A NETWORK PLANNING AND DESIGN DECISION SUPPORT TOOL FOR INTEGRATION OF LOW CARBON TECHNOLOGIES AND SOLUTIONS

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ABSTRACT

The predicted penetration rates of low carbon technologies (LCTs) for heating and transport will place additional stresses on planning and design activity within Distribution Network Operators (DNOs).

DNOs are obliged to provide cost-effective solutions for network reinforcement and designers are faced with the complexities of new technology and a rapidly changing use of the electricity network, particularly at low voltage. Performing network assessments and identifying the most feasible solution places a significant resource burden on network operators.

This paper provides an overview of a Network Planning and Design Decision Support (NPADDS) tool which is being developed as part of the UK's Customer-Led Network Revolution (CLNR) smart grid project. The tool is demonstrated by performing an assessment of a network area based on a range of LCT penetration scenarios for which it proposes solutions based on a database of historical or anticipated costs and benefits.

INTRODUCTION

The UK Government's plans to meet targets for legally binding carbon emission reductions (34% on 1990 levels by 2020) involve the proliferation of distributed generation and electrification of heating and transport [1]. The UK's Department for Energy and Climate Change (DECC) has published a set of scenarios for Low Carbon Technology (LCT) ownership [2]. The scenarios involve significant penetration of LCTs such as electric vehicles, heat pumps and solar photo-voltaics (PV).

DNOs face a higher risk of overloads and voltage excursions from permitted levels due to increased LCTs on the distribution network. The effort to address this so far has largely focussed on trials involving novel network technology and demand-side response, with little emphasis on transferring the knowledge into 'business as usual' activity. As a DNO licence condition [3], designers must provide the least cost feasible solution and will therefore be obliged to consider new interventions as they become viable. They will also need to keep abreast of advances in performance and costs.

To facilitate widespread connection of LCTs, the connections, design and planning functions within Distribution Network Operators (DNOs) must adapt to be able to:

- Routinely assess the effect of LCTs and the changing use of electricity over time;
- Allow for the inclusion of new solutions;
- Apply new design practices consistently;
- Cope with the anticipated volumes of connections.

The resource and skill levels needed are likely to increase significantly. Also, the use of a rigid set of policies and design guidance conflicts with a rapidly changing design environment.

CUSTOMER-LED NETWORK REVOLUTION

The Customer-Led Network Revolution (CLNR) project is being run by UK DNO Northern Powergrid along with project partners EA Technology Ltd, Durham University and British Gas. The project is funded under Ofgem's Low Carbon Network Fund. The project aims to trial customer propositions and network equipment with the underlying premise that additional capacity in the network can be released. In addition to network monitoring, the solutions being investigated in the project are:

- Enhanced Automatic Voltage Control;
- Demand-Side Response;
- Electrical Energy Storage;
- Real-Time Thermal Rating;
- Unified control system.

The project is split into five Learning Outcomes [4]. Learning Outcome 5 is dedicated to transferring the knowledge gained during the design, installation and operation of the interventions into business as usual activity.

One aspect of this is to create a decision support software tool to help DNO planners and designers assess the network and select the most appropriate solution (smart or conventional). This tool is called NPADDS (Network Planning and Design Decision Support).

SOFTWARE FUNCTIONALITY

NPADDS is a software tool aimed at network planners, designers and connections staff to allow the assessment of the distribution network for voltage and thermal issues and to propose solutions where constraints are identified. The following components of NPADDS are discussed:

- Network Assessment;
- Solutions Engine;
- Central Database.

The components are presented through a user interface to provide a consistent design environment which follows the process flow of the connections, systems design and planning functions within Northern Powergrid.

Network Assessment

The assessment function within NPADDS accesses network data held in a separate Oracle Spatial database. Parameters such as customer types, customer quantities, cable impedances, transformer types and spatial data are considered. In many instances, connections can be permitted without reinforcement following a cursory assessment of the network and more complicated studies are not required. To this end, the tool contains three levels of network assessment complexity: **heuristics, worst case and time-of-use**. The user selects the simplest assessment type and only considers a more complicated assessment if necessary.

