EXPERIENCES FROM INTEGRATING DISTRIBUTED GENERATION IN NORWAY: RESULTS FROM A DSO SURVEY 2010/2011

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ABSTRACT

This paper reports the results from a survey conducted in 2010/2011 among 14 Norwegian distribution system operators (DSOs) concerning their experiences with integration of distributed generation (DG) in distribution networks. The survey shows what kind of problems DSOs experience caused by DG connected to their networks, how the DSOs approach the problems and what kind of planning methodologies and tools the DSOs are using to overcome the problems.

The results of the survey show that most of the DSOs have experienced problems with DG units connected to their network, despite the network reinforcements that have been necessary to integrate many of the DG units. The survey also shows that several of the DSOs are expecting a considerable increase in the number of DG units in their distribution networks in the years to come. This increase will probably be accelerated by the introduction of green certificates by 01.01.2012[1], which is expected to increase the profitability of many DG projects. Some of the DSOs have started to address the challenges in their planning methodologies, improving their planning procedures in order to optimize the DG integration process and decrease the need of expensive grid reinforcements. Still, only a few go beyond the normal planning procedures for networks without DG.

INTRODUCTION

Distributed generation (DG) is expanding fast worldwide, driven by electricity market liberalization and to an increasing extent, environmental concerns [2]. In the search for clean energy, DG from renewable energy sources is a good option for many countries and Norway, with its large potential for small scale hydro power, is no exception.

However, as in the rest of the world, integration of DG has brought new challenges to the network operators, for example optimization and decision challenges related to limited transfer capacity in the existing networks, fluctuating power production and handling of violations of voltage quality threshold values.

Integration of DG also creates a need for new methodologies concerning network planning compared to traditional practices, e.g. handling of uncertainty regarding how many of the planned DG units will be built, where these DG units will be located, when these units will be ready for grid connection [3] and what analyses to perform [4].

This paper reports the results from a survey conducted in 2010/2011 among 14 Norwegian distribution system operators (DSOs) concerning experiences with integration of distributed generation in MV networks. The survey shows what kind of problems DSOs experience caused by the connection of DG to their networks, how the DSOs approach the problems and what kind of planning methodologies, techniques and tools the DSOs are using to overcome the problems.

BACKGROUND

DG in Norway

In Norway, there is a large potential for distributed generation based on renewable energy sources, mainly wind and hydro. Small scale hydro is the predominant type of DG being built. These are generation units up to 10 MW [5], often connected to the MV distribution network. In 2010, there were over 900 small scale hydro power plants in Norway, counting for approximately 73 % of the total number of hydro power stations, but only approximately 5.5 % of the average yearly production in TWh, see Fig. 1 [6].

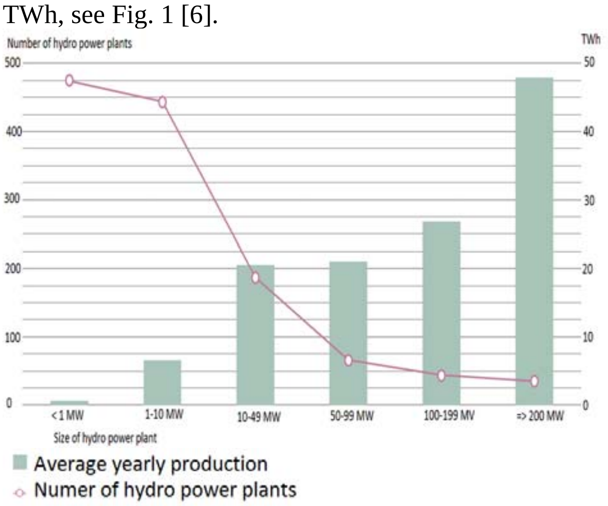

Figure 1 Number of hydro power plants, and total average yearly production as a function of size of power plants [6]

In 2010, the remaining potential for small scale hydro in Norway was estimated to be 16.5 TWh [6]. This potential mostly lies in small rivers without reservoirs, in mountainous regions that are sparsely populated and far from main load centres. The DG generation vary with the availability of water in the river, and hence have substantial seasonal variations. Peak production (which will occur usually during spring) will not be in phase with the system peak load (which usually will occur during the winter, when the run of rivers is low).

