Smoothing peaks and troughs: intermediary practices to promote demand side response in smart grids

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Smoothing peaks and troughs: intermediary practices to promote demand side response in smart grids

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Abstract

This paper investigates the development of Demand Side Response (DSR) in the context of smart grid initiatives on regional distribution networks in the UK. DSR is an emerging approach to augment asset management in the electricity sector, where network capacity is acquired from demand side actors (e.g. major commercial customers) who reduce their electricity demand at peak times by using their own generators or by shifting electricity consumption outside peak periods. DSR has a very different institutional arrangement compared to conventional network reinforcement for peak demand, since capacity is acquired via commercial and contractual arrangements rather than ownership and property rights. Thus, we cast DSR as an institutional innovation and identify important actors in such developments. Key among these are 'aggregators' who are companies that aggregate the DSR capacity from a number of commercial customers to provide capacity for the Distribution Network Operator (DNO.) Exploratory case study research was conducted by the authors as part of a smart grid initiative, with a particular focus on the work of aggregators. Our findings identify aggregators as intermediary agents situated between utility firms and customers with DSR capacity and brokering relationships between them. Aggregators create receptivity for DSR by identifying potential adopters of DSR (e.g. distribution network operators and electricity network customers) and construct persuasive and pervasive propositions that renders DSR a valid energy management initiative that accords with an organisation's business priorities and institutional arrangements. It is through this process that aggregators are important actors who facilitate and create a tighter fit between DSR and the contexts in which it is deployed. Thus, this paper provides insights on the work of aggregators in DSR developments and identifies them as potentially important actors in smart grid futures.

Key words: Demand Side Response; Aggregators; smart grids; institutional innovation; intermediaries; receptivity

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1 Introduction

Smart grids are promoted in the UK and other countries to address a number of challenges in energy supply and demand, which include decarbonisation of the electricity system, ageing infrastructure and to ensure affordable power (1, 2, 3, 4). An overall smart grids approach is defined by the European Commission as "*an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both in order to efficiently deliver sustainable, economic and secure electricity supplies*" (1). Following this broad definition, transitions to smart grids are socio-technical as it involves both social and technical changes that are likely to affect and replace established practices such as energy production, distribution and consumption. (5, 6, 7). Traditionally, electricity has been generated in large power stations and is distributed across a country (or even internationally) through a high voltage grid system. Electricity is then taken from this system and fed into a regional electric network infrastructure that supplies electricity to end users. This regional electricity network infrastructure is owned and managed by *distribution network operators* (DNOs). DNOs do not generate electricity; their responsibility is to ensure there is a reliable supply to all the domestic and non-domestic end users in their region and to do this in a cost-effective manner. Thus, in technical terms, distribution networks consist of, among other things, technical infrastructures situated between high voltage transmission grids and end users. When DNOs are faced with sustained increased demand for electricity, they would traditionally use engineering solutions to increase infrastructure capacity. This might include installing new power lines and building new substations. While such approaches to network management work well in a traditionally structured electricity distribution system, they do not fit emergent changes in the energy sector. Such changes include increased use of electricity for heating and transport as well as increased uptake of renewable and decentralised forms of energy production. These changes require more capacity in energy production and distribution as well as new forms of flexibility in the system such as energy storage and demand side interventions to avoid network failure. Thus, for a transition to flexible smart grids, there needs to be the development and uptake of innovations that would not only involve a change in technology, but also changes in human relationships, which both constrain and enable socio-technical transitions.

Developments of smart grids in the context of distribution networks include innovations to overcome network constraints where traditional network reinforcement is becoming expensive or inappropriate. A variety of technical approaches have been used to instrument, manage and control network infrastructure. Some include energy storage, such as battery packs, to serve peak demands or store surplus supply. A non-engineering smart grid measure is Demand Side Response (DSR), which is defined by Ofgem as the change in demand from a consumer in response to a price signal (9). In the UK, the National Grid has for a number of years used DSR to help manage peak loads on the national high voltage distribution system (10). At the regional distribution level DSR is in its infancy but is developing in various smart grid projects (11, 12, 13, 14). Here it can be used by DNOs to overcome network constraints (15). However, development of DSR is not without challenges. For supply side actors, such as DNOs, DSR is very different from how utilities in the energy sector typically manage network capacity. Traditional measures, such as network expansion, is upstream of the user's electricity meter where infrastructure (e.g. electricity distribution networks) is specified and sized to meet demand. Here, the engineered solutions to overcome network constraints are owned and entirely managed by the DNO itself. In contrast, DSR goes beyond the electricity meter into the premises of end users to reduce demand. A critical challenge associated with DSR therefore relates to its capacity to change practices of electricity demand (10). In such instances, rather than relying on the performance of assets that are controlled and owned by the DNO, capacity from DSR is acquired via commercial and contractual relationships. Thus, DSR can be regarded as an innovative method for managing assets that has very different institutional procedures compared with traditional and centralised arrangements of network reinforcement. Consequently, for DSR to develop and support low carbon and smart grid transitions, changes in the institutional arrangements that shape patterns of electricity production, distribution and consumption are needed (16). However, there is a paucity of research which explicates such institutional dynamics inherent with socio-technical change, which has to be considered to better understand development and uptake of DSR. This paper therefore addresses this gap in knowledge. Focusing on the DSR on a distribution network, it casts DSR as primarily, but not exclusively, as an institutional innovation.

