6-18-2022

SMART METERS AND DEMAND SIDE MANAGEMENT IN SMART GRIDS – EXPLORING CHALLENGES AND OUTLINING FUTURE RESEARCH DIRECTIONS

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SMART METERS AND DEMAND SIDE MANAGEMENT IN SMART GRIDS – EXPLORING CHALLENGES AND OUTLINING FUTURE RESEARCH DIRECTIONS

Research in Progress

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Abstract

This research in progress paper explores smart meters and demand side management (DSM) challenges and how this is perceived by suppliers of smart grids. It builds on semi-structured interviews and a literature review showing that smart meters are a highly important, relevant, and interesting research topic. We identify a need to include knowledge on how to develop smart meter technology further as well as how to increase both supplier and energy user engagement and involvement in development of smart meters technology. Our research shows that there exist gaps between: policies, goals and expectations on one side and implementation and use of smart meters on the other side. Based on initial results we conclude that there is a need to explore DSM and smart meter technology further and to learn from a social-technical IS perspective to overcome a one-sided perspective, or even deterministic view, on technology.

Keywords: Demand-side management, Smart meter, Smart grids, Social-technical.

1 Introduction

To achieve a more sustainable and green future is a major issue today in the society in general and in several subject areas. Information systems research (ISR) is no exception, where e.g. green IS has been on the agenda for several years (Singh and Sahu, 2020, Ågerfalk et al., 2021). Today IT artefacts are becoming more and more integrated and embedded in different infrastructures. In this paper we focus on smart grids, where so called smart (electricity) meters, with embedded IT and e.g. user interfaces, are implemented with the intentions to inform customers (energy users) and also to be a part of managing demand in smart grids in order to achieve more sustainable energy systems including smart grids.

Demand side management (DSM), energy management or demand response (DR) as a part of sustainable energy systems is a tricky and problematic issue (Honarmand et al., 2021). According to Palensky and Dietrich (2011) electric energy systems has historical been infrastructures that are more or less unidirectional and top-down oriented, consisting of a limited number of large power plants that feed into the grid with the main objective to keep demand and supply balanced. They state that keeping this balance is a crucial aspect in operating the system. Keeping this balance is what DSM is about. Gellings (1985) defined DSM as the planning, implementation, and monitoring of activities designed to influence customer use of electricity resulting in desired changes in the utility's load shape. This includes activities such as load management, new uses, strategic conservation, electrification, customer generation, and adjustments in market share (Gellings, 1985). Gellings (1985) also stated that in order to succeed there is a critical need for improving communication between the utility provider and their customers in which they give customers more information. This is where the smart and digital (IT) services are added today. However, since this, 1985, the need for information in order to deal with demand response has changed a lot and being even more critical. Not at least as a result of micro-production, since the grid has to be integrated with distributed generation of electricity (Meliani et al., 2021). This means that information has to be provided both to producer as well as users of energy if the "energy side" should be able to contribute to sustainability. For instance, an energy customer needs improved control over their energy consumption to be able to decrease the usage, and at the same time the energy producer needs to have information about both production and usage to be able to balance supply and demand (Meliani et al., 2021, Honarmand et al., 2021, Jamal et al., 2021).

When integrating IT artefacts in grids these becomes smart grids according to Gao et al. (2012) who defines smart grids as "dedicated information networks that enable information communication between devices, applications, consumers and grid operators" (Gao et al., 2012) However, integrating IT artefacts is according to Goulden et al. (2014) not enough to achieve smart grids, they claim that there is a need for having a change among energy users (the demand side). This links smart grids to smart meters and DSM, and makes this an important area to study within ISR, with an interest in studing and understanding users. This is also in line with Fang et al. (2011) stating that smart grids are one approach to solve issues around DSM. Goulden et al. (2014) states that if a smart grid should have a possibility to solve problems of controlling supply of energy with the demand side, consumers has to become smart energy users. An important part of being a smart user deals with for instance understanding comsumption patterns and be able to measure use of electricity in a household using a smart meter. Smart meters, according to Wunderlich et al. (2019) are "[…] digital electricity meters that allow bidirectional (or two-way) communication between the meter (installed in a home) and an energy supplier through smart metering technology".