Distribution networks in Norway

The Norwegian MV distribution system has been developed over many decades and is in general an ageing infrastructure. By law, distribution companies are required to offer indiscriminate access to the network to all network users – both end-users and producers. DSOs are hence obliged to connect DG units and make the necessary network investments, given these investments are socio-economic rational. When network reinforcements are needed in order to connect new DG units, the DSOs can charge the DG owner for his/her share of the reinforcement costs. This practice reduces the economic risk for the DSOs and is done in the majority of connection cases. However, these costs can be substantial and will add to the total DG investment costs, and might make the future DG owners reconsider or postpone their investment decision. If there are possibilities that other DG units will be built in the same area, the owners of these DG units will have to share the costs and this might be worth waiting for.
In total there are approximately 150 network companies in Norway which are regulated by the income cap regime [7]. The majority of network companies have few customers, se Fig. 2.

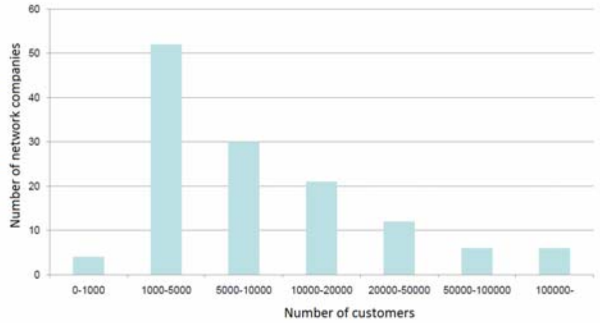

Figure 2 Number of network companies and customers [7]

The distribution networks in areas with high DG potential are often weak MV networks with limited - or even non-existent transfer capacity.

SURVEY RESULTS

General information

In order to gather information on the status of DG integration and planning in Norway, a survey was conducted in the OiDG[1]-project. 14 DSOs responded to the survey, providing their information on the status of DG integration. Some general information about DG from the DSOs participating in the survey is provided below:

- All respondents were responsible for planning of distribution network, 8 for both distribution and sub-transmission networks, while 4 respondents were responsible for distribution, sub-transmission and transmission networks.
- The 14 respondents have 368 DG units connected to their distribution network. The number varies between 0 and 22 DG units (below 1 kV) and 2-40 DG units (1-22 kV).
- 92 % of the DG units connected today use hydro as energy source, 3 % wind, 3 % bio and 2 % natural gas.
- 12 out of 14 have reinforced the network as a consequence of connection of DG units.
- 11 out of 14 have collected investment contributions to finance the necessary network reinforcements.

All respondents have mapped the <u>potential</u> for DG in their area, see Fig. 3.

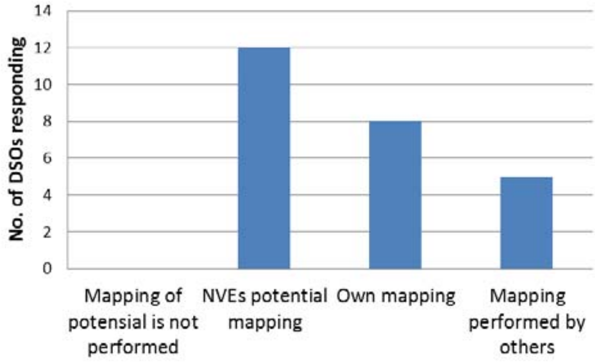

Figure 3 How mapping of potential for DG is performed

The potential was mapped using the following sources of information:

- The Norwegian Water Resources and Energy Directorate (NVE) national mapping of potential [8].
- Their own mapping of potential.
- Mapping performed by others, like other DSOs in the same region or production companies which are part of the DSOs company group.

Two DSOs used all the three sources in their mapping of potential, one used just mapping performed by others, while four used only the mapping performed by NVE.

