Consumers' perspective on smartness compliance of electricity meters in Sweden

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Abstract

Smart Grid replaces the traditional grid to distribute and transmit electricity with the use of digital communication technology to achieve benefits such as improved efficiency, reliability integrity, availability, and confidentiality. One of the most important devices in the smart grid infrastructure is the Smart Meter. Many countries around the world have introduced smart meters to achieve various goals such as efficient energy consumption, demand side management, load management etc. Sweden was one of the first countries in Europe to introduce smart meters. However, despite the successful first wave of smart meter rollout in Sweden, Swedish electricity market still has several challenges to overcome to achieve the objective of demand side flexibility and efficient energy consumption. The main influences on these challenges are the functional differences of smart meters installed by different energy suppliers and obstacles related to consumers' perspective. In 2017, the Swedish government regulated a solution to the functionality difference of smart meters problem by introducing five minimum functional requirements for smart meters to be achieved by 2025. To bring solutions to consumers' perspective related obstacles, a thorough exploration is required. With millions of electricity meters being replaced in Sweden to meet the newly regulated minimum functional requirements, to ensure the success of the second wave of smart meter rollout in accordance with Swedish energy market goals and objectives, it is crucial to understand the consumers' perspective in compliance with these functional requirements to overcome the current and potential obstacles. This proposed research is expected to understand consumers' perspective in compliance with the minimum functional requirements of second wave of smart meters rollout in Sweden.

Keywords

Smart Metering, Smart Grid, Smart City, Digitalization, Smart Meter, Demand Side Management

1. Introduction

"Smart Grid" plays a significant role in energy management by replacing the traditional grid system to act as a real-time solution for monitoring and remote controlling issues associated with the traditional no-smart system. Baidya, Potdar, Pratim Ray and Nandi, 2021 describe smart grids as the backbone of existing energy production and supply scenario in today's society. Unlike the traditional grid, smart grid is an intelligent grid and can store, communicate, and make decisions while the traditional grid can only transmit or distribute electric power [12]. This smart communication feature of smart grid system brings the "Smart Meter" to focus within the smart grid context and makes it one of the most important devices used within the smart grid. The smart meter, as described by Zheng, Gao and Lin, 2013[15], is an advanced energy meter with several sensors and control devices supported by dedicated communication infrastructure that obtains information from the end users/consumers' load devices and

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measures the energy consumption and then provides added information to the utility company and/or system operator [15]. However, despite the detailed definitions provided for smart meter and its functionality, in many parts of the world, smart meter is simply a concept for grid development or in its very early stage in the deployment process and has not been able to reach its optimal functionality effectiveness level. Moreover, replacing a traditional electricity meter with a smart meter simply cannot build a sustainable energy infrastructure and help achieve its goals thus requires addressing technical challenges and improving consumer interaction [1]. Therefore, it is still questionable how smart do smart meters need to be to reach the objectives of the concept itself. It is also questionable how the 'smartness' is defined in a smart meter because smart meters possess different functionalities in different parts of the world and there is no defined 'smartness' or standard minimum functionality levels for smart meters to classify electricity meters as smart meters.

This paper is structured to explore the smart meter context in Sweden by creating a timeline with major events taken place in Swedish energy sector since 1996 and explains how smart meters were first introduced to Sweden and what problems were faced during the first wave of smart meters rollout in Sweden. This problem overview is used as the base for the main research question in this paper by taking into consideration the goals and expectations related to Swedish energy consumption. The next section is about the previous research that have been carried out on similar contexts related to the problems within smart meter context in Sweden. Then the main research question and its scope and methodology will be explained. Finally, the proposed questionnaire is presented with an explanation for each question in terms of aims and objectives.