Institutions are human relationships that structure opportunities via constraints and enablement (17). They provide order and predictability to social 'everyday' practices such as driving a car, forming a queue or indeed managing distribution networks. Seen in this way, institutional theory offers an approach to investigate how individuals or organisations shape and are shaped by social institutions, which in turn helps to create an understanding of how certain institutional arrangements develop and change (18, 19). Here institutional theory founded upon notions of rational choice from neo-classical economics is avoided and the new institutional school which views institutions as cultural explanations of social and cultural phenomena is drawn upon. Such theoretical perspectives have informed research on *inter alia* low carbon energy transitions (16) and sustainable consumption (cf. 20). For example, in the context of consumption, customer demand (e.g. mobility, comfort) is satisfied through material artefacts such as a car. In such instances, ownership and property rights constitute a dominant form of institution, where owning a car is a preferred institutional arrangement fulfilling the demand for mobility (*ibid)*. This institutional perspective provides an understanding of how patterns of production and consumption are bounded by institutional settings in society and identifies institutional innovation as necessary for alternative and potentially more sustainable systems to come about.

An institutional perspective on innovation relates to the process through which changes might occur in socially constructed rules that define and constrain everyday activities (21). Such a process involves multiple actors, including firms, industry associations and advocacy groups that are configured by their institutional environment; and engage in the transformation of institutional arrangements with different resources, justification principles and conflicting worldviews. Since DSR impacts upon multiple institutional environments such as DNOs, policy, end-users, and requires changes in these, this makes institutional theory an appropriate approach to explore developments of DSR. Research on DSR to date has focused on the role of certain key actors such as end users and system builders (cf. 22) who are important for the development of institutional arrangements required of DSR. However, little attention has been given to intermediary actors known as aggregators, who have been crucialin the development of DSR.

Aggregators are commercial firms that operate in electricity markets. They act as third-party intermediaries that engage with commercial and non-domestic electricity users to provide demand side response services for electricity grid operators (e.g. the National Grid and DNOs) (9). They do this by aggregating DSR capacity from a number of non-domestic industrial and commercial customers (I&C customers hereafter) to provide network capacity for the DNO. Thus, aggregators are potentially important players in energy futures. The role of aggregators could change as smart grid technologies develop. For example, the development and uptake of energy storage as source of flexibility to balance supply and demand and overcome network constraints is likely to affect the aggregator business model. The development of energy storage is, however, another matter and is not considered in this study. Rather, this paper focuses on aggregators as intermediary agents situated in between DNOs and I&C customers mediating and facilitating development and uptake of DSR and begins to unpack their somewhat hidden work in smart grid developments.

2 Theoretical perspective

The work of aggregators does not fit neatly into discrete institutional environments (e.g. energy producer, network operator or users), but in between particular institutional settings, notably DNOs, grid infrastructures and end users. Institutional theory was therefore selected to analyse development and uptake of DSR in energy sectors with a particular focus on the role of aggregators. This perspective identifies that institutions are the underlying rules of social activities, which guide what actors can and cannot do in particular situations (18, 19). Indeed, the availability of technical artefacts such as infrastructures also constrain and enables social activities, but institutions connects socio-technical configurations that work and stabilises these (cf. 8). Institutions are typically divided into formal and informal constraints (23). Formal constraints are the explicit rules that guide and constrain social activities, e.g. written policies and regulations. For instance, since DNOs are natural monopolies, their work is constrained by government regulations (e.g. the UK's Ofgem's RIIO-ED1 price control scheme) that affects to some extent what they can and cannot do. Informal constraints are the implicit codes and conventions, including norms and values that are embedded in everyday life. For example, engineers working in the utility sectors tend to follow cognitive routines and conventions that lead them to look in particular directions and not in others to overcome network constraints (24). Thus, institutions play a key role in stabilising existing and developing new socio-technical configurations (25; 26). Institutions are always developing, a process shaped by the availability of new technologies as well individual actors and their organisations (27; 28).

