal overload, voltage higher than statutory limits or voltage lower than statutory limits. We do not expect the SIM to determine and resolve those relating to power quality

- as these tend to require more detailed consideration that is not suited to automated analysis.
- Apply one of 6 intervention techniques or default reinforcement to find a number of ways to prevent the constraint. This will result in a number of possible solutions.
- Continue to expand all solutions until multiple paths through the evaluation period have been explored.
- Save all successful paths through the evaluation period that were found into a database for future analysis

This will produce a tree of results where the trunk of the tree is the start of the evaluation and the leaf nodes are all solutions that reach the end of the evaluation period.

Figure 1 shows an example search tree for a simulation that spans 6 years. A red dot represents a network constraint violation and a green dot represents a network operating without any network issues. Initially the network is free of constraint violations . As the load grows, the NMT determines that there will be a constraint violation in year 2 and applies the intervention techniques to solve the problem. This results in 5 different fixes (a fix being the application of an intervention technique or combination of techniques which resolves a network constraint violation), 3 of them (2a, 2b, 2c) would require further fixes in year 3 while 2 other (2d, 2e) would be sufficient up to year 4. At each point where multiple fixes are proposed by the NMT, the Experiment Runner decides which branch to expand next based on a set of technical and economic criteria. The diagram shows that not all branches have been continued to the evaluation horizon, for example branches 2a and 2e were not selected by the Experiment Runner. The process continues until a number of paths through the search tree that finish in year 6 is found. Each such path is a RESULT (series of network fixes in time) that would allow the target network to operate without network constraint violations the evaluation period. All RESULTs for a single RUN are grouped into a RESULT SET.

For clarity the constraints that arise need not occur at exactly the same location, but occur within the area of network being evaluated.
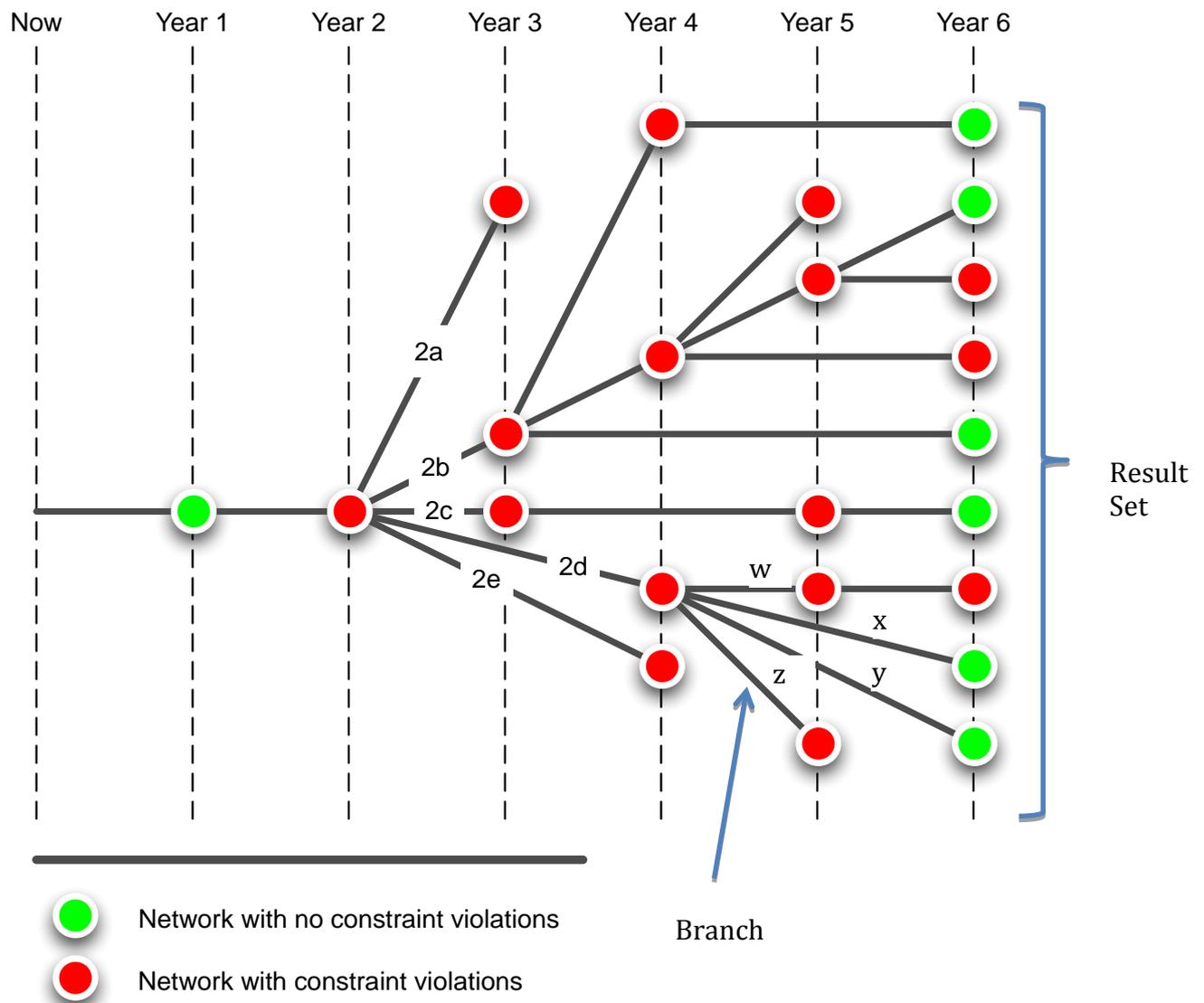
Figure 2. SIM search tree example

Selective Branch Expansion.

For a simple planning task on a small area of network with a relatively short evaluation timeframe the number of branches for the potential solutions may be handled relatively quickly and it may be feasible to assess all the possibilities completely.   However for analysis of a larger area of network over a longer timeframe the number of potential branches to be considered will increase dramatically.

Where it is not feasible to explore all the branches, then a selective branch expansion algorithm is used. In this case there is a trade-off between the processing power /time and the probability that the branches that have been explored will ensure that the optimum results are found.   By using an algorithm that selects the most "favourable" branches for expansion it is likely that we will obtain the optimal solution in the solution set.

For the example in Figure 2, let's consider the branch point in year 2.
There are five different fixes that can be applied which will each have their own costs.   While there are seven overall techniques there are different variations of these, so for example if a transformer was overloaded it might be possible to either replace it with the smallest size that would resolve the immediate capacity problem, or it may be possible to install a larger transformer than required at the time in anticipation of further load growth.

We will know the cost metric from the cost model for each of the branches 2a - 2e until another constraint is found. Using a simple branch expansion metric the initial branch order is gained.

Branch	Years of constraint free operation	Cost Metric summed over the relevant years	Branch expansion metric Cost per year	Preferential order of expansion
2a	1	15000	15000	5
2b	1	8700	8700	2
2c	1	9000	9000	3
2d	2	17000	8500	1
2e	2	22000	11000	4

Subsequent evaluations consider the whole cost per year up to the branch point. For example consider the branching that occurs after branch 2d. There are four possible fixes, w,x,y and z.   Branches x and y do not have any more constraint in the evaluation period and so form the end points of two different solutions. However there is still a requirement to assess whether it is preferable to expand branch w, z, or go back to and expand an earlier branch.

Branch	Years of constraint free operation	Cost Metric summed over the relevant years	Branch expansion metric Cost per year	Preferential order of expansion
2d, w	2+1	17000 + 8,800	25,800/3 = 8600	Expanded in preference to branch 2b or 2c
2d, z	2+1	17000 + 11,500	28,500/3= 9500	Preferred to branch 2e or 2a

In this case the branch 2d – z is not expanded further as the algorithm has a cut-off limit which prevents this. This cut-off is likely to be expressed in the number of Results that have been found.

It may be possible to improve on this basic cost per year metric to incorporate other ways of managing the generation or preferential selection of branches, for example we might want to exclude branches that resulted in installation work within the same substation within three years.

3.1.7. Network modelling tool

The NMT is used to evaluate network investment plans using a range of technical criteria, such as Customer Minutes Lost (CML)s, Customer Interruptions (CI)s, losses. In addition, the NMT is used to perform power flow study on the target network and determine the best ways to resolve a network constraint violation using one of six novel intervention techniques or traditional reinforcement.

3.1.8. Network model visualisation tool

The network model visualisation tool is used to display nodal models representing the 11kV power networks. The network model visualisation tool is used by other SIM components for the following tasks
- Select network area to analyse
- Browse network
- Browse, create and update patches
- Assign costing models to sections of the network
- Assign load profiles to sections of the network
- View network interventions of a single RESULT

3.1.9. Results

This section gives an introduction to the functionally in block 9 of Figure 1
This represents a database that will store multiple runs of the SIM. For each RUN the following items will be stored:
- All the parameters of the run such that the RUN could be recreated.
- A list of results for the run (RESULT SET). Where a result is a unique set of network fixes such that it remains free of network constraint violations from the start to the end of the analysis period. There may be many hundreds or thousands of results for a single RUN of the SIM. For each result there will be:
  - The network state in each year
  - The list of annual patches that are applied in each year
  - A number of predicted performance metrics for the network in each year, e.g., the key performance metrics are expected to be CMLs, CIs and losses. The full set of performance metrics will be determined once the network modelling tool has been selected. These metrics will be converted into a financial value and weighted for optimisation.
  - A cost of investment as predicted by the costing model(s) for each year.
    By splitting the investment cost into costs for each year it is possible to model both initial and ongoing costs. It is expected that a customer disturbance factor will be calculated and translated into an equivalent cost.

Therefore if the analysis period is 38 years and on average there are 1000 results for each network run and the experiment RUN SET consisted of 100 RUNS there will be:
- 100 RUNs in the database
- 100,000 results in the database
- 3,800,000 annual network states in the database

These figures relate to a single experiment performed by an Engineer. Multiple experiments or larger experiments could result in 10's or 100's of millions of results and network states.

3.1.10. RESULT browser

This section gives an introduction to the functionally in block 10 of *Figure 1*.

The database described in section 3.1.9 will contain the RESULTs of several and possibly many hundreds of RUNs of the SIM. Therefore there could be many millions of results and annual network states in the database however the features provided to sort and filter through the results should still allow the result set to be navigable by 11kV planners.

The reporting modules described in sections 3.1.11 and 3.1.12 require a selection of these RUNs and RESULTs to have been made. The functionality in this unit will support the Engineer in selecting the RUNs and/or RESULTs to include in the reports.

The SIM should allow the Engineer to search for and select RUNs using any mix of criteria based on the input parameters to the RUNs. For example:
- All RUNs using costing model 3 or
- All RUNs that include area X
- All RUNs that do not include patch B

Additional criteria that may be used include:
- The RUN SET or RUN identifier
- The Engineer
- The date of the request

It must be possible to combine these criteria to allow the Engineer, for example, to select her own RUNs in the last week that looked at area X but that assumed that patch B was not going to be implemented. It must be possible to save and recall selections so that report may be rerun.

A visualisation tool should be provided to allow the Engineer to investigate the content of a selection. For example, is there any repetition of network area or what cost models exist in the selection?

From the visualisation tool it must be possible to tune the selection by identifying runs to exclude. From the visualisation tool it must be possible to view multiple selections and perform set operations such as union, intersection etc. to create new selections.

Given a selection of runs (RUN SET) it must then be possible to select one or more results. Several default options will be available:
- Select all the results
- Select all the results with total costs in the 20-80th percentiles
- Select all the results with total costs in the 20-40th percentiles
- Select the most cost effective result
- Select the best result including the weighted impact of all the evaluation parameters (Cost, network performance, customer impact, losses, safety, etc.)

Allowing these different selection mechanisms allows the user to select according to either best value for money or those solutions that can be accommodated in a constrained budget.

Once a selection of results has been made a visualisation tool will be provided to allow the Engineer to investigate the results. This will include the frequency of different patches, costs over each year, customer minutes lost (CML) changes etc. It must be possible to add and remove results from the selection using the visualisation tool.

It must be possible to save and recall selections of the results. From the visualisation tool it must be possible to view multiple selections and perform set operations such as union, intersection etc. to create new selections.

3.1.11. RESULT SET visualisation tool

This section gives an introduction to the functionally in block 11 of *Figure 1*.

The RESULT SET visualisation tool provides functionality associated with the Strategic Planner's and Policy User's use cases. The SIM offers these users new ways to support their business activities, but often requirements evolve with experience so initially we do not want to specify the exact format of the required reports. Instead the SIM will be able to export an aggregated form of the results so that it could then be used as the basis of further queries and reports using Excel or Access or other suitable packages. This also offers flexibility to accommodate changing reporting requirements within the business or from Ofgem.

The initial statistical reporting will create a spreadsheet that contains all the data available for each selected RESULT for each selected RUN.

We expect that other reports, with specific purposes will be built on this "all data" report during the evaluation phase of this project. WPD may choose to select specific reports for implementation during rapid application development sessions that will follow delivery of the core SIM functionality.

The initial data will include:
- All parameters that specified the RUNs.
- For each RUN
  - For each RESULT
    - For each year of the analysis
      - The patches applied
      - The costs from the cost model
      - All evaluation parameters (losses, CI, CML)
      - A Bill of Materials (BOM) for any Patches that give a BOM.
    - Totals for all the parameters
  - The best and average cost across all the results.

The relationships in this data are represented diagrammatically below
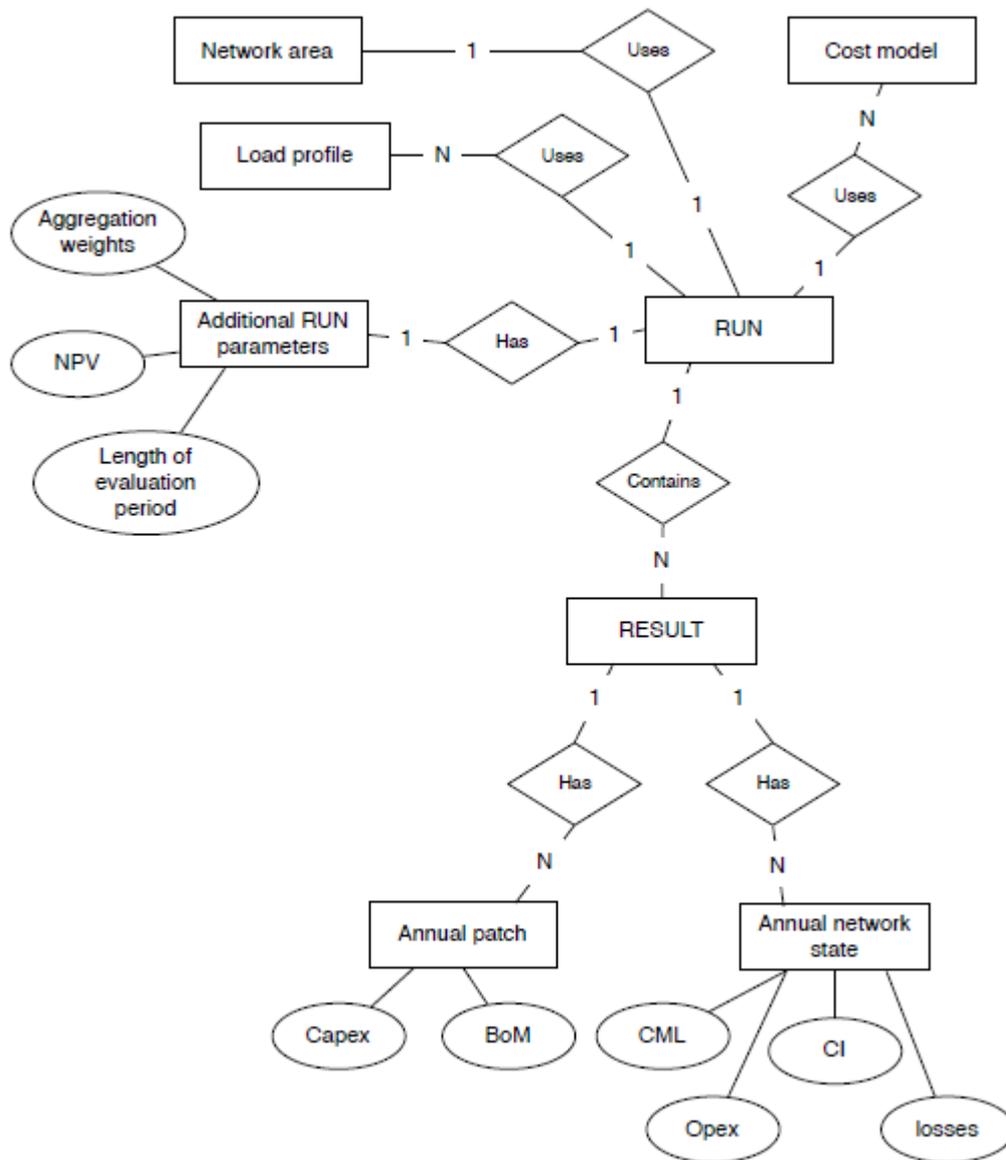
Figure 3. Data Entity diagram for the Result Set Visualisation Tool

In addition, it will be possible to access the Results store directly for custom data analysis using third-party data mining software. This would be required to determine for example the relationships between types of network and the results.

