Smart Grid Indicators for the Swedish Regulatory Authority for the Implementation of the Clean Energy Package

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Abstract

The Swedish Energy Markets Inspectorate (Ei) is an authority which is commissioned to strive for well-functioning energy markets. The EU directive 2019/944 contains requirements on the national regulatory authorities with respect to the system operators smart grid development that includes energy efficiency and the integration of DER. In addition, the member states should promote effective system operation. In order to assess smart grid development, it is important to identify indicators (both technical and economic) that objectively reflects the smart grid implementation in a Swedish context, that can be used in the regulatory context. This article contains the preliminary results of a feasibility study regarding smart grid indicators as a tool for assessment and supervision to reflect the smart grid development in Sweden.

1. Introduction

The Swedish Energy Markets Inspectorate (Ei) is an authority which is commissioned to strive for well-functioning energy markets. The responsibility of Ei is to oversee that the distribution system operators (DSOs) and the transmission system operator (TSO) comply with the Swedish Electricity Act regarding reliable and effective networks by fulfilling requirements for the delivery of electricity.

The clean energy package (CEP) transforms the regulatory framework for the energy system. Increased penetration of weather-dependent and variable generation, distributed energy renewables (DER), energy storage, new smart technical solutions, electrification of the transport sector and industry, including digitalisation are a few of the trends that challenge and create new opportunities for the energy system. Several of these trends also contributes to electricity becoming a more important energy carrier. An effective energy system transition involves a modernisation of the electricity network. The modernisation is often referred to as an implementation of the smart grid.

The concept of the smart grid involves technical and administrative solutions pertaining to an increased flexibility for the utilisation of the electricity grid. The customer perspective finds the most prominent benefit associated with smart grids as the possibility of an increased customer influence by enabling more active choices on the market. It could be to actively control consumption through an aggregator or utilise new products and services for energy efficiency. The societal perspective finds the benefit in effectively utilising available energy and more importantly avoid utilisation that has a negative impact on the environment.

The desired result associated with smart grid development is to establish efficient utilisation of the existing network that is in the process of an energy transition and a long-term sustainable development for the network. Smart grid development can be qualitatively and quantitatively measured by different indicators, for example, hosting capacity of renewable energy resources, losses and reliabilities. These indicators may further be used by the Swedish National Regulatory Authority (NRA), Ei, to supervise the smart grid development in accordance with the EU directive 2019/944 which is part of the CEP. Smart grid indicators and a combination of them need to be analysed before they can be utilised by Ei to assess the DSOs and TSOs smart grid development.

The EU directive 2019/944 contains requirements on the national regulatory authorities with respect to the DSOs smart grid development that includes energy efficiency and the integration of DER. In addition, the member states should promote effective system operation. In order to assess a smart grid development, it is important to identify indicators (both technical and economic) that objectively reflects the smart grid implementation in a Swedish context and that can be used in the regulatory context. This article contains the results of a feasibility study regarding smart grid indicators as a tool for assessing and supervising the smart grid development in Sweden.

2. Other relevant legislations and data already collected today by the Swedish NRA

Ei determines a revenue cap for each DSO (~170 different) and for the TSO. The revenue cap is adjusted based on e.g. the continuity of supply (CoS) and the performance regarding efficient grid utilisation. The Swedish power system and its regulations are described more in e.g. [1] and [2].

Ei already collects a lot of data. A part of the project is hence to evaluate which of this data that can be used as it is or within the calculation of smart grid parameters. The data collected are primarily used for the revenue cap regulation and to monitoring the compliance with regulations. All DSOs annually report over 30 different data parameters for each customer (gives more than 165 million data items per year). This collection includes e.g. customer category, annual energy consumption and production, voltage level and a large amount of outage categories. Besides all data on a customer level, the DSOs and the TSO annually report a lot of economic and technical data to Ei on an aggregated level (e.g. energy consumption, production, losses, length of different feeder categories and different expenditure categories). Furthermore, each four year, there are additional data collected related to the revenue cap regulation regarding; for example, component information (age and categories).

Besides the revenue cap regulation, there are a lot of other legislations related to power systems that can be of interest to consider within the project. One example are functional requirements for smart meters. The minimum smart meter requirements should be implemented by 1 January 2025 by the DSOs. One of the requirements is that the smart meter should be able to save the active energy in both directions every hour and be able to convert to every fifteen minutes for more information see [3].

3. Overall objective for the smart grid development

The overall objective of the smart grid implementation is aimed towards: energy efficiency, integration of energy generation from renewable sources and resiliency. This paragraph explains each part and puts it into a Swedish context.

3.1. Energy transition – integration of renewable energy sources

The integration of renewable energy sources (RES) is one of the initiatives to reach EUs transition to a climate neutral society in 2050. Sweden has set ambitious climate action goals. One of the Swedish energy- and climate goals is that:

- Electricity production in the year of 2040 should be 100 percent renewable.

