OVERALL CHALLENGES AND RECOMMENDATIONS CONCERNING THE INTEGRATION OF SMALL SCALE HYDRO IN MV DISTRIBUTION NETWORKS

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ABSTRACT

Norwegian distribution companies are currently experiencing that the connection of small hydropower plants to distribution networks is causing problems due to limited transfer capacity in the existing grids and violation of voltage quality threshold values. The situation is expected to escalate in the future when the number of new units will increase considerably due to favourable incentives for investing in renewable generation.
This paper discusses the overall challenges and network solutions to support new DG connections.

INTRODUCTION

The Norwegian electricity supply is dominated by hydropower, representing more than 96% of country's generation. While the potential for large scale hydropower is almost entirely utilised, there is still a significant potential for small scale hydropower using the country's many small rivers and waterfalls suitable for electricity generation. A large share of this potential is expected to be developed quite rapidly in the next 10 years due to new incentives created through the Swedish-Norwegian green certificate market which is made to fulfil the commitments to EU renewables targets [1]. Although there are significant wind power resources and some potential for solar power, small scale hydro generation is and is expected to be (in the near future) the main technology for distributed generation (DG) in Norway.

The hydro resources are not equally distributed across the country and so the challenges of large scale integration of DG in the distribution grids are more prominent in some regions. There are approximately 150 distribution system operators (DSO) in Norway governed by the income cap regulatory regime, i.e. they hold a concession to build and operate the network in a specific area and are obliged by law to offer non-discriminate access to all network users – both end-users and producers. Although not all DSOs are affected by DG, a recent survey among those that are, shows that the main challenges with DG integration are voltage and stability problems and problems related to protection and control equipment [2]. Because most small scale hydro units are located in remote areas with a weak MV distribution grid, their integration will typically require a modification of the existing grid or construction of new grid infrastructure if the existing grid is unable to support the DG connection.

This paper describes the situation regarding DG in Norway, highlighting the impacts that small scale hydropower have on MV distribution networks, pointing out overall planning challenges and technical recommendations for DSOs.

SMALL SCALE HYDRO GENERATION IN NORWAY

To reach the goals of the new EU's RES Directive, Norway has to increase the share of renewable energy generation to 67.5% by 2020 - up from 58 % in 2005. This obliges the government to increase the incentives for renewable energy generation or to decrease consumption. A first step was made when Norway in January 2012 joined Sweden in a common green certificate marked. The certificate market is expected to provide 26.4 TWh of renewable energy in the two countries by 2020, mainly through the development of wind farms and small-scale hydro generation.

As illustrated in Figure 1, a recent estimation made by NVE[1], shows that the remaining potential for developing small scale hydro generation (with a capacity under 10MW) is substantial and could reach 15.8 TWh.

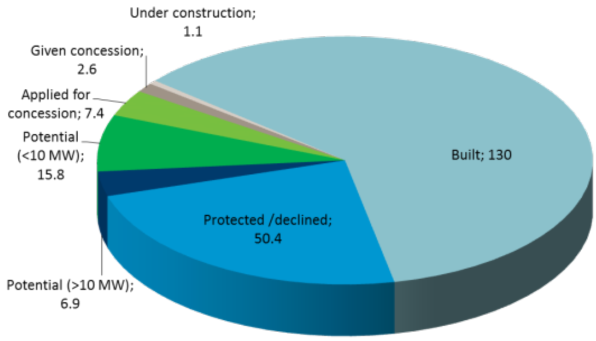

Figure 1 The hydro power potential in Norway by January 2012 (values in TWh) [3].

Small-scale hydro power is already the dominant DG technology in Norway today, representing 92 % of the total number of DG units [2]. In 2010, there were over 900 small hydro power plants representing 73 % of the total number of

1 NVE - Norwegian Water Resources and Energy Directorate

hydro power stations, but only 5.5 % of the average yearly production in TWh.

The DG potential mostly lies in small rivers without reservoirs and thus the generation units and distribution system must be dimensioned for the periods of large inflow, or the water is lost. In addition, peak production (spring/ late summer) is not in phase with peak demand, as illustrated in Figure 2.