A crucial question related to smart meters is then what the energy suppliers as one part of the smart grid thinks and perceives being the outcome of implemented smart meters. According to Wunderlich et al. (2019) smart meter technologies is an under researched topic and they state that more research are needed. As stated above, it is relevant for IS researchers, because it includes digital representations (smart technologies), infrastructures and services, users, supply and demand dimensions. In this research in progress paper we highlight the supplier perspective on smart meter implementation. We explore how this is perceived at the energy supply side and what they describe being crucial regarding smart meters functionality if having impact on DSM in the short run and to achieve sustainable energy systems in the long run. This means that the questions addressed in this paper are: (1) How does energy supplier perceive impact smart meters could have on demand side management challenges in smart grids, and (2) What is needed regarding development of the context around smart meters if objectives of smart meter technologies should be a success?

The rest of the paper is organized in the following way: the next section, section 2, defines and present some research on smart grids and smart meters. Section 3 then continues with presenting the research method used and some empirical data from a case study consisting of two organizations making up embedded cases on an energy producer, supplier and distributor. Section 4 then discuss the findings from the literature with the empirical data suggesting some future development. The final section then presents some conclusions and future research directions.

2 Smartness of smart grids and smart meters

Smartness of smart devices is defined by Alter (2019) as a designed entity that performs and controls functions with the attempt to produce useful results through activities from information that may or may not be specified by its designers. Dupont et al. (2010) describe that in a smart electricity system (smart grid), consumers is an integral part and creates an intelligent grid allowing electricity users to take new choices resulting from new technologies, new information about electricity consumption, and new ways of electricity pricing. This is in line with Avancini et al. (2019) who state that smart grids together with smart meters are part of an intelligent energy network (IEN), make it easy controlling power balance and DSM by integrating communication and control capabilities. This is related to a discussion around demand response programs, which are defined by Siano (2014) as programs that changes the normal consumption patterns in response to changes in the price of electricity or to incentives designed to induce lower electricity use when that is needed. However, Makhadmeh et al. (2019) state that a major problem is how to optimize power demand in the grid, particularly during peak periods, controlling the stability of the power system, which directs to a smart meters as the interface between supply and demand. This is in line with what Dedrick et al. (2015) describe when they state that new knowledge around smart meters, as disruptive technology, are needed when adopted in a context of regulated monopoly.

Smart meters technologies could be described as the interface between energy supplier and energy users and to fully realize the benefits it is crucial that the technology is adopted by the energy user (Wunderlich et al., 2019, Corbett et al., 2018). Avancini et al. (2019) continue by stating that the whole idea with smart grids is that the technique should be able to handle power supply and consumption more effective by integrating communication efforts with controlling efforts. This is seen as problematic since power supply systems from the start, way back, was implemented as a system generating and distributing electricity without really having any involvement or engagement from the user side (Palensky and Dietrich, 2011, Dedrick et al., 2015). Gungor et al. (2011) state that for 100 years, no change in the basic structure of the electrical power grid has taken place, and experiences have shown that the hierarchical, centrally controlled grid is ill-suited to the needs of today. According to Gungor et al. (2011) the smart grid is a modern electric power grid infrastructure that improves efficiency, reliability and safety at the same time as it integrates renewable and alternative energy sources. Palensky and Dietrich (2011) state that among energy management, which means to optimize the energy system, plenty of experience exist in optimizing energy generation and distribution. They further state that it is the demand side and DSM that needs attention. DSM is a portfolio of measures to improve the energy system at the side of consumption, ranging from improving energy efficiency by using better materials, over smart energy tariffs with incentives for certain consumption patterns, up to sophisticated real-time control of distributed energy resources.

All this makes that reliable and real-time information becomes a key factor for reliable delivery of power from generating units to end-users in the smart grid. However, it also highlights that information and communication technology in the form of smart meter technology that allow bidirectional communication is crucial (Wunderlich et al., 2019). The importance of having bidirectional communication is emphasized by Gungor et al. (2011) whom suggest that there are two types of information infrastructure needed for information flow in a smart grid system, firstly a flow of information from sensor and electrical appliances to smart meters, secondly, a flow of information from smart meters to the utility's data centers. From this it can be said that the smart meter has a very important and crucial role in the development of the smart grid. This then means that it is crucial to define and describe what kind of technology a smart meter is.