Heuristics
In this context, heuristics refers to the application of rules to provide a basic assessment. A set of rules based on simple network parameters such as conductor length, type and number of consumers are being integrated into NPADDS. This assessment type highlights network areas that have ample capacity for the connection of moderate levels of additional load and reduces the workload associated with performing more detailed network assessments, such as those involving load flow engines. This is intended for high-volume, but simple, network connection requests.

Worst Case
This assessment type uses load flow engines and operates under the premise that all connection points are simultaneously consuming or exporting at their least favourable levels. Two scenarios are used:

- Maximum load, minimum generation, and
- Minimum load, maximum generation.

These typically correspond to summer and winter load profiles, particularly where generation is dominated by PV.

Time-of-Use (TOU)
A TOU assessment involves presenting customer load/generation usage profiles to a load flow engine to consider the daily and seasonal patterns of load use. The load flow engines being used by NPADDS are DEBUT™ for LV assessments (~415V) and IPSA™ for MV assessments (6.6kV to 20kV).

Solutions Engine

The range of solutions available that a designer may choose is increasing as new products come to market and emerging fields such demand-side response become viable. NPADDS applies a common set of design guidance in the form of a central database of solution costs and benefits. NPADDS provides solution support to a network designer by:

- Providing a ranked list of potential solutions to a given constraint using Solution Templates;
- Allowing the designer to model solutions on the network model and perform a detailed assessment.

Solution Templates
The Smart Grid Forum [5] produced a set of generic Solution Templates to parameterise the costs and benefits of a range of novel and conventional solutions. The templates include data on the effect on voltage and thermal headroom, costs, life expectancy, disruption and risk. Faced with a network constraint, NPADDS applies a cost benefit function to create a merit order of the applicable solutions, and combinations of solutions, that have the potential to resolve the constraint.

Detailed Solution Assessment
Once the network has been assessed for constraint violations and solutions have been proposed, using the tempaltes, the designer will have the option of assessing the proposed solutions in more detail by directly including them onto the network model. The accuracy of the solution modelling will be verified from results of the network trials.

Central Database

The NPADDS Database is the central repository for all configuration settings and generic data, storing load profiles for all classifications of customers, constraint limits such as permitted voltage levels, Solution Templates and clauses contained within policy and guidance documentation. Using metadata within policy documents, NPADDS will provide context specific guidance relevant to the user activity.

SOFTWARE IMPLEMENTATION

NPADDS is a web-based application built using the Microsoft.NET Framework. The application sits above two Oracle databases with a software interface separating the NPADDS business logic from its two load flow engines, DEBUT™ and IPSA™, for low voltage and high voltage analysis respectively. This separation will allow alternative load flow engines to be used with relatively little effort.

Neither engine provides a Microsoft.NET interface; therefore a wrapper has been developed to manipulate input and output text files. DEBUT™ is a desirable choice for low voltage assessments, as it supports seasonal time-of-use analysis, based on a set of user defined consumer profiles.

In order to consolidate the differing network and connectivity models expressed by DEBUT™, IPSA™, Northern Powergrid and other DNOs, a generic model for representing and communicating electrical networks is required. To meet this need, the Common Information Model (CIM) was selected for use in both the NPADDS software layer and the Oracle network database. The CIM is an open standard which is growing in popularity in the energy industry. It was originally developed by the Electric Power Research Institute (EPRI), and now consists of a collection of standards managed by the International Electro-technical Commission (IEC). By representing networks in an industry standard format, the potential for communication with other systems and data sets in the future is enhanced.

NPADDS DEMONSTRATION

In order to demonstrate the NPADDS tool, a sample LV network area has been selected. The Wooler Ramsey 20kV/400V substation serves the south-east area of Wooler, Northumberland, supplying 199 customers. The feeder which is the focus of our demonstration serves 126 domestic customers. The substation is a 315kVA ground mounted transformer and the feeder construction is a mix of overhead and underground radial conductors. There are 16 Economy 7 domestic customers (lower night-time tariff) and 110 standard single tariff domestic customers comprising of a mix of detached, semi-detached and terraced housing.

