WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

CADET (Curtailment and Dispatch Estimation Toolkit)

CLOSEDOWN REPORT

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Contents

Executive Summary

The design of electricity distribution networks has historically used an 'edge case scenario' approach where the 'snapshot' of winter maximum demand with minimum generation and summer minimum demand with maximum generation output have been used.

The continued growth in the connection of DER (distributed energy resources) requires the network to be run in a more flexible manner by curtailing DER to defer significant capital expenditure for network reinforcement. In order to accurately determine the level of DER curtailment all 17,520 half hour periods in a year ideally need to be considered.

The aim of this NIA (Network Innovation Allowance) project was to develop a methodology to determine curtailment (and dispatch) of DER to an acceptable level of accuracy without having to consider all 17,520 half hourly periods.

The project was to be undertaken using two methodologies (Alpha & Beta) in three phases.

Method Alpha developed a Load Factor based technique to cluster half hourly data and validated it against the load duration curve for the calculation of total energy. Whilst this method was accurate in calculating the total energy it does not provide a suitable input for curtailment studies and for the calculation of the curtailed energy.

Method Beta attempted to parameterise daily demand curves into two models prior to modelling the effect of weather conditions and proposed a 'Four Peaks' model for further investigation.

The project has been closed down early as the techniques developed under Method Alpha were not suitable for further development in the calculation of curtailed energy. There is no benefit in expanding these techniques to other technology types or locations.

1 Project Background

The development of distributed energy resources termed DER (such as wind, solar photovoltaic, hydro, landfill gas, CHP etc.) will displace existing conventional methods of generation which historically have provided the necessary response characteristics to maintain the overall integrity of the network. The output of the DER is both variable and uncertain because of its intermittency. On the demand side too, uncertainties are growing due to changes in consumption patterns (e.g. with electric vehicles etc.). This scenario is thus transitioning to a less predictable and more stochastic world.

The most common form of analysis undertaken by any DNO for network planning is a load-flow study taking into account the maximum coincident load. With more DER (particularly wind and solar photovoltaic generation), the snapshot of the maximum coincident generation, will also become relevant for network planning. Currently carrying out a multitude of modelling analysis using half-hourly flows at each network point, for different types of DER and demand technology presents WPD with a scaling problem – doing this for an historical year is manageable, but trying to do this for forward planning purposes, using a further number of future energy scenarios would be impracticable using the current software. It is therefore imperative that new modelling capabilities are required to address these challenges.

It has been recognized that WPD will need to develop “forecasting future energy volumes across the network (under different scenarios) to highlight opportunities for flexibility, operability issues and to identify when strategic reinforcement will be needed” in order to facilitate its transition from DNO to DSO. The purpose of this project is to develop customer behaviour models for all types of demand, generation and storage that can be used as an input to the Energy Curtailment (and/or dispatch) Estimation techniques that WPD is developing. There are about 17,520 half-hours in a year; preferably this project will identify sufficient commonality that needs to be assessed to arrive at MWh figures for a year to perhaps several hundred. Specifically, this project will provide a more accurate visibility of future curtailment and potential for flexibility required under modelled scenarios.

2 Scope and Objectives

The main objective of the project was the development of customer behaviour models for all types of demand, generation and storage that can be used as an input to the Energy Curtailment (and/or dispatch) Estimation techniques that WPD is developing.

The project was to be delivered using two different methodologies each having three phases.

Objective	Status
Quantify the customer type behaviour to enable the estimation of energy curtailment and dispatch by network flexibility	✓
Reduce the number of studies required to achieve the first aim to a reasonable level of accuracy by the grouping of sufficiently similar snapshots of customer behaviour before electrical analysis is carried out.	✗
The development of customer behaviour models for all types of demand, generation and storage that can be used as an input to the Energy Curtailment (and/or dispatch) Estimation techniques that WPD is developing.	✗