3.1.12. RESULT visualisation tool

The SIM will be able to visualise a single RESULT using a network diagram in each year of the evaluation. The network will be shown in a geographical layout with closely spaced assets displayed using one-line diagram. This tool will also provide all the normal analytical functions provided by network modelling tools such that the Engineer may further evaluate the consequences of adopting the

particular RESULT. Within the tool it must be possible to move backward and forward in time to investigate the network structure and asset details in any year.

It will be possible to run multiple instances of the RESULT visualisation tool in parallel, e.g., to visualise several different RESULTs simultaneously in different windows.

3.2. Operating Environment

The SIM operates within an infrastructure of components provided by WPD. This section sets out constraints for SIM in terms of the WPD components it must be able to operate with.

Network

The system will operate over a distributed network, with the core system located at WPD's IT centre and users of the system at remote sites. The network effective characteristics (TCP/IP link) between sites available for use by the SIM are:
1.   Bandwidth: 30Mb
2.   Latency: 20ms
The client will provide this infrastructure. Figures given are per concurrent user. A dedicated low latency gigabit network will connect all components co located at WPD's IT centre.

Database

The system will provide several persistent data stores. All data will reside within a commercial database engine provided by the customer. Cranfield University will provide the database definition and all software required by database applications. WPD will provide and support the database engine for the delivered software. Cranfield University will provide and support it's own database server for development and research purposes. The data base engine to be used is: Oracle 11g
Performance analysis at the end of the project implementation will identify the required database capacity and performance. As part of the design phase we have also considered functionality that could be reduced or removed in order to ensure that performance is maintained and this is included for reference within Section 10.

Application server operating system

The server side components will be required to operate on a machine hosted by WPD's IT department.
The operating system will be: REDHAT LINUX ENTERPRISE SERVER version 6.
Cranfield University will provide and support its own application server for development and research purposes.

Client Operating System

The users will access the system via a number of client side components installed on their desktop machine. These machines will:

1.   Use 32 bit MS Windows version 7

2.   Have network access to the application server
3.   Have Internet Explorer version 8

4. Comparison to Workstream 3 Model

There is some overlap between the modelling work carried out by the Smart Grids Forum Workstream 3 and the SIM. The table below is intended to clarify the key differences and similarities between the models.

Aspect	WS3 Model	SIM
Voltage layers covered	All voltages	11kV only
Network analysis mechanism	Networks categorised as representative network types	Analysis of actual networks using a nodal model.
Techniques modelled	Wide variety of techniques plus traditional reinforcement.	Traditional reinforcement plus 6 new 11kV Techniques.
Scenarios used	3 DECC scenarios plus 1	4 Preset scenarios plus variable features to set up new scenarios as required.
Investment strategies	Business as usual, Top down and incremental	This does not support Topdown vs. Incremental analysis directly. The technique costs assume a marginal of the costs of the enabling technologies. The additional one-off enabling technology investment would be calculated and added in manually. Business as usual vs. smart can be modelled by making techniques unavailable within the evaluation period.
Time series data used for modelling	Seasons / days/ 39 years, 3 days (Summer average , Winter peak , Winter average) 48 half hours per day.	38 years 18 season day types per year. (Weekday, Saturday, Sunday x Averages for Autumn , Winter, Spring, Summer, High summer Plus Winter peak, summer peak, summer minimum 48 half hours per day.
Aspects analysed	Thermal overload Voltage Fault Level	Thermal Voltage Fault level analysis will be performed as a sense check after networks are changed rather than for each half hour and day type.
Modelling process	Looks to anticipate the best solution using a merit order approach with additional considerations added in, e.g. ensuring that that the techniques will solve the constraint for a specified time period.	All technical solutions that resolve the constraint are initially considered. This approach creates many branching results which can multiply up to a large number of solutions quickly. To manage the impact on performance, an algorithm is used to expand branches in a preferential order which is likely to ensure the best solutions are calculated within the time limitations.
Network Headroom estimation	Overall percentage values for each network type	Calculated for each network with the network modelling tool
Technique headroom release	Overall percentage value for each technique	Calculated for each technique as applied to each network.
Load estimation	GL Noble Denton model. More detailed modelling for domestic customers but few	Energy Savings Trust model More complete I&C modelling with a number of domestic customer profiles

	I&C archetypes.	derived from analysis.
Mapping of customers to network	Based on averages	Based on real customer-to-network mapping
Mapping of Low carbon technology uptake and efficiency changes for customers	Based on regionalising the national DECC scenarios	Determined by customer type and mapped through to distribution substations via customer – network connectivity
CML/CI and losses impacts	CML/CI and losses impacts are based on generic assumptions for each technique.	Network model derived benefits can be calculated for CML/CIs and Losses.
	Disturbance factor	Disturbance factor approach adopted from WS3 model
Cost changes over time	Technologies mapped onto different future cost curves according	This is facilitated within the cost models. Any cost curve can be accommodated.
Cost NPV assumptions	A fixed discount rate is assumed.	This is facilitated within the cost models and can be tailored
Clustering	Degree of clustering can be varied within the model	Clustering would need to be altered within the energy model rather than the SIM
Tipping points	Assessed in the report	Could be assessed manually from the reports but is not part of the system functionality.
Modelling wider electricity sector	This is beyond the scope of the network model but is part of the overall model that includes the economic assessment	Not a feature of this model
Asset replacement	While reinforcement is expected to last for 40 years, new solutions are expected to go after 20 years and are removed from the model as is their benefit.	Technique lifetime will be specified to trigger replacement capital or removal of solution and replanning of a network to ensure the optimal solution rather than a like-for-like replacement.

5. Users and characteristics

This section lists user classes of the SIM and provides an introduction to each user class.

SIM Design Blueprint

Figure 4. Use case diagram

Referring to Figure 4. Use case diagram, the SIM has 4 user classes: 11kV Planner, Strategic Planner, Policy User and Research User. 11kV Planners, Strategic Planners and Policy Users represent three main business user types. Because the system is a prototype tool all functionality will be available to all users. The specification of functionality uses the term Engineer to refer to all user classes.

The 11kV Planner would use the SIM to plan work on a specific area of the network, reacting to external requests such as connecting a new load or replacing an asset. The 11kV Planner should be able to implement connection and replacement options, which are a special kind of patches. Unlike other patch types, only a single connection-option or replacement-option can be applied to the selected network area for the evaluation period. Both patch types are

considered as a part of solution and included in cost of investment calculations. Additionally, 11kV Planner may choose to examine a solution in detail (Figure 1. Outline of SIM structure block 12) using visualization of the network model that must support conventional network analysis functions provided by NMTs.

The Strategic Planner would want an overall view of the expected work volumes for large areas of networks, typically a whole DNO area. Investment plans are being produced using the same tools as the 11kV Planner, however, the results are visualized in a different manner. The Strategic Planner does not inspect solutions using a network diagram, instead, the statistical reporting feature is used to analyse aggregations of results for individual primaries that constitute the selected area of interest.

The Policy User would be interested in understanding the implications of changing the way the networks are managed currently, using a combination of functionality offered to 11kV Planners and Strategic Planners. Namely, the Policy User may inspect individual solutions using the network model view, analyse aggregations of solution sets or explore difference between solutions and solution sets.

The detailed description of use cases in in Appendix B – Use Cases.

6. Input Descriptions

This section gives brief description of the inputs to the SIM.

6.1. Network Data

The network modelling tool needs information about the network to be evaluated. The network is described by defining a set of nodes and the connections between them. The network data will be extracted from existing systems that contain the relevant information about the assets and their connectivity such as the GIS or Control room systems.

6.2. Network Patches

The network simulations are expected to cover long periods of time. The SIM needs to be able to model planned work and auto generated changes to the networks. All these changes are referred to as patches. A patch is a set of annual patches, with the years they will be applied. An annual patch is a set of changes to the network. A change could be:

- Addition of a new network component.
- Removal of a component
- A change in the parameters of a component.

Some patches will be manually created by users editing the network whereas some may be generated automatically using predefined algorithms. Some planned network changes deal with complex projects that have many separate stages. For this reason we have defined a patch so that it can include a set of changes that can occur over a number of non-contiguous years. It is important that we have a mechanism to incorporate planned changes into the analysis. Examples of changes include

- Increasing the size of a transformer
- add an interconnector,
- replace a section of overhead line with underground cable
- add automation to switchgear

 These changes may affect the nature of any network constraints and the best solution to deal with them.   Network changes would mostly affect the configuration of the nodal model or the assets within the model.

However we also need to allow for changes to default values used by network modelling tool. For example, we may expect a decreased fault rate as we achieve compliance with the tree cutting requirements of ESQCR.   We may expect shorter response times as we adopt new working procedures etc.

6.3. Scenario Load / Generation Data

To model the 11kV networks accurately we need to estimate the demand and generation at the network nodes where electricity enters or leaves the network. Previously we have estimated demand data based on the number of customers, but we expect to improve our understanding of the demand with more accurate values for the load at distribution substations and HV customer supply points. Also we will develop models to represent likely generation which may act either as a network inflow at a node or to reduce the demand at a node. We expect the modelling to consider any half hour period of time for one of the given day types, rather than a single assumed maximum demand for the year which is the current approach.

As part of Falcon we are developing an Energy Model that will create the various load scenarios. The energy model will model distribution substation l
load profiles projected over future investment planning horizons based on different localised uptakes of low carbon technology and different economic environments.

These will include profiles built on externally recognised scenarios such as those contained in DECC's UK Low Carbon Transition Plan and the Smart Grids Forum (SGF)/redpoint "central scenario" being developed for use by all DNOs in ED1. Load scenarios will reflect a defined set of assumptions for low carbon technology uptake, building improvements and economic growth. . It is   The energy model development is being carried out by the Energy Savings Trust and combines existing models of energy use by domestic customers with newly developed models for industrial and commercial customers. Uptake of new technologies is determined by "propensity" matrices that reflect information about customer properties and demographic data.

The SIM will use a number of deterministic load scenarios to reflect different assumptions about future load. The Engineer will be able to compare RESULTs from different load scenarios, e.g., by planning two RUNs for the same target network but with different load scenarios selected. The Engineer will be able to select both RUNs in the RESULT Browser and to export relevant RESULTs for each RUN into a spreadsheet for comparison and analysis.

6.4. Additional data to support the modelling of techniques within the NMT.

The interface to the energy model may also be the mechanism by which the SIM is presented with the data required for modelling the techniques.
For example to model dynamic asset rating certain parameters are assumed for ambient temperature, windspeed etc. These variables are also likely to be inputs to the energy model as well and so typical values may be presented for the day types used for analysis.

In order to apply the commercial techniques we will require an estimate of the

likely capacity for the commercial techniques at each distribution substation. The energy model will be required to calculate this value and pass it to the SIM.

6.5. Costing Models

In order to develop a plan for future investment and to help determine the optimum solutions, the SIM needs to understand the cost of different types of work. These costing models must be developed and managed by the SIM. Differences in the costing model may have a significant impact on the recommendations developed through the SIM. There may be a large number of different costing models, driven by different predictions for future technology prices and economic factors.

A costing model will convert the cost factors associated with patches into a financial indicator. This indicator is then used for the optimisation of the model. Please refer to section 3.1.4 for a more detailed description of cost models and their application

6.6. Technique Models

The technique models are used to specify the way in which the techniques operate in practice.
These are required so that the changes to the assets, network configuration or load flows that result from implementing a technique can be modelled. For example if a transformer is assessed as briefly exceeding its static rating we would expect to be able to model the transformer using a dynamic asset rating approach. This would involve modelling the transformer's critical temperature for a given load profile and would therefore require a thermal model and algorithms that could be applied within the network modelling tool (or possibly the SIM) These technique models are described in more detail in Appendix B Technique Descriptions.   The technique models will be refined and revised to reflect the learning from the Falcon trials.

7. Requirements specification

The use cases for the system were determined in a series of semi-formal interviews and workshops with the prospective users of the system, including 11kV Planner, Strategic Planner and Policy User. The use cases were reviewed by the customer. Based on the use cases a functional Cranfield University developed a set of functional and non-functional requirements that were reviewed during several workshops.

Each of the requirements has the following form.

Requirement Number) requirement name
Requirement detail:
Non-functional requirements associated with the particular requirement
Scope of supply

Develop/Import Networks, Patches, Load profiles, etc.

Network: A complete definition of the whole 11kV system managed by the Network Operator. Including, but not limited to:

- All equipment positions and classes
- All connectivity
- All characteristics and parameters needed to model the network

To implement the functional requirement for Figure 1. Outline of SIM structure. block 1-3 , the SIM must:

Requirement 1) Load the Network definition from an authoritative source
1. All correctly specified elements of the network in the authoritative source must be loaded with the correct positions, connectivity and parameters.

- Load the entire WPD network in less than 12 hours.
- 100% of operations: All elements of the network in the authoritative source must be transferred or reported as an error.
- >99% of operations: All elements of the network in the authoritative source must be transferred or correctly reported as an error.

A small number of false positive error reports are acceptable in a prototype system. For experimental purposes false negatives may incur a significant quantity of work before they are detected and are thus unacceptable.

The 12 hour time span represents an overnight batch job for a task that should be completed no more frequently than on a weekly basis The updates for existing network modelling tools are carried out no more frequently than a monthly basis, so this should be more than adequate for business requirements.

SIM Harness

Requirement 2) Any errors/omissions/inconsistencies in the data source must be reported and stored.

1. All incorrectly specified elements of the network in the authoritative source must be loaded to the extent that the data is consistent with the correct elements.

2. A log of all missing elements and the reason will be available to the Engineer.

- All errors will be reported.
- All errors will be logged
- <1% of error reports will be erroneous others will be semantically correct.

SIM Harness

Requirement 3) Highlight network errors/omissions

1. The Engineer should be able to select an error message

2. Where the error message relates to a physical component the SIM should highlight the component on a network diagram.

- All error messages will be correctly tagged.

1.   Sim Harness
2.   NMT

Requirement 4) Support the Engineer in correcting network errors/omissions

1. The Engineer will be able to correct any network errors or omissions.

- The responsiveness of the editor will conform to acceptable HCI requirements.

NMT

Requirement 5) Allow the Engineer to view the network in a geographical layout

1. The Engineer will be able to graphically view all the parameters/connectivity/geographical layout of any part of the network.

- The responsiveness of the editor will conform to acceptable HCI requirements.

NMT

Requirement 6) Network analysis:
The network analysis functionality will be agreed between WPD and their NMT vendor. This will include analysis to determine where constraints are breached for thermal voltage or fault level limits.