1.1. Smart Meters in Sweden

The electricity being used in Sweden is manufactured both domestically and abroad. Sweden's electric power system underwent a major reform in 1996 and deregulated its electricity market on 1 January 1996. Before this deregulation, there was no wholesale market and no competition at the retail level. Consumers bought their power from the local electricity company which either generated its own power or acquired it from another member of the industry, which was the traditional structure of the electricity industry around the world, whether in private, national or municipal ownership [3]. Since then, electricity distribution via the electricity network takes place in a monopoly while trade in electricity is deregulated and customers have approximately 120 suppliers to choose from. The Swedish Energy Markets Inspectorate (EI) monitors the electricity market and regulates the electricity network operations [5].

Followed by the regulations adopted by the government in 2003, Sweden was one of the first countries in Europe to introduce smart meters, in order to fulfil the requirement of accurate, mandatory monthly/hourly metering for consumers based on the size of consumption instead of estimated invoices, by 2009 [8]. Some other key objectives the Swedish government considered when mandating monthly billing were,

To improve data handling between electricity Distribution System Operators (DSOs) and electricity retailers during consumer switch

To enhance competition in the electricity market

To encourage behavioral changes resulting in increased energy efficiency due to greater awareness of consumption

The expectation when bringing this regulation was to lower electricity consumption and lead to electricity savings of 3-4% by providing immediate feedback to the consumers of their consumption [9].

The functionality of smart meters has since then evolved to frequent measuring, but the varying functionalities of smart meters introduced by different distribution system operators has endangered consumers' rights to be treated equally [8].

Considering this concern, the Swedish Energy Markets Inspectorate (EI) has developed a new regulation introducing five minimum functional requirements for all the electricity meters in the low voltage network, to be achieved by 2025, in terms of; 1)Extended measurement, 2)Registration of active energy every hour or fifteen minutes and power outages, 3)Customer interface, 4)Remote collection of

measured data and power outages, 5)Remote updating of software, settings and control the power of the meter [8].

Extended measurement feature enables the electricity meter to measure and register energy use for both directions in terms of total withdrawal and input of energy. This is to ensure that the DSOs have sufficient information for efficient network operation. For the consumer side, electricity consumers can use this feature to get information for evaluating different energy services. The expectation when introducing this requirement is to promote efficient network operation and facilitate integration of micro production in the network [8].

Registration of active energy every hour or fifteen minutes requirement is introduced to increase customers' possibility to be active in the market and to to empower the customer while registration of power outages is to facilitate the DSOs to pay compensations to customers when power outages take place. Hourly or fifteen minutes data is important when developing demand side response services and electricity contracts to send out the right market signals. With this feature the electricity meter should be able to save active energy in both directions every hour and be able to convert every fifteen minutes so that it allows it allows customers to get a better awareness of their energy consumption [8].

Customer interface requirement enables customers to have a electricity meter that is equipped with a customer interface supported by an open standard for the customer to be able to take part of the measured values. The purpose of this requirement extends to empowering customer to promoting demand side flexibility and energy efficiency to the creation of developed energy services market [8].

Remote collection of measured data and power outages promote efficient data collection and with this feature, DSOs can read the extended measured values and outage information remotely. This requirement enables reduced personal costs increase the accuracy of the outage information and reduces DSO workload.

The last requirement – remote updating software, settings and control the power of the meter helps avoid expensive cost of electricity meter replacement with technology updating so that new requirements can be introduced remotely and in the most cost-efficient way by avoiding operational costs such as field visits. This also allows DSOs to turn the power on and off remotely when required. As of today, the government legislation to introduce these five minimum functional requirements for smart meters have influenced the replacements of many electricity meters in Sweden and leading to the second-generation of smart meter rollout in Sweden.

1.2. Problem Overview

According to Sernhed, 2008 [10], the core driving factor that led Swedish government to regulate monthly billing and introduce smart meters was due to customers' dissatisfaction and complaints about the past billing process and to increase customers awareness on their energy consumption and to achieve other objectives such as, estimated savings of 2%-3% on energy consumption, new development of electricity and network tariffs and an improved electricity market [10].