All respondents have mapped the <u>plans</u> for DG in their

1 SINTEF-project "Optimal infrastructure for seamless integration of distributed generation" (OiDG) - http://www.sintef.no/Projectweb/OiDG/

area, see Fig. 4.

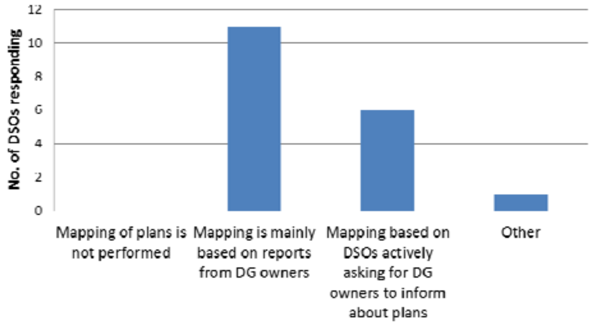

Figure 4 How mapping of plans for DG is performed

The majority (11 of 14) has based the mapping of plans on reports from DG owners. In these cases DG owners contacted the DSO to inform about the plans. 6 out of 14 have actively asked for DG plans, for instance through media, 4 out of 14 used a combination of the reports from DG owners and actively asking for DG plans.
Nine of the DSOs have a total of 85 planned DG units with concession in their area, while five respondents do not know how many DG units with concession there are in their area. Two DSOs have over 20 DG units with concession, see Fig. 5, hence some of the DSOs will experience a considerable increase in the number of DG units in their area in the years to come. 94 % of the DG units with concession will use hydro as energy source, 5 % wind and 1 % bio. This is not a complete overview of the number of DG units that the DSOs can expect to require connection to the network, as units below 1000 kW normally have exemption from the obligation to acquire a concession.

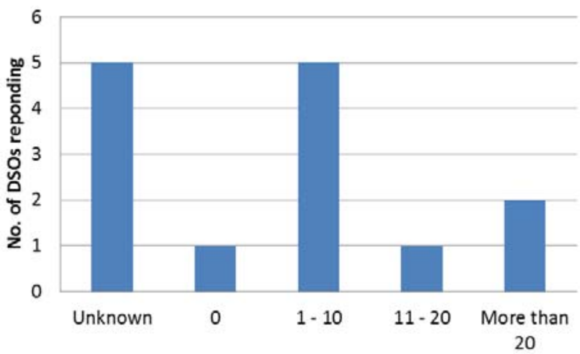

Figure 5 Number of DG units with concession

Problems and solutions

A clear majority (11 of 14) of the respondents answered that they have already experienced operational problems with connected DG units. The nature of these problems is presented in Fig. 6, highlighting voltage problems as the major troublemaker. Other reported problems were stability problems and problems related to protection and control equipment. It is noticeable that none of the DSOs have reported any thermal problems. The explanation could be that local voltage problems occur before the thermal limits of the network are reached. In addition, the DSOs often have large experience and competence in performing stationary load flow analysis and evaluating compliance with thermal limits.

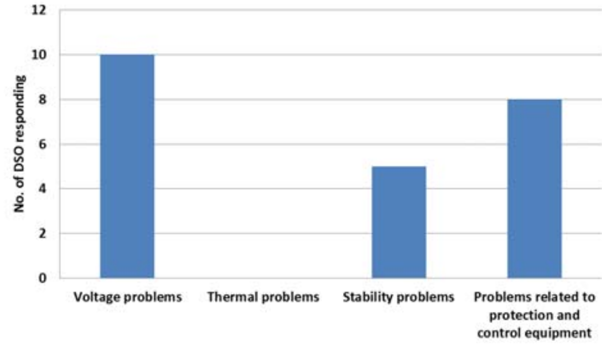

Figure 6 Types of operational problems experienced with connected DG units

Of those who have experienced operational problems, 10 of 14 found it necessary to initiate actions to solve the problems, see Fig. 7. Here, it can be seen that temporary reduction in production and change in operation modus are the most common measures initiated. Change in operation modus could, for instance, be to change the regulator setting from constant power factor mode to constant voltage mode. New voltage bands means reducing the voltage limits allowed for the DG unit, since the old voltage bands caused problems.