N/A

NMT vendor

Requirement 7) Support the Engineer in editing the network

1. The Engineer will be able to perform any change to the network and edit any parameter of any equipment.
2. The network will remain consistent at all times.
3. Any edits prohibited by the system will generate appropriate error messages.
• The responsiveness of the editor will conform to acceptable HCI requirements. • It will never be possible to perform an editing operation the creates an inconsistent network • <0.001% of operations will be incorrectly prohibited.
NMT

Requirement 8) Save an Annual patch
1. All changes that have been made since the network was loaded will be included in the patch.
2. Functionality defined under Requirement 10) will allow the current edited network state to be recovered by reloading the initial network and then loading the saved Annual patch.
3. A list of necessary network elements or characteristics required such that the patch can be applied is calculated. These are referred to as the patches constraints.
4. The Annual patch's list of constraints is sufficient, such that if the constraints are met then the Annual patch can be loaded and always result in a consistent network.
5. The Annual patch's list of constraints are all necessary; such that if any constraint is removed then point 3 above fails.
6. It will be possible for the engineer to specify cost variables and BOM for an Annual patch when it is saved.
• 99% of operations will complete in <10s.   • 99.9% of operations will complete in <1m.   • All operations will complete in < 2m.   • 99.9% of operations will result in a stored patch that can be reloaded and results in a correct recall of the saved state.   • 99.99% of operations will result in a stored patch that can be reloaded and results in a correct recall of the saved state or an error message stating the reason the patch could not be saved.
NMT

Requirement 9) Save an Annual patch by increment
1. All changes that have been made since the network was loaded, that were not included in any other Annual patch, will be included in the patch. 2. Functionality defined under Requirement 10) will allow the current edited network state to be recovered by reloading the initial network and any other Annual patches that were present and then loading this saved Annual patch. 3. The Annual patch's list of constraints is sufficient, such that if the constraints are met then the Annual patch can be loaded and always results in a consistent network. 4. The Annual patch's lists of constraints are all necessary; such that if any constraint is removed then point 3 above fails. 5. It will be possible for the engineer to specify cost variables and BOM for an Annual patch when it is saved.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m. • 99.9% of operations will result in a stored patch that can be reloaded and results in a correct recall of the saved state. • 99.99% of operations will result in a stored patch that can be reloaded and results in a correct recall of the saved state or an error message stating the reason the patch could not be saved.
NMT

Requirement 10) Load an Annual patch
1. If the constraints are met by the current network then all changes saved in the Annual patch will be recovered. The network will always be correct and consistent. 2. If any of the constraints are not met then the Engineer will be informed of the constraint and reason for failure. No changes will be made to the network.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m. • 99.9% of valid operations will result in a valid network that correctly implements the changes stored in the patch • 99.99% of valid operations will result in a valid network that correctly implements the changes stored in the patch or an error message stating the reason the patch could not be saved. • No patch with invalid constraints will affect the network in any way.
NMT

Requirement 11) Create a multi year patch
1. A series of Annual patches have been linked together. Each will represent successive years work.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
NMT

Requirement 12) Load multiple multi year patches
1. It will be possible load multiple patches, setting different base years for each patch.   2. Only mutually consistent patches will be loadable.   3. Inconsistent patches will result in error messages informing the Engineer of the inconstancies. Nothing will be loaded.
• 99% of operations will complete in <10s.   • 99.9% of operations will complete in <1m.   • All operations will complete in < 2m.
NMT

Requirement 13) Viewing multiple multi year patches
1. It will be possible scroll time forward and backward through the time period coved by the loaded patches.   2. All analysis and viewing functionality will be available for any year instance of the network.
• The responsiveness of the editor will conform to acceptable HCI requirements.
NMT

Requirement 14)	The default selection status a multi year patch can be changed
The default selection status a multi year patch can be changed	
• The responsiveness of the editor will conform to acceptable HCI requirements.	
NMT	

Requirement 15)	Producing and managing load profiles
The system will correctly incorporate the functionality for producing load profiles being agreed between WPD and EST. (Energy saving trust)	
The non functional requirements will be defined between WPD and the EST	
NMT	

Requirement 16)　　　Producing cost models
1. It will be possible to specify the financial cost of each of 10 variables in any year.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m. • The responsiveness of the editor will conform to acceptable HCI requirements.
SIM Harness

Requirement 17)　　　Managing cost models
1.　　It will be possible to group cost models together to produce unions. 2.　　Where the same item is specified differently in the two models the Engineer will be asked to select.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m. • The responsiveness of the editor will conform to acceptable HCI requirements. • All error messages will state the differences in specification.
SIM Harness

Requirement 18)   Saving cost models
1.   It will be possible to save a cost model so that it can be used in the experiment.   2.   It will be possible to reload the cost model and achieve an identical state to the point at which the cost model was saved.
99% of operations will complete in <10s.   99.9% of operations will complete in <1m.   - All operations will complete in < 2m.   99.9% of operations will result in a stored cost model   99.99% of operations will result in a stored cost model or an error message stating the reason the cost model could not be saved.
SIM Harness

Select costing model

To implement the functional requirement for Figure 1. Outline of SIM structure. block 5, the SIM must:

Requirement 19)   Allow the Engineer to assign costing model to network components
1.   The Engineer should be able to select a sub set of the network.   2.   The Engineer should be able to assign a costing model to a selected part of the network. A specific part of the network may be the whole network, a selected area of interest, everything except the selected area, interventionintervention technique or a class of equipment.   3.   The actual costing model for an asset or technique is determined by the order of application. i.e. Applying a cost model will override any cost model already in place for the network elements concerned. So that if several cost models are applied to overlapping areas of the network then the order in which they are applied will define which ones apply to the overlapping areas.
• The responsiveness of the editor will conform to acceptable HCI requirements.
1. NMT   2. SIM Harness   3. SIM Harness

Requirement 20)   Any errors/omissions/inconsistencies in the assigned costing models must be visible to the Engineer
1.   The list of elements that have missing/incomplete costing information should be available to the Engineer   2.   The Engineer can select an error message.   3.   Where the error message relates to a physical component the SIM should highlight the component on a network diagram.
• 99.99% of errors will be correctly reported.   • All reported errors related to a physical asset will be linked to the asset.
1. SIM Harness   2. SIM Harness   3. NMT

Select costing model

Requirement 21) Allow the Engineer to save costing model selection
1.   It should be possible to save the assigned costing models set so that it can be re-applied for further runs
99% of operations will complete in <10s.   99.9% of operations will complete in <1m.   - All operations will complete in < 2m.   99.9% of operations will result in a stored cost model selection   99.99% of operations will result in a stored cost model selection or an error message stating the reason the cost model selection could not be saved.
SIM Harness

Requirement 22) Allow the Engineer to load costing model selection
1.   It should be possible to load a previously saved set of costing models   2.   The Engineer should be able to deselect any previously assigned costing models within a set
99% of operations will complete in <10s.   99.9% of operations will complete in <1m.   - All operations will complete in < 2m.   99.9% of operations will result in a restored cost model selection   99.99% of operations will result in a restored cost model selection or an error message stating the reason the cost model selection could not be loaded.
SIM Harness

Select network area and patches to analyse

To implement the functional requirement for Figure 1. Outline of SIM structure block 5, the SIM must:

Requirement 23) Allow the Engineer to select a network area to analyse
1. The Engineer should be able to select a network area to analyse using a graphical interface displaying network model
• The responsiveness of the editor will conform to acceptable HCI requirements.
NMT

Requirement 24) Automatically select or deselect patches based on the default setting
1. For the area of interest the SIM must automatically select or deselect patches based on the default setting
• Processing will take a maximum of 5 seconds.
SIM Harness

Requirement 25)   Allow the Engineer to modify which patches are selected
1.   The Engineer should be able to browse through the library of existing patches and select additional patches 2.   The patches shown to the Engineer must be related to the network area of interest 3.   The Engineer should be able to deselect any previously selected patches
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 26)   Load selected patches
1.   Check the selected patches for mutual consistency 2.   Apply selected patches to the authorised network 3.   Any inconsistencies in patches or the selected patch set and the authorised network must be reported to the Engineer. The authorised network should not be modified in this case.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
NMT

Requirement 27) Save selected network area of interest and patch selection
1. The Engineer should be able to save selected network area of interest and patch set so that it can be recalled for future runs
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
SIM Harness

Requirement 28) Load network area of interest and patch selection
1. It should be possible to load a previously saved selection of network area and patch set 2. The Engineer should be able to alter his selection of a network area
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
1. SIM Harness 2. NMT

Select load profiles to use and set other run parameters

To implement the functional requirement for Figure 1. Outline of SIM structure block 5, the SIM must:

Requirement 29)   Allow the Engineer to assign load profile to network area or substation
1.   The Engineer should be able to select a sub set of the network.   2.   The Engineer should be able to assign a load profile to a specific part of the network. A specific part of the network may be the whole network, a selected area of interest or everything except the selected area.   3.   The load profile for a substation is determined by the order of application. i.e. Applying a load profile will override any load profile already in place for the network elements concerned. So that if several load profiles are applied to overlapping areas of the network then the order in which they are applied will define which ones apply to the overlapping areas.
•   The responsiveness will conform to acceptable HCI requirements.
1. NMT   2. SIM Harness   3. SIM Harness

Requirement 30)   Any errors/omissions/inconsistencies in the assigned load profiles must be visible to the Engineer
1.   The list of substations that have missing/incomplete load profiles should be available to the Engineer   2.   The Engineer should be able to select an error message.   3.   The Engineer should be able to view the substation or network area with a missing/incomplete load profile graphically
•   The responsiveness will conform to acceptable HCI requirements.
1. SIM Harness   2. SIM Harness   3. NMT

Requirement 31) Allow the Engineer to save load profile selection
1. It should be possible to save the assigned load profile set so that it can be re-applied for further runs
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
SIM Harness

Requirement 32) Allow the Engineer to load a load profile selection
1. It should be possible to load a previously saved set of load profiles 2. The Engineer should be able to deselect any previously assigned load profiles within a set
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
SIM Harness

Requirement 33) Allow the Engineer to set the evaluation period for a RUN SET
1. The evaluation period specified by the Engineer will be used for the batch calculation associated with the RUN SET.
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 34) Allow the Engineer to set the failure criteria for a RUN SET
1. The failure criteria specified by the Engineer will be used for the batch calculation associated with the RUN SET.
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 35) Allow the Engineer to enable or disable specific intervention techniques for a RUN SET
1. Only the intervention techniques specified by the Engineer will be used for the batch calculation associated with the RUN SET.   2. This will be implemented by giving a base year for each intervention. The intervention will be considered after that year.
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Find and store all the results

To implement the functional requirement for Figure 1. Outline of SIM structure block 6, The SIM must:

Requirement 36)   Evaluate target network until a failure is detected
1.   The SIM should be able to use the load estimates from load profiles to evaluate a target network for each year through the evaluation period until a regular or an N-1 fault mode results in a network failure 2.   If the end of evaluation period is reached, the SIM should be able to save the solution into the database of results (see block 6 of Figure 1. Outline of SIM structure)
• 99% of operations will complete in <1m per year of analysis • All operations will complete in < 2m per year of analysis
1. NMT 2. SIM Harness

Requirement 37)   Apply 6 intervention techniques or default reinforcement to the target network
1.   For the target network with a failure the SIM should be able to apply one of six intervention techniques or default reinforcement to resolve the problem 2.   Each application of the intervention technique creates an alternative solution with a corresponding version of the target network that could be evaluated further through the evaluation period 3.   The target network should remain consistent at all times, i.e., all proposed applications of intervention techniques should not conflict with changes in the target network for the remainder of the evaluation period.
• 99% of operations will complete in <1m per technique • All operations will complete in < 2m per technique
NMT

Requirement 38)   Determine cost of Interventions
1.   The SIM should be able to determine the cost of interventions using data from costing models
99% of operations will complete in <10s.   99.9% of operations will complete in <1m.   - All operations will complete in < 2m.
SIM Harness

Requirement 39)   Determine the best solution to expand next
1.   The SIM should be able to select which version of the target network to evaluate next based on a set of performance criteria 2.   The SIM should continuously expand the alternatives until the whole search tree has been explored or the maximum evaluation time reached.
99% of operations will complete in <10s.   99.9% of operations will complete in <1m.   - All operations will complete in < 2m.
SIM Harness

Requirement 40) Allow the Engineer to delete records from the data store
1. The Engineer should be able to delete solutions from the data store
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 41) The SIM should be able to store solutions for further analysis
1. For each solution, the following information should be stored: a. Load scenario that was used in the experiment b. Costing model set that was used in the experiment c. A snapshot of the target network that was used in the experiment d. Any other parameters that may be required to re-evaluate the solution e. The patch encoded by the solution f. A number of performance metrics for the network in each year in the evaluation period g. A cost of investment as predicted by the costing model for each year in the evaluation period
• No more than 1 result in 10000 will not be stored correctly. • The result store will be available 99% of the time on request • No incorrect records will be stored. • Once stored records will be duplicated to a backup within 24 hours.
SIM Harness

Browse all the plans. Selecting one or several for display/reporting.

To implement the functional requirement for Figure 1. Outline of SIM structure block 9, The SIM Must:

Requirement 42)   Allow the Engineer to visualise the parameter ranges or other metadata, which were used to create the RUNS stored in the Database. The Engineer will be able to see representation of individual runs.
1.   The Engineer should be able to see all RUNS stored in the Database   2.   The Engineer should be able to narrow down what RUNS are displayed based on any value in the parameters or other metadata, which were used to create the RUNS   3.   The Engineer should be able to order displayed RUNS based on any value in the parameters or other metadata, which were used to create the RUNS   4.   Given a RUN it should be possible to view all simulation results (RESULT SET) that are stored for that RUN
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 43)   Allow multiple concurrent visualisations
1.   It should be possible to perform any operations on multiple concurrent visualisations (Requirement 42).
• The responsiveness will conform to acceptable HCI requirements   • Up to 3 consecutive visualisations on a standard user machine.
SIM Harness

Requirement 44)   Allow the Engineer to select and deselect RUNs within the visualisation environment. The selected RUN SET can be saved.
1.   A subset of the visualised RUNS will be selected. 2.   No element of the set identified by the Engineer will be omitted form the selection 3.   No element in the selection will not have been selected by the Engineer. 4.   The selection will be saved so that it can be recalled.
•   The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 45)   Allow the ENGINEER to recall a RUN SET previously saved.
1.   A RUN SET previously saved under Requirement 44). The RUN SET and visualisation is identical to that before it was saved. 2.   It will be possible to carry out any operations on a recalled RUN SET that could have been performed before it was saved.
•   99% of operations will complete in <10s. •   99.9% of operations will complete in <1m. •   All operations will complete in < 2m.
SIM Harness

Requirement 46)   Allow Engineer to perform the UNION, INTERSECTION and DIFFERENCE operations on any two RUN SETs.
1. The content of the resulting RUN SET will conform to the definition of the operation performed and the content of the two input RUN SETs.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
SIM Harness

Requirement 47)   Allow the Engineer to select all results for a run in the RUN SET
1.   All the results will be added to a RESULT SET for a run in the RUN SETs
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
SIM Harness

Requirement 48) Allow the Engineer to modify a RESULT SET by selecting results within the 20-80th percentiles for any value.
1. Given a selection for the analysed parameter, such as investment in year 20 or total CML in the analysis. All results whose value not in the 20th-80th percentiles will be removed from the RESULT SET.
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 49) Allow the Engineer to modify a RESULT SET by selecting results within the 20-40th percentiles for any value
1. Given a selection for the analysed parameter, such as CAPEX in year 20 or total CAPEX in the analysis. All results whose value not in the 20th-40th percentiles will be removed from the RESULT SET.
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 50) Allow the Engineer to select the most effective result in any RESULT SET based on any value in the results.
1. Given a selection for the analysed parameter, such as CAPEX in year 20 or total CAPEX and an evaluation criteria (minimise, maximise, closestTo). All results whose value is least optimal will be removed from the RESULT SET.
• The responsiveness will conform to acceptable HCI requirements.
SIM Harness

Requirement 51)   Allow the Engineer merge two or more result sets together.
1.   Given two RESULT SETs based on results from the same model run the resulting RESULT SET will contain the UNION of the content.
•   99% of operations will complete in <10s. •   99.9% of operations will complete in <1m. •   All operations will complete in < 2m.
SIM Harness

Requirement 52)   Allow the Engineer save the process for creating result sets.
1.   The process that that created a result set using the functionally designed above can be saved such that it can be recalled at a later date.
•   99% of operations will complete in <10s. •   99.9% of operations will complete in <1m. •   All operations will complete in < 2m.
SIM Harness

Requirement 53)   Allow the Engineer to apply a saved process for creating result sets to all runs in a RUN SET.
1.   A RESULT SET is created for every run in the RUN SET using the saved process.
• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
SIM Harness

Visualise Solution

To implement the functional requirement for Figure 1. Outline of SIM structure block 12, the SIM must:

Requirement 54) Display network diagram
1. The SIM should be able to display the target network in a geographical layout with closely spaced assets (e.g., within a substation) shown using one-line diagram 2. The target network should have changes encoded in the solution clearly marked
• The responsiveness will conform to acceptable HCI requirements.
NMT

Requirement 55) Allow the Engineer to analyse target network
1. The Engineer should be able to view all the parameters of assets / connectivity information of any part of the target network 2. The Engineer should be able to use standard analytical tools (e.g., power flow) provided by NMTs to examine the target network 3. The Engineer should be able to move backward in forward through the evaluation period to investigate the network in any year 4. The Engineer should be able to print a representation of the network in any year.
• The responsiveness will conform to acceptable HCI requirements.
NMT

Requirement 56)   Display multiple results simultaneously
1.   It should be possible to display several sets of solution metrics in multiple windows at the same time   2.   It should be possible to display solution network diagrams in multiple windows at the same time
• The responsiveness will conform to acceptable HCI requirements. • Up to 3 consecutive visualisations on a standard user machine.
1. SIM Harness   2. NMT

Statistical reporting

To implement the functional requirement for Figure 1. Outline of SIM structure block 11, the SIM must produce the reports detailed below. The input data will be a set of experimental runs. For each run a set of results will have been selected using the functionality described in section 3.1.7.

