WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

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Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

NIA Project Annual Progress Report Document

Date of Submission

Jun 2022

Project Reference

NIA_WPD_058

Project Progress

Project Title

Peak Heat

Project Reference

NIA_WPD_058

Funding Licensee(s)

WPD - Western Power Distribution (East Midlands) Plc

Project Start Date

February 2021

Project Duration

1 year and 4 months

Nominated Project Contact(s)

Ricky Duke

Scope

This project presents a unique opportunity to learn to what degree heat pumps will impact the LV networks, during the average winter day, the average winter peak as well as in a 1 in 20 winter event. The project will also investigate the market for domestic thermal storage and the ability of thermal storage to help solve constraints on the distribution network. The project will deliver this through five work packages:

1. Customer segmentation and archetype creation - defining the relevant archetypes of interest
2. Heat market landscaping – characterising the range of technologies with a focus on domestic thermal storage
3. Customer modelling - exploring the range of impacts on load profiles from heating technologies including modelling the impact of ‘1 in 20’ peak winter condition, and the flexibility that these may deliver.
4. Area typology modelling - assess the impact that heat electrification will have on four local distribution network typologies.
5. Cost benefit Analysis, analysis and recommendations - drawing together all the findings from the research. This will include conducting a high-level CBA to identify the potential lowest cost options

Objectives

- Look at the latest heat pump loads based on current strategies around heat pump operation (it should be noted that there has been significant development in controls and optimisation strategies for heat pumps in the last few years).
- Investigate the impact of heat pumps based on specific typology areas, considering the effects of clustering on our network.
- Investigate the trade-off between smart shifting of loads and cost to upgrade the network.

- Access the impact of a peak winter (1 in 20) on the network due to both direct (e.g. poorer heat pump performance in cold conditions) and indirect (e.g. customer behaviour during these events) effects.
- Examine the potential market and role for domestic thermal storage.

Success Criteria

This project will be successful if is clearly identifies and characterises the range of flexibility and storage mechanisms which can be used to help reduce the impact of heat pump loads on the distribution network.

This will be broken down into a number of specific success outcomes:

- Creation of demand profiles that can be incorporated into main business planning tools for future network development planning and load growth modelling
- An assessment and understanding of how heat pumps operate in different types of buildings (e.g. construction, size) and regions of our network. Clarity and further understanding of the impact of factors such as building stock and climate on profiles.
- A better understanding, including profiles, of how heat pumps perform in cold weather conditions.
- Assessing the impact that the electrification of heat will have on different LV distribution network typologies
- An understanding of how and when can heat load be shifted to manage network loading whilst maintaining the required customer service.
- An overview of the sources of flexibility and how thermal storage stacks up as an enabler of flexibility. This includes assessing the overall economic case for these sources versus upgrading the network.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

Performance against the project success criteria is as follows:

1. Creation of demand profiles that can be incorporated into main business planning tools for future network development planning and load growth modelling. COMPLETED.

Time series demand profiles have been created for different house archetypes under different scenarios, including outdoor temperature scenarios, flexible tariff scenarios, and heat pump flexibility scenarios. This data has been provided in an Excel format that can be easily used by the wider WPD team. In addition, time series demand profiles have been provided in Excel format for each of the distribution substation archetypes, again including different flexibility scenarios, and also for different heat pump uptake scenarios.

2. An assessment and understanding of how heat pumps operate in different types of buildings (e.g.construction, size) and regions of our network. Clarity and further understanding of the impact of factors such as building stock and climate on profiles. COMPLETED.

Individual house heat modelling was performed in work package 3. This included modelling for different building archetypes, which indicated how heat pumps perform differently dependent on the size and thermal insulation of residential buildings. The load was modelled over a 2-month period (January and February) for average and 1-in-20 (coldest) winter periods, so a comparison of how load profiles vary based on outdoor temperature could be made.

3. A better understanding, including profiles, of how heat pumps perform in cold weather conditions. COMPLETED.

As per the above point, load profiles from average and 1-in-20 peak winter periods were provided for all of the building archetypes and flexibility scenarios considered in work package 3. As expected, the 1-in-20 winter profiles had higher demands than the average winter, and therefore they were used for the peak load modelling.

4. Assessing the impact that the electrification of heat will have on different LV distribution network typologies. COMPLETED.

To assess different LV distribution network typologies, several distribution substation archetypes were created based on the number and type/mix of building archetypes that were connected to each substation investigated.