Although there has been an increased efficiency in appliances with technology development, the growing population and other factors such as weather, the economy and energy efficiency still affect energy consumption and according to the following figure, it can be seen that energy use in Sweden has historically been at an even level and has not been lower [6].

In the task to increase demand side flexibility, the Swedish energy markets inspectorate has chosen the following definition which is quite different to other definitions on demand side flexibility.

"Demand side flexibility is a voluntary change in the demand for electricity from the grid during shorter or longer periods, caused by of some type of incentive."

According to this definition, demand side flexibility is mainly customer focused and starts from a customer's electricity consumption instead of demand from the grid [11].

However, despite the updated billing process, newly developed electricity and network tariffs and somewhat improved electricity market, the Swedish electricity market still has challenges to overcome to achieve the goal on lower energy consumption and improved demand side flexibility due to several limitations within the smart meter context.

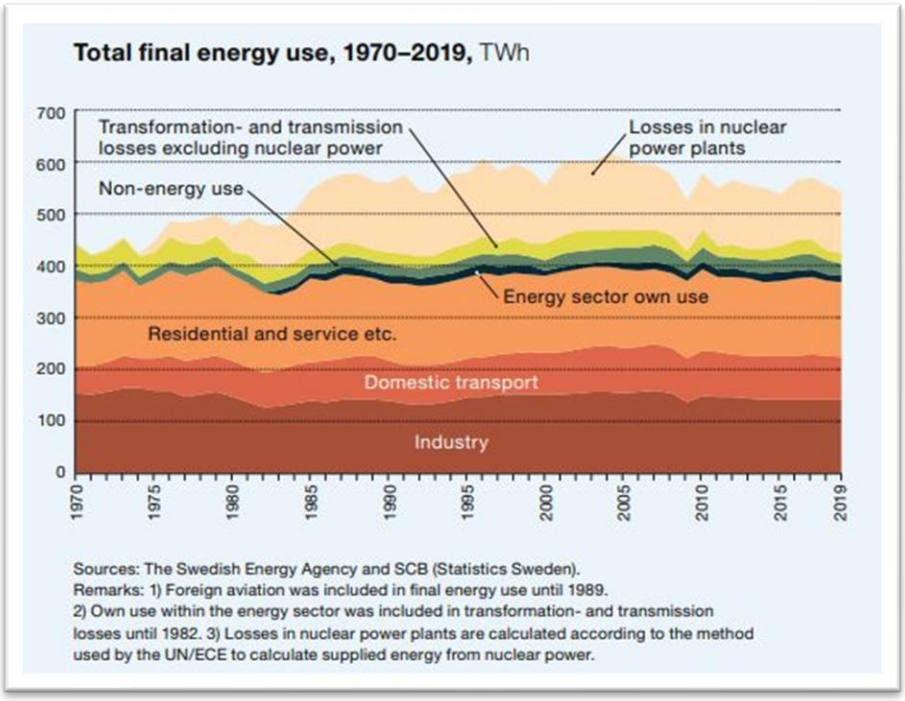

Figure 1: Total final energy use, 1970–2019, TWh [6]

Moreover, according to the Swedish Energy Markets Inspectorate, from a consumers' perspective, there are four types of obstacles to increased demand side flexibility [11].

-Customer interest in demand side flexibility is low.

-Customers do not know about the potential of flexibility and lack the technical equipment that makes it easy for them to offer their flexibility.

-There is currently a limited range of smart services and contracts for customers who wish to be flexible, and there is no tool for comparing and evaluating the offers that are available.

-There are market barriers and other obstacles for customers selling their flexibility to markets and/or network owners.