3 Success Criteria

Success Criteria	Status
A data table of a number of snapshots, each with a breakdown of the main customer technology types describing their output in per unit basis on a MW installed base.	✓
A duration multiplier for each snapshot to describe how many half hours the snapshot represents.	✓
An index for each half hour reduced into a snapshot so that the underlying attributes of the half hour can be extracted, allowing the grouped curtailment of that snapshot to be apportioned across those specific attributes	✗
The methodology followed to determine the snapshot groupings documented for future usage and dissemination to other network and system operators.	✗

4 Details of Work Carried Out

The aims of the project were to:

(a) collate and use data to quantify the customer type behaviour to enable the estimation of energy curtailment and dispatch by network flexibility; and

(b) reduce the number of studies required to achieve the first aim to a reasonable level of accuracy by the grouping of sufficiently similar snapshots of customer behaviour before electrical analysis is carried out.

The work was to be carried out in phases using two innovative methods as follows:

Method Alpha

Phase 1**:** Analysis of half hourly data for a summer for the South West licence area by developing a Stochastic Load Flow algorithm, assessing load profile/correlations with meteorological data, and assessment of hourly, daily, weekly and monthly groupings.

Phase 2: Expansion of Phase 1 techniques across a yearly profile by developing the WPD generation/demand clusters; for each cluster, repeating the studies described in phase 1, for a set location; and developing other technology types excluded or minimised under phase 1.

Phase 3: Generalisation of techniques to other locations by applying the developed techniques to other licence areas and locations; and iteration to establish grouping techniques based on data from other locations.

Method Beta

Phase 1: Understand the three main independent variables affecting load profiles; weather, demand growth and generation growth across grouped climatic regions. Perform a study based on the "Monte Carlo" method – that of repeatedly analysing random inputs (conditions) to establish the distribution of outputs (loadings).

Phase 2: Expansion of Phase 1 techniques across a yearly profile by developing the WPD generation/demand clusters; for each cluster, repeating the studies described in phase 1, for a set location; and developing other technology types excluded or minimised under phase 1.

Phase 3: Generalisation of techniques to other locations by applying the developed techniques to other licence areas and locations; and iteration to establish grouping techniques based on data from other locations.

The following work was undertaken for the 2 methods described above:

Method Alpha

Phase 1: Using normalised mean profiles, a load factor based approach was used to cluster half-hour demand periods and various generation technology types at a number of locations in the South West. The load factor based approach was validated against a load duration curves in terms of electrical energy showing a 2% error. However when determining curtailed rather than total energy the error significantly increases and therefore not suitable in curtailed energy calculations. In addition the load factor based approach does not retain the data relating to a specific half hour and therefore is not suitable for curtailment analysis.

The correlation between the load profiles and temperature and humidity were investigated. It was concluded the assessment of load profile correlation with meteorological data particularly temperature and humidity cannot be used to determine if there is commonality. The results indicate there is little correlation between demand and temperature plus humidity. Also during the summer season there is a negative correlation between demand and temperature (9am to 9pm) and demand and temperature plus humidity (8am to 8pm). It was concluded the relationship between electricity consumption and temperature is non-linear and complex.

Since the output from Phase 1 was not suitable for further development Phases 2 & 3 were not undertaken.

Method Beta

Prior to modelling the effect of weather conditions on demand, the daily demand curve needed to be described as a number of parameters. A parametrised curve could be fitted to the observed curve by conventional optimisation techniques. The weather dependence can them be modelled as a variation of the parameters.

Two parameterised models (Three Peaks & Four Edges) were investigated on a selection of weekday and weekend demand curves for 4 locations. In the majority of cases either of the models produced a good fit. In order to make the optimisation faster and any correlation with weather data clearer a ‘Four Peaks’ model has been proposed for further investigation and development.