Indeed, formal institutions, such as regulations that affect energy sectors, are changing. For instance, following the UK Energy Act 2013, the UK regulator, OFGEM, launched a capacity market for demand side measures (22). However, this does not mean that DSR has become a mainstream activity in energy sectors to address capacity constraints on electricity utility networks. Rather, it can be viewed as a niche activity in these sectors with potential to grow and become mainstream. Further uptake of DSR requires a change in the informal institutions of electricity production and consumption. For example, DSR requires particular sets of skills and competences to identify and engage end users in such arrangements. However, such skills and working practices may not be common within DNOs, possibly constraining the development of DSR. Thus, while institutional change is necessary it is particularly difficult to achieve change in informal institutions.

Informal institutions are regarded as more pervasive, long lasting and difficult to change or move away from compared to formal institutions (29, 23). For example, while formal rules and regulations in the energy sector might change to support smart grid developments (e.g. DSR), informal institutions such as (cultural) routines that guide behaviour of social organisations (e.g. a DNO) can be harder to change. An institutional perspective recognises that change in formal institutions (e.g. regulations) is not sufficient to embed DSR in the institutional landscape. The potential for DSR to have significant impact on energy sectors is therefore not only constrained by existing regulations but also informal institutions, e.g. cultural routines and behaviour of actors operating in these sectors, including end users. Thus, following Jolly and Raven (30), institutional theory is useful to understand how innovations (e.g. DSR) might develop to become more embedded in energy sectors, i.e. develop into a more mainstream activity that is part of the broader institutional landscape. In this context, aggregators are identified as key social agents in shaping developments of DSR. As third-party intermediaries situated in-between a DNO and its customers, aggregators mediate and facilitate relationships between them, which is as an important aspect in development and uptake of DSR. Notably, this is because these actors have skills and competences lacking in DNOs to deploy DSR. Thus, we adopt the concept of intermediaries to understand the work of aggregators in shaping institutional arrangements of DSR.

Following the work of Moss et al. (31), we understand intermediaries as social actors who work in-between core actors (for example, producer and user, entrepreneurs and adopters) who make connections and enable a relationship between them. Intermediaries are far from neutral players, but are actively involved in ordering and defining relationships and as such act as mediators and facilitators of innovation and change. For instance, in an analysis of green electricity labelling schemes, Rohracher (32) investigates the role of intermediaries, notably nongovernmental organisations, to shift electricity markets toward a higher share of renewable energy resources. Here, intermediation activities reframe energy markets by simultaneously shaping supply-side structures and as an agent that articulate and translate consumer preferences on demand side. In a related study, Janda and Parag (33) use the conceptual term 'middle-actors' (not 'intermediaries') to investigate the work of building professionals to improve energy performance in buildings. In contrast, to frame processes of social and technological innovation as top down or bottom up, they adopt a middle-out perspective that identifies building professionals as agents of change located in between top and bottom and has capacity to affect change upstream, downstream and sideways (33; 34) While this middle-out perspective brings important contribution to understand multi-scalar dynamics of innovation process, this paper adopts intermediary concept to understand the relational work in-between institutional environments.

A distinguishing feature in research on intermediaries is not the focus on organisational characteristics or form, but more specifically the work they perform. Thus, the work of intermediaries to influence innovation processes, so called innovation intermediaries, has gained traction in research on innovation and sustainability transition (35, 36). Here, a form of innovation intermediaries is one that is situated between producers and consumers where new technologies (e.g. low carbon technologies) require adjustment and re-innovation in particular locales in which they are adopted (c.f. 35). In such instances, intermediaries can work to facilitate and configure new technology to suit local particularities. Indeed, we found the concept of intermediary to be a useful analytical label for conceptualising the work of aggregators in the context of DSR. However, this concept does not precisely help us analyse how aggregators inflect developments of DSR through their work in between institutional settings, notably DNO and end-users. To account for the work of intermediary actors (aggregators), an additional conceptual framework known as Access Mobility Receptivity (AMR) was identified from the technology transfer literature.

AMR identifies innovation as an interactive process involving intermediaries who translate and redefine knowledge of a new technology to facilitate a tighter fit in the context in which it is to be deployed (37). Seen this way, the development and uptake of innovations (including institutional innovations such as DSR) constitute three interrelated processes:

- Accessibility – Intermediaries make innovations accessible in conceptual and practical terms. Potential adopters who may be receptive to innovations are identified. Promotional materials about the innovation are developed accordingly.
- Mobility –Innovations travel through intermediary channels in iterative fashion from the developer to potential adopters. Both the innovations and aspects of the potential adopters are considered and may be redeveloped in this process.
- Receptivity –is the extent to which there exists adopters that has both a willingness (or disposition) and ability (or capability) to accept, absorb and utilise the innovation.

