# The potential of renewable energy in the Swedish Distribution Networks

## A case study in southern Sweden

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*Abstract* — **The study aims to identify the potential for small-scale establishment of wind power in southern Sweden. The results are based upon empirical data from questionnaires and interviews with Distribution Network Operators (DNOs) in southern Sweden.**

**The investigation shows that there is available capacity in the distribution networks of between 875 to 1036 MW, where grid connection could be offered without high reinforcement costs. Further, several DNOs in southern Sweden has an administrative approach to their business activities. One third of the DNOs have no knowledge of the most common smart grid technologies. Two thirds of the DNOs have not considered using the services of any smart grid technologies. The Swedish Energy Markets Inspectorate is currently developing new incentive models to encourage network operators to make their grids "smarter". The result of this work will be very important in the future.**

***Keywords-component; wind power; smart grid; distribution networks.***

## I. Introduction

Today, renewable energy is expanding all over the world. The European development is mainly driven by EU targets for renewable energy and climate, and Germany has taken a leading role in the transition. In Sweden the development is driven by the Swedish-Norwegian electricity certificate system, which has a target of 26.4 TWh of renewable electricity generation from 2012 to 2020. A large part of the Swedish electricity is being produced in the northern parts of the country. This means that the transmission system has to transport large quantities of electricity to the south of Sweden where the demand is greater. At the same time, several countries show trends that are leaning towards a more small-scale and local production.

If more power is connected on a distribution level instead of transmission level the energy is produced closer to the consumers and losses are minimized. It is important to investigate challenges for integrating small projects with wind power and other renewable energy to the distributions networks.

This study aims to identify the potential for small-scale establishment of wind power in southern Sweden, typically plants with installed capacity between 0,1 to 20 MW, connected to the distribution networks. A further aim is to investigate how this potential can be increased by the use of smart grid technologies.

## II. Method

### A. Questionnaire

The questionnaire was sent to 89 DNOs in the eight most south located counties in Sweden. The questionnaire contained 16 questions, and was estimated to take between 10 and 15 minutes to answer. Firstly, there were some short questions to map the respondent, followed by questions about the DNOs existing connected, and in-process electricity production plants. Secondly, the questionnaire contained questions about rated available capacity in the distributions networks and obstacles to connect more renewable energy. The third part handled smart grids and was aimed to map the knowledge and usage of smart grid technologies. The response rate was 58 %.

### B. Interviews

Criteria were set up to choose the most interesting questionnaire answers to dig deeper into and call the respondent for an interview. Four local DNOs were chosen, as well as the three biggest DNOs in Sweden, E.ON, Fortum and Vattenfall.

The interviews were divided into three categories; following questions from the questionnaire, connections and reinforcements as well as smart grid technologies and future.

## III. Results

The result is based on the answers on the questionnaires, the interviews and workshops with a group of experts. The electricity production plants that are considered in the results are between 0,1 to 20 MW.

### A. Integrations

According to the Swedish Energy Markets Inspectorate it is possible for DNOs to charge for proactive

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reinforcements that are done in advance for a coming power plant. It requires that the DNO can prove the reinforcement was aimed for coming new connections. If an expected connection does not come about, the DNO itself has to cover the costs. This risk is avoided though, if the DNO only builds for today's need of reinforcements, a way of working that might not be the most long-term optimal way.

If a DNO consider it impossible to connect the power applied for by a wind power developer, the DNO can refer to the overlaying subtransmission network for connection. 40 % of the respondents answered "I don't know" to the question at what power span they refer to the overlaying network. The explanation is that it depends on where in the network the project will be connected, but the DNO will reinforce the grid and make a connection possible as soon as a sharp order is handled in. Every establishment of renewable energy has it own unique ground and wind conditions as well as grid connections capabilities. Wind conditions are often better in rural areas where the grids are weak and a connection will therefore be more expensive there than close to a well developed network, e.g. close to a city.