When analyzing these challenges further, one key challenge that leads to other challenges can be seen against reaching goals and lowering energy consumption within smart meter context. It is the lack of consumer awareness of their potential and role within the context to improve efficient energy consumption. This outcome has derived because, despite the thorough understanding of the potential challenges within smart metering context, the initiatives taken to improve consumer awareness and to involve consumers´ perspective within the context are weak and low. Vassileva and Campillo, 2016 have identified the lack of consumers' interaction with the smart meter and the lack of consideration of consumer' perspective in smart meter deployment as the main obstacles against reaching goals within the smart meter context [13].

One common reason that leads many digitalization projects around the world to failure is ignoring the potential resistance from the non-users in the design phase. This ignorance can lead to misconceptions and other resistance factors and encourage non-users. For example, it has been reported in some parts of the world about health hazards caused by having a smart meter installed in a house environment from exposure to radiofrequency [2]. In order to avoid resistance factors and to avoid creating non-users, it is important to address critical consumer concerns such as these and improve consumer awareness prior to smart meter deployment.

In addition to these challenges there are various barriers and other resistance factors against smart meter rollouts due to consumer dissatisfaction caused by various reasons in many other parts of the world. For example, one way to improve efficient energy consumption is to manage electricity consumption during peak periods efficiently which requires decreased use of household electrical devices during peak periods so that it helps manage the load on the electricity grids during the peak

periods and helps the consumer in return to reduce the consumer's electricity bill [1]. Nevertheless, in order to achieve this level of efficiency, it is vital that the consumer agrees on this. Therefore, for a successful smart meter deployment, it is important to ensure that the consumers are cooperative and are non-resistant within smart metering context.

In general, there have been many concerns among users/consumers from various countries over smart meter rollout over the past years that has led to delay the smart meter roll out and even to stop entirely in some countries [14].

Table 1

Consumer concerns over smart meter functionalities [14]

	Smart Meter Functionality	Consumer concerns	Consumer Assets Affected
01.	Storage of fine-grained consumption data.	Will provide insights into a household's living patterns to the extent that it could reveal the appliances used and activities conducted by the household.	Confidentiality, Security, Privacy
02.	Two-way communication and automated meter reading using various technologies.	Data susceptible to interception during transmission leading to modification or destruction of information.	Integrity, Availability of data and power, Privacy, Security.
		Exposures to radio frequency waves causing electro hypersensitive (EHS)	Health, Safety
03.	TOU tariff to reduce peak demand	Unable to avoid the peak period due to various reasons.	Comfort, Convenience, Financial
04.	Remote switching (disable and enable) of supply.	Possibility of getting disconnected by error or deliberate attempts by anti-social elements.	Safety, Security, Control
05.	Enable energy export and calculation of net usage.	Currently smart meter does not check before injecting the energy into the system and that could destabilase the system.	Availability of power, safety

Since Sweden has quite successfully regulated and rolled out the 1st generation of smart meters and was one of the first countries in Europe to embark on nationwide deployments of smart meters, the importance of user/consumer perspective is mainly required to successfully deploy the second wave of rollouts of smart meters, to optimally utilize the smart meter element and objectives within the smart grid and to avoid associated user/consumer concerns as much as possible. To achieve the efficient user-

centric energy consumption objectives and to improve demand side flexibility, it is important to improve consumers' awareness about their role in energy saving as well as the role of smart meter within smart grid infrastructure and to encourage consumer interaction with the smart meter in order to improve better and efficient energy consumption. Therefore, it is important to consider "consumers' perspective" as one of the most important aspects within smart grid research context.

1.3. Research aims and objectives

This research is aimed to understand smart meter consumers' perspective in general in compliance with the minimum functional requirements regulated for the 2nd generation of smart meter roll out in Sweden. The research methodology is planned to be designed to meet the following objectives:

- To understand the current level of consumer knowledge about the electricity meter.
- To understand the current level of consumer interaction with the electricity meter.
- To understand consumers' definition of smartness in electricity meters.
- To understand the consumer interest on the smart electricity meter.
- To understand consumers' concerns on smart meters.
- To find out the consumers' level of awareness about the minimum functional requirements of the future smart meters.
- To understand how important consumers find the minimum functional requirements of new smart meters.
- To understand consumers' expectations on smart meters.

