IMPLEMENTATION OF DEMAND SIDE MANAGEMENT AS A SOLUTION FOR DISTRIBUTION NETWORK OPERATION AND MANAGEMENT

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ABSTRACT

This paper outlines an investigation of demand side management resources and potential impact on distribution networks to be undertaken by ESB Networks, the Irish distribution system owner and operator. The objectives and drivers of such a trial are introduced along with field trial implementation pre-analysis and potential network impact.

INTRODUCTION

The European Commission has mandated distribution network regulatory frameworks to incentivise demand side management (DSM), as an option to investment in peak capacity [1] For this to offer a feasible technical solution it is important to establish what reliable resource is available and its impact on distribution networks. In addition in order to harness the full benefits of future demand side management services offerings, whose most significant purpose is to address challenges at a wider system level, the benefits and implications for distribution networks needs to be known so that this would be included in the technical and commercial market and control framework for the delivery of such services.

In this paper ESB Networks considers how a comprehensive field trial of aggregated domestic demand response and storage could be undertaken that would enable in-depth analysis of demonstrated results for future planning purposes. The aim of such a trial would be to establish the impact and potential benefits to the distribution system.

Demand response and network impact measured using smart metering and network measurements, would be analysed and applied in advanced simulation and modelling, Loss reduction achievable could be quantified and the reliability of load response evaluated. The potential for network capacity deferral, asset optimization, local voltage management, load flattening or increasing variable generation integration will be assessed

PROJECT OUTLINE

To enable comparison across resources, the project would size the resource groupings to give a statistical expectation of delivering similar capacity. This comparable resource size is taken to be a 25 kW response.

The DSM resources compared would be as follows:

1. aggregated domestic loads for peak shaving
2. aggregated domestic loads for flexibility
3. aggregated domestic loads – control group
4. distributed battery storage (25kW)
5. medium sized battery storage

Separate trial groups for “load” and “flexibility” would be required, with loads suitable for turning OFF included and automated in group 1 and those suitable for turning ON in group 2. A single larger (commercial) customer could be part of group 1 and 2.

The aim of this project would be to establish the resource in terms of expected load and response, and its potential impact. The development of the systems or technologies required for a commercially deployed system is beyond the scope of this trial. Thus in so far as possible, simple techniques will be applied to ascertain the technical resource with analysis aided by superposition of measured results in advanced simulation and modelling.

RESOURCES

Domestic load – determination of the resource

The Irish Smart Metering trial 2009-2010 [2] gave an indication of the potential domestic DSM resource – showing peak load could be reduced by as much as 13.9%. This trial applied time-of-use tariffs which did not vary inter-day, therefore behaviour changes could be planned in advance. For dynamic demand side management, the flexible load is only that which can be instantaneously turned on or off.

	1700	**1800**	**1900**
other	6%	7%	5%
cooking	23%	20%	16%
PC, peripherals	11%	11%	11%
Fridge	26%	23%	21%
TV	8%	8%	8%
Lighting	11%	16%	23%
Washing + dry	14%	17%	16%
% flexible load	40.11%	39.70%	36.24%

Table 1: Average domestic load make-up over peak period

Different loads are suitable for reduction or increase. Loads suitable for reduction include refrigeration, auxiliary lighting or others depending on customer lifestyle. Loads offering potential demand increase include wet appliances, electric vehicles (EV), water heating (DWH) and storage heating (DSH). Domestic load curves from 5 EU counties [3] indicate that no more than 40% of domestic peak demand is from wet or refrigeration loads, as in Table 1

Based on Irish appliance penetration [4] and appliance load curves [5], 200 W of flexibility is indicated in Table 2 as the average household flexible load at the peak period.

Appliance	Penetration	Average at peak [W]	Penetration weighted load [W]
Dishwash	53%	79.52	42.1456
Dryer	64%	140.76	90.0864
Washer	98%	53	51.94
Fridge	100%	18	18
		Total	202.172

Table 2: Potential flexibly based on appliance load curves and penetration

This is in excess of the 130 W reported in [6] as potential flexible load per household in the UK. Applying the 13.9% reduction [2] (achievable through automation) to 40% (as per Table 1) of domestic after diversity maximum demand (ADMD) of 2.3kW gives a flexible load of 128W at peak time, in line with the 130W cited above. Taking a household figure of 125W, then a power of 25kW would require 200 customers.

Automated load response could be implemented by installing smart plugs for all appliances to be controlled, with pre-set non-delivery or delivery periods. Participants could be asked to leave wet appliances (for increase) loaded and set when they want a cycle run, such that once the smart plug for that appliance energises a wash / dry cycle will run. Automation in this manner will ensure that if a load is "available" it will respond as required, though its availability will depend on customer behaviour.

Selecting a trial area with a high penetration of DSH and DWH could give a good indication of the potential resource and impact where these are available or with future growth in these loads. Their inclusion would aid meeting the rated capacity for a group with typical rated demands of 2.6kW per DSH installation and 3kW per DWH installation. Both are load types suitable for group 2 (flexibility). It is estimated there have been 80k installations each of DSH and DWH in Ireland [ref Quantum] (nearly 40% [ref CSO stats]).