As presented by Zheng et al. (2013) smart meter is one of the most important devices used in smart grids. They define a smart meter as an advanced energy meter that obtains information from end users' load devices and measures the energy consumption of consumers and then provides added information to the utility company and/or system operator. Lewis et al. (2012) also highlights feedback and supporting other types of control technologies. The whole idea of smart meters is that these devices should be installed in households and give a more sophisticated way of measuring energy consumption compared to conventional meters (Giest, 2020). They should record consumption patterns and then influence behavior as a nudging tool, using feedback mechanisms for energy consumers to learn to connect their actions with the resulting energy consumption and ideally develop a routine that leads to lower energy use. Zheng et al. (2013) presents some potential benefits from implemented smart meters, one example is that consumers are able to estimate bills and thus manage their energy consumptions to reduce their electric bills. For the utility's they state that they can use smart meters to realize real-time pricing, and by that limit the maximum electricity consumption and try to encourage users to reduce their demands in the periods of peak load. Venables (2007) even state that smart meter makes smart users!

Abrahamse et al. (2005) have reviewed a number of studies on intervention in household energy conservation. They found that there is no clear intervention for getting the best impact on energy savings and thereby decrease environmental impact. Instead, they claim that interventions have been employed with varying degrees of success. Providing more information tends to result in higher knowledge levels, but not necessarily in behavioral changes or energy savings. Providing rewards have resulted in rather short-lived effects. Providing feedback has had some merits, in particular when given frequently. The intervention that smart meters provide consist of feedback about energy use. According to Abrahamse et al. (2005) feedback is often suggested as a solution for promoting energy conservation. Geller (2002) state that the ideal situation is when the feedback is given immediately after the behavior occurs. However, Geller (2002) says that some challenges with smart meters remains and these are: first, how to get a substantial numbers of these devices in people's homes, second, how to get attention to these devices regularly, and how to make user respond appropriately to the feedback. Geller (2002) claim that one solution could be to increase the cost of energy and by that way motivate attention and reaction to consumption feedback, however, usually such increases are gradual and thus are barely noticed. This actually directs the attention to dynamic prices as presented by Makhadmeh et al. (2019) as one way to solve DSM problems. It could be said that dynamic prices are essential to encourage consumers and demand-side service providers to reduce consumption during periods of peak demand (EC, 2012). However, in the electricity sector dynamic prices as stated by EC (2012), has traditionally resulted in small effects on demand volumes. It could also be said that the effect of feedback on energy consumption is insubstantial with information strategies resulting on average, in short-term reductions of only 2% (Buchanan et al., 2015) However, as claimed by Buchanan et al. (2015) even to get this small reductions the consumer has to engage with an in-home-display (IHD). This suggests that just implementing a smart meter does not really makes any difference. How this is perceived by stakeholders at the supply side is what this paper aims at exploring. The next section presents shortly the ongoing research project and the work done to get to some preliminary findings.

3 Research method and empirical data

3.1 Research Approach and Case Introduction

The empirical part of this piece of research is based on a qualitative and interpretative case study (Walsham, 1995) consisting of two organizations making up embedded cases (Yin, 2009). The anonymous, embedded case organizations (labelled PowerGrid and Electricity Supplier) is independent organizations owned and controlled by a Swedish local government (Municipality). PowerGrid is responsible for the power infrastructure (the grid) in the municipalities region, and has a monopolistic role, governed by Swedish laws and regulations. The Electricity Supplier acts on a market with several other suppliers and provide electricity and services to private and commercial actors, their business is not only regulated to the region of the Municipality.

The embedded case organizations have several initiatives in digitalization and within a smart city context. At the moment one project is connected to implementation of new smart meters. The main reason for this implementation is new regulations on what the meter should be able to do when it comes to measuring and providing measurement on energy use. This is described by the former Minister of Coordination and Energy in Sweden Ibrahim Baylan in the following statement: *"The next generation of smart electricity meters is now being introduced in Sweden. They will give customers better tools to be active in the electricity market, while the electricity meters ensure safer operation of the electricity networks"* (Government Office, 2018).