In order to perform the network level modelling, an assignment of the homes that would have heat pumps installed had to be created. Heat pumps were allocated to house archetypes based on which archetypes were considered most suitable for heat pump installation, for example larger houses with space for heat pumps and good insulation
are better candidates for heat pumps than smaller houses with poor insulation.

The level of heat pump uptake was adjusted based on a moderate and a high uptake scenario, in accordance with forecasted heat pump values taken from WPD's Distribution Future Energy Scenarios (DFES). The network level modelling was then performed using the PLEXOS software package. Using PLEXOS allowed for stochastic load
profiles to be included in the analysis, i.e. each individual customer connected to a distribution substation archetype had their own unique load profile, this accounts for diversity between different households. This modelling provided the expected peak load on each distribution substation archetype.

The distribution substation peak loads were also modelled based on different flexibility scenarios, similar to those investigated in work package 3. The network modelling provided an assessment of which substation archetypes were forecasted to be overloaded with the inclusion of heat pumps, and for the different flexibility and heat pump uptake scenarios.

5. An understanding of how and when heat load can be shifted to manage network loading whilst maintaining the required customer service. COMPLETED.

Different flexibility solutions have been modelled in work packages 3 and 4 to provide an indication of the amount of peak load reduction and load shifting that can be achieved through adoption of each solution. The flexibility solutions considered included hot water flexibility (allowing the heat pump to generate hot water at flexible times), temperature flexibility (where heat pump users have more flexible temperature settings during the day), installing buffer tanks, installing electrical batteries, and various combinations of the aforementioned solutions. At the individual house level the modelling found that, depending on the flexibility solution applied, there could be a tendency to shift the load to different times during the day rather than to reduce the overall load.

6. An overview of the sources of flexibility and how thermal storage stacks up as an enabler of flexibility. This includes assessing the overall economic case for these sources versus upgrading the network. ONGOING.

An assessment of flexibility has been performed in the network level modelling. The results from the network level modelling led to the development of a cost benefit analysis (CBA), and this CBA includes a comparison of the costs to implement flexibility solutions versus the cost of traditional substation reinforcement.

The cost benefit analysis is largely complete and awaiting review prior to finalisation.

Required Modifications to the Planned Approach During the Course of the Project

Modifications to the planned project approach are detailed below:

- The work package 3 modelling was planned to be completed in Excel, but this later changed to modelling in PLEXOS. It was planned to use PLEXOS in work package 4 from the outset, and using it for the individual house level modelling in work package 3 provided efficiencies when the load profiles were extended to the network level modelling. The load profile outputs from work package 3 were still provided in Excel format so that they can be used by the wider WPD team.
- The scope for work package 4 included development of LV feeder archetypes for the purposes of modelling the system, however during the course of the project this changed to development of distribution substation archetypes. Detail on the number and type of customers (e.g. detached houses, flats etc.) connected to each LV feeder was not available for this study, but this information was available at the distribution substation level. Hence substation archetypes could be created based on the number of customers and the representative mix of house archetypes connected to each substation. In total, 16 of distribution substation archetypes were created for the work package 4 modelling.

Lessons Learnt for Future Projects

A number of lessons have been learnt on the project to date. These are summarised for each work package below.

Work Package 1 – Archetype creation:

- Split sites (sites with split 11kV busbars) need careful consideration since the demand headroom information for these sites can be misinterpreted. The headroom should be confirmed with reference to the information presented in the Long Term Development Statement.

Work Package 2 – Heat market landscaping

· Heat pump manufacturers were consulted to determine the most appropriate hot water generation strategy for heatpumps. Several different approaches can be adopted, with some manufacturers recommending two one-hour generation periods ahead of the morning and evening demands and others recommending charging the cylinder in the middle of the day when outdoor temperatures are highest. For customers on a cheaper overnight tariff, hot water can be generated in these periods to reduce costs. Heat pumps can also be set up to recharge the cylinder whenever the temperature falls to 10°C below the set temperature. The difference between the actual temperature and the set temperature will determine what capacity the heat pump operates at, and hence how much current it draws. Because hot water can be stored efficiently for several hours, hot water generation is an important source of flexibility. However, it can also be a source of peaks on the network, if many homes have heat pumps set to generate hot water in the same short window each day.

Work Package 3 – Customer modelling

- It was found that the analysis that was planned to be completed in Excel for work package 3 (modelling the houseusing inputs from

AECOM) can be undertaken successfully in PLEXOS. As such, the PLEXOS model was preparedt o represent the house as a heat battery, optimise heat pump space heating demand, including non-electric heating demand, and hot water / thermal storage use according to price optimisation, ensuring temperature does not drop below a certain limit.