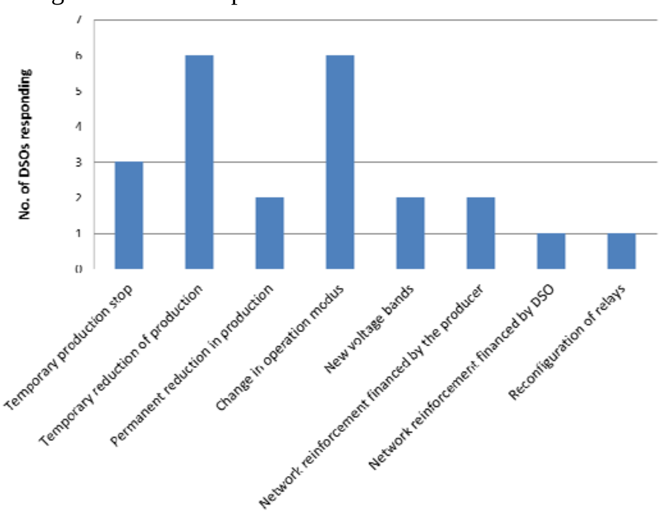

Figure 7 Actions initiated to solve operational problems caused by DG

Methods and tools used in network planning

12 out of 14 reported that they use several support tools when performing network planning with DG. 10 out of 14 used guidelines developed by the DSOs themselves. In addition, guidelines from different national organizations were used.
All DSOs participating in the survey perform stationary load flow analysis and 12 out of 14 perform short circuit

analysis themselves as part of network planning with DG. In addition, 8 out of 14 DSOs perform relay planning, see Fig. 8. None of the DSOs perform all of the analyses shown in Fig. 8, but two DSOs perform five of the analyses. Those DSOs that are only responsible for distribution network typically perform two analyses; stationary load flow and short circuit analysis.

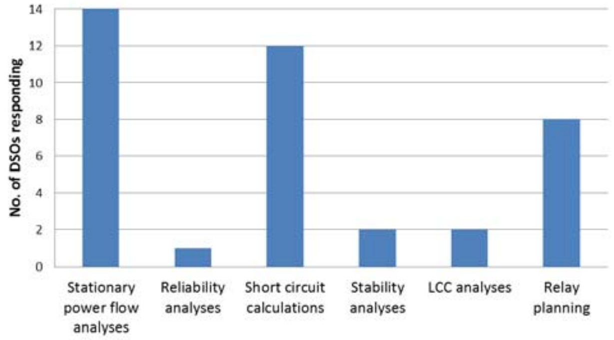

Figure 8 Analysis performed by the DSOs in connection with network planning with DG

8 out of 14 DSOs have established fixed routines for the whole process of integrating DG; from gaining knowledge about the plans for DG to the network connection is established. The need for fixed routines will of course vary with the number of DG units the DSO have in their network. Higher number of DG units increases the probability of having fixed routines.

CONCLUSIONS

This paper shows that, in some areas, it is expected a large increase in the number of DG units connected to distribution network. The introduction of the common green certificate market in Norway and Sweden is expected to make more DG project profitable and may increase the number of DG units even more. However, the number of planned DG units varies greatly between the different DSOs, depending on the availability of natural resources. Due to the fact that Norway is a mountainous country with a lot of precipitation, small hydro power plants are the dominating DG units today and also expected to be so in the future. Most of the DSOs responding to the survey have already experienced operational problems with existing DG units. These problems are related to voltage, stability and protection and control equipment. It is also interesting to note that none has reported any thermal problems. Temporary production stop and change in operation modus have been the most common actions initiated to solve the operational problems. A majority of the DSOs use several support tools when performing network planning with DG. Stationary power flow analysis and short circuit analyses are the most common analyses performed by DSOs in connection with network planning with DG. The use of stability analyses for DG planning purposes are among the subjects that are currently investigated further in the OiDG-project.

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