To establish the potential resource available for switching,, all group 2 participants will have smart plugs pre-set to simultaneously activate, with activated times varying over the trial period. The smart plugs could be set to turn ON every 10 hours (for a 2 hour duration) for example, or every 5 hours (1 hour duration), thus periodically testing the different time slots of the day or night over the duration of the trial.

The typical frequency and duration of periods where generation exceeds a pre-defined level relative to load will be determined through analysis of the output of local wind generation. This will be used to tailor the automated timing regime. The measured load response will then be applied in accurate high granularity time series modelling of the network to give an indication of the loss reduction and voltage effects, were the measured response during simulated "flexibility" periods to coincide with actual wind generation peaks.

In addition to a monitored pre-trial control period for all groups, a third group should be included in the trial to give control data specific to the test period to normalize any seasonal or anomalous loading periods. This group should be interspersed with the trial groups so that environmental or social factors do not disproportionately influence results.

Commercial / Industrial Load

Medium / large commercial or industrial loads would be excluded from this trial. The response of facilities with MIC's greater than 30KVA up to loads of several hundred kW response has been demonstrated through programmes including Winter Peak Demand Reduction Scheme (WPDRS), Powersave and Short Term Active Response (STAR) over durations ranging from 5 minutes (STAR 2008) to the 2 hour peak (WDPRS) to extended periods.

Simulation of this information and comparison with information obtained in a trial of smaller scale resources which would require an 8 homes to deliver just 1KW averaged response would be carried out in order to compare the benefits of both.

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Embedded generation

As of December 31st 2011 there is a total installed wind capacity of 1631MW in Ireland, of which 862 MW (53%) is connected to the distribution system. Of this, over 100 installations are MV connected (10kV or 20kV) with installed capacities from a few hundred kW to tens of MW. The vast majority of these feed into the MV busbar of 38/MV stations, over 20 feed at MV into 110kV stations, with a further 49 installations embedded on existing load feeding MV circuits.

Locating the trials on networks with embedded wind, offers scope for higher loss reduction, voltage control (depending on windfarm technology), and increased renewable generation hosting capacity.

Battery Storage

Both medium scale and smaller distributed storage, available with integrated control and communications in modular form, should be included in this trial. Community Energy Storage (CES) units as deployed in [ref AEP] of 25kWh capacity, max power 25kW, can be installed either to charge / discharge based on a predefined cycle or following network parameters. If these units were to be successfully demonstrated, multiple units could be coordinated either through SCADA or additional control technology (Distribution Energy Manager, DEM), however local and pre-set automated control is possible.

Storage facilitated network management services warranting investigation in this trial include peak shaving or load flattening and decoupled active and reactive performance as is an increasing feature of battery systems. Existing DG has been installed with firm capacity for export, such that full MEC can be exported at all times, therefore for trial purposes the charging and reactive power compensations activities of storage units could be controlled based on an assumed lower network capacity a predefined level below the MEC, indicating system functionality and the potential for network voltage management and additional export.

Electric vehicles

At a domestic charge rate of 3.6kW, the inclusion of EVs could be included and this would significantly reduce the number of participants in group 2 to reach the required capacity.

MicroPlanet LV regulators

ESBN conservation voltage reduction (CVR) trials currently underway have revealed an overage 0.5-0.8% (rural) or 0.9-1% (urban) reduction in active power for a 1% voltage reduction. MicroPlanet low voltage regulators could deliver local CVR for customers fed from a single distribution transformer. With a typical rural distribution transformer feeding 5-15 customers and ADMD of 2.3 kW, the rural CVR response measured to date under a 3% voltage reduction (which trials to date have shown not cause customer concern or breach or voltage standards) would deliver a demand reduction of 2 – 8.6 kW.

To ensure that the measured response of all groups can be accurately attributed to CVR or individual load DSM response, MicroPlanet local CVR should be applied to transformers feeding households which are *not included individually* in the trial groups. However MicroPlanet groups could be included in the resources contributing to the rated 25 kW capacity of group 1.

NETWORK SELECTION

For proof of concept purposes a network for this trial may be best selected to have a relatively high resource. The selection of a rural network is required to co-locate with embedded generation. ESB Networks smart metering analysis showed that the rural customer profile categories with highest annual loading are those in the southeast and southwest (7000-8000 kWh p.a. average). In spite of high DG penetration in the Northwest, this region consistently showed the lowest average demands.

POTENTIAL IMPACT

Deferred capacity savings

Analysis of the cost benefit of peak reduction or energy efficiency undertaken in [7] indicated savings of €700k p.a. per 1% saving in residential peak demand and just over €1m p.a. per 1% overall residential consumption reduction based on detailed network reinforcement plans for the next 10 years.

