ACTIVATING RESIDENTIAL DEMAND SIDE RESPONSE TO RELIEVE NETWORK CONGESTION

Peter DAVISON
Newcastle University
Newcastle upon Tyne, UK
peter.davison@newcastle.ac.uk

Simon BLAKE
Newcastle University
Newcastle upon Tyne, UK
simon.blake@newcastle.ac.uk

Andrew SPENCER
Northern Powergrid
Newcastle upon Tyne, UK
andrew.spencer@northernpowergrid.com

Emma BURTON
Northern Powergrid
Newcastle Upon Tyne, UK
emma.burton@northernpowergrid.com

Stephane LEE-FAVIER
GenGame Ltd
Coventry Technology Park, UK
stephane@jarmacoe.com

ABSTRACT

The potential for Distribution Network Operators (DNOs) to facilitate future network growth at the lowest costs for customers will come not only from smarter, more flexible network assets, but also from utilising customer flexibility, in the form of demand side response (DSR). To date, dynamic forms of DSR have been used commercially, mainly with Industrial and Commercial (I&C) customers, by the transmission system operator (TSO), and trials have been undertaken by DNOs with I&C, SME and residential customers on projects such as the Customer Led Network Revolution [1] This paper provides initial results from another Northern Powergrid (a UK DNO) project, entitled Activating Community Engagement (ACE) This project is being carried out in partnership with GenGame Ltd, Serious Games International Ltd and Newcastle University. Its aims are to examine both a new recruitment method for engaging domestic customers, and to test the GenGame's effectiveness in delivering residential DSR services to the distribution network not through tariff based incentives, but through the medium of gaming. The project commenced in 2015 and is jointly funded by Northern Powergrid from its network innovation allowance and by Innovate UK. Recruitment commenced in November 2015 and the project runs to the end of 2017. This paper presents preliminary results from a small number of initial trial members detailing the engagement structure and end-user data.

INTRODUCTION

Static demand side response from domestic customers in the UK and Europe has been present for some time. Many consumers in the UK have for decades responded to a specific time of use (TOU) tariff, referred to as Economy 7, to give reduced rates for electricity overnight [2]. Whatever the personal motivation for engaging with such a tariff, whether related to working hours, a desire to save money by shifting existing practices or due to ownership of electric storage heating, the fact remains that the pricing incentives of Economy 7 have moved demand away from periods of peak loading.

The role of domestic DSR in the transition to smarter grids is a natural extension of this demand shifting capability. Increased information provision to end consumers in the form of smart meters and in-home displays combined with smart-enabled, remote controllable devices could lead to dynamic pricing schemes, automated load control and overall energy efficiency improvements [3, 4].

This paper will firstly outline the challenges faced by DNOs in sourcing a localised DSR from residential customers. An explanation of the initial engagement strategy of the ACE project follows including a detailed description of the initial case study area. Initial analysis of the early stage data is presented, followed by conclusions and discussion of the further work to be carried out.

CHALLENGES FACED BY THE DNO

Geographic vs Electrical

Access to a sizeable aggregated source of DSR in a targeted geographic area is clearly key to DNOs success in addressing localised network constraints. This contrasts with services such as frequency response, currently provided by aggregators to the TSO, where there is minimal need for geographic or electrical localisation. The largest level of aggregation at which a DNO could consider the use of aggregated domestic DSR is at the Grid Supply Point, but more commonly will be at the Primary substation level or below. Scenarios such as mitigation or deferment of network reinforcement, load switching services to accommodate more Low Carbon Technologies (LCTs) or embedded generation (EG) sources are likely candidates for service requirement, along with those outlined earlier. Constraints at higher voltage could be addressed by the provision of DSR from industrial and commercial customers but, for constraints at lower voltages, engagement with residential customers will be required.

Financial

If a DNO is able to reliably use residential DSR, in addition the emerging use of I&C customers, they will have a greater DSR resource available to them to address network constraints and avoid or defer network reinforcement The DSR may be contracted either directly or via aggregators and has, to date, been carried out successfully by the TSO for larger industrial and commercial customers, and in trials undertaken by the GB DNOs. Problems arise when considering a similar contract for residential consumers since the potential financial rewards on offer are likely to be less attractive due to the smaller kVA demand response achievable by individual residential customers. As such, outlining the rationale for personal involvement is extremely difficult when taking into account the perceived level of effort required [5].

Temporal

Whilst static ToU tariffs such as that trialled in CLNR [3] will provide some additional headroom throughout the year, the ability to target these to a specific geographic area at a specific time is limited. The initial trial period for the ACE project is aimed at identifying the DSR capacity to mitigate winter peak loading scenarios that only occur for a short number of hours. If a DNO were to retain residential DSR services all year round for such an event, the likelihood of a response being available when required would certainly be minimised. A stimulating method of engagement via either the DNO or the aggregator seems a sensible solution therefore, and represents one of the key factors of the GenGame which uses a dynamic approach to target a response within particular time periods.