Seen in this way, intermediaries assist in the development of receptivity to DSR initiatives by working in iterative fashion in the relational space between the DNO and I&C customer. Such processes may involve changing the DSR proposition and working with the I&C customer to redevelop their business practices to achieve receptivity. This analytical approach has informed research on developments of service innovations and product service systems (38, 39). In this paper, DSR represents an innovation that develops in the relational settings of DNOs and their customers. In this context, aggregators are viewed as important intermediary agents who perform entrepreneurial activities and create receptivity to DSR in relational settings. The key role that aggregators fulfil is that they 'aggregate' together a number of I&C customers in order to be able to offer the National Grid or a DNO a particular amount of load or demand reduction at particular times. The aggregator has expertise to engage I&C customers to participate in a DSR programme, and in exchange takes a cut of the income involved. In this paper we focus specifically on how aggregators influence and shape *receptivity* concerning DSR developments, which in turn shape and are shaped by institutional arrangements. How data were collected and analysed is considered in the next section.

3 Method and analytical framework

This study followed a case study research approach to collect and analyse data on the work of aggregators in DSR developments. A case study is an experimental inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially where the boundaries between phenomenon and context are not clearly evident (40). This approach was selected because DSR as a phenomenon cannot easily be separated from the contexts in which it is implemented. The setting selected to investigate development of DSR was the smart grids development Project FALCON (Flexible Approaches for Low Carbon Optimised Networks). Project FALCON, which ran from 2011 to 2015, was led by the British DNO, Western Power Distribution, and was part the UK government-funded smart grid programme funded through the Low Carbon Network Fund (LCNF). The LCNF was established by the Office of Gas and Electricity Markets (Ofgem) and provides financial support for DNOs to develop and implement smart grid initiatives. Indeed, project FALCON led WPD to develop further DSR initiatives, and their relationship with aggregators has therefore also developed further since this project was completed in 2015. WPD has built a network of partnerships that generate income for I&C customers such as local businesses and allow DNOs to accommodate increasing demand for electricity without having to reinforce the grid. The role of aggregators in developing the skills and competencies explored in this paper remain of key relevance to the expansion of DSR practices in Smart Grid programmes.

The authors role in project FALCON was to complete stakeholder engagement activities with trial participants, notably internal actors at the DNO, as well as external organisations such as aggregators and I&C customers involved in DSR trials. The relationship between the authors and the project led by the DNO enabled data to be collected for project reporting purposes as well as for research on a range of smart grid developments. Working in relationship with participants in the field being studied offers an opportunity for the researchers to engage with the experience, action and meaning of a phenomenon in context (41). However, such working relationships between researcher and field can at the same time involve a risk of the researcher being 'captured' by key informants (42). The researchers can, for example, be influenced by social actors in the field in terms of what is perceived relevant, how it is interpreted as well as who they interact with or not, and consequently what voices are heard while silencing others. While there are no easy ways around these issues of collecting data via participatory methods, the authors have considered these implications as part of developing an in-depth insight on the work of aggregators in the context of DSR drawing on data collected from project FALCON. Specifically, the researchers involved in the project followed ethical protocols and maintained a transparent but critical dialogue with project participants around research procedures.

Consistent with the case study approach, qualitative data were collected from multiple sources using a variety of methods, notably participant observations (e.g. project meetings and industry related events), interviews and document reviews (43). Data were collected during the project trials that ran from autumn 2011 to autumn 2015. Specifically, data via observations were collected from two workshops organised by the researchers and involved participants from the FALCON project (e.g. project manager and consultants enrolled by WPD). The workshops focused on learning outcomes derived from project FALCON. Data were recorded via notes taken during the workshops, which were shared among the workshop participants and informed subsequent project reports. Data were also collected from reports on the FALCON project available in the public domain (cf. 44) and observations made from attending two events in which findings from the FALCON projects were presented to stakeholders. The first event was organised in London in 2014, where representatives from the DNO community disclosed information about their experience from developing and testing DSR in their LCNF funded smart grid projects. The second event was organised in 2015 by WPD and was held in

Milton Keynes, where information about the outcome from the DSR trials in FALCON were disseminated and discussed.

Data via interviews were collected from project participants (aggregators, I&C customers as well as internal DNO staff) involved in the project trials. Interviewees were selected in dialogue with the project manager. A total of 12 interviews were completed and involved 8 senior managers working at aggregator firms, 2 network planners at the DNO and 2 I&C customers. The interviews were recorded and transcribed. The interview themes and questions were developed by the researchers in collaboration with the FALCON project manager. The interview themes and associated questions were developed to gain insights from key informants on:
1) core business activities;
2) experiences from participation in the FALCON trials;
3) view on the developments of DSR.
The purpose of the interviews was thus to collect data from participants involved in the trials, with particular reference to their roles and experience of the trials as well as views on DSR.