- Initial results from modelling by AECOM of heat demand profiles for homes showed slightly unrealistic ramp up times and assumptions around heating capacity. Model reruns were made to include dynamic set-point adjustment prior to start of heating to cater to extreme cold periods and heating capacity limits, and adjustment of the heating capacity limits based on heat loss calculations.
- Differences between profiles produced by the AECOM building physics model and profiles produced in PLEXOS (underestimation of heat demand in PLEXOS model on coldest days) can be explained by the absence in PLEXOS of the ability to model the effect of thermal mass of a building. The PLEXOS profiles were brought in line with AECOM profiles by applying a factor representing the effect of this thermal mass variable.
- At the individual house level on a variable tariff it was found that peaks were shifted from evening periods to morning periods, rather than reduced. Peaks were higher in scenarios with electrical batteries, as these are an additional load. However, by applying limits to total electricity demand, loads could be spread more evenly across the day, and peaks could be reduced with the addition of storage. This illustrates the importance of having the right market signals to incentivise the use of storage in a way that is most beneficial to the network.
- The heat demand modelling assumes that the heat pump would be able to deliver all of a property's heat demand (i.e. additional heating through other electrical / resistive heating is not required). This assumption was based on guidance from heat pump manufacturers. Further study could include investigating the demand in existing properties with heat pumps installed, and assessing whether the heat pump alone provides sufficient thermal input to meet the demand.

Work Package 4 – Area typology modelling

- At the network level it was found that, with high levels of heat pump uptake, the introduction of flexibility measures shifted peak demands from high price to low price periods on an Agile-type tariff, rather than reducing peaks. Rather than introducing electricity supply limits to counter this, the ToU price was adjusted to try to encourage peak shaving rather than peak shifting. It was determined that a tariff with low overnight rates, high peak rates, and a linear change in prices between the two had the desired effect.
- Preliminary results from the network level modelling suggest that electrical batteries (50% uptake among homes with heat pumps) and flexible hot water generation are the most effective measures for reducing peak loads. Flexible hot water generation should be relatively easy to incentivise for households. However, batteries are expensive investments, and it is possible that the costs might outweigh the benefits. Temperature flexibility and buffer tanks were found to be less effective.

Work Package 5 – CBA, Analysis and recommendation

- Assumptions for battery uptake used in the Peak Heat project are illustrative only. In work package 4 it was found that there is not a great deal of additional benefit (in terms of reduction in peak loads) when uptake of batteries exceeds 50% of homes with heat pumps. However, it is noted that battery uptake is forecasted to be much lower in practice. DFES indicates that only around 2% of all WPD customers will have heat pumps in 2030, in the Consumer Transformation scenario. The 50% uptake has been taken as the illustrative scenario for the Peak Heat project to provide an indication of the maximum amount of flexibility that batteries could offer if a wide rollout took place.
- The CBA model confirmed that pre-emptive transformer replacements, i.e. avoiding multiple upgrades of the same substation, result in improved net present value benefits compared with the incremental upgrades to the next size up.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

The following list gives a summary of the project's outcomes so far:

- Work Package 1 report – detailing the selection of the primary substations for the study and methodology /development of the customer archetypes.
- Work Package 2 report – outlining the different types of heat pump technologies and flexibility solutions available. Also include commentary on forecasted market trends for heat pump uptake.
- Work Package 3 report – describing the methodology behind the individual house archetype load modelling, including presentation of the different flexibility scenarios considered and results from the modelling.
- Work Package 4 report – takes the outputs from work package 3 and scales them up to network level modelling. The report presents the development of the distribution substation archetypes alongside the assumptions used, and the results from the modelling are presented.

The above reports are available on the project website now, with the work package 5 report expected to be finalised and uploaded soon.

In addition to the above, the demand profile data from the individual house level modelling, and network level modelling, has been provided in an Excel format. Updates on the project have been disseminated to the wider WPD team in a virtual workshop (21 September 2021), and to interested industry stakeholders in the WPD Innovation Showcase Event (06 December 2021).

Data Access

The up-to-date outputs from the project can be found on the dedicated project website here. The website contains the relevant documentation and information that has been generated by the project team along with the latest progress summary.

Further details can be requested by contacting the WPD's Innovation Team (wpdinnovation@westernpower.co.uk).

Foreground IPR

No foreground IPR has been generated.