Requirement 57)   Full report.

Given a RUN SET and a selection of RESULTS a report will be produced that details:
 	
• All parameters that specified the runs.
• For each run
    o For each result
        ▪ For each year of the analysis
            • The patches applied
            • The costs from the cost model
            • All evaluation parameters (losses, CI, cml)
            • A BOM for any Patches that give a BOM.
        ▪ Totals for all the parameters
    o The best and average cost across all the results.

• 99% of operations will complete in <10s. • 99.9% of operations will complete in <1m. • All operations will complete in < 2m.
SIM Harness

8. Prototype Visualisation and Draft Operations Manual

The Prototype Visualisation consists of a series of screens detailing the user interface of the SIM. The screens are accompanied with user scripts that describe how to perform a certain task, e.g., patch creation using the interface presented by the visualisation prototype.

9. Ways to reduce the elapsed time of a Run

The SIM will have to perform a large number of calculations. From demonstrations we assume that an NMT takes approximately 50 ms to calculate a momentary power flow. For a 100 node network it would take 50 ms * 18 (number of day types) * 48 (number of half-hours) = 43.2 s to check network constraint violations for a single year.
To check all N-1 operation modes, the system would take at least N times more time, i.e., 4320 s or 1.2 hours. Additionally, each time an N-1 mode occurs, the network is reconfigured using switching operations. Optimising the switching sequence would incur additional overhead.
The maximum length of the evaluation period is 38 years, therefore just to check if the network is functional over the length of the evaluation period, it would require 45.6 hours.

Referring to Figure 2, calculation of even small search trees may require several months. Since such processing times are clearly unacceptable, several potential ways to reduce the computational requirements of the SIM were identified. The decision about what measures should be implemented is reserved until an NMT is selected and actual performance figures of the NMT are established.

Action	Impact on Solution	Impact on Performance
No of days in Model (currently 18 day types, this could be reduced)	Currently it is observed that only certain day types produce peak load on the network. With increased adoption of new technologies such as DG, the correlation between day types and load becomes uncertain. Analysis of different load scenarios is necessary.	Potential reduction of up to 18 times.
Reduce from Half Hourly to something else	Increasing half hourly intervals would considerably affect most intervention techniques, and consequently quality of solutions.	Possible 2-4x reduction
Make assumptions on N-1 condition modelling	Full N-1 analysis could be substituted by simplified checks, e.g., failure near a primary transformer or not checking for voltage problems. For current networks failure near a primary transformer is likely to be the worst case scenario. Effects of DG and DES adoption should be analysed	Up to 20x reduction
Take a more pragmatic approach to branching, i.e. be more flexible about	The Result set may not include the optimal solution. The volume of comparator data is reduced which may affect research / reporting	

the degree to which evaluation takes place)	queries	
How much use of parallel running can the solution make	Parallel evaluation of multiple solutions, different N-1 operation modes for a single solution, etc., do not have any effect on the quality of solution.	Potentially unlimited. In practice limited by operational cost increase.

10. Benefits, risks, assumptions

10.1. Benefits

The design will bring in the following benefits
- Investigating long-term effects from network changes
- More effective decision making based on modelling the real network
- Robust network evaluation using existing network modelling tools
- Familiar network modelling and analysis interface
- Flexible data analysis using RESULT Browser and ability to export RESULTs into a spreadsheet for further inspection

10.2. Risks

Risk	Impact	Probability	Mitigation
The SIM design does not meet customer requirements	High	Low	The design will be reviewed by the customer. Review will be extended to an expert panel and other DNOs
The SIM is difficult to test	Low	High	
The SIM is too slow	Low	High	The SIM will run multiple evaluations of the target network in parallel. Several possible way to reduce computational requirements of the SIM are detailed in section10.
The SIM evaluates technical network metrics incorrectly	High	Low	An existing network modelling tool will be used to evaluate technical network performance.
Reports do not meet customer expectations	Low	High	The SIM will export the RESULT SET into a spreadsheet application for further analysis Reporting requirements will be better understood once the SIM is functional. Specific reports may be implemented during rapid application development

			sessions, which are planned towards the end of the development cycle.
A SIM experiment produces too many results	Low	High	The SIM will include a RESULT browsing and selection tool that will be able to select specific RUNs first and then filter RESULTs for each run according to a set of criteria.
The interfaces between various parts of the system are poorly defined	High	Low	
The software is too difficult to use	Low	High	Rapid development cycles allow for some changes after user testing The SIM is a prototype tool with limited user base. As such, the users can be extensively trained to use the SIM.
The SIM is not maintainable	High	Low	
The SIM results are not reliable	High	Low	Long hand validation of results in the testing phase Field tests of intervention techniques.

10.3.   Assumptions

1. N-1 conditions starting at a certain time and lasting a fixed time
2. Interventions on a yearly basis
3. The network does not need to be improved until a network constraint violation is reached.
4. Battery storage should be cyclic.

11. Glossary / Data Dictionary

Annual patch	AP	A set of mutually consistent changes to a network that are made at the same time. Normally these will be used to model all the changes in a year.
Annual substation load profile	ASLP	Load profile for a single substation for a period of 1 year. ASLP is composed of characteristic curves for all season & day combinations.
Authoritative Source		
Bill of Materials	BOM	A list of the materials necessary to complete the work on a patch.
Network change		Change to a network, e.g., addition or removal of a new asset.
Authorised network model		11kV network as loaded from the authoritative source
Collaboration Project Plan		See contract
Connection option		A patch that is specific to a new customer request; contains a connection point

Costing model		The process by which the probable cost of a specific network modification of other intervention at a specific location is estimated. A costing model will convert the cost factors associated with patches into a financial indicator. This indicator is then used for the optimisation of the model. In any year the following factors will be present: • Up to 10 factors relating to work performed via patches in that year. The initial values will be used. • The same 10 factors relating to work performed via patches in previous years. The on-going values will be used. • Each of these 10 factors will be summed. • The losses, CMLs and CIs predicted by the NMT in that year. The costing model will have a costing for each of the 13 factors in each year of the evaluation. Thus allowing a total cost to be calculated. The cost for each factor in each year should be built up by combining the expectation of equipment and staff costs in that year and any allowances that the user wishes to make for net present value.
Customer Interruptions	CI	The number of supply interruptions recorded per 100 connected customers in a year
Customer Minutes Lost	CML	The average number of minutes that a customer has their supply interrupted. We call this 'Customer Minutes Lost
Default reinforcement		A method for modifying 11kV network by replacing an asset with a higher capacity equivalent.
DINIS		NMT produced by Mitsubishi
Distribution Network Operator	DNO	A company licensed to distribute electricity in GB
Energy model		The internal model to produce load profiles
Evaluation period		Time interval specified in years. The SIM evaluates a target network through each year in evaluation period.
Fault level constraint		The maximum current in a component during fault conditions
Feeder		A section of 11kV network emanating from a substation
Fix		The application of a technique that successfully resolves a network constraint violation.

Flexible Approaches for Low Carbon Optimised Networks	FALCON	The name of the Project
GROND		An NMT
Half-hour load value		Average load value for half-hour period for a single substation
Intervention technique		A method for modifying 11kV network in order to address power flows that either exceed the expected network capacity and/or cause power quality issues (e.g. unacceptably high or low voltages). 6 new techniques are modelled within SIM along with default reinforcement. **Engineering techniques:** Dynamic asset rating Automatic load transfer Meshed networks Battery Storage **Commercial techniques** Demand side management Distributed Generation
Load estimates		The estimated values in a load profile.
Load index		Utilisation measure to be defined
Load Profile		Is the load at a single substation for all 48 half hours in 18 days types for every year in the evaluation period.
Load scenario	LS	Load Scenario is a load profile for each substations in the network .
Low Carbon Networks Fund	LCNF	lowcarbonuk.com
Multi Year Patch		A set of APs that are to be applied in series. This allows work to be defined with a series of annual steps towards a final outcome.
N-1 failure mode		A method of calculating network resilience. Each component is assumed to have failed in turn. The network loading for each component is the maximum across each of the failures.
Network area of interest		Section of the authorised network model selected for solution search
Network constraint		A constraint that affect the structure of the 11kv network. These may be thermal or voltage.
Network model		
Network modelling tool	NMT	The part of the SIM that performs the engineering evaluation and analysis of a network

Network state		The configuration of the network.
Patch		A term for either an Annual Patch or a multi year patch for use where the two are treated identically.
Power flow		A steady-state analysis of the power system that focuses on various characteristics of AC power (i.e.: currents, voltages, power factor)
Power quality		
Price control submission		
Primary network		A section of 11kV network connected to a primary substation
Replacement option		Patch that is defined by 11kV Planner as part of Asset replacement or diversion use case
Result	RESULT	A single plan for investment in interventions that allows the network state to meet all its constraints between the start date and the end of the analysis period.
Result set	RESULT SET	A set of Results that all relate to a single run. They show all the alternatives for investment in interventions that allows the network state to meet all its constraints between the start date and the end of the analysis period.
Run	RUN	An invocation of the SIM to perform predictive analysis with one set of input parameters.
Run set	RUN SET	One or more RUNS which logically cover a range of invocation parameters. For example, these could be different geographical areas or costing models.
Scenario investment model	SIM	Planning and investment modelling tool, includes NMT and simulation harness
Simulation harness		The part of SIM that performs source data management, experiment planning and results processing tasks
Solution		**Content model:** simulation-parameters **Attributes:** 'patch' - changes that are defined by the solution 'solution-specific-patch' 'network-model' - network model that was used to search for solution 'load-scenario' 'selected' - the solution is selected by the 11kV Planner for implementation 'solution-specific-patch' ::= <connection-option> | <replacement-option> A series of network reinforcements over prediction horizon to support solution-specific-patch

Target network model		Network area of interest + any non solution-specific patches that are applied to it prior to solution search
Total cost		
Western Power Distribution	WPD	The electricity distribution network operator for the Midlands, South Wales and the South West.

Appendix A – Prototype Visualisation

SIM Design Blueprint

1. Create a new patch

NEW PATCH CREATION

To Create a New Patch

- Click the **'Patches'** tab. (figure 1)

- Click **'New'** to create a new patch - A table appears containing the following fields: **Name, Area, Year, Author/Owner** and **Actions**. (figure 1)

- The attributes are either filled in or automatically obtained from the **Network Model**. Only patch **Name** (the name of the patch) can be inputted by the user. **'Area'** represents the section of the network to which the patch is to be applied, and is based on the postcode. The default (authorised)network map for the area inputted will be displayed on the 'Network Model' screen to the right (figure 3). **Area** is determined automatically based on the area selected in the **Network Model** (location of assets that were modified / added / removed). **'Year'** refers to the year(s) over the which the patch is to be applied. This is selected using the slider at the bottom of the **Network model** (Figure 3). When developing the patch only one year at a time can be selected; **Years** will be Displayed in the table automatically based on the years selected when developing a patch on the network diagram.'**Author'** is assigned automatically from the login name. under the **'Actions'** field, a button is displayed which enables the patch to be set as on/off by default when an experiment is being carried out.

- The **Affected Assets** table (figure 2) appears after the necessary information has been filled into the patch creation table, and displays information about the assets affected by the patch selected and contained in area shown in the network model . Only asset **Name** can be inputted by the user. **Status** is determined automatically based on user input to the network diagram. **Modified** – timestamp of last modification (filled automatically). **Type** - again, filled automatically based on user interaction with the network diagram. The **'undo'** symbol is used to undo the last action performed. Click **'Select All'** to select all the assets which are listed in the **Affected Assets** table (figure 2). The selected assets are then highlighted in the network model map according to their status. Alternatively, the assets can be selected one or more at a time by clicking on them. **'Inspect'** displays additional information about an asset which has been selected either from the **Network Map** or the **Affected Assets** table. Only one asset can be 'inspected' at a time, hence if more than one asset is selected, the **'Inspect'** button is greyed out.

- The **Network Map** (figure 3) displayed can be modified manually by using the '**Add'**, **'Select'**, **'Remove'** and **'Zoom'** buttons to manipulate assets on the map. Assets can be dragged into place on the map. Any modification on the network map causes the information displayed in the **Patches** and **Affected Assets** tables to change.

- When satisfied with the patch creation click '**Save'** on the Network Model (figure 3) to save the patch.

2. Load a patch
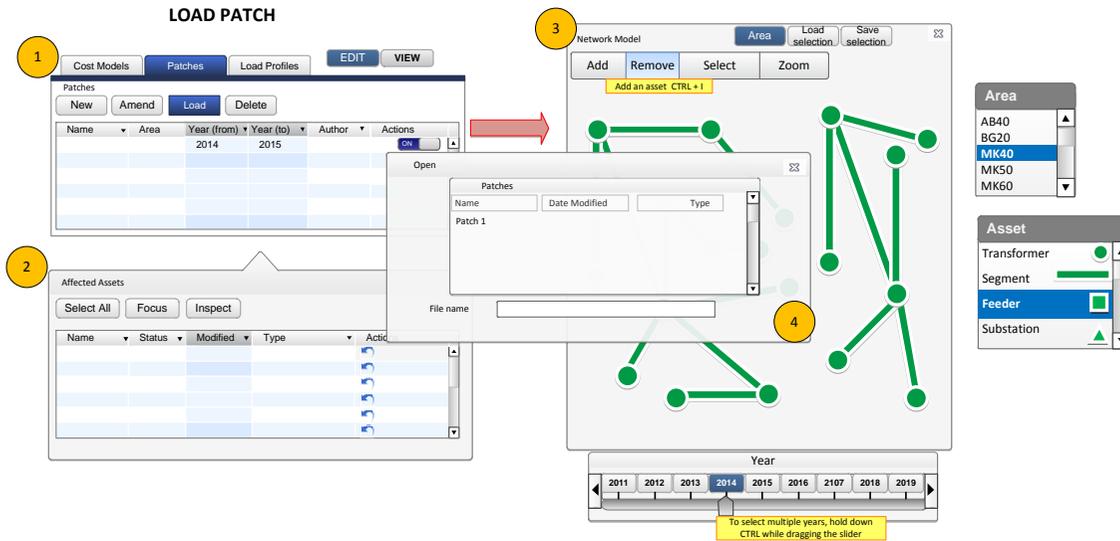
LOAD PATCH

To Load a Patch

- Click the **'Patches'** tab. (figure 1)

- Click **'Load'** to load a patch from the default database - A menu appears asking the user to select patch from the list of patches. (figure 4)

- The selected patch appears in the **'Patches'** table. 'Area', 'Year' (from and to), and Author are automatically entered from the Patch properties. Under the actions field the default status of the patch (selected or not by default) is shown. This attribute can be manually modified

- Repeat the process to load new patches. It is up to the user to either specify the patches corresponding to the network area selected, or expand the network area. If not an error message will be received.