Proposition:

- The improved consumer knowledge on their energy use patterns and costs, interaction and awareness of the smart meter can lead to lower electricity consumption.
- Taking consumers' perspective into consideration when designing and deploying minimum functional requirements for smart meters can lead consumers to efficient electricity consumption.

1.4. Previous research on similar context

In April and May 2014, Iana Vassileva and Javier Campillo developed and carried out an online survey in Västerås, Sweden in collaboration with the local city-owned electric power and district heating provided, in order to understand the perceptions and preferences of smart meter users. The survey approach was targeted to provide an overview of how and what is happening in relation to the full-scale rollout of smart meters in Sweden and was specifically targeted to understand the consumers´ perspective on full scale adoption of smart meters in Sweden [13].

The findings of the research mainly showed the lack of detailed enough electricity consumption information offered by the distribution system operators (DSOs) as a main barrier to the successful adoption of smart meters.

1.5. Research question

In line with Swedish Energy Markets Inspectorate´s regulation influenced Swedish government´s legislation to implement minimum functional requirements for smart meters by 2025, millions of electricity meters in Sweden are being replaced [4].

In order to achieve the optimal functionality effectiveness and for the success of smart meters and to meet the EI´s regulation objective in terms of efficient user-centric energy consumption for better demand side flexibility, it is important to explore and understand the consumers' perspective, emotions and level of awareness about the functionality of smart meters and its role in energy saving.

Therefore, the main question based on which this research is expected be caried out is,

- What is the consumers' perspective on smartness of electricity meters in compliance with the minimum functional requirements for electricity meters introduced by the Swedish government leading to a 2nd generation smart meters rollout in Sweden?

1.6. Methodology and Scope

The main research methodology expected to be followed in this research is qualitative – semi- structured interview method. The designed questionnaire will be followed up as the base for the interviews to explore consumer´s perspective on smart meter context in terms of emotions, expectations, concerns, and awareness. The questionnaire is designed in compliance with the research objectives. The participants will be able to provide short yes or no answers or will be able to explain their answers further in terms of how/what/why based on their willingness. The intention is to explore and understand their perspective in general but in detail about their awareness of the five minimum functional requirements introduced for smart meters and to understand their problems and concerns related to energy in Sweden.

Inhabitants from different geographical locations of Sweden to be chosen randomly as the participants for the interviews based on their will and contentment to participate in the interviews.

The interviews will be conducted both in real life and online, depending on the preference and convenience of the interviewees.

Table 2
Research Questionaire

Number	Question	Objective
1	Do you have a smart electricity meter at home?	To understand the current level of consumer knowledge about the smart meter. To understand the consumer interest on the smart meter. To understand the current level of consumer interaction with the smart meter.
2	When did you get your smart electricity meter installed?	
3	Do you know what 'smart' features your current electricity meter has that makes it a smart meter?	
4	Has the smart electricity meter been useful for you to reduce your electricity consumption?	
5	What features do you think make your electricity meter 'smart'?	To understand consumers' concerns on smart meters.
6	What features would you like to have in your new smart electricity meter?	To understand consumers' expectations on smart meters.
7	Are you aware about the minimum functional requirements regulated by the government for new smart electricity meters and do you know what features will be added?	To find out the consumers' level of awareness about the minimum functional requirements of the future smart meters.
8	How important do you think the minimum functional requirements regulated by the government for new smart electricity meters are?	To identify users and non-users of the smart meter and smart grid To understand methods to improve consumer knowledge and awareness of the role of smart meter for efficient energy consumption.
9	Can you think of any further minimum functional requirements for smart meters?	
10	Are you aware about how smart electricity meters can contribute for efficient electricity consumption?	

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