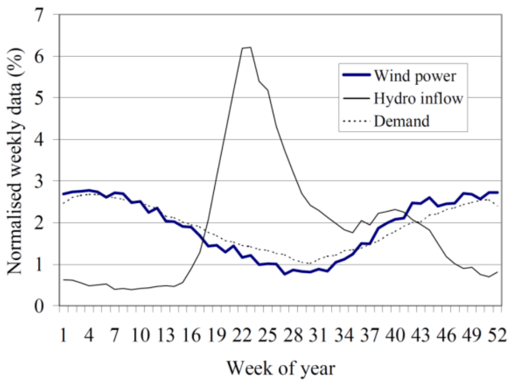

Figure 2 Normalised weekly data for wind power, hydro inflow and electricity demand in Norway [4]

Moreover, due to the fact that peak production tends to coincide over large areas, typically in spring, bottlenecks in the network can be found at different voltage levels, including the transmission between different regions and to other countries.

DSO CHALLENGES WITH DG INTEGRATION

DG integration adds substantial complexity to distribution network development planning and operation.

First, the DSO bears a considerable risk of over or under investing due to uncertainty regarding the volume and timing of DG.

DSOs are obliged through their licence conditions, to connect DG units and make the necessary network investments, given that these investments are socio-economic rational [5]. When upgrading the grid, the DSO must analyse the potential and make a prediction about the number and size of future DG connections.

Those who want to build a DG unit should contact the network company. The general rule is that the first to contact or sign a contract with the network company is first in line to get grid connection (first come, first served). The DG developer designs the DG unit and informs the DSO about the plans (site, size, type of installation). The DSO then evaluates whether the DG unit can be connected (i.e. whether the existing network can handle the planned DG-unit) or if investments are necessary. The DSO proposes the point of connection to the network and checks the possible influence the new unit(s) may have on the grid and informs the builder about special requirements and restrictions.

The DG developer must also apply to NVE for concession to exploit the water resources, often as a parallel process to the network connection. Although the process to obtain such concession has been recently improved (for example applications from the same areas are coordinated and projects that are not clarified with regard to network connection are given a lower priority) there is still a relatively long waiting time.

There is generally a very high uncertainty regarding new DG connection since sometimes announced DG plans can suddenly change: the project does not receive concession, the developer decides to abort the plans or the installed production equipment differs significantly from what was initially discussed with the DSO.

Some of the investment risk the DSO can share with the DG developers. When network reinforcements are needed, the DSOs can charge the DG developer(s) for a part of the investment costs. The costs can be allocated between all generators that require connection within 10 years after the reinvestment is made [6].

Second, the DG introduces technical challenges which influence network operation.

Most of the unexploited water resources in Norway are in sparsely populated areas, with weak grid connections or no grid connection at all. DG connections are often far from the load centres, which often results in long medium voltage feeders transporting the energy from the DG units to the transmission grid. The long feeders combined with large variations in production makes the system particularly exposed to voltage problems, with high voltage at the end of the feeder when generation is high.

NETWORK SOLUTIONS FOR DG INTEGRATION

When connecting a new DG unit to the grid there are technical and economic issues that the DSO has to take into account.

Technical requirements include the power quality regulations - such as satisfying the over/under voltage limits, rapid voltage changes and flicker value limits [7] and other important requirements such as safe fault clearing and hindering the unit from causing stability problems.

Other considerations are of economic nature. Grid connection should be done in the most cost effective way, fulfilling all important technical requirements. Obliged by licence conditions and income cap regulation, the DSO has to plan the network in a socio-economic manner by optimising and weighting the investment cost, grid losses, maintenance cost and future need for grid reinforcements. To account for the uncertainty in the timing and volume of DG connections the DSO can define a set of possible scenarios describing future DG development and identify network solutions in each scenario accordingly [8].

In practice, the DSO will have three main options when considering a grid connection.

- Allow connection using the existing MV network. This alternative requires available grid hosting capacity. Analysis of voltage quality, short circuit currents and stability issues might be necessary.
- Allow connection using the existing MV network with modifications. The grid structure stays unchanged and measures are taken to handle the new and/ or increased power flows and disturbances. This can be done through improved control with reactive power, upgrade of specific components and 1:1 OLTC-transformers or voltage boosters.
- Redesign of the network, building new lines or upgrading to higher voltages.