- The **Network Map** (figure 3) displays the Network Area selected and assets contained therein

3. Select and delete a patch

PATCH SELECTION AND DELETION

Delete a Patch

- Click on the **'Patches'** tab

- Click on the **'Edit'** button

- Select the Patch to be deleted in the **'Patches'** table

- Click the **'Delete'** button

- A warning dialog box appears with the message 'Are you sure you want to delete this patch?'

- Click **'Yes'**

4. Select Multiple Assets

SELECTION OF MULTIPLE ASSETS

To display the statuses of all assets contained within a patch on the network map

- Click the **'Patches'** tab. (figure 1).

- Click the 'View' button to enter display mode. (figure 1).

- Click on the patch to be displayed in the 'Patches' table. The assets affected by the patch are displayed in the 'Affected Assets' table (figure 2).

- Select the assets to be displayed (hold down shift or control and click to select more than one asset). The assets affected are displayed on the network map (figure 3). with their borders highlighted in red. The years the assets were changed (for a multiyear patch) is displayed both in the 'affected assets' table under the column 'Year Changed' and on the slider underneath the network map (affected years are highlighted). Moving the slider will result in the assets on the 'affected assets' table being de-highlighted and only the assets affected during the year the slider is positioned to be highlighted in the table and displayed on the Network map. To select more than one year on the slider, hold down the control key and click on the years.

- The attributes in the tables can be arranged (ascending, descending, alphabetical order etc.) using the arrows beside the field title in the table.

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5. Create Cost Model

CREATE COST MODEL

To Create a Cost Model

- Click on the **'Cost Model'** tab (figure 1)

- Click on the **'Edit'** button to enter edit mode

- Click on **'New'** to create a new cost model. Only the name of the cost model can be inputted all other fields are automatically inputted. When a cost model is created it is set to **'ON'** by default

- After the name has been specified, press the Enter key to display the **'Parameter'** table (figure 2)

- Losses, CMI, CI and 10 other cost factors are displayed. Use the slider under the network model (figure 3) to select the year (which will be displayed in the 'Year' column) and input the value for each of the factors. To add another year, click **'Save'**, then select another year with the slider the **'Year'** column will change to reflect the value selected. Alternatively a set of values can be loaded from an external source by clicking **'Load'** or default values can be inputted by clicking **'Default'**. A warning message **(Are you Sure)** will be displayed if 'Default' is clicked to prevent inadvertent erasure of previously inputted values.

- When satisfied with the cost model created, click **'Save'**

6. Group Cost Models

GROUP COST MODEL (CREATE UNION)

To Create a Union

- Click on the **'Cost Model'** tab

- Click on the **'Edit'** button to enter edit mode

- Select the Cost Models to be linked. Click the 'Group' button

- If there is a conflict in the Cost Models selected, an error model is displayed

- Click **'Save'.** There is a prompt to choose a name for the Union.

Appendix B – Technique descriptions

1 Purpose

The purpose of this document is to specify how the different Techniques will be applied in the SIM. The techniques are explained to a degree which would allow them to be codified. We expect that for optimal performance the techniques will be modelled within the network modelling tool, though where this is not possible or optimal, elements of the techniques may be modelled within the SIM harness.

The technique models for the SIM will be similar to those used by the Falcon trials management system. However there will be some differences in how the models are applied as the trials system will have access to real time data. An example of this is given in Appendix 2. This document does not specify the physical trials scenarios or the trials experiments. These are documented in the Trials Use Case documents.

2 Dynamic Asset Ratings

2.1 Dynamic Asset Ratings – Description

2.1.1 Application

Dynamic Asset Ratings technique may be used where there are thermal issues identified on the network. It will not support the resolution of voltage issues and may make even create or exacerbate voltage issues.

2.1.2 Continuous current ratings

Thermal issues are usually identified by comparing current against continuous current ratings. Continuous current ratings ensure that the asset does not experience more thermal gain than can be dissipated to the environment and so the asset temperature does not increase above its critical value.

As the environmental conditions vary during the year, the continuous current ratings are higher in the winter than in the summer.

2.1.3 Thermal modelling

The Dynamic Asset Rating technique models the asset temperature in conjunction with additional monitored information. This may allow an asset to temporarily run above the continuous current rating for the asset, so long as the asset remains below its critical temperature.

The Dynamic Asset Rating technique will be based on the Thermal models to be built for each asset. The current expectation is that the thermal model will have a number of seasonal inputs which include ambient temperature, wind speed and solar gain. Some of these seasonal inputs may also be granulised to time of day e.g. daily temperature profile may be used rather than just a noon day temperature value.

For each period the thermal models will consider;

1) thermal gain from power flow through the asset, magnetising heat gain, solar gain etc.
2) thermal losses arising from convection, radiation and conduction,
3) the critical temperature of the asset at the start of the period
4) Possibly the heating effects from previous periods

This will enable the calculation of the asset critical temperature (general temperature of the asset or the asset hotspot temperature) to be calculated. There will be a number of attributes held against an asset which will determine the thermal model to be used and also the parameters within the thermal model (e.g. there may be a thermal model for a specific type of cable and the model may contain parameters which are dependent on the surroundings of the asset (i.e. type of ground, laid in ducts, laid in air)).
In terms of the thermal modelling, this technique requires knowledge and calculation of the asset conditions from the previous period. An assumed set of conditions for the asset will be made for the start of each day type. (This should be the same temperature of the asset at the end of day under normal operating conditions i.e. not under N-1 conditions). If we can assume that the asset temperature at the start and end of the day are the same then we do not need to model the impact of a small residual temperature gain each day over several days.

Inputs
- Weather values for time period (ambient temp, wind speed, solar gain)
- Load for time period
- External cooling equipment on/off
- Asset temperature at start of time period

Asset Specific Thermal Model
Temperature change = fn (thermal gain, thermal losses)

Thermal Model Outputs
Calculated temperature at end of time period. (Also used as input for next time period)

Evaluation

The algorithms to be used for each asset are still being developed but will follow these processes.

2.1.4 Impact on asset life

The life of an asset may be dependent on the temperature at which the asset is operated. For each asset a model will be required to describe the reduction in asset life on the temperature at which the asset is operated.   This evaluation may require integrating time periods at different temperatures. Modelling within the SIM will be at a granularity of 30 minutes which will reduce the accuracy of the evaluation, however where real-time data is available, e.g. for the Falcon trials, this may be calculated more accurately.

2.1.5 Maximum critical temperature

Each asset will need to have its maximum critical temperature specified as an attribute. The asset critical temperature will be a single value and not seasonally dependent. It should be assumed that we operate the dynamic asset rating to avoid reaching the maximum critical temperature at any time. The maximum asset critical temperature may be dependent on

1. The acceptable reduction of life of the asset as a consequence of its operating temperature (e.g. a 20% reduction in asset life)
2. Other safety factors (e.g. OHL sag, critical temperature of ancillary equipment (tap-changers, joints, clamps etc.)

(Note: Previously an option of pre-cooling transformer assets using fans and pumps was considered an enhancement of the technique. At this stage this enhancement is not being considered).

2.1.6 DAR - Costing the use of the technique

The cost modelling in the SIM will be developed with two options The cost model will need to reflect the impact of

- reaching a certain temperature
- repeated separate instances of reaching a certain temperature
- the aggregate impact of a duration at a certain temperature.

Therefore there will be a requirement for the modelling tool to provide this information to the costing model (in the SIM Harness).

3   Automated Load Transfer

3.1   Automated Load Transfer – Description

Automated Load transfer may be used to resolve both thermal and voltage issues. Automated Load transfer can operate into two modes. The two modes are

(1) Pre-Determined Sequence
(2) Optimised Configuration

Each mode will be separately modelled and are described below.
As part of the technique automated switchgear will be applied in the network model. This will only be achieved by changing attributes of current manual switches to either a remote controlled automated switch or circuit breaker. The choice of an automated switch or circuit breaker will be dependent on the number of switching operations that the asset is required to perform.
There will be a limit to number of switching operations that can be part of a switching sequence. This limit will be determined by reference to the control system used for the trials or any existing limit for the control room systems.

3.1.1 Pre –Determined Sequence

This operating mode will be event driven and on the occurrence of the event will perform a pre-determined switching sequence. There may be different switching

sequences for different events. The event may be a voltage or thermal issue in the intact network or during an N-1 contingency.

Where the event is in the intact network, then a "reverse event" will also need to be established to return the network to its start conditions.

For this mode of operation of the technique there are two steps

(1) Establish positions of automated switchgear and a Pre-Determined sequence to resolve a network issue

(2) Apply the Pre-Determined sequence as required to try and resolve the network issues as they occur (in the future). This will include "reverse events" to return the network to its pre-switched state.

Step 1 is performed once only at the initial request for applying the technique. Step 1 changes the attributes of assets (manual to automate) and establishes the Pre-Determined sequence.

 Step 2 is then used whenever a network issue requires resolution in the Step 1 implementation year or later years, by changing the state of the asset (opened or closed) dependent on the Pre-Determined sequence.

3.1.2   Optimised Configuration

This operating mode will be based on the load forecast for the whole day, modelling each period of the day and determining the optimum configuration of the network to resolve network issues whilst minimising the cost of operation. Minimisation of the cost of operation will only be performed for intact network issues and not issues during an N-1 contingency.

For this mode of operation of the technique there are two steps

(1) Establish positions of automated switchgear to resolve a network issue

(2) Each time the technique is required utilise an optimisation algorithm to consider the most optimum switching positions across the whole day which should include minimisation of costs of operation. *(The cost of operation is still to be determined but may include losses, CMLs/CI, switch operations.)*

3.2   Automated Load Transfer – Costing the use of the technique

The following data will be required to be passed from the Network Modelling Tool to the SIM Harness.

- Implementation - Number of manual switched converted to automated switched or automated circuit breakers
- Operational - For each day type in each year on or after the technique has been applied – the number of operations of existing or new automated switches.

4   Meshed Networks

4.1   Meshed Networks - Description

Meshed Networks may be used to resolve both thermal and voltage issues. When a request for establishing a meshed network to resolve a network issue, the technique will

(1) Create a mesh by closing one or more open points to resolve the network issue. In establishing the mesh the effects on voltages, load flows (especially creation of circulating currents) and fault levels need to be considered.

(2) Determine the number of protection zones. This will be a balance of a cost of each protection zone and the reduction in CMLs/CIs.

The method and policy for creating the required minimum number of protection will be developed by WPD prior to design and build.

Where a Meshed Network cannot be established without exceeding fault level capability of existing assets then where the assets have a capability less than the standard capability at that voltage level, the assets should be identified for replacement. (Replacement asset costs will need to be included in the financial assessment of the technique).

4.2   Meshed Networks – Costing

The following data will be required to be passed from the Network Modelling Tool to the SIM Harness.
- Implementation - Number of manual switched converted to automated switched or automated circuit breakers to support the protection zones.
- Operational - None

5   Energy Storage

5.1   Energy Storage - Description

Energy Storage may be used to relieve both thermal and voltage issues. Energy Storage (ES) Units may be operated in three modes, each of which may be considered a separate technique. The operating modes are
- Event Driven only
- Fixed Schedule
- Optimised

We assume that it is possible to communicate to the energy storage device e.g. when an event occurs elsewhere on the network this will trigger the response by the energy storage device.
These operating modes are described in detail below
When applying the technique the following steps will be required:
1. Select the size of Energy Storage Unit
2. Select the location of the Energy Storage Unit
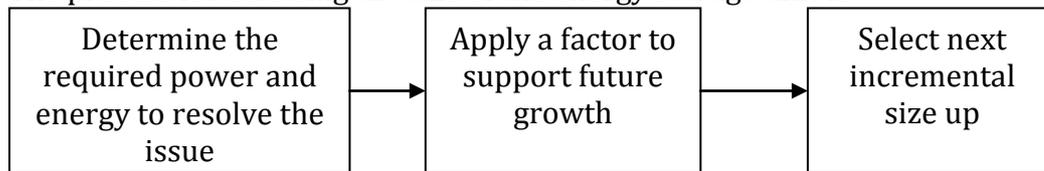3. Assign the Operation mode

Steps 1 and 2 are common to all operating modes.

5.1.1 Selecting the Size of the Unit

Energy Storage Units will be available in fixed incremental sizes. There are two aspects to the size of an Energy Storage Unit namely:

- Power output/consumption
- Energy output/consumption

The process for selecting the size of the energy storage unit is

Determine the required power and energy to resolve the issue	→	Apply a factor to support future growth	→	Select next incremental size up

The method of determining the required power and energy is described below. The "future growth factor" will be a fixed factor that will determined by WPD and provided to the SIM.

5.1.1.1 Thermal Issue Sizing

Radial or Open ring network arrangement

For a network thermal issue in a radial or open ring network arrangement, the required power capacity is determined by the difference between the maximum power flow and the capacity of the asset with the thermal issue. The minimum required energy storage is the energy delivered across all periods above the capacity of the circuit.

Required power capacity

Minimum energy to store/discharge = yellow area

Asset

Where the yellow area ...sed by excessive demand then the power capacity will be the discharge power capacity of the Energy Storage Unit. Where the thermal issue is being caused by excessive distributed generation then the power capacity will be the charge power capacity of the Energy Storage Unit. For example consider the situation where a thermal issue is caused by an asset which has a power flow 400 kW for 2 hours through an asset with a capacity of 350 kW. The required power of the energy storage unit would be 50kW (400kW-350kW). The required energy of the energy storage unit would be 100kWh (50kW * 2 hours). If the "future growth factor" is 1.2 then the energy storage unit power requirement would be 60kW and energy requirement would be 120kWh.

Meshed Network

For network thermal issue in a meshed network arrangement the sizing will be dependent on the location of the storage unit. A "base" capacity/energy storage is initially calculated as for an radial/open ring network arrangement above. In addition a "sensitivity factor" is required to be determined. The sensitivity factor will be dependent on the location of the energy storage unit. The sensitivity factor is calculated as the change in flow in the asset with the thermal issue (in MW) when a 1 MW increment of load (or generation) is placed at the energy storage unit location. (This sensitivity factor will normally be less than 1). The

minimum required capacity/energy storage for an energy storage unit at L to resolve an thermal issue on asset i will then be determined as the

$$Minimum\ Required\ Capacity_{iL} = \frac{BaseCapacity_i}{SensitivityFactor_{iL}}$$

where

BaseCapacity$_i$ -   the required capacity for asset i which has a thermal issue as calculated for radial and open ring networks

SensitivityFactor$_{iL}$ - the Sensitivity Factor for asset i on an incremental change of load at node L

The Sensitivity Factor may be different for each period of the day. The minimum required capacity will be therefore determined by the maximum value over all the time periods of the analysis.

When doing the calculations for energy storage then these will need to be performed for all time periods and the summed.

5.1.1.2 Voltage Issue Sizing

Where there is a voltage issue concurrent with a thermal issue then the resolution of the thermal issue will normally resolve the voltage issue and therefore initial sizing of the Energy Storage Unit will be based around the thermal issue sizing.

Where there is a voltage issue without a thermal issue a methodology for determining sizing will be developed. This may be based around Voltage Sensitivity Factors (similar to Sensitivity Factors for thermal issues if these can be assumed to be linear around the operating conditions for each time period.