The study shows that 10 % of the respondents of the questionnaire refer to the overlaying grid already by projects of 5 MW. These respondents consider their distribution network full, which indicates that they have an administrative approach to their business. The name "distribution network" is an old name indicating that the network was built only for distribution of electricity to the consumers, not for connecting power production and taking care of possible surplus production. This old name and mindset still lasts for a part of the DNOs. The knowledge and preparedness for connecting projects of power production can therefore vary.

It is necessary to discuss how the Swedish electricity network system can be drifted as optimal as possible. From a system perspective, how should a DNO handle a connection application in the most rational way? According to one of the DNO chiefs the easiest solution would be if all new renewable energy were big offshore wind power plants connected to the transmission networks in a conventional way as big power plants, water and nuclear power, were connected years ago. In this way Sweden could connect a big share of renewable energy at the same time as the DNOs role and way of working does not change. Further, this helps DNOs not being a reason for delays in the development of renewables.

### B. *Investments*

Reinvestments are the biggest expenditures for most of the DNOs. Vattenfall Distribution's reinvestments correspond to 50 % of all investments in their distribution networks every year. Remaining investments are in for example new connections of industries or generators, as well as in for example IT.

Today reinvestments and upgrading of the networks is an ongoing work, which often takes place first when the grid has reached the technical lifespan of 40 years. When upgrading these networks there is a chance for the DNOs to prepare the grids for being "smart" by building in smart technologies needed in a near future. Here, it must be considered that new technology may have shorter technical and economical lifespan and that more built in techniques means a bigger risk due to more sources of errors. The regulation of the revenue framework does neither contain obstacles nor incentives to invest in smart technologies. But when investing in new technologies the amortization period and yield rate are the same as for old technologies, which can be seen as an obstacle if the lifespan for new technologies is shorter than for old ones.

### C. *Available capacity*

The cost for a grid connection of a wind park varies widely. Normally the distributions networks as well as the subtransmission networks have to be reinforced to be able to handle new power production. A connection with "moderate reinforcements" can for example be a project where the distribution and subtransmission networks do not have to be reinforced, a location with an unused compartment in the transformer station or a place with a generator that is no longer running.

The receivers of the questionnaire were asked how big the available capacity in their networks is with "moderate reinforcements". The average available capacity of the respondents is 4,9 MW, which in total is 254 MW. The distribution of the answers is shown in Figure 1.

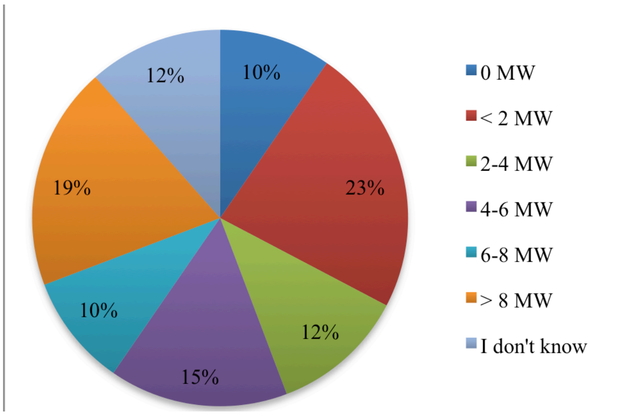


Figure 1. Available capacity with moderate reinforcements.

E.ON, Fortum and Vattenfall operate the biggest part of the studied area. This fact is also the answer to why they could not answer this question with a number. Instead a calculation has been done based on the number of customer as well as on the length of the grid length of these three operators. E.ON, Fortum and Vattenfall have 46 % of the total amount of customers and 60 % of the total grid length in the studied area. Consequently, based on the number of customers the available capacity of the three grid operators would be 405 MW. The corresponding result based on the length of the grids is 626 MW.