Assessment Scenarios

The LCT data provided by DECC include Low, Medium and High take-up scenarios. Using the Medium LCT growth scenario in [2], the predicted take-up rates for Heat Pumps, Electric Vehicles and Solar PV installations were mapped onto the housing stock type for various years (Table 1). For the network model, an even distribution of LCTs was assumed.

Year	LCT Quantities		
	Heat Pump	Electric Vehicle	Solar Photo-Voltaic (kW)
2012	1	0	12
2020	36	54	176
2025	126	171	296
2030	126	211	504
2040	126	272	656

Table 1 – LCT predictions mapped onto Wooler Ramsey

The electricity usage profiles were taken from [5]. Figure 1 shows a screenshot of the network visualisation aspect of NPADDS which allows the designer to view a network area and select feeders for assessment.

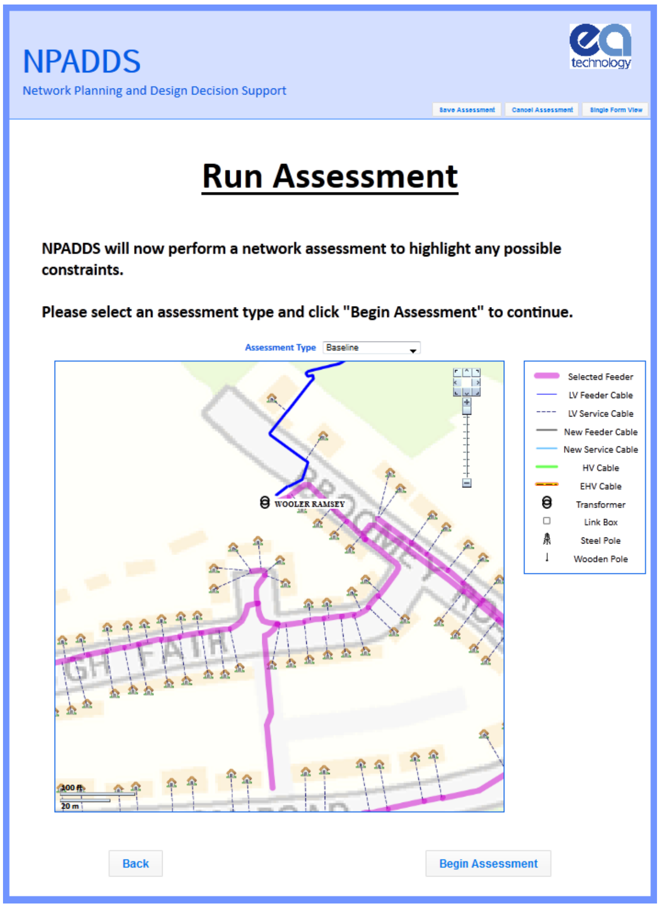

Figure 1 – NPADDS Network Assessment Wizard

Assessment Results

The TOU assessment within NPADDS was used to assess the maximum voltage drop and voltage rise along the feeder if no reinforcement of the network was undertaken. Substation and conductor loads were also compared with their respective static ratings.

Year	Maximum Voltage Drop (%)	Maximum Voltage Rise (%)	Peak Load (% of transformer rating)	Maximum Conductor Load (% of rating)
2012	5.7	1.4	76	66
2020	13.9	6.4	167	145
2025	26.6	11.8	446	359
2030	29.8	13.9	483	379
2040	31.9	18.2	537	426

Table 2 – Assessment results for LCT take-up rates to 2040 on Wooler Ramsey Feeder A

Bases on DECC's LCT scenarios, these results indicate that near-term network reinforcement should be significantly over-specified to cater for future demands. This raises the importance of forecast accuracy. Table 3 allows comparison of the Low, Medium and High DECC LCT take-up scenarios for 2020 [2].