5.1.2 Selecting the location of the Unit

Not all secondary substations have the capability to accept Energy Storage Units. The substation attribute shall indicate whether or not it has the capability. The maximum power capacity of an Energy Storage Unit shall not exceed a fixed % of the transformer capacity of the substation. Where a single substation is not able to support the required capacity Energy Storage Units may be selected to place across a number of substation. The total capacity of the energy storage units should be equal or greater than the required capacity.

Where there is a voltage issue to be resolved the location of the energy storage Unit shall be at the location closest to the largest voltage deviation (Note although this would normally be at the lowest voltage but in a scenario where there are a large amount of DG installed then this may be at a highest voltage where the voltage issue is caused by high voltages).

Where there is a thermal issue the location shall be at the substation downstream of the circuit with the thermal issue.

5.1.3 Operating Modes of the Energy Storage Unit

There are a number of operating modes that may be used
1. Reactive – Voltage and thermal
2. Planned – Fixed schedule for each day type
3. Planned – Optimised based on predicted demand curve

5.1.3.1 Reactive

This mode will charge and discharge based on preset voltages and thermal overloads.
Voltage triggers will be based on the voltages at the local and adjacent substations.
For radial networks the thermal triggers will be based on the upstream circuits and whether any of the circuits have exceeded their rated capacity.
For meshed networks the thermal triggers will be based on any circuit in the mesh that has exceeded its rated capacity.
The Charge/Discharge rules described below are for low voltage issues and load driven thermal issues.
(A similar set of rules will be established for high voltage issues or generation driven thermal issues. These will broadly be the same as the low voltage load drive issues but charging at the High Trigger Voltage or generation driven thermal issue).
The type of issue will need to be determined prior to applying these rules.
<u>Discharge</u>
The Energy Storage Unit shall discharge whenever the voltages at the local and adjacent substations drop below a set value (Low Trigger Voltage). The rate of discharge will be increased in steps until the voltages are above a target value (Low Target Voltage). The Low Trigger Voltage and the Low Target Voltage will be fixed values determined by WPD.
The Energy Storage Unit shall discharge whenever the power flow on a monitored asset exceeds its rated capacity. The rate of discharge will be based of restoring the circuit to within its rated capacity.
For a radial or open ring network the monitored assets will be any circuit upstream from the Energy Storage Unit. For meshed networks the monitored assets will be those which have Sensitivity Factor greater than a set value (This value is yet to be determined).
<u>Charge</u>
The Energy Storage Unit shall charge whenever the voltages at the local and adjacent substations are at least a set value (Minimum Charge Voltage) and the headroom of the relevant circuits are at least a certain value (Minimum Charge Headroom). (Headroom is the difference between the rated capacity and the circuit power flow). The amount of charge shall not allow the voltage to exceed a set value (Maximum Charge Voltage) and shall not allow any circuit to exceed its rated capacity.

5.1.3.2 Planned – Fixed schedule

This mode will charge and discharge based on charge discharge schedule. The Schedule will be optimised in the year of installation. There will be separate schedules for each of the season day types. The optimisation process shall consider the whole day and minimise cost of operation. (The cost of operation is still to be determined but may include network losses, CMLs/CI, charge/discharge losses.) The charge level of the energy storage unit shall be the same at the start and at the end of the day for each day type.

5.1.3.3 Planned – Optimised based on predicted demand curve

This mode will charge and discharge schedule will be optimised for each day that is being analysed. (Note for the first year this should be the same as the Fixed Schedule in 5.1.3.2. However in following years this may change as the substation demand curves may change). The optimisation process shall consider the whole day and minimise cost of operation. (The cost of operation is still to be determined but may include network losses, CMLs/CI, charge/discharge losses.) The charge level of the energy storage unit shall be the same at the start and at the end of the day for each day type.

5.2   DSM/DG - Costing the use of the technique

The following data will be required to be passed from the Network Modelling Tool to the SIM Harness.
- Implementation - Number and size of energy storage units
- Operational - For each day type in each year on or after the technique has been applied – the number of charge/discharge cycles and the depth of charge/discharge

6   Demand Side Management and Distributed Generation

6.1   Demand Side Management and Distributed Generation - Description

Demand Side Management (DSM) and Distributed Generation (DG) may be used to relieve both thermal and voltage issues. Although DSM and DG are specified together in this section, when they are applied as a technique they will be applied independently. DSM and DG can be operated in two modes
1. Reactive
2. Planned

The Reactive Mode will provide response within a timescale to resolve the issue as a consequence of N-1 contingency occurring and will therefore need to provide the response with [20] minutes (Reactive Response). The planned mode may be used resolve issues in the intact network (Planned Response) or provide notice of potential need to provide response if an N-1 contingency arises (Potential Response).
The extent to which DSM and DG may be used will be dependent on the availability of DSM and DG on the networks under analysis. The forecasted demand will provide an estimate of prospective available DSM and DG demand/generation. A Scenario definition will include contractable factors (separate factors for DSM and DG and for Reactive Response, Planned Response and Potential Response) which will convert these prospective available DSM and DG demand/generation into contractable quantities
The technique will then use the contractable DSM and DG to resolve identified thermal and voltage issues. This will be done using the total contractable volumes. However separate costs may be incurred for availability and usage. The technique will be required to report the actual volumes that are used to resolve the identified issue.

6.1.1 How do the techniques help to resolve network issues?
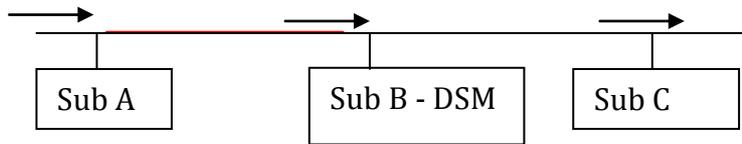
	DSM – demand reduction
Overloaded circuit	Reducing load at Substation B can relieve the overloading of an upstream circuit e.g. the circuit between Sub A and sub B.
Low voltage	Reducing the load at sub B can help improve voltages along the circuit
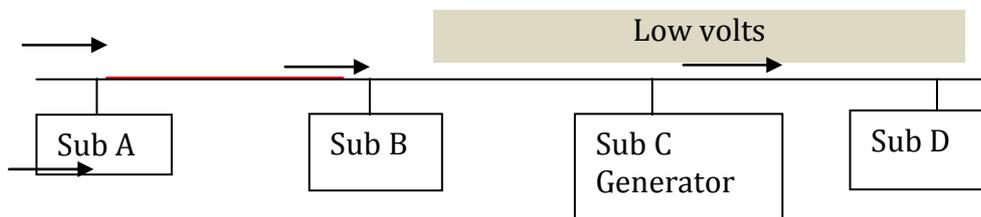
	Generator Support – increased generation
Overloaded circuit	Increasing generation at sub C can reduce the overloading in an upstream circuit
Low voltage	Increasing generation at sub C can improve the voltage at sub C and surrounding substations.
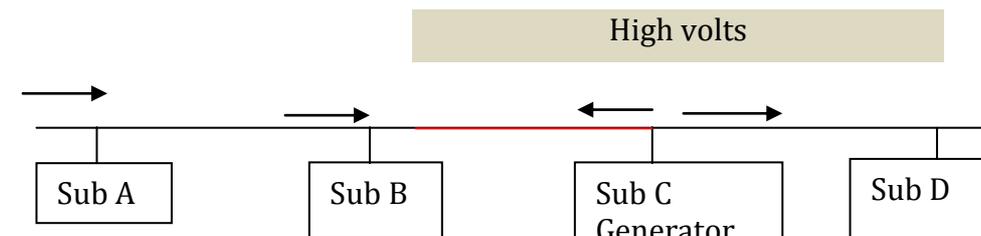
	Generator Support – constrained generation (not preferred)
Overloaded circuit	Constraining the generation can reduce the overloading in a circuit which is carrying the exported current
High voltage	Constraining the generation can reduce issues with High voltage if the generation is the source of the high volts.

6.1.2 What are the forms to be modelled within the network modelling too

DSM and DG can be operated in the following modes
3. Reactive - Post event (e.g. immediately after a fault or other unexpected event occurs)

4. Reactive – short notice (short notice of potential problems arising that day)
5. Seasonal (Routine DSM / DG participation on given types of day regardless of the daily circumstances.)

6.1.2.1 Reactive – post event.

The Reactive Mode will provide response within a short timescale to resolve network issues subsequent to an unforeseen event, such as a fault or the overrun of a planned outage. This technique will therefore be applicable to resolve constraints which relate to n-1 contingencies.

We expect to be able to identify that a fault has occurred within a negligible timeframe. Service providers will be expected to provide a response within [20] minutes of notification.
This value is based on what has been achievable in trials carried out by Northern Powergrid but also reflects that reactive DSM / generator response must be provided quickly to provide value.

If response times are long then this may breach thermal constraints for overloaded cables. However it is also likely in the case of a fault that there would be operational teams that can get to site and take other actions to resolve the issues, i.e.
- repairing the fault to allow normal network configuration to be restored.
- further network switching to spread the load across adjacent feeders
- use of mobile generators. (these are normally used to restore supplies to faulted sections of network but these could be used to resolve network issues in the same way as a battery.)

Thus the real value of reactive DSM is managing network constraints until such time as these can be addressed by operational interventions.

The duration of the required response should reflect the likely time for operational staff to get to site and enact alternative measures, but also the load shape. It is likely that network constraints related to fault conditions would initially be present at peak times only. The duration of the load curve peak will therefore also be a factor in setting the required response duration.

In exceptional events, such as severe storms where we experience a very high number of concurrent faults, then longer periods of DSM may be useful as staff will take longer to attend to faults. However, we do not intend to simulate an exceptional event within the SIM.

6.1.2.2 Reactive – short notice

This may happen when a change in normal network configuration occurs off peak, but are expected to continue into peak hours when network issues are expected to arise. In this case customers could be given advance notice of the

requirements which might result in more customers being able to participate in providing this service.   This would be too complex to model in the SIM/NMT, but should be considered for the trial to get a rounded view of take-up and response rates.

6.1.2.3 Seasonal

This is expected to be the method used to resolve network issues that arise when the network is intact. It is assumed that the issues are short-lived and localised so that DSM/DG is a valid approach. Widespread or long duration network issues are likely to be better managed by reinforcement.

6.1.2.4 Summary

DSM / DG features	Reactive	Reactive – short notice	Seasonal Planned – longer notice period
Issues managed	Voltage and Thermal loading	Voltage and Thermal loading	Voltage and Thermal loading
Notice period	None	2 – 4 hours	Notice agreed at signing contract.
Response timescales	Short – 15 -20 mins	Short response should be within 10 mins. of required time of day due to some advance notice	Instant – response should be possible at the required time due to long notice period.
Duration of response	Fixed period 3-4 hours	Fixed period 3-4 hours	Expected constraint time period plus half hour before and after.

6.1.2.5 Different DSM Impacts

When asked to reduce load DSM providers can do so in different ways, which will have a different impact on the load curve.

1) Switch to own generation.   In this case the customer does not need to change how they use their energy, only the source of the power. There are no effects on the load curve before or after the event.
2) Load reduction. In this scenario the load is reduced during the DSM period and is not shifted to another part of the day.
3) Load time-shifting. In this case the load that was reduced during the DSM period is transferred to other parts of the day. e.g. pre-cooling refrigerators to allow them to be switched off at a planned time.   Load associated with industrial process deferred to a later part of the day.

The SIM / NMT should be able to adjust the load profile to reduce the total load by the DSM capacity. Where load is shifted to a period after the DSM duration then the SIM/ NMT should be able to add the shifted load to the normal total load values.

The example below shows DSM applied for periods 3-8 with a reduction of load in this time and the additional load shifted to time periods 9-14.

Time period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Total load	10	11	15	14	14	13	14	15	11	10	10	11	11	10	11	10
DSM capacity	2	2	3	4	5	4	3	3	2	2	3	4	4			
Adjustment	0	0	-3	-4	-5	-4	-3	-3	+3	+4	+5	+4	+3	+3	0	0
Adjusted load	10	11	12	10	9	9	11	12	14	14	15	15	14	13	11	10

In modelling new contracts the default assumption should be that load is shifted as this is likely to be the more onerous condition.

6.2 Modelling DSM/DG within the SIM.

The SIM/ Network Modelling tool to be able to
1) Determine whether DSM/DG can resolve a network constraint.
2) Optimise the locations used to apply DSM / DG
3) Change the attributes of the substations where DSM /DG has been applied such that the normal load pattern can be changed to represent the load pattern with DG/DSM applied.

We do not expect the modelling of DSM/DG to involve a two way interface to the energy model, even though this is the location where most is known about customer loads. Therefore we need to qualify what information is used in the SIM/NMT in order to determine the form of the interface between the Energy model and the SIM.

6.2.1 Energy Model functionality

6.2.1.1 Customer level DSM capability

The Energy model will hold information about customers including customer type, which will give an indication of how their load is made up from the various constituents, e.g. heating, lighting, motive power, refrigeration, consumer electronics etc. These types of use can be characterised in terms of their technical ability to be used for DSM

Technical DSM capacity			
Energy type	Shiftable Y/N	Typical duration	Notice period for use
Building Heating	Y	2 hours	Under 15 mins
Lighting	N		
Refrigeration	Y	3 hours	Under 15 mins
Control systems and electronics	N		
Etc…			

However, in reality it is likely that not all customer types will be able to make use of all types of technically shiftable load. This may vary by customer type or by individual customer.

Therefore it may be useful to consider the value of contractable load, which cannot be greater than the technically shiftable load.
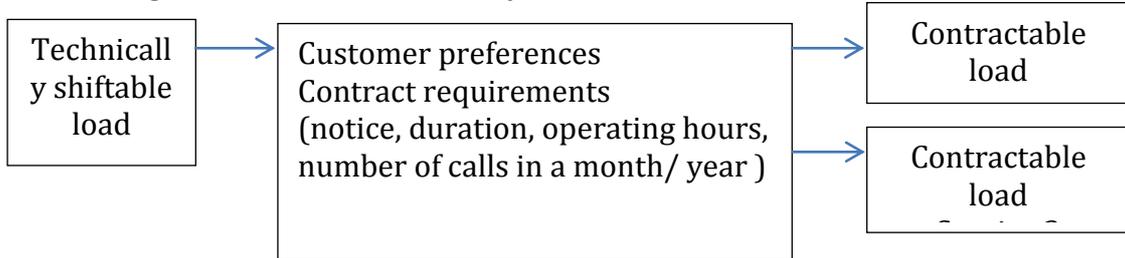
The process of determining customer preferences is beyond the scope of FALCON and so some basic assumptions will be included within the energy model to translate technically shiftable load into contractable load.

The contractable load will reflect the relevant requirements for that contract such that a company may have a contractable load that is available for seasonal demand side management but no contractable load for post fault response.

DSM services to be applies within the SIM / NMT should therefore be specified within the energy model and the potential response of customers calculated at the same time as the distribution substation loads are calculated for a load scenario.

Two services should be specified, one seasonal and one reactive. Therefore the information to be summated for each customer will be the total load, seasonal DSM capacity and reactive DSM capacity.

Total load for each half hour

Seasonal DSM capability for each half hour

Reactive DSM capability for each half
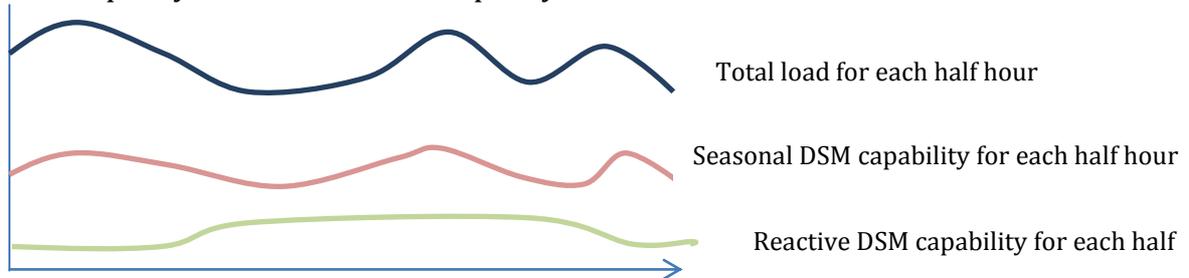
For DG customers the values will also include
- Seasonal additional generation capability
- Reactive additional generation capabilit

Total load for each half hour

Seasonal DSM capability for each half hour

6.2.1.2 Aggregation at the distribution substation

While contracts will be placed with individual customers, we want the interface to pass values that represent the distribution substation as a whole.