Same calculations were done on the DNOs not answering the questionnaire. This sums up in two numbers when all available capacity from the respondents; the non-respondents and the three biggest DNOs are taken into consideration. Based on the number of customers there is a total of 875 MW available capacity in southern Sweden. Based on the grid length there is a total of 1036 MW available capacity in southern Sweden.

10 % of the respondents answered that they have no available capacity with "moderate reinforcements". The most common reasons were fear for overvoltage and DNOs that want to dimension the grid based on the demand. This

indicates a lack of interest to let produced electricity be fed in to the overlaying networks. Other limitations mentioned in the questionnaire were wires, cables and transformers. Further investigation is needed to identify potential incentives and attitudes to connect more renewables in the distribution networks.

Urban electricity networks are generally strong and have a big amount of available capacity. On the opposite, in rural areas the networks are weak and in most cases in need of reinforcements. It is a paradox with urban areas' big potential for wind power integration where buildings are dense and the small potential for wind power integration in rural areas where other conditions for building wind power generators are good. On the other hand, the big potential in urban areas can be utilized by solar power. Studies on monthly energy production in Germany show that wind and solar power interacts in a complementary way [1]. Consequently, the conclusion can be drawn that a mix between energy sources, e.g. wind and solar, has a big potential from a systems perspective.

*D. Knowledge of smart grid technology*

Results in the project show that 30 % of the DNOs have no knowledge of the most common technologies for smart grids. The most well known technologies are demand response and interruptible capacity. These technologies were used in the 80s but became less interesting when the Swedish electricity market was regulated in the 90s. With today's demand of integrating more renewables and need of matching production and consumption, these technologies are required again.

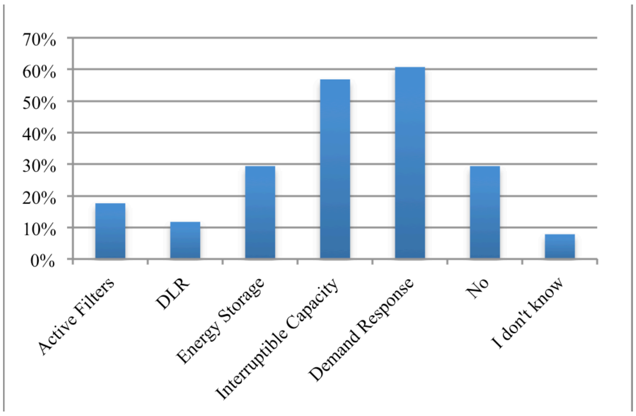


Figure 2. Respondents' knowledge of smart grid technologies.

The small DNOs expressed that they are too small to be early adopters and take the risk of testing new technologies. The big DNOs on the other hand stated that they are too big, and have too many customers that would be affected if they test new technology and something would go wrong. This again, witness of an administrative approach of the DNOs and that development and optimization are not priority.

*E. Use of smart grid technology*

When the DNOs answered the question "Have your distribution company considered using any of the listed smart grid technologies?" 67 % of the respondents answered "No". The most common technologies that the DNOs have considered to use are response demand and interruptible capacity. With regard to the result of the knowledge of smart grid technologies, this answer is not surprisingly. It is likely that the 30 % share that does not have knowledge of smart grid technologies has answered "No" on this question too. Still, 37 % of the DNOs that have knowledge decided not to use any.

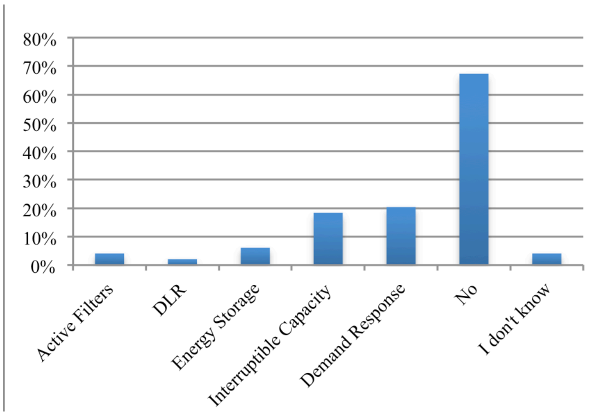


Figure 3. Distribution of smart grid technologies that responding DNOs have considered using.