Table 3 below shows the peak reduction on a distribution transformer with customer connections as per ESB Networks LV design guidelines with a single 25kW DSM unit present, and the % penetration of EV, DSH or DWH to meet the 25 kW rating without any other domestic load contracted. In all cases the % penetration of EV, DSH or DWH is significantly lower than the national average penetration of nearly 40% for DSH or DWH or the national 2020 EV target of 10%.

Trafo kVA	No. custs	Planning peak [kW]	Peak reduction	EV	DSH	DWH
200	100	239.7	10.43%	6.94%	9.62%	8.33%
400	220	515.7	4.85%	3.16%	4.37%	3.79%
630	350	814.7	3.07%	1.98%	2.75%	2.38%

Table 3: Peak reduction with a single 25 kW DSM group and the % EV, DSH or DWH penetration (in isolation) required for 25 kW capacity

Figure 1 shows the % peak load reduction on these transformers based on connected household participation level (125W reduction each at peak) in the absence of any EV, DSH or DWH.

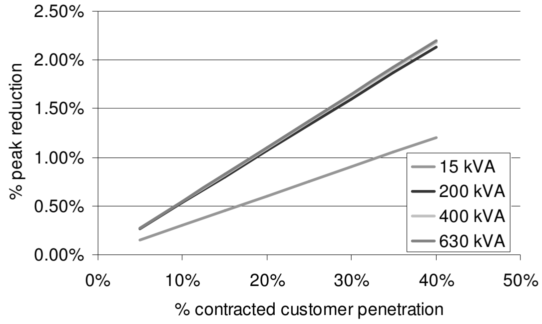

Figure 1: Peak reduction per % household DSM participation (no EV, DSH or DWH)

Figure 2 shows the peak reduction based on customer participation level with 5% EV penetration, 15% each DSH and DWH penetration on a network supplying 90% domestic load with a normal peak of 90% of rated capacity.

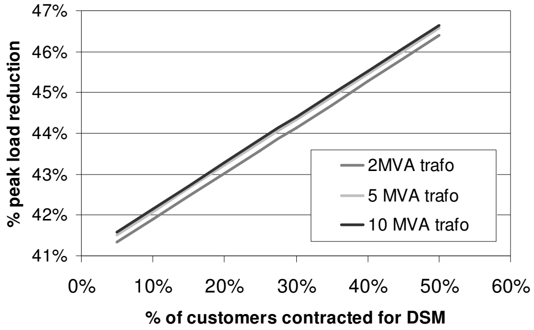

Figure 2: Peak reduction per % households DSM participation with 5% EV, 15% each DSH and DWH.

With approximately 70% of MV bus bars experiencing an evening peak and 80% of evening peak load comprising domestic load, even in the absence of DSH or DWH and with no growth in EVs, extrapolation of these reductions per domestic DSM penetration level indicates significant cost savings. However such extrapolation could only be undertaken if trials indicate a high reliability of response.

Loss of life without DSO framework

Analysis on the loss of life impact on a distribution transformers loaded to ESBN normal planning guidelines, investigated the case where there is a single DSM rated cluster (25 kW), 5% EV penetration and 15% each DWH and DSH. The baseline loading profile of the transformer was derived based on the average customer profile for rural customer in the southwest, revealed in investigation of Irish smart metering trials.

Figure 3 illustrates the distribution transformer loss of lifetime days per day where a DSM period of increase is applied over any period of the day.

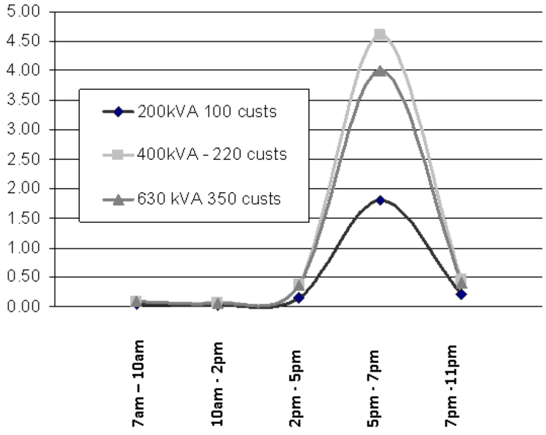

Figure 3: Transformer life days per day with unregulated DSM

Were this cyclic overload to be a regular feature of transformer loading, as is the potential where there is 3rd party operated DSM in the absence of a DSO agreed technical framework, it could have significant effects on transformer lifetime and increased costs in replacement and maintenance cycles. Conversely, if DSM were be managed to take into consideration DSO benefits, additional benefits could be leveraged from the single demand resource.

FURTHER QUESTIONS

Verification of the potential impacts above, the reliability and scale of domestic load response, comparison of the functionality, cost and operability of storage with aggregated domestic response will all be enabled through the field trials and analysis outlined above. Another key issue is that of the applicability of DSM or storage in network management, particularly that of voltage management in the presence of embedded wind generation. Such voltage management could prove a useful tool but local voltage management would require a level of automation and network intelligence so its implementation would have to be subject to proven benefits as will be investigated in this trial.

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