5 Performance Compared to Original Aims, Objectives and Success Criteria

Objective	Performance Review
Quantify the customer type behaviour to enable the estimation of energy curtailment and dispatch by network flexibility	Whilst a technique has been devised to quantify the customer type behaviour the results are not a suitable input for curtailment studies. This was due to the estimated energy curtailment not being of an acceptable level of accuracy.
Reduce the number of studies required to achieve the first aim to a reasonable level of accuracy by the grouping of sufficiently similar snapshots of customer behaviour before electrical analysis is carried out.	As the grouping of sufficiently similar snapshots did not retain the data relating to specific half hour periods it was not possible to undertake this objective
The development of customer behaviour models for all types of demand, generation and storage that can be used as an input to the Energy Curtailment (and/or dispatch) Estimation techniques that WPD is developing.	Not achieved

6 Required Modifications to the Planned Approach during the Course of the Project

Rather than change the project approach it was decided that the aims/objectives could not easily be achieved, so it was decided to terminate the project early.

7 Project Costs

Activity	Budget	Actual
WPD Project Management	£6,290	£5,726
Contractor/Consultancy Contracts	£140,384	£77,358
Purchase of Weather Data	£30,000	£2,400
Total Cost	£176,674	£85,484

8 Lessons Learnt for Future Projects

Topic/Area	Learning generated
Other	Though outside the scope of the Study, possible applications of the LF-based technique for system losses estimation and demand forecasting were identified
Behavioural	A direct comparison of the energy flows from each generator could not be carried out without having their actual MW outputs; each technology type has a separate normalised output
Data	The sparsity of the medium CHP (5MW to 50MW) generation type data hence there was no need to evaluate the load factors.
Data	There was no energy storage (e.g. pumped hydro, flywheels, heated water tanks etc.) profile provided but we note that WPD has been working with Regen to develop an approach to model the growth and operation of storage
Forecasting	It is imperative that many of the issues previously dealt with at the transmission level will become apparent at distribution voltages as DNOs transit to DSOs. For example, the integration of DG in any DNO can introduce new dynamics and time frames. Therefore, it is important, in the long-term, to investigate introducing system dynamic investigations as part of distribution network planning.
Data	As part of method Beta it was learned that much of the weather data is “modelled”, rather than actual observations.
Behavioural	As part of method Alpha, potential applications of the Load factor technique were identified, for example to assess 11kV network technical losses.
Forecasting	From the work carried out as part of Method Beta a ‘Four Peaks’ model has been proposed to parameterise the demand curve. Further investigation of this modelling technique is required

	before attempting to determine correlation with weather data.
Forecasting	The Load factor method of reducing data was found suitable to calculate ‘total’ energy over a period with an acceptable level of accuracy. However this method is not suitable to calculate energy curtailment or as in input to curtailment studies. Therefore the project was terminated early.

9 The Outcomes of the Project

The outcome of the project has shown that whilst a load factor technique may be used to calculate electrical energy it does not provide suitable inputs for energy curtailment due to the loss of accuracy and coincident output of demand and generation output.

The investigations carried out confirmed that the assessment of load profile/correlations with meteorological data, particularly temperature and humidity cannot be used to determine if there is commonality between the half-hours.

Therefore method Alpha of the project was not completed.

Method Beta developed the parameterisation of a demand curve before assessing correlation with meteorological data. A ‘Four Peaks’ model has been proposed, which requires further investigation before attempting to determine correlation with weather data.

The project has highlighted the use of a Load Factor technique not being suitable for use in reducing the data requirements for curtailment calculation. In addition one of the methods used showed difficultly in the correlating demand with weather data. However another method of parameterising the demand curve could be investigated/developed further in relation to correlation with weather data.

10 Data Access Details

Please see the WPD website for available project data

www.westernpower.co.uk/Innovation/Contact-us-and-more/Project-Data.aspx

11 Foreground IPR

All new learning that has been created throughout the project has been captured and made publicly available. More information can be found on the project webpage:

https://www.westernpower.co.uk/innovation/projects/cadet

12 Planned Implementation

Due to the early termination of this project, there is no output planned for business as usual.

13 Contact

Further details on replicating the project can be made available from the following points of contact:

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Glossary

Abbreviation	Term
CHP	Combined Heat and Power
DER	Distributed Energy Resourced
DG	Distributed Generation
DNO	Distribution Network Operator
DSO	Distribution System Operator
LF	Load Flow