Year 2020	Maximum Voltage Drop (%)	Maximum Voltage Rise (%)	Maximum Substation Load (% of rating)	Maximum Conductor Load (% of rating)
Low	13.2	4.9	155	134
Medium	13.9	6.4	167	145
High	15.2	7.9	188	158

Table 3 – Effect of Low, Medium and High LCT estimates on Wooler Ramsey Feeder A

Using the "Medium" LCT estimates, Figure 2 shows a load comparison between 2012 and 2020 from data extracted from NPADDS.

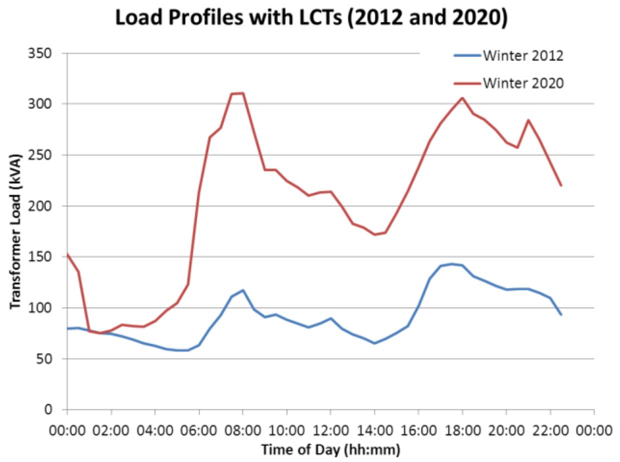

Figure 2 – Transformer Load Profiles (2012 and 2020)

Proposed Solutions

A cost benefit function is applied to the Solution Template data to produce a merit order for the 2020 "Medium" scenario as shown in Figure 3.

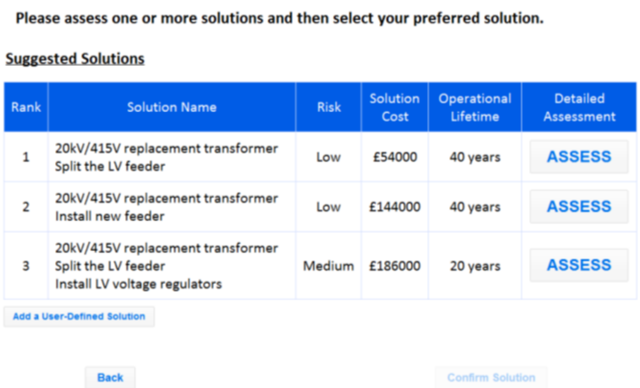

Figure 3 – Solution Template screenshot for 2020

The top three results produced by the cost benefit function are based on uprating the transformer and either splitting or installing a new LV feeder. In this specific case, the use of novel solutions such as energy storage and demand-side response either have high costs or cannot provide the required headroom compared with conventional solutions according to data in the Solution Template.

CONCULSIONS

The work of distribution network planners and designers will become more complicated with the advent of LCTs and novel solutions. Assistance will be required to select the most appropriate solutions in response to load growth and new network connection requests. Designs should also be applied consistently and linked to policies.

This paper presents the NPADDS software tool which can be used by planners to assess when the network can no longer support the envisaged load and by designers to provide the most cost-effective connections using both smart and conventional solutions.

The example shows the effect of LCT uptake scenarios on a heavily loaded network. The solutions proposed by NPADDS, using generic templates, are selected to allow the network to operate without further connections until 2020. On this example network no smart solutions are put forward by the decision support tool. Results from modelling the LCT scenarios into the future highlight the need for accurate forecasts of LCT penetration during network planning and design activity.

FURTHER WORK

The NPADDS software tool is still in development. Further work includes:

- Development of heuristics for simple network assessments;
- Assessing solutions within specific network areas;
- Modifying the solutions engine to account for the time that the solution is expected to be viable;
- Integrating MV and LV assessments to more accurately determine available headroom;
- Development of the policy database to provide context specific links to document clauses;
- Incorporating learning from the CLNR project and other LCNF and smart grid projects.

The NPADDS tool is scheduled for completion end 2013.

REFERENCES

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