Data related to the smart meter implementation project in this case was collected in 2020 through 9 semi-structured interviews (Myers and Newman, 2007) with informants from the embedded case organizations. 5 interviews were conducted face-to-face, while 4 of the total number were held using Microsoft Teams due to the COVID-19 situation. The interviews were held in Swedish and quotes translated to English by the authors. The interviews were guided by an interview guide that had some overall themes such as what a smart grid is, the role of different actors within and linked to a smart grid, smart applications connected to the grid (such as meters, mobile apps etc.), and the role of different dimensions of sustainability. The themes was discussed during the interviews and open ended questions asked during the discussion. The empirical data was then analyzed from the specific topic of this paper, namely: How does energy supplier perceive impact smart meters could have on demand side management challenges in smart grids, and What is needed regarding development of the whole context around smart meters if objectives of smart meter technologies should be a success. In parallel, we did a hermeneutic literature review (Boell and Cecez-Kecmanovic, 2014) to develop knowledge on core concepts and the phenomenon, smart meter technology and DSM, studied. A content analysis approach (Krippendorff, 2018) was then used as a part of a reflexive research process (Alvesson and Sköldberg, 2009). As a part of assuring quality in our interpretations and the ongoing analysis, two seminars with representatives from the case organizations were held. During these seminars our initial analysis was presented and discussed and this then made that we got input and more data for the next phase of analysis. Initial findings around the five gaps, presented in section 4, was presented and discussed. During the seminars representatives that were interviewed as well as some representative from the case organization not interviewed were present. Feedback gained at the seminars both acted as a quality assurance on our initial findings as well as getting some additional insights in the interview data. The seminars and the initial findings also influenced the literature review in the way that we got new input into the hermeneutic literature review.

3.2 Empirical data and initial findings

Empirical data show that stakeholders at the supply side see an evident problem with energy users' interest in energy consumption. They perceive the overall energy user as an individual that more or less not at all are interested in saving electricity and definitely not interested in solving DSM problems. Relating this to attention around smart meter technology, it is claimed that electricity is a low-cost and low-interest product. This is expressed heavily by respondents at both the PowerGrid and the Electricity Supplier. They strongly claims that electricity is a low-cost and low-interest product. A sales representative at the Electricity Suppliers describes that there are very few customers that are interested in knowing something from the smart meter. He state it in the following way: *"it is probably usually a man in the 40s to 50s who feels like having very, very much control as well as knowing how it works with electricity network and electricity trading, the electricity meter and wants to know its specific consumption"*

This question about consumption comes from the fact that the new smart meter has a USB port (a HAN port) as part of requirements on the new meters. One of the representatives at the PowerGrid organization state that there basically are only two requirements on the new smart meters. He describe them in the following way: *"The HAN port is, this is the requirement for the new one, there are two requirements really. One is that you must be able to take faster readings. Every quarter…going down to the minute level in the long run. And then it is that the customer himself should be able to connect the electricity meter and get different data, currents and consumption and whatever it may be. I do not see it doing any good for us…Customer port it can be called. You could say, like a USB port."*

These citations is just a few example of statements demonstrating that the new smart meter has two functionalities: first, the meters should record readings on consumption more often than before, and provide data on the consumption to both consumers and providers. At the same time, it is clear that the stakeholders at the supply side claim electricity to be a low cost and low interest product. It is also clear that they do not really see how the new smart meters that are in the process of implementation will make a difference. The question is then why this is the case and what development that is needed to change this situation and make the smart meter implementation successful.

4 What future development and use of smart meters is needed?

As we could identify so far is that the interviewees perceive that the new smart meters will have low impact assisting them in solving DSM problems. The analysis of the empirical data reveals that there exist some gaps between what is intended with implementation and use of smart meters and what the supply side identify as a potential outcome of the new smart meters. Below we present five significant gaps explored in the present study, and mirror them in previous studies, in order to outline areas for future development and use of smart meters.