COMMUNITY GROUPS: A POTENTIAL SOLUTION?

In an attempt to address the constraints and challenges outlined previously, Northern Powergrid is trialling The GenGame on its ACE project. The ACE project's recruitment techniques and the aggregation and control provided by The GenGame together produce a unique proposition to domestic consumers. It is hoped this method can be used to recruit participants in a targeted geographic area, encourage early participants to recruit additional participants in their neighbourhood, maintain interest over a long period of time whilst providing a response when needed by the DNO. The GenGame is an online platform designed to achieve this by using both gaming and competition and offering individual and community prizes for participation.

This approach represents a 'double dividend' for the DNO in that through the use of such community organisations the 'catchment area' of the group is likely to be small enough such that any available response remains relatively localised, and also the total of the financial incentive available in aggregation presents a more attractive sum to the group as a whole rather than for the individual.

Within the first phase of the project participants will be awarded points for use of appliances through a smart plug in their home and additional points for allowing remote control of whichever devices have been connected. These points will be awarded simultaneously to both the individual participants and to a nominated local charitable/community organisation. Prizes are available for both the community groups and individuals in this first phase although the prizes available as an individual are deliberately smaller than those on offer for the community group.

The benefit of the community groups is not however simply limited to their geographic location. There are a number of additional potential benefits to their involvement, which the project is testing.

- The community groups provide a pre-existing structure for recruitment. A nominated group leader for each group has the ability to communicate more effectively with existing group members and those who may be interested in providing support
- The group structure provides the possibility for both inter and intra group competition. This competitive element could engage more participants for the project as a whole.

Local organisations register for the trial through a nominated group leader and participants can choose to nominate an additional organisation if they do not support the existing groups in the project.

At the end of a stipulated period, the top 5 competing community groups share a total prize fund, which is awarded proportional to the number of points scored by each group. The overall prize fund total is proportional to the number of overall players.

EQUIPMENT

As an additional incentive for participating, each trial participant is given an internet of things (IOT) enabled smart plug. The plug can be controlled through use of a manual I/O interface on the plug itself, or through use of an application on a mobile or tablet device. This application also has a 'speedometer' type visualisation of voltage, power and current. These values are typically updated at roughly 5 second intervals. For the purposes of this project, these values are stored external to the application at a fixed 20 second resolution.

The remote method of control has been adapted for use in this project, such that GenGame in the role of the aggregator and actuator has the capability to issue an automated control signal to a specified combination of devices in the trial. In this manner, the form of DSR available sits firmly in the domain of dynamic demand side management (DSM). The willingness for an end user to not only experience external automated control has been commented upon previously [6]. The manual 'override' facility of the chosen device does allow the end user to 'opt-out' of a load control event, though clearly a magnitude of accumulated points are forfeited due to this action. A further expansion of the trial is likely to include the use of 'current clamps' to monitor whole house consumption as something of a proxy measure for smart meters.

TRIAL AREA AND COMMUNITY ENGAGEMENT

The wider area chosen for initial targeting is a largely rural area in County Durham, in the North East of England. The unitary authority (UA) for County Durham is Durham County Council. The UA area is additionally sub-divided into 14 local administrative areas known as area action partnerships (AAPs), with a brief which includes consulting with local residents regarding funding for local services and organisations. The specific initial trial area is focused on one of these AAP areas. The electrical network in this area is a section of radial 20kV MV distribution network comprised mostly of overhead line, which is likely to become constrained in the future.

Initial recruitment was carried out through discussion with the local AAP organisation. This was felt to be a suitable method of identifying and gauging the interest of local community groups. Further to this initial round of recruitment, the services of a local community coordination group have been contracted, in an attempt to improve the level of participation and to provide feedback on future recruitment and public engagement methods.

RESULTS

The initial results presented in this paper cover the period from 1/2/2016 to 28/02/2016 and are based on the small number of participants recruited over this period to develop analysis techniques pending the recruitment of additional participants. Figure 1 shows the average power observed on the total number of smart plugs in aggregate. The smart plug has a number of specific states and these are of importance as to the overall results presented here. The plug can be observed as being 'online', which by definition describes the fact that the plug is connected to its local Wi-Fi network. The plug can additionally be on or off, depending on whether or not a control signal has been sent to the plug or if the user has manually operated the plug. For the purposes of these initial results only times where the plug is observed as being 'online' and 'on' are of interest. Further work will examine when considering a larger sample as to the percentage of plugs which after having been handed out are simply unused, or have intermittent connections to the local Wi-Fi network. From the relatively small sample shown in Figure 1, a number of conclusions can be drawn. The difference between the available plug power for curtailment varies somewhat significantly between weekdays and the weekend (whether split into Saturday and Sunday or not). There usage of plugs also appears to follow roughly a typical domestic demand curve. One theorem is that after initially trialling a number of appliances in order to determine the appliance most likely to deliver the maximum points, that appliance will not be changed. If this was the case, then over a longer period of time it would be expected that the profile of available plug responses would be roughly flat throughout the day (although the effect of an appliances duty cycle must also be taken into account). The shape of the observed profile would however indicate that the more typical practice on average is to use appliances through the smart plug which are more 'to hand'. This is perhaps due to the relatively minimal number of load control events which have occurred to date, and could change significantly.