These qualitative data were analysed during and after the project was completed using a flexible analytical template (45). The analytical template was developed using a funnel approach to facilitate analysis (46). The funnel approach refers to exploratory research that becomes more focused as research proceeds. Thus, we collected data about the smart grid initiative and simultaneously reviewed literature on smart grids with a particular focus on DSR, as well as literature on innovation studies. This enabled an analytical template to emerge from an interplay between data collected and literature reviewed. The analysis began with an initial focus on DSR as the phenomena. As our research proceeded, we identified that DSR as a means to augment network management by shaping electricity demand was at odds with the existing institutional arrangements in this context. Thus, for DSR to develop, changes in the institutional arrangements that shape patterns of electricity production, distribution and consumption would be needed. Therefore, an institutional perspective was adopted to analyse development and uptake of DSR since institutions play a key role in stabilising existing socio-technical configurations as well as for developing new ones. Following this perspective, institutions are always developing and shaped by the availability of new technologies as well individual actors and their organisations. This enabled us to identify aggregator firms as key intermediary players in shaping development of DSR. The AMR framework was then adopted to account for the work of aggregators in creating receptivity to DSR in this relational setting. Thus, the analytical template consists of:

- DSR as an **institutional innovation** that is very different from established arrangements to augment asset management on regional distribution networks
- Aggregators working as **intermediary agents** situated in between DNOs and customers, working back and forth, and
- Aggregators **creating receptivity** to DSR in these relational settings

This analytical template helped to transform rich and complex data into meaningful interpretations.

4 Analysis

Similar to many other smart grid initiatives in the LCNF programme (c.f. 47, 48, 49) the aim of FALCON was to identify better ways to manage the 11 kV electricity distribution network. Western Power Distribution (WPD) is the DNO in this region and the principal actor in the FALCON smart grid project. DNOs are generally engineering focused firms that specialise in managing large scale electricity infrastructure assets. Operating and maintaining a safe and robust electricity network and to ensure security of supply to customers is a key priority for a DNO. As was noted in the introduction to this paper, reinforcing distribution network assets is the main way DNOs address increased demand

and peaks on the network, which is both guided and constrained by complex sets of formal and informal institutions. Informal institutions include (cultural) routines that enable and constrain social action. For example, the notion of "predict and provide" is a well -established approach in utility asset management. Formal institutions include explicit rules developed by, amongst others, Ofgem, which is the regulator for gas and electricity markets in the UK and which determines what DNOs can and cannot do on their networks.

The purpose of developing and implementing DSR trials in the FALCON project was to test how DSR can be deployed as a routinized and formalised approach to help manage the distribution network (42). There are principally two ways for customers to provide DSR capacity:

1) load reduction, which means that a customer responds to a request from the DNO to avoid performing a practice that requires electricity at a particular time. For example, at times of peak electricity demand, non-essential electrical equipment could be turned down or off. An example of this might be a water company turning off some reservoir pumps for half an hour, or air conditioning paused in an office block.
2) distributed generation, which means that a customer uses their own electricity generator to maintain practices that require electricity thus reducing their electricity take from the grid. For example, a number of organisations that require uninterrupted electricity supplies have backup generators. These could be used to also provide a DSR service.

In contrast to engineered solutions, DSR initiatives aim to change demand and involve commercial relationships between the DNO and its I&C customers. In this analysis, DSR is therefore conceptualised as a socio-technical innovation that that require new forms of institutional arrangements to become more established as mainstream activity in the energy sector.

4.1 DSR conceptualised as institutional innovation

The market for DSR in the UK electricity sector became established when the National Grid began to use aggregator services to balance electricity supply and demand on the transmission network via programmes such as Short-Term Operating Reserve (STOR). Here, DSR can be described in terms of formal and informal institutional aspects, as it involves legal contracts between the National Grid and DSR providers as well as established routines for deployment of DSR. However, DSR is a marginal approach for the National Grid and used at a very small scale compared to other balancing measures, e.g. large-scale stand-by power generators. An aggregator summarised this situation as:

So, demand response is like a new layer of opportunity to better use renewables to better get the energy efficiency objective and at the end to review CO2, at the end it is much less costly than build renewable plants or build generation or nuclear (Aggregator 3).

As stated by aggregator 3, DSR is novel and has potential to be more cost effective than providing additional generating capacity. Thus, the role of aggregators is to aggregate demand reduction as illustrated by the quote below:

What we are trying to do is to aggregate demand reduction from many industrial and commercial facilities and the sort of call that virtual power plant or virtual avoidance pool, we can sell to National Grid as part of the balancing services (Aggregator 2).