For each half hour period

Customer	Service 1 capability	Participation rate (willingness	Response reliability (Likelihood	Adjusted service 1 capability	Service 2 capacity	Etc.

		to contract service)	of response when called)			
A	X1	Y1	Z1	= x1*y1*z1		
B	X2	Y2	Z2	=x2*y2*z2		
C						
Combined value				= max + combination factor * 2nd largest value		

Values for participation rates and response reliability are likely to be default values based on customer types. Again, refining these values is beyond the scope of FALCON.

The combination factor should represent the likelihood of being able to sign up two customers simultaneously, which will be less than the likelihood of signing up each customer individually.
This combination factor = y1 *y2

We do not expect to assume more than two contracts per distribution substation.

6.2.2   Optimising the assumed locations of DSM / DG to substations on a feeder

The commercial contracts are likely to have two separate cost elements

(1) a retainer payment, and
(2) event related payments.

Therefore it is unlikely to be cost effective to speculatively set up contracts with every customer willing to provide services. There needs to be an assessment of requirements and a mechanism to optimise the contracts that are sought. The likely frequency, duration, location and nature of constraints should be assessed to target customers whose services are most likely to be useful. This assessment should be over a period of X years as contracts would be expected to last Y years.

6.2.2.1 Planned requirements

(1) Determine the constraints experienced over a year under normal running conditions
(2) Determine the total pool of potential DSM / DG capacity (seasonal capacity)
(3) Prioritise the constraints including frequency as well as impact
(4) Find the optimum set of contracts by finding the best contract to manage the highest priority constraint and then adding additional contracts as required.

6.2.2.2 Reactive requirements

As above only reflecting constraints under n-1 conditions and reactive capacity.

6.2.2.3 Modelling the response in the SIM / NMT

This must prevent double counting of response i.e. cannot allocate reactive response if this is being used for seasonal response.   It is likely that contracts will have a maximum number of calls per year set in the contract. Again, this will be aggregated to a distribution substation level and response treated as it is by a single customer. This value will be a default value that is set for all distribution substations regardless of the type of customer and therefore does not need to be calculated within the energy model. The number of planned response actions per year needs to be tracked within the SIM and DSM so that once the maximum number of response actions is reached then the technique is not used to solve further constraints. For post fault response we will assume that the number of faults per year is as expected and that contracts have been set up on a probability basis which is suitable.

6.3 DSM/DG - Costing the use of the technique

The following data will be required to be passed from the Network Modelling Tool to the SIM Harness.

- Implementation – Required Contracts including type (Reactive, Short Notice, Planned) and the volume for each contract type
- Operational - For each day type in each year on or after the technique has been applied – the amount of time and quantity that each contract type will be called.

7 Conventional Reinforcement

These are actions that would traditionally be taken when an asset is, or would be operating outside its normal rating for a period beyond that acceptable to the DNO. This could be the result of a new load connection, load growth, or adjacent network reconfiguration. In the case of new load connections it is assumed, clarification of the new load requirement have taken place and that the existing network load data has been confirmed.

7.1 Overloaded transformer.

Should the load on any transformer on the network exceed 100% of its nameplate rating it should be replaced with a larger standard size transformer or an additional transformer. The SIM Harness shall select the appropriate transformer sizing by:
Considering the maximum load at that node for the assessment period based on the Load Scenario selected, it shall select the either the lowest rating transformer that meets the maximum load identified. Where the maximum load exceeds the highest rated transformer then it shall select two or more same size standard transformers to be operated in parallel. Standard size transformers are typically 100kVA, 200kVA, 315kVA, 500kVA, 800kVA and 1000kVA. For maximum loads up to 1000kVA a single standard transformer will be selected. The table below

identifies the transformer configurations where the maximum load exceeds 1000kVA

Maximum Load	Required Transformers
>1000kVA and <= 1600kVA	2 * 800 kVA
>1600kVA and <= 2000kVA	2* 1000kVA
>2000kVA	3*1000kVA

Note: Loads greater than 3000kVA are not deemed to be feasible if the current maximum node demand is below 1000kVA

7.1.1   Falcon Modelling.

Where a single replacement transformer is being selected then all the attributes of the replacement transformer shall be used and connected at the same nodes as the existing transformer being replaced.
Where more than one replacement transformer is being selected then depending on the capability of the Network Modelling Tool/SIM either a standard configuration will be adopted or an enhanced configuration shall be adopted.
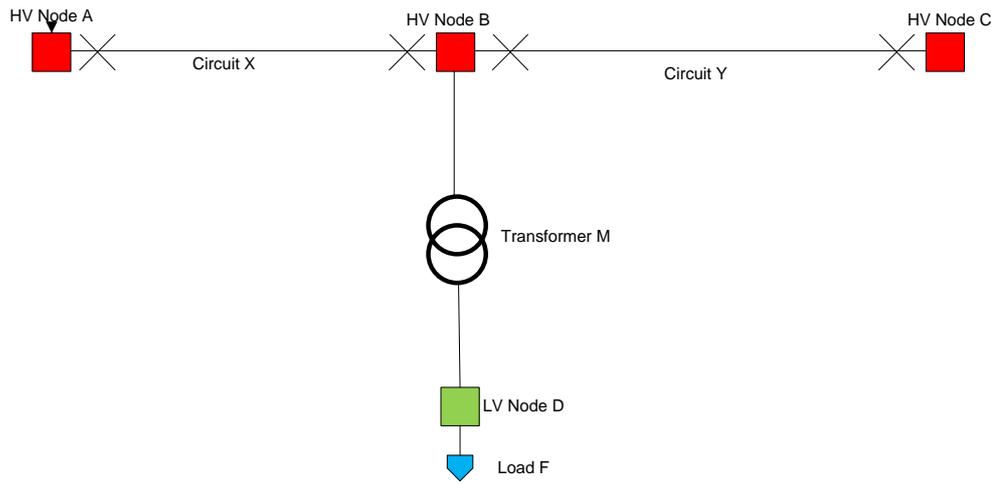
Standard Configuration
A standard configuration shall be that no new nodes are created and both transformers are connected across the same nodes as the existing transformer that is being replaced. This configuration has the disadvantage that the load cannot be split (i.e. there cannot be an open point between the two transformers on the HV network)

Enhanced Configuration
An enhanced configuration would require the two transformers to be modelled on separate HV nodes with a zero impedance circuit between the nodes which contains an automated/remote controlled switch. The two transformers would be connected to separate LV nodes. See diagrams below. This will require the following in terms of modelling:
- Creation of a new HV Node and a new LV node
- Changing the load on the existing LV (50% of existing load)
- Placing 50% of the load from the existing LV node to the new LV node
- Create a new zero impedance branch between the new HV node and the existing HV node
- Moving one of the HV circuits from the existing HV node to the new HV node
- Connecting one of the new transformers between the new HV node and the new LV Node
- If the two transformers are different to the existing transformer, replace the existing transformer with the attributes of the new transformer 2812

SIM Design Blueprint

HV Node A   HV Node B   HV Node C

Circuit X   Circuit Y

Transformer M

LV Node D

Load F

Network with Overloaded Transformer

HV Node A   HV Node B   HV Node C

Circuit X   Circuit Y

Transformer N2   Transformer N1

LV Node D

Load F
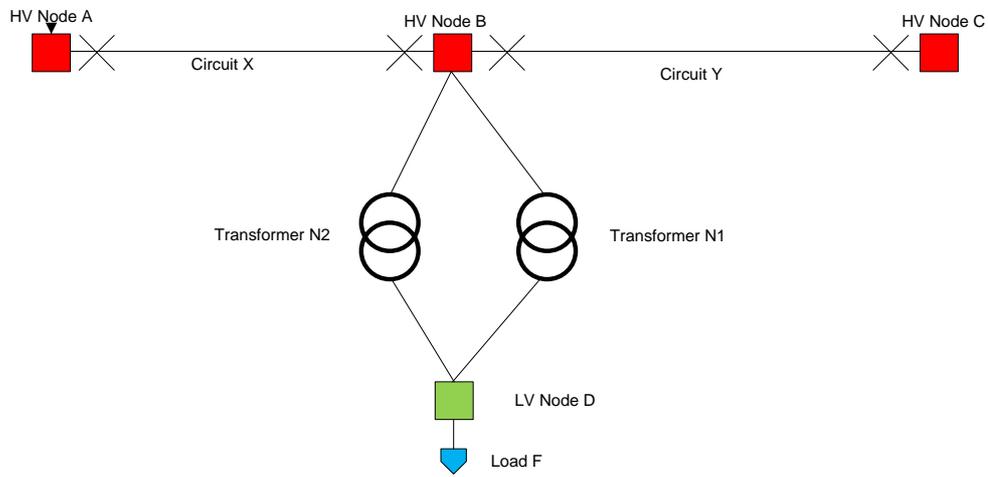
Network with Overloaded Transformer – Standard Configuration for network modelling where 2 transformers are required

HV Node A   HV Node B1   HV Node B   HV Node C

Circuit X1   Circuit W   Circuit Y

Transformer N2   Transformer N1

LV Node D1   LV Node D

Load F2   Load F1
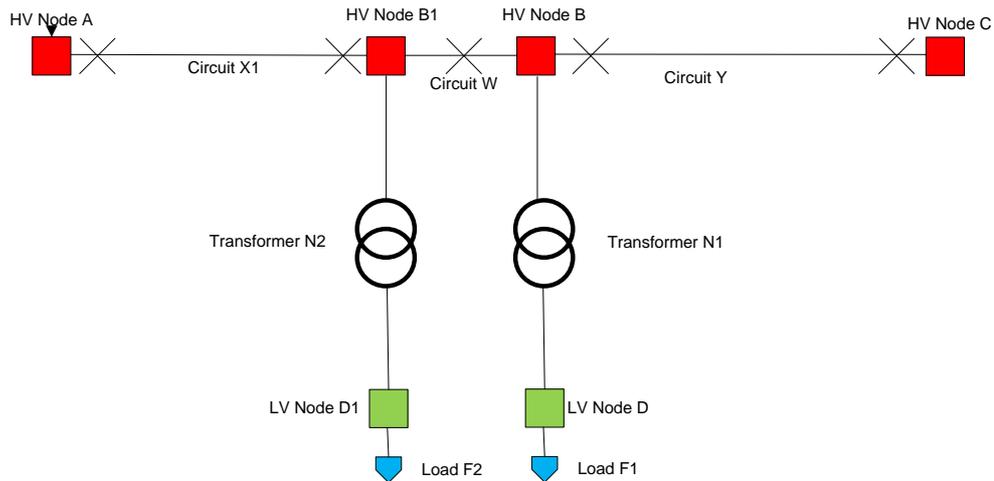
Network with Overloaded Transformer – Enhanced Configuration for network modelling where 2 transformers are required

Although modelled at the same site, for costing purposes it will be assumed that the second transformer will be installed at a separate site.
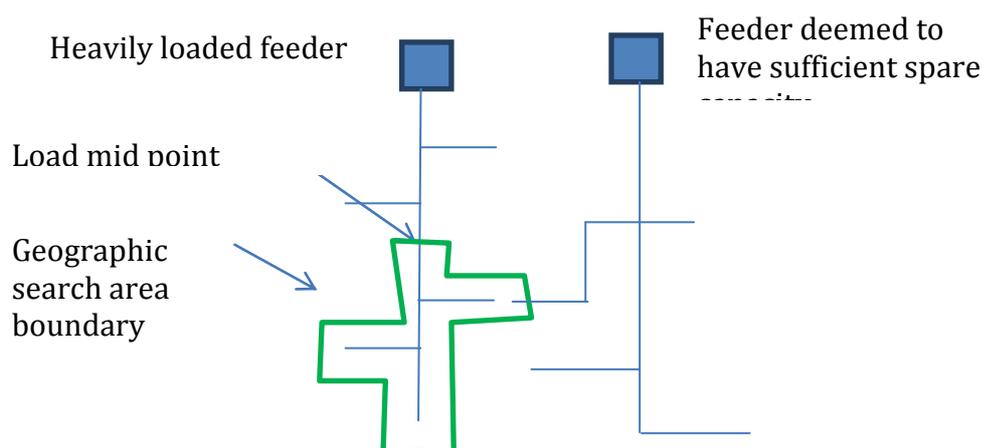
7.2 Network Thermal or Voltage issue

7.2.1 Split the feeder. Transfer half or some of the load on to another existing feeder.

Install a new standard size cable or overhead line section that joins two feeders in order to transfer load from an overloaded feeder to a lighter loaded feeder such that the same percentage headroom is available on each feeder after the connection.

<u>Falcon modelling</u>
To model this programmatically in Falcon we would need to;
(1) Calculate whether there was a more lightly loaded feeder in the vicinity of the overloaded feeder. We could simplify this by restricting the search of feeders to that within the same primary and specifying a capacity limit over which feeders should not be considered. E.g. a filter could exclude feeders with a peak loading of over 66% capacity under normal running arrangements.
(2) Search for potential cross connection points. The loading mid-point of the heavily loaded feeder could be identified. Rules could be applied from pre-defined preferences to select or exclude sections of the feeder that fall in the lower half. E.g. a minimum OH line or cable size to avoid. A geographical search area, or set of areas could be defined to encompass the area around the circuit deemed suitable for connection, for example 100m. A programmatic search could be made to identify any parts of a candidate lightly loaded network within the geographical search area.
(3) Select a cross connection point. A prioritisation process could be applied to select the optimum connection point based on a combination of factors including distance , difference in capacity between feeders etc.
(4) Update the nodal model with the new connection point and disconnect the transferred section of network from the original feeder. Here a default cable / OH line type would be required which could reflect whether the feeders involved were predominantly overhead or underground. A straight line route between the feeders could be assumed.

Heavily loaded feeder

Feeder deemed to have sufficient spare capacity

Load mid point

Geographic search area boundary

7.2.2 Replace part of feeder - Replace the section of 11kv Feeder that is overstressed.

Where a short 'clean' section of a feeder is overloaded, replace with the next larger standard size cable.

Falcon modelling
This is functionally equivalent to the replacement of the transformer with one of a larger capacity. To model this Falcon can change the attribute of the overloaded circuit to represent replacement with an overhead line / underground cable of greater capacity.
The requirement for a section of feeder to be "clean" is hard to specify programmatically but a minimum length could be specified. Then the process would be a simple change of line type unless the existing cable / overhead line were already at the maximum capacity. We would assume that cable would be replaced with cable and overhead line with overhead line.

7.2.3 New split feeder.   Run a new feeder from the Primary to a midpoint on the feeder and joint into existing feeder.

Where the overloaded section of the circuit is substantial and transferring a section of network to a lightly loaded nearby feeder is not possible. Install a new standard size cable or overhead line from a spare circuit breaker at the feeding primary to the mid-point on the overloaded feeder and split the load such that percentage headroom the new and existing feeders are approximately equal.

Falcon modelling
Here we need to programmatically carry out the following steps.
 (1) Assess spare capacity at the primary for an additional feeder.   This should be identifying circuit breakers that are labelled as spare or that are identified as feeder breakers but do not have significant length or customers attached.
 (2) Determining the node representing the load mid-point for the circuit. Modifying the nodal model to reflect the new connectivity. A new connection between the spare feeder and the midpoint could be created on a straight line basis or could be created to follow the path of the existing

feeder. Whether the connection is overhead line or underground cable will be determined by the predominant type of the "top half" of the existing feeder.