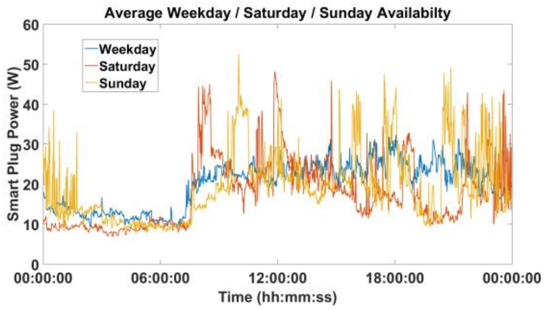

Figure 1 – Average Weekday, Saturday and Sunday power used through smart plug

Figure 2 shows the 95th and 99th percentiles of plug power values in the overall weekday period. As can be seen there is a significant difference between the 95th and 99th percentile values. The potential reason behind this apparently significant difference could we be due to the relatively limited amount of useful data which has been gathered to date. Within the period over which data has been presented in this paper, there is the inclusion of a large amount of 'start-up' time for each of the participants. None of the participants had a pre-existing smart plug and perhaps more time is needed before they become more accepting of the technology. These periods are represented by the plug being registered as online, but having no appliances used through it, thus registering large numbers of zero power readings, affecting the overall average. It is hoped that with greater numbers of participants and after more time to gather data, that more meaningful numbers can be attributed to these data analysis metrics.

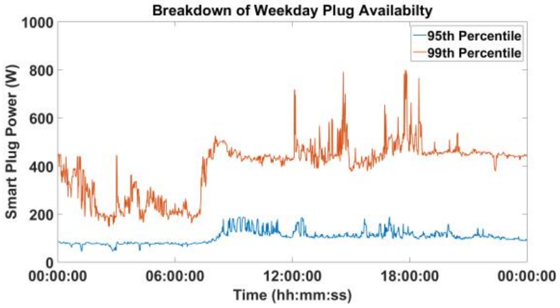

Figure 2 – 95th and 99th percentile of Weekday Smart Plug power values

CONCLUSIONS AND FURTHER WORK

This paper has provided an overview of the ongoing ACE project and has presented some preliminary results from the observed data from a small number of initial participants. The project runs up to the end of 2017 and recruitment of additional participants over this period is required before any statistical significance of the results can be determined, however it is clear that the role of the GenGame aggregator in the ACE project, and the combination of individual prizes and community prize funding to provide localised services to a DNO are key areas in which the results of this project will be unique. Over the remaining lifetime of the project, additional research will be carried out to determine optimum methods of engagement and also to understand the types of customers that are willing to participate in such a proposition and the types of domestic appliances these participants are comfortable offering for DSR, in an attempt to link up with existing work in the social science domain concerning the perceived flexibility of end users. If the trial proves to be successful this work will be followed up with the development of a planning tool that enables a DNO to estimate the residential DSR potential in specific geographic areas based upon the demographics of the area and the types of appliances available.

REFERENCES

[1] J. Yi, P. Wang, P. C. Taylor, P. J. Davison, P. F. Lyons, D. Liang, *et al.*, "Distribution network voltage control using energy storage and demand side response," in *Innovative Smart Grid Technologies (ISGT Europe), 2012 3rd IEEE PES International Conference and Exhibition on*, 2012, pp. 1-8.

[2] V. Hamidi, F. Li, and F. Robinson, "Demand response in the UK's domestic sector," *Electric Power Systems Research*, vol. 79, pp. 1722-1726, 12// 2009.

[3] G. Whitaker, "Insight Report: Domestic Time of Use Tariffs," http://www.networkrevolution.co.uk/project-library/insight-report-domestic-time-use-tariffs/2015.

[4] F. Economics, "Insight Report: Domestic Direct Control Trials," http://www.networkrevolution.co.uk/project-library/insight-report-domestic-direct-control-trials/2015.

[5] K. Buchanan, N. Banks, I. Preston, and R. Russo, "The British public's perception of the UK smart metering initiative: Threats and opportunities," *Energy Policy*, vol. 91, pp. 87-97, 4// 2016.

[6] M. J. Fell, D. Shipworth, G. M. Huebner, and C. A. Elwell, "Exploring perceived control in domestic electricity demand-side response," *Technology Analysis & Strategic Management*, vol. 26, pp. 1118-1130, 2014/11/26 2014.