At the regional distribution network level (networks covering 11kV to 132kV), formal institutional arrangements for DSR, similar to that of STOR, do not exist. There are, however, some informal arrangements where DNOs request I&C customers to turn down load to avoid network failure. Thus, while forms of DSR already exists in terms of formal and informal institutional arrangements in the electricity sector (such as the National Grid and DNOs), it is not used as a regular and formal activity by DNOs. The DSR trials in the FALCON project (and other LCNF projects) can therefore be viewed as an exploration that might lead to further uptake of DSR on regional networks. This means that DSR may become more widely adopted by actors in the electricity sector (e.g. DNOs) to form part of their asset management routines. Aggregators are identified as important players in facilitating DSR developments as depicted by one aggregator:

"It is actually acting as a bridge in between you know it is a matter of understanding what the National Grid or DNO or the supplier want. So, there is a role acting as a bridge with the client to such that the client say okay, how the client can deliver something that can meet the grid, or the DNO requirement. So, there is that sort of role of interpreter, translator, the bridge, that is sort of role as we have it at the moment" (Aggregator 5)

As illustrated by the quote above, aggregators are working as intermediary agents building human relationships between utility firms (e.g. DNO) and end-user with DSR capacity. How such relationships develop forms the focus in the next.

4.2 The role of aggregators working as intermediary agents

The participation of I&C customers is necessary for DSR to work effectively. Ways of engaging with and recruiting them to DSR programmes is therefore central to development and uptake of DSR. This was also the case in the FALCON project, where recruitment of participants in DSR formed an important aspect to investigate since this is not a skill familiar to DNOs. Engaging with customers to engage them in DSR schemes is an important role familiar to aggregators as were noted by aggregator 1.

"You have to engage with users on that network in order to get them to turn down. So it really steps outside the box for DNO because it is not a natural space to be in as a DNO" (Aggregator 1)

A number of organisations were recruited by aggregators to participate in the FALCON trials (44). These organisations were located in the Milton Keynes trial area and were characterised as large electricity users with very different operations and activities e.g. water treatment and supply, education, district heating and health care. A common characteristic across these organisations was that they had embedded electricity generation on their sites (e.g. diesel generators) which were installed as back up generation but could also be used to provide DSR. However, the appropriateness of using diesel generators for the purpose of DSR can be challenged on the grounds of air quality and carbon reduction objectives. This is a common type of DSR capacity and was at the time seen as a valid source for this trial, but should DSR become more widespread, then the issue of the type or even use of generators would need addressing. This is a point acknowledged by this aggregator.

Our focus is on automatic response not in stand by generation. So, we use stand by generation as a second guess, but we think that stand by generation, so using diesel generators with CO impact, it's not the way ahead, okay. There is much more to do on the demand response side on trying to load shed, load shift or even disconnect their loads during a period of time so getting energy savings at buildings (Aggregator 2).

Working as intermediary agents, aggregators saw they played an important role in developing a relationship with demand side organisations and recruiting them for the DSR trials in FALCON. In building such relationships, aggregators constructed persuasive and pervasive commercial propositions that rendered DSR a valid energy management initiative that accorded with an organisation's business priorities, e.g. revenue stream, cost savings, carbon management and

Corporate Social Responsibility agenda. As illustrated below, this is a process that takes time and requires skill in developing the relationship.

And, of course, when we go, you know, we need a very compelling value proposition and that is how we build relationships. We got there and say look, this is the value proposition, this is what it will do in terms of money and carbon reduction strategies and towards a kind of sustainable future, and you need to work on them, but it will take time because we can't instantly, you know, these are not very sort of sophisticated energy people, they are very sophisticated on other things but not in terms of energy (Aggregator 2).

Thus, aggregator make DSR accessible to organisations with DSR capacity in conceptual and practical terms. Here, conceptual terms relates to DSR and associated value propositions. In practical terms, aggregators develop technological capabilities to ensure DSR services. One way to acquire technological capability is via relationships with firms that have such capability as illustrated by the quote from Aggregator 2 below:

We have a partnership agreement with Technology Firm just for the technology platform, they have got, you know, the technology platform that we need to be able to automatically aggregate all these loads in different buildings (Aggregator 2).

This shows that aggregators build and maintains multiple relationships to make DSR work. This includes, for instance, relationships with end users and firms with technological capabilities needed for DSR. Furthermore, they also develop relationship with utility firms to translate and redefine DSR for them. A key priority for a DNO is to ensure security of electricity distribution. The aggregators in this project worked closely with the DNO to design and test commercial relationships between the DNO and I&C customers with particular focus on DSR as a reliable solution to ensure network capacity. Prototype contracts were therefore developed by aggregators in this project to make DSR a more reliable asset management approach and included, for instance, the planning of DSR events. The DNOs and their customers preferred DSR activities to be scheduled in advance, specifying the number, time and date for DSR events when they knew peak loads occurred. To facilitate the management of DSR activities, the aggregators had installed equipment on their clients' site to monitor such activities. In some instance, equipment to control DSR activities were installed which enabled the aggregator to control aspects of their clients DSR capacity.