The goal implies that Sweden in 2040 no longer uses fossil fuels (e.g. coal, oil and natural gas) for electricity production [4]. To reach the goal, the electricity grid needs to integrate a large amount of RESs, such as hydro power, wind power, solar power and bioenergy. In 2018, the share of renewable energy was 54,6 % of the total energy consumption [5]. Facilities such as larger hydro power plants are often connected to the transmission grid, while distributed generation, e.g. small-scale solar power, is often connected to the regional or local distribution grid (the different voltage levels are described in [1]). Therefore, not only the transmission grid, but also regional and local distribution grids should gear up for the transition.

RESs increases variability in electricity production. In order to facilitate this integration, network operation needs to adapt to this new generation profile. Wind power curtailment or activation of flexibility services could be considered as measures to accommodate more renewable energy.

Another energy and climate goal in Sweden is to rapidly reduce CO_2 emissions:

- Net zero emission should be 85 % lower, at the latest by 2045, than 1990, 85 % of the reduction should be in Sweden
- The emission level in 2030 should be 63 % lower than 1990
- Emissions from the transportation sector in 2030, including domestic flights, should be 70 % lower than 2010

These goals will lead to an increased amount of electric vehicles (EVs). In 2018 the number of EVs increased with 52 % in Sweden. In a smart grid context, these EVs will be used to accommodate more renewable energy by charging while the electricity price is low and discharging to the grid when the electricity price is high.

On a future electricity market with more variable electricity production, along with an increased focus on electrification, it is important to utilise all flexibility resources in the electricity grid, e.g. flexible production, storage and demand response. Increased flexibility in the grid will involve:

- Reliable data available to all market actors regarding for instance available demand response and renewable energy production.
- The existence of well-functioning flexibility markets with well-established market conditions.
- Correct pricing signals that reaches the customer. For instance by using tariffs, smart meters, and smart metering data systems (SMDS).
- That flexibility could be seen as a reliable alternative to traditional grid reinforcement when there is a need for increased capacity.
- New consumption patterns.

3.2. Energy efficiency – asset management and efficient operation

Traditionally, the Swedish electricity system has been able to connect new customers continuously unproblematically. With an increased electricity production and electricity consumption, this situation has changed. It's no longer considered socially economically justifiable to dimension the grid with an overcapacity, since this is not associated with optimal utilisation [6]. This requires an entirely new approach to asset management than the traditional grid reinforcements and construction.

With an increasing age of the grid assets and increasing amount of distributed generation, both the energy losses and the risk of interruptions increases. At the same time it is possible to free new capacity, instead of constructing new electricity facilities, for instance by investing in new technical solutions that increases grid utilisation and to make use of demand response, by e.g. operate lines with a dynamic ranking, use reactive power compensation, perform real-time control of transformers on-load tap changers and to promote demand response. This allows for operation close to its maximum capacity limit without compromising system stability. The effect of this is to delay grid reinforcements and to connect more consumers with the existing asset base. For some components, it is also possible to use diagnostic data to determine the optimal time for replacement. Such an exchange minimises the risk of failure events related to component failure. A better ability for risk prediction, allows network companies to implement measures to minimise the overall risk picture; e.g. if a grid company can predict power peaks, the company can use disconnected loads or increase the price signal in the grid tariff, thereby avoiding bottlenecks in the electricity grid. The new approach to asset management also means taking into account new technologies and opportunities, instead of traditional network reinforcement, before replacing components to achieve cost and energy efficiency.

One of the Swedish energy and climate targets for 2030 is that energy usage should be 50 % more efficient in 2030, compared with 2005 [4]. The concept of energy use includes both energy consumption and energy transfer. To contribute to energy efficiency, electricity grid operation needs to be more efficient, i.e. to reduce transfer losses. This can be done, for example, by increasing automation in the electricity grid. Through automation, the system can respond quickly enough with its own functionality and it is possible to reduce resources from operational personnel. By promoting demand flexibility in order to achieve a smooth flow in the grid, losses can also be reduced in energy transfer.

3.3. Resilient and reliable electricity grid

Today's society relies on the availability of electricity and the general trend of electrification means that we will be even more dependent on electricity in the future. This trend is due to more EVs, a greater need for cooling in the summer, increased amount of heat pumps that requires electricity and that society becomes more high-tech. A well-functioning electricity supply is therefore essential for the function and development of society.

An important aspect of a resilient grid is the system stability, which is the power grid's ability to withstand disturbances. These disturbances can occur, for example, in the event of loss of production or load. System stability is commonly divided in to frequency stability, voltage stability and angular stability. With more intermittent electricity production e.g. solar and wind power, there will be less inherent inertia of the system that is obtained from heat, hydro and nuclear power. This change means that the electricity grid needs to be designed according to the new conditions and there is a need for new or developed system services (services to maintain system stability).

One of the challenges with a higher proportion of intermittent electricity generation is reduced inertia in the system, which reduces the system's resistance to disturbances. The inertia is created by "heavy" rotating generators and turbines e.g. hydro and nuclear power. Less system inertia creates a need for faster frequency response which could be obtained through flexibility services. Another way of limiting disturbances due to less system inertia is the introduction of synthetic inertia.