The first gap explored was a gap (1) between national policy and early implementation practice of smart meters from the perspective of policy and policy makers. The policy stated relatively clear that smart meters should aim at solving problems related to demand-side management challenges. The whole idea was that smart meters should provide both consumers and providers with data that could be used for assisting the provider with controlling flexibility in the demand-side. Already implemented meters and "new" meters that now being implemented does not provide this kind of information to neither the consumers or the providers. From the literature and the information gained from the interviews around implemented smart meters, smart meters functionality needs to be developed further if the whole idea of these technology should be fulfilled. For instance Zheng et al. (2013) claim that smart meter in the future need to have a built-in ability to disconnect-reconnect certain loads remotely and that it could be used to monitor and control the users' devices and appliances to manage demands and loads within "smart-buildings". This is then functionality that comes from the supplier side and directly aims at solving demand-side management problem and is in fact a smart meter functionality needed if developing a grid too become smarter. This could then be seen as intelligence in the smart meter and is probably one thing Corbett (2013) ask about when claiming that smartness "will not live up to its name if not critically assess what intelligence is actually being created and how it is being used". This is also in line with the claim that impacts of smart metering on utilities has experienced little research attention (Corbett, 2013).

The second gap is (2) between ownership and control of the smart meter as an IT artefact. When analyzing the case from the perspective of the different views that the PowerGrid and the Electricity Supplier provides us with. To some extent there exist a tension between these parties in how they approach the whole idea of smart meters. The PowerGrid organization needs to make sure that the infrastructure works, and that electricity is delivered without any problem. The Electricity Supplier also has an interest in that infrastructure works but at the same time they need to support customers with other types of services, such as assisting them in developing consumers' own micro-production. Interesting to notice is that neither of these two stakeholders are really interested in delivering services that could assist consumers in saving energy by using the potential that could exist from smart meters. One reason for why the Electricity Supplier not really are interested in this is the fact that smart meters and data from smart meters is owned by the PowerGrid company. It is also a fact that the historic roots of the case organizations and how they from their history perceives and describes their boundary of their business influence their thinking and their action related to smart meters to a very high extent. According to both the PowerGrid and the Electricity Supplier their business end point is with the meter and what happens in the household is not seen as their business.

This direct us to the third gap, which is a gap (3) between technology and use. When analyzing the data from the perspective of technology in use, it is striking that the PowerGrid has to do the implementation of the smart meters but they do not regard this as a tool for the consumers to use. They know that the meter is equipped with a USB port that could be used for getting data on consumption, but they do not inform the customer about this and they do not see this as part of their obligation. From this it could be claimed that the technology that are installed is not in a good way connected to the user side of the electricity (grid). A crucial question is then what functionality that is needed from the perspective of saving energy. It is also a question what is needed in this direction if a smart meter should or could be seen as a nudging tool. It is clear that technology exist but functionality has to be developed if it should come into use at the consumer side (de Souza et al., 2018, Wunderlich et al., 2019). From a supplier perspective it can clearly be stated that if the smart meter technology not are used at the consumer side it is not useful for the supply side dealing with DSM challenges.

Gap four (4) is existing between infrastructure and service. It can be claimed that neither of the case organizations are really interested in developing services from the infrastructure they provide. As stated above they see for instance supporting in-home displays (IHD) with data as outside the scope of their business. Also, this could be related to nudging as stated above. For instance, Krishnamurti et al. (2013) claim that smart metering with IHD and websites providing feedback by visualization of consumption have been investigated as a nudge to support users in saving energy. However, Kroll et al. (2019) refers to Fan et al. (2017) which claims that there is low emphasis on the design of these systems and state that there is a lack of mobile applications which can strongly promote energy-savings in smart home apps or in combination with smart meters. Kroll et al. (2019) then state that smart meters could most likely support consumers to better understand their energy consumption and digital nudges to motivate them to save energy. This is in line with Krishnamurti et al. (2013) that investigated what design of an IHD that was most appreciated by energy users. The claim they make is that a simpler more generalized format of information provision has the potential to be more effective than a personalized IHD. A crucial question to solve is that the users do not really understand the information that is provided directly from a smart meter. This means that information needs to be "translated" into something that is both understandable and at the same time interesting. According to Krishnamurti et al. (2013) if the IHD is paired with the smart meter and the smart grid, a sophisticated IHD could provide customers much higher resolution feedback about their electricity consumption. What they then state is that if this feedback is presented in the right way, customers should be able to correct their mental models of how appliances use energy in much greater detail, allowing them to more easily engage in energy efficient behavior (Krishnamurti et al., 2013).