In planning DSR events, it was also found useful to avoid competition between DSR programmes on the market. Since the National Grid uses DSR to balance the transmission network that covers multiple regional distribution networks, the National Grid and the DNOs may have to compete for DSR capacity. This competition in the market is illustrated by this quote:

So, what we are looking to do is, so we will put the contract in place for the client and then it is, we will look at the opportunities available from DNOs and other opportunities from triad, from the National Grids other programmes (Aggregator 5).

At the time when data were collected for this study, aggregators were negotiating with both National Grid and DNOs to develop codes of conducts for DSR (c.f. 50). This includes for example to ensure that DSR can develop on regional distribution networks without conflicting with DSR programmes on the National Grid level. This was emphasised in one aggregator response:

"So, the approach that needs to be there is actually recognising multiple contributions rather than I am claiming this asset for me. So how can we set up some arrangement that means that the action of the response or the flexibility that is there is able to be used as many participants as possible in a coordination" (aggregator 4)

While the National Grid can use DSR from any part of the grid connected to the transmission network, distribution networks are geographically constrained by their regional remit. This raises issues concerning the viability of using DSR at this level. Perhaps the most significant aspect is the geographical scale of deploying DSR on the distribution network. In the FALCON trials, DSR was tested on the local 11kV network. At this geographical scale there were few clusters of large electricity consumers with DSR capacity. Thus, it was recognised in this trial that DSR may be more successful at a larger network scale (e.g. at the 33 kV and 132 kV networks), where DSR can be sourced from a larger geographical area with a greater number of electricity customers with DSR capacity. Furthermore, the cost of reinforcing distribution networks differs between scales. In general terms, the cost of reinforcing distribution networks increases with voltage levels: the cost is relatively low at 11kV and increases at higher voltage levels. Deploying DSR at the 33kV or 132 kV networks may therefore be more commercially viable for a DNO.

Having analysed the role of aggregators working as intermediary agents, this analysis shows that aggregators go back and forward between the DNO and its customers brokering relationships between them. It is through this process of working as intermediaries that aggregators create accessibility, mobility and receptivity to DSR, which in turn shapes developments of DSR in this context.

4.3 Aggregators creation of receptivity to DSR

Aggregators create receptivity to DSR by constructing persuasive and pervasive propositions for its users, DNOs and, in particular, I&C customers. They do so by negotiating DSR arrangements with these users by translating and redefining the notion of DSR to make it fit with multiple contexts (e.g. the DNO), the regional distribution networks and on the premises of customers. For example, aggregators construct propositions for how DSR can effectively work for DNOs in terms of a reliable asset management approach. They also construct commercial propositions that renders DSR a valid energy management initiative which accords with an organisation’s business priorities.
It is through this process of translating and redefining the notion of DSR that aggregators create receptivity for DSR; that is the willingness and ability of DNOs and customers to use DSR.

Aggregators have knowledge and skills relevant for creating receptivity for DSR. They also have technical capabilities in terms of monitoring and control equipment necessary for executing DSR events. Technological capability is important for DNOs, as it helps to ensure that DSR generates a valid and reliable asset management approach. It can also be seen as a service for organisations with DSR capacity not having to manage DSR events themselves. DSR is a relatively low-income generating activity for these organisations, which is not worth the cost of setting up inhouse expertise. With DSR skills and expertise provided at scale by the aggregator, participation becomes economically viable.

From the viewpoint of the DNO, aggregators also have competences and skills required to identify suitable I&C customers and establish contractual relationships with these to provide DSR capacity to DNOs. In brokering such relationships, aggregators engender receptivity to DSR among I&C customers. One aggregator noted the importance of such skills:

Ultimately that is part of the kind of skill set, that if a DNO wants to go directly they will have to develop that skill set. There is no sales department located within distribution networks (Aggregator 1)

Since the completion of Project FALCON, WPD has continued to develop its DSR capability (51). The competences developed through previous trials have been used to design a DSR proposition that is viable for both the DNO and their commercial customers. This has involved WPD building a network of partnerships that generate income for I&C customers such as local businesses and allow DNOs to accommodate increasing demand for electricity without having to reinforce the grid. Aggregators remain part of this network, but their role is changing as DSR moves towards becoming a standard practice. In Project FALCON, WPD needed the aggregators to provide the skills and understanding to deliver DSR capacity. At that time, they had very little of this in-house. At this early stage, DSR was a minor niche activity around which the aggregators had developed as service companies to National Grid and the DNOs.