The electrical system is dependent on continuous access to high-quality electricity delivery. In the event of a power failure, high costs are bestowed on society. Some customers are sensitive to interruptions regardless of length (e.g. expensive reboots), while others are more sensitive to long interruptions (e.g. cooled merchandise). Many costs are difficult to value, such as reduced comfort for private customers. When businesses and other sectors of society are affected by electricity outages, the societal economy is affected in various ways through direct and indirect costs.

The energy transition could affect the quality of supply. Therefore, it is important that this aspect is included in the smart grid assessment. The use of smart grid solutions has the potential to ensure that the grid is resistant to disturbances. A well-connected network with sensors, smart electricity meters and automatic control allows for higher reliability in electricity delivery. Monitoring, control and automation are prerequisites to a resilient electricity grid.

The final aspect is that of cyber security. Smart grid solutions have two sides to it in relation to cyber security. The increasing number of digitally-connected devices that interact with control systems is steadily increasing, along with the fact that each new input also increases the risk of potential attack-surfaces to the system. Energy networks include more and more digital interfaces to a variety of actors outside the boundaries of the energy system. On the other hand, smart grid technology can increase the resilience by contributing to the visibility of the grid. Also, customisable controllers can ultimately enable system technicians to detect faults earlier, restore the grid faster and operate the grid with more flexibility.

4. Smart grid indicators

The purpose of smart grid indicators is to reflect the development of the modernisation process of implementing smart grid technologies. The actual realisation of the concept of a smart grid will take on many different forms depending on the actual physical grid, in particular circumstances governing the transition and legislation. Hence, not all modernisation processes will look exactly the same and there will have to be some overlap between indicators to allow for these discrepancies.

The secondary reasons for collecting smart grid indicators could be: help policy makers and authorities to design incentives to improve the smart grid. The smartness of a particular type of Swedish grid or the Swedish grid as a whole can also be compared to other areas or countries respectively. Furthermore, the results of projects that applies to development in smart grids can be evaluated. [7]

4.1. Evaluation criteria

In the process of evaluating the smart grid indicators evaluation criteria have been chosen that reflect the overall aim of the initiative. The probable main criteria for smart grid indicators in the regulatory context in Sweden are:

- Measurability/computability – is it possible to objectively measure or calculate the indicator?
- Relevancy – is it relevant for the smart grid context?
- Openness – Is it possible to publish the indicator? Does it represent sensitive information?
- Responsiveness – Can DSOs affect the indicator?
- Technology neutrality – is the indicator technologically neutral?
- Ability to quantify consequences – does the indicator have the ability to quantify consequences?
- Availability – Is it practically possible to collect data for the indicator from the DSOs?
- Representativeness – Is the indicator representative for the smart grid development of the DSO? Area? Or line?

4.2. Possible smart grid indicators

Possible smart grid indicators could either be or could reflect the following:

- Hosting capacity
- Maximum power injection
- Losses in transmission and distribution
- Voltage variation
- Capacity factor
- Resiliency
- Efficiency
- Grid Utilisation
- Load factor
- Operational ratio
- Energy not withdrawn from renewable sources due to congestion or security risks
- Percentage of Smart meters in the overall fleet
- Share of renewable energy

5. Future work

The coming project will involve choosing a reasonable set of smart grid indicators for the overall objective. This involves a more comprehensive analysis of suitability both in the short and long term, test pilot and a substantial work of identifying a coherent definition for each indicator.

6. References

[1] C. J. Wallnerström, Y. Huang, G. Wigenborg, L. Ström, and T. Johansson, 'Incentive scheme for continuity of supply in the Swedish revenue cap regulation from 2020'. CIRED 2019, Madrid, Spain, June 2019, paper no 946
[2] C. J. Wallnerström, Y. Huang, G. Wigenborg, L. Ström, and T. Johansson, 'Incentive scheme for efficient grid utilization in the Swedish revenue cap regulation from 2020'. CIRED 2019, Madrid, Spain, June 2019, paper no 0948
[3] Y. Huang, E. Grahn, C. J. Wallnerström, and T. Johansson, 'Smart meters in Sweden- lessons learned and new regulations'. AIEE, 2018
[4] 'Sveriges energi- och klimatmål - Energimyndigheten', http://www.energimyndigheten.se/klimat--miljo/sveriges-energi--och-klimatmal/, accessed 9 March 2019
[5] 'Användning av förnybara energikällor – Ekonomifakta', https://www.ekonomifakta.se/fakta/energi/energibalans-i-sverige/anvandning-av-fornybara-energikallor/, accessed 9 March 2019
[6] The Energy Markets Inspectorate (Ei), 'Incitament för effektivt utnyttjande av elnätet', EI R2015:07, 2015
[7] B. Dupont, L. Meeus, R. Belmans, 'Measuring the "Smartness" of the Electricity Grid', 7th International Conference on the European Energy Market, IEEE Xplore, Madrid, Spain, July 2020