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## 7.3   Conventional Reinforcement - Costing the use of the technique

Typical costs will be established for each type of conventional reinforcement. Where the conventional reinforcement is a replacement of the Secondary Substation transformer then whenever an additional transformer is required then this will be assessed in terms of cost as being installed at a new secondary substation site.

SIM Design Blueprint

Appendix 1 - Workstream 3 model Conventional solutions

13.2.1 Overview
The following diagrams and explanations detail the solutions that are included where any coloured circuits or transformers indicate new assets provided by the solution. It should be noted that the diagrams refer to LV implementation of the solutions, but the solutions will also be applicable at HV and EHV as described in the accompanying text.

1. **Split the feeder** i.e. transfer half of the load of the existing feeder onto a new feeder
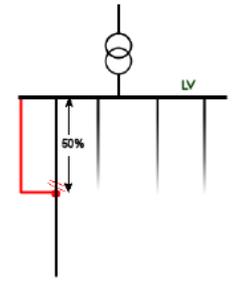

 2.**Replace the transformer**

3.New split feeder i.e. run a new feeder from the substation to the midpoint of the already split feeder and perform some cable jointing to further split the load, resulting in three feeders each having approximately equal loads). It should be noted that the total amount of cabling required to deliver this solution has been calculated to be equal to the cabling required to deliver the "split feeder" solution, but there is additional cross-jointing required meaning that the costs are slightly higher. The figures in the diagram of 33% represent the load that now exists on each feeder as against an unreinforced case, but are not representative of the relative cable lengths of each feeder.
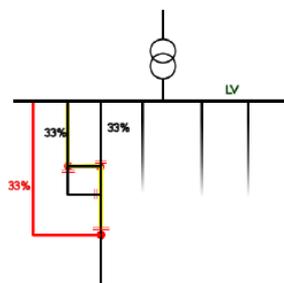
4 **Minor works** at LV this would involve the installation of a new pole mounted, pad mounted substation or second transformer at a pre-existing substation to take half of the load from the substation being reinforced but with limited HV cabling required, while at HV and EHV it will take the form of an additional transformer being installed at an existing site.
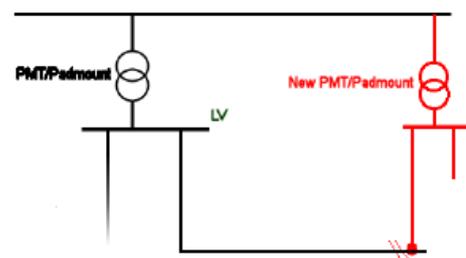
5 **Major works** at LV this would involve the construction of new distribution substations with associated LV cabling to integrate these substations into the heavily loaded network, and also some HV cabling to allow the new substations to be fed from the relevant primary substations; at higher voltages the principle is the same,

with the construction of a new primary substation or bulk supply point and associated cabling.
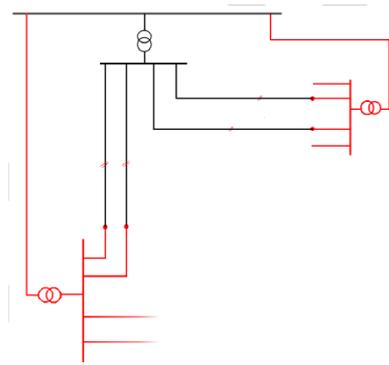
These solutions are available at all voltages (LV, HV and EHV). Unlike the smart solutions, the conventional options are considered to increase in cost over the years as material prices increase. The starting costs of the first three solutions listed are based on DPCR5 figures taken from Ofgem's analysis.

To derive specific costs for the 'new feeder' and 'split feeder' solutions, an assumption has been taken regarding the length of circuits. It is assumed that at LV circuits are 1km, at HV they are 4km and at EHV they are 15km. These assumptions are reflected in the costs attributed to these solutions. It is possible to alter the costs directly if a user wishes to consider circuits of different average length.

Beyond the splitting of feeders and replacement of transformers, there is also the option for minor and major work at LV, HV and EHV. These options allow for the cases where more significant investment is needed for portions of the network that have undergone significant periods of load growth. The costs associated with these options do not come directly from DPCR5 figures, but have been agreed with the Network Operators as being reasonable in facilitating a wholesale reinforcement that would serve to increase headroom by an order of magnitude. Therefore, they are necessarily high and will appear at the lower end of the priority stack.

Appendix 2 – Example of different data availability for SIM and Trials

The table below shows the data required to support real time cable ratings. This example shows that for the SIM some generic assumptions will need to be made as it will not be possible or practical to provide all the data items.

Information	SIM	Trial
How the cable is laid (i.e. in a group or ungrouped, ducted or unducted)	Generic assumption	Determine from viewing plans in EMU
Duct characteristics	Generic assumption	Determine from viewing plans in EMU
Cable/duct configuration	Generic assumption	Plan info
Conductor type and size	EMU	EMU
Insulation type	EMU	EMU
Sheath type	EMU	EMU
Soil resistivity	Generic assumption	Location specific assumptions
Initial Conductor temperature	Season / Day based assumption	Measurement or calculated value using real time data
Soil or air temperature	Season based assumption	Measurement
Soil depth	Generic assumption	May be able to find something from plans or find when digging to fit sensors
Thermal resistivity	Generic assumption	Can map out areas of different type of ground
Drying out of soil	Generic assumption	Measurement
Load curve	Data from EST energy model	Measured data / EST model prediction
Loss load factor	Generic assumption	Calculated from measurements
Soil thermal diffusivity	Generic assumption	Measured / based on local assumption
Utilisation	Generic assumption	Calculated from load data

Appendix C – Use Cases

1. Develop long term plan to handle load related growth

Context of use   Strategic planner develops a long term plan for a set of primary networks that includes Bill of Materials (BOM), direct budget and required labour mix. The plan can then be used to support a price control submission and/or to guide to Procurement/HR to give a long term forecast of the required labour /.

A strategic planner may wish to use different sets of cost variables and weightings according to the nature of the plan. For example they may wish to create a plan that reflects future values for CML / CI incentive rates or benchmark costs rather than current values.

Having the ability to select / deselect techniques to be applied allows the user to compare traditional reinforcement with a smart grid approach and compare the cost of solutions that are considered high or low risk.

A single simulation run for the Strategic Planner constitutes one-by-one analysis of selected primaries in a manner similar to 11kV Planner and aggregation of the highest ranked solution for each network into a summary report

Scope	SIM	
Level	Blue	
Primary Actor	Strategic Planner	
Stakeholder & Interests	Stakeholder	Interest
	Strategic Planner	Produce long-term plan to handle load-related growth
	SIM	Create BOM, direct budget and required labour mix

Trigger

Preconditions   User logged in to SIM with username and password

Minimal Guarantees   Maintain a log of user actions

Success Guarantees   Long-term plan is produced

Frequency   Yearly

Main Success Criteria

1   Create multiple simulation runs by setting area of analysis, patches, prediction horizon, load scenarios, asset cost, incentive rates, NPV criteria, failure criteria, specific intervention techniques,

2   Run simulation and save results to store (see 1.2)

3   Browse and compare results
4   Strategic planner selects an aggregation to be implemented
5   Produce BOM
6   Produce direct budget
7   Produce required labour mix
8   Model at least primary and its directly connected primaries at a time
9   Maximum processing time is 1 day for a DNO area

Extensions

1a   Tag and group networks
         Select networks by attribute
              o   network level (primary, feeder, distribution substation)
1b   o   overground / underground
              o   rural / urban / commercial
              o   network size

2. Browse and Compare results (aggregation)

Context of use

Scope	SIM	
Level	Blue	
Primary Actor	Strategic Planner	
Stakeholder &	Stakeholder	Interest
Interests	Strategic Planner	Browse and compare results
	SIM	Display aggregated results from multiple simulation runs

Trigger	
Preconditions	User logged in to SIM with username and password
	Solutions available in solution store
Minimal Guarantees	Maintain a log of user actions
Success Guarantees	Display aggregated solutions and solution details
Frequency	Yearly

Main Success Criteria

1   Set of runs to be compared can be selected
2   Display aggregate solutions for the selected primaries in a tabular view (intervention techniques x years) with cells listing number of interventions, cost and required labour
3   Filter solutions
4   View multiple solutions at a time

3. New local generation

Context of use	11kV Planner is operating on an area network and several adjacent networks, looking at a well-defined region of the circuit to connect a new local generation following a customer request.

Scope	SIM	
Level	Blue	
Primary Actor	11kV Planner	
Stakeholder &	Stakeholder	Interest
Interests	11kV Planner	To ensure that a new local generation is connected
	SIM	Create patch reflecting the selected solution

Trigger	Customer request
Preconditions	11kV Planner logged in to SIM with username and password
Minimal Guarantees	Maintain a log of user actions
Success Guarantees	A patch reflecting network change is produced
Frequency	Daily

Main Success Criteria

1. Create multiple simulation runs by setting area of analysis, connection options, patches, prediction horizon and load scenarios
2. Run simulation and save results to store
3. Browse and compare results
4. 11kV Planner selects a result to be implemented

4. New load connection planning

Context of use   11kV Planner is operating on an area network and several adjacent networks, looking at a well defined region of the circuit to connect a new load following a customer request.

Scope	SIM	
Level	Blue	
Primary Actor	11kV Planner	
Stakeholder &	Stakeholder	Interest
Interests	11kV Planner	To ensure that a new load is connected
	SIM	Create patch reflecting the selected solution

Trigger	Customer request
Preconditions	11kV Planner logged in to SIM with username and password
Minimal Guarantees	Maintain a log of user actions
Success Guarantees	A patch reflecting network change is produced
Frequency	Daily

Main Success Criteria
1   Create multiple simulation runs by setting area of analysis, connection options, patches, prediction horizon and load scenarios
2   Run simulation and save results to store
3   Browse and compare results
4   11kV Planner selects a solution to be implemented

5. Run Simulation and save results to store

Context of use

Scope	SIM	
Level	Blue	
Primary Actor	11kV Planner	
Stakeholder &	Stakeholder	Interest
Interests	11kV Planner	Run simulation and save results to store
	SIM	Save results to store

Trigger	Engineer request
Preconditions	11kV Planner logged in to SIM with username and password
	Simulation run created
Minimal Guarantees	Maintain a log of user actions
Success Guarantees	Results saved to data store
Frequency	Daily

Main Success Criteria

1   Create a set of solutions
2   Save solutions to data store

6. Asset replacement/diversion

Context of use	1 External trigger (e.g. safety requirement, new technology solution, condition of asset highlighted from inspection, quality of supply problem, voltage complaint, interference of supply, repetitive interruptions due to failing asset) 2 Internal trigger (e.g. exceed 100% design load)

Replacement options
- Like for like (nearest modern equivalent)
- Replace with improved asset
- Change capacity (under or over utilised asset)
- If cable or overhead line change route or switch from one type to another
- Forced to move asset (e.g. loss of legal rights)

Scope	SIM	
Level	Blue	
Primary Actor	11kV Planner	
Stakeholder &	Stakeholder	Interest
Interests	11kV Planner	Minimise network downtime and improve reliability
	SIM	Create patch reflecting network change
Trigger	Fault rate threshold is reached OR quality of supply is affected OR customer request	
Preconditions	User logged in to SIM with username and password	
Minimal Guarantees	Maintain a log of user actions	
Success Guarantees	A patch reflecting network change is produced	
Frequency	Daily	

Main Success Criteria
1 Create multiple simulation runs by setting area of analysis, replacement options, patches, prediction horizon and load scenarios
2 Run simulation and save results to store (see 1.2)
3 Browse and compare results (see 1.3)
4 11kV Planner selects a solution to be implemented

7. Browse and compare results (single result)

Context of use

Scope	SIM	
Level	Blue	
Primary Actor	11kV Planner	
Stakeholder &	Stakeholder	Interest
Interests	11kV Planner	Browse and compare results from different simulation runs
	SIM	Display results

Trigger	11kV Planner wants to browse the results store
Preconditions	11kV Planner logged in to SIM with username and password Simulation results available
Minimal Guarantees	Maintain a log of user actions
Success Guarantees	Display a ranked list of solutions and solution details
Frequency	Daily

Main Success Criteria
1   Set of runs to be compared can be selected
2   Display a ranked list of solutions
3   Filter solutions
4   View details of multiple solutions at a time

8. Explore network model

Context of use

Scope	SIM	
Level	Blue	
Primary Actor	11kV Planner	
Stakeholder &	Stakeholder	Interest
Interests	11kV Planner	Explore authorised network model with some patches applied
Trigger	11kV Planner wants to browse the network model	
Preconditions	11kV Planner logged in to SIM with username and password	
Minimal Guarantees	Maintain a log of user actions	
Success Guarantees	Display the network model in a geographic layout	
Frequency	Daily	

Main Success Criteria

1   Display the authorised network model
2   Allow the 11kV Planner to add, remove, [de-]select patches
3   Display detailed information about assets
4   Provide standard power network analysis functionality to the 11kV Planner

9. Alternative approaches to network modelling

Context of use	Contrast the approach adopted in the EPSRC CASCADE project with the selected modeler and any alternative options.
Scope	SIM
Level	Blue
Primary Actor	Research User

Stakeholder & Interests	Stakeholder	Interest
	Research User	

Trigger	N/A
Preconditions	User logged in to SIM with username and password
Minimal Guarantees	Notify the user in case of any errors
Success Guarantees	Ability to plug in different network modelling modules and compare results
Frequency	

Main Success Criteria

1   Ability to reconfigure, deconstruct and re-engineer SIM components.
2   Create multiple simulation runs by setting area of analysis, connection and replacement options, patches, prediction horizon, load scenarios, asset cost, incentive rates, NPV criteria, failure criteria, specific intervention techniques
3   Run simulation and save results to store (see 1.2)
4   Browse and compare results (see 1.3 and 3.3)
5   Model at least primary and its directly connected primaries at a time

10. Alternative approaches to cost modelling

Context of use	Compare the proposed approach with other industries' methods, latest SAS research, and the TERA (Techno-Economic Research Assessment) Tool developed by Cranfield.
Scope	SIM
Level	Blue
Primary Actor	Research User
Stakeholder & Interests	Stakeholder Interest Research User
Trigger	N/A
Preconditions	User logged in to SIM with username and password
Minimal Guarantees	Notify the user in case of any errors
Success Guarantees	Ability to plug in different economic models and compare results
Frequency	

Main Success Criteria

1 Ability to reconfigure, deconstruct and re-engineer SIM components.
2 Create multiple simulation runs by setting area of analysis, connection and replacement options, patches, prediction horizon, load scenarios, asset cost, incentive rates, NPV criteria, failure criteria, specific intervention techniques
3 Run simulation and save results to store (see 1.2)
4 Browse and compare results (see 1.3 and 3.3)
5 Model at least primary and its directly connected primaries at a time

11. Hybrid optimisation & multi-objective optimisation/decision support

Context of use	Multi-objective problems can be modelled as single-objective by using objective ordering. For the problems within the scope of FALCON it may be difficult to establish the objective priority in advance. The cost to the decision maker is, therefore, very high, as the aggregating fitness function directly impacts search, possibly causing it to miss some compromise solutions. In contrast, a multi-objective problem formulation allows the practitioner to delay the choice until the tradeoff surface is obtained, therefore improving quality of obtained solutions.
Scope	SIM
Level	Blue
Primary Actor	Research User

Stakeholder & Interests	Stakeholder	Interest
	Research User	

Trigger	N/A
Preconditions	User logged in to SIM with username and password
Minimal Guarantees	Notify the user in case of any errors
Success Guarantees	Ability to change optimisation method and presentation of results
Frequency	

Main Success Criteria

1   Ability to develop and set new optimisation (search) algorithms.
2   Create multiple simulation runs by setting area of analysis, connection and replacement options, patches, prediction horizon, load scenarios, asset cost, incentive rates, NPV criteria, failure criteria, specific intervention techniques
3   Run simulation and save results to store (see 1.2)
4   Ability to create custom visualisation of solutions and solution sets
5   Browse and compare results (see 1.3 and 3.3)
6   Model at least primary and its directly connected primaries at a time