Additionally, aggregators are contributing to developments of codes of conduct associated with DSR, which is relevant to growing the DSR market and preventing conflict between demand for DSR on the distribution network and the National Grid (50). Thus, by translating and redefining DSR to become attractive to I&C customers as well as utility firms, aggregators contribute to the development of human relationships as well as relationships between humans and technology, and thus to the institutionalisation of DSR. In this way, aggregators consolidate and extend these arrangements to better establish DSR, particularly on the electricity distribution networks. Hence, aggregators can be viewed as important innovation intermediaries influencing development of DSR. As more utility firms (notably DNOs) and their customers participate in DSR programmes, it could become more embedded in the energy market as a valid and legitimate form of asset management.

5 Discussion and Conclusions

Through the lens of institutional theory, this paper has shown the important role of aggregators now and in future developments of DSR. Our findings identify DSR as an institutional innovation where aggregators work with DNOs to shape demand to augment network management. Exploratory case study research was conducted on the DSR trials within the LCNF funded smart grid project FALCON, undertaken in Milton Keynes and led by the regional DNO. I&C customers connected to the regional distribution network can provide DSR by reducing the amount of electricity they take from the grid for which they are financially compensated. The LCNF funded FALCON project created a window of opportunity for developing and testing DSR in the context of regional distribution networks and to identify the institutional relationships required for DSR to become a mainstream practice on these networks. The DSR trials in the FALCON project (and other LCNF projects) can therefore be viewed as experimental steps towards further uptake of DSR on regional networks.

Institutionally, implementing DSR represents something very different from more established forms of the electricity industry’s asset management approaches of conventional reinforcement. A notable difference between conventional reinforcement and DSR is that network capacity is acquired via commercial and contractual relationships rather than ownership and property rights. Asset management involving contractual arrangements are, arguably, a weaker form of institution compared to the latter. First, they require customers to participate in DSR programmes. Second, they exist only for the duration of the contracts involved. Third, DSR does not match well with the institutional arrangements in the utility sector that are geared towards engineering solutions to enhance network capacity. Thus, change in such institutional arrangements are needed for DSR to work and aggregators are identified as important actors to inflect such developments.

Aggregators work with utility firms (e.g. DNOs, the National Grid) and I&C customers with DSR capacity brokering relationships between them. Specifically, aggregators identify potential adopters such as DNOs and I&C customers who are both able and willing to adopt DSR as part of their organisational remit. However, the ability and willingness of DNOs and their customers to adopt DSR is not necessarily something that is ‘there’ to tap into. Rather, receptivity is constructed in the contexts in which DSR can be used. Here, aggregators create receptivity by constructing persuasive and pervasive commercial propositions that render DSR a valid energy management initiative that accords with an organisation’s business priorities and institutional arrangements. For example, aggregators engage with organisations that have back-up generation on their premises and thus have ability to provide DSR capacity and offers a financial compensation to them which makes DSR a potential business proposition. They also construct prototype contracts that engender DSR a reliable and valid asset management approach that accord with a DNOs priorities, e.g. security of electricity distribution. Additionally, aggregators are contributing to developments of codes of conducts associated with DSR, which is relevant to growing the DSR market. This includes, for example, to ensure that DSR can develop on distribution networks without conflicting with more established DSR arrangements developed with the National Grid. In such instance, aggregators work as intermediaries to align DSR programmes at different network levels, notably National Grid and regional network levels. In this way, working as intermediaries, aggregators facilitate a tighter fit between DSR and the context in which it is to be deployed.

In this paper we have identified the work of aggregators to be important for DSR developments. Notably, working as intermediaries, aggregators builds relationships between humans and technology and create receptivity to DSR, which contributes to the institutionalisation of this innovation. They do this by translating and redefining DSR to make it accessible and attractive to actors on the energy market including I&C customers as well as utility firms. In translating and redefining DSR to fit multiple contexts, aggregators consolidate and extend these arrangements making DSR better established on the energy market and in particular on the electricity distribution networks. As more utility firms (notably DNOs) and their customers participate in DSR programmes, DSR has moved to become more embedded on the energy market as a valid and legitimate form of asset management. WPD now regards DSR as having moved from being a trail to rolling it out as part of their ‘business as usual’ (51). As such, the skills and role of the aggregator appear to be moving in-house to WPD, with the aggregators providing more specialist input. This illustrates that the role of an intermediary in transitions changes as the transition progresses. Thus, this paper contributes with insights on aggregators in DSR developments and identifies their work as intermediaries to be important for transition to smart grid futures. Specifically, it suggests that institutional perspectives can help reveal the work of intermediaries brokering relationships between institutional environments and facilitating new institutional arrangements. How power play proceeds in such processes is, however, underdeveloped and could therefore form the basis for further research.

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