The study shows that the economic incentives are the biggest barrier for DNOs to test smart grid technologies. There is a need of new smart grid technologies to be tested and demonstrated. If DNOs regulated revenue cap is too low, or designed in a way that does not give incentives for investments in new technology, the development can be prevented or slowed down. Based on the wide spread in knowledge of smart grid technologies, it might be a challenge to develop an effective incentives system that fits all DNOs.

In times where more local produced renewable energy is connected to the distribution networks the role of the DNOs is changed and developed. New tasks require new competence. Between the years 2012 and 2016 there is an employment demand of 8 000 new energy engineers in the energy sector [2]. Hence, it might lead to a challenge recruiting skilled staff to the distribution companies, a fact that is supported by the interviews with DNOs.

A case study of the E.ON offshore wind power plant in Kårehamn, Sweden, shows an innovative solution using a smart grid technology. The 50 kV electricity line near Kårehamn can handle only 20 MW, but with some modifications they allowed a 36 MW wind power plant to be built. The reason is that E.ON uses a Dynamic Line Rating (DLR) system which uses temperature sensors on the lines to, when needed, control the wind park if the current is too high and the temperature gets too high which gives too much sag on the line. Thanks to the system E.ON managed to integrate 160 % of the allowed power and at the same time avoid, or postpone, an expensive investment in the network. The Swedish regulation does not encourage this kind of solutions. The Swedish Energy Markets Inspectorate has proposed an addition to the regulations suggesting that DNOs should be encouraged to decrease energy losses in the lines. The DLR solution though, probably increases network losses, but is more cost effective towards electricity consumer since a big investment was avoided. This shows as an example of how important regulations are to stimulate cost effective and smart grid solutions.

## IV. CONCLUSIONS

The DNOs from the southern Sweden who participated in this study, show an average available capacity of 4.9 MW (per DNO), with "moderate reinforcements" of the grids. The investigation shows that there is a available capacity in the distribution networks of between 875 to 1036 MW, where grid connection could be offered without high reinforcement costs. If DNOs would identify the locations that require only "modest reinforcements" to enable grid connection, many relatively cost effective grid connections of renewable energy can be offered.

Several DNOs in southern Sweden has an administrative approach to their business activities. There is lack of interest in the transition from the traditional view of the business that involves distributing electricity to the customers, and move toward a newer way of thinking that involves the development of more locally connected renewable power plants and increased use of the grid by using smart technologies.

One third of the DNOs have no knowledge of the most common smart grid technologies. Two thirds of the DNOs have not considered using the services of any smart grid technologies. One reason to the lack of knowledge is the aforementioned administrative approach. A conclusion that can be drawn from this is that the DNOs need a lot more information about both smart grids and connection of renewable energy to the distribution networks.

One reason for the lack of interest is probably lack of incentives for DNOs to invest in or to test and demonstrate smart grid technologies. The Swedish Energy Markets Inspectorate is currently developing new incentive models to encourage network operators to make their grids "smarter". The result of this work will be very important in the future. The fact that the competence among DNOs varies greatly could be a challenge for the Energy Markets Inspectorate.

About half of the DNOs' investments in the electricity grids are reinvestments. When rebuilding the grids, the DNOs could take the opportunity to prepare their grids to become "smarter". This is a hard task that could be facilitated by clear long-term goals that relates to the Swedish electricity grid system. Currently there is no critical need for smart grids and therefore it is difficult for the DNOs to know what is required of the grids and what can be prepared. Germany has already encountered problems with the electricity grid due to the extremely rapid and large expansion of renewable energy. Germany can therefore provide an example that Sweden can draw important lessons from.

## REFERENCES

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