Finally, it seems like that there exist a problematic situation between the case organizations that comes from the fact that they are not really allowed to collaborate. This results in gap five (5) which just like gap two (2) is grounded in the fact that the smart meter is implemented and owned by the PowerGrid. The PowerGrid also is the one that has "control" over data from the meter. This is the situation even though the data from the meter most likely is about consumption data, and therefore seems to be of relevance for the Electricity Supplier. During the interviews it was emphasized that smart meter data is not really of interest for the PowerGrid. The Electricity Supplier claimed that the whole situation is also problematic from the situation of consumers integrity. This "internal" gap is a gap that deals with scope and responsibility surrounding the smart meter having its roots in regulations, market hindrances and different interest from different stakeholders at the supply side. The difference between gap five and gap two is that gap five is actually a gap that comes from outside pressure and it is a gap that the case organization has to live with as long as the regulations does not change. This is then closely related to the ongoing discussion around aggregators and their role in DSM (Gkatzikis et al., 2013, Mohammad and Mishra, 2019).

5 Concluding discussion and future research direction

This research in progress paper delivers an initial exploration of how stakeholders at the supply side perceive the role smart meter technology have or not have in solving Demand Side Management (DSM) problems. It is shown that there are significant gaps between: policies, goals and expectations on one side and implementation and use of smart meters on the other side. From the empirical data we claim that the tension between ambition and practice surrounding the smart meter technology needs to be taken into account by developing both functionality and usage of technology. What we see in the case is actually that stakeholders at supply side in a very negative way describe that the meters are already outdated when implemented. The smart meters has the possibility to measure real time energy consumption, but there are several uncertainties making the meters not used in that way at the moment. A major reason for this seems to be that it is unclear who has control over the data as well as how the data should or could be used. This is definitely an issue for further research. The empirical data also implies that the interviewees do not really see that the energy consumers have enough competence and/or interest in relation to why they should be engaged in solving DSM challenges. It is clear that this is a two-sided problem: First, electricity is a low cost and low interest product, Second, stakeholders at the supply side clearly state that they see their business and engagement end at the same time they have delivered the electricity to customers meters. The effect of this is that the suppliers have very low interest in assisting customers so that they could be of assistance in solving

DSM problems. The question is then how to implement and develop smart meter technology and the surrounding context around usage so that smart meter technology actually become a smart tool also when it comes to DSM and in the long run also drive a more smart (Gil-Garcia et al., 2016) and sustainable society. This also highlights questions around aggregators, such as who they are, what they should do, and what role they will play in DSM..

Electricity as a low cost and low interest product may also change, as we see an increase of prices on the energy market and calls for a more green future taking climate change into account. This clearly directs us to that this is a research challenge that needs a more thorough socio-technical and multi-perspective and stakeholder thinking (c.f. e.g. recent calls from Ågerfalk et al., 2021). Future research on smart grids can learn from previous ISR, several gaps above can e.g. be found in previous ISR and in other settings like e.g. smart cities (Granath et al., 2021), but also inform ISR with studies on applications of IT artefacts embedded in energy infrastructures. Our future research direction is then to explore how the digitalized smart meter should be developed in the future in relation to the five identified gaps: What functionalities are needed; what data are useful, and who as well as how should that data be used? All in all, this also directs us to explore this from different perspectives. Based on this result we conclude that there is a need to explore this further and to learn from a social-technical IS perspective also in the context of smart meters to overcome a one-sided, or even deterministic, perspective on technology.

6 Acknowledgements

This work has been conducted within the program “Resistance and Effect – on the smart grid for the many people” funded by the Kamprad Family Foundation.

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