Whenever grid upgrade becomes necessary, all future loads and DG should be included in the investment plans.

Options for increasing hosting capacity

Figure 3 presents a summary of available measures to increase hosting capacity in distribution networks. The measures are placed in the figure according to the domain in which action is taken. To the left are the actions that are fully in the control and responsibility of the DSO, such as network upgrades and transformer tap-changers.

Moving to the right side of the figure, there are actions that involve distributed generation and network customers. Controlling the active power produced by the plants is the most intrusive action and thus requires a well-defined regulatory and contractual framework.

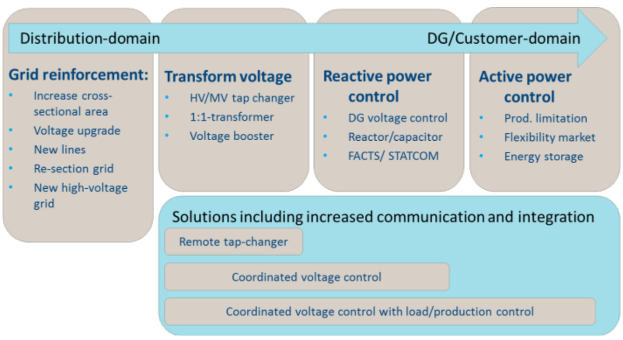

Figure 3 Options for upgrading DG hosting capacity

Measures requiring communication and integration between units in the grid are presented in the lower box. Remote tap-changer control refers to a system for operating the HV/MV tap-changer in an optimised way, based on measured voltages on the MV feeders [9]. Advancing even further, the control of DG units' set-point for reactive power, or even the active power set-point, can be centralised [10].

Most of the mentioned strategies are already evaluated in different projects, e.g. the Austrian DG Demonetz – Konzept [11], by mapping the potential and cost of DG integration with the different strategies

In Norway, capacity problems when connecting DG units have normally been handled through network upgrades. The possibilities of improved tap-changer operation and local voltage regulation have to some extent been exploited, although not fully.

A voltage booster for MV feeders with distributed production, enabling significant production increase, is being tested [12]. The voltage booster is an attractive choice for voltage correction in long feeders because it is transformer-based, and therefore not causing as large reactive power flows as voltage regulation in the DG units.

Active power control in distribution networks is generally not accepted under the current Norwegian regulation, but there has been allowance for temporary limitations in production, awaiting upcoming grid upgrades. These limitations are based on mutually agreed contracts between DG owner and the network company, or between two DG units of which one has more generation flexibility.

Allowing DSO control of the production in periods of limited capacity could have a socio-economic potential, saving grid investments and increasing the utilisation of the grid. However, designing a regulatory and contractual framework for increased control of the power production would also inflict challenges. It would, among other things, change the way distribution grids are operated, and profoundly change the role of the DSO, compared to what is the case in Norway today.

GENERAL RECOMMENDATIONS

This section summarises recommendations for DSOs in the DG connection process. Since every new connection can have characteristics which call for case-specific solutions and adjustments, the recommendations relates mainly to the work processes related to DG connections.

This paper acknowledges the existing guidelines and recommendations proposed by SINTEF [13, 14] and REN [15]. These guidelines for planning and handling of DG connections are already used by many DSOs today and include: recommended work processes for network companies, recommended work processes for DG developers, standard contracts for connections and standard requirements for DG units. As a consequence, processes have been streamlined and communication has improved. The actors, both network companies and developers, have become more competent.

Harmonisation in the planning and handling of DG connections is welcomed by both DSOs and developers, facilitating the communication between the two and the connection process in general. It can be made possible by establishing a common understanding and framework across company and industry boundaries which should include:

- A framework for early information exchange between DG developers and DSO. The DSO relies on information from the DG developers to prepare for future connections and reliable long term planning which can reduce costs as well as risks of network investments. For the DG developer, early information on requirements, costs and network conditions can be included in development plans and give incentives to alleviate grid capacity issues.
- A well-founded methodology for planning with DG, which would take into account uncertainty with regard to future DG connections and result in a strategy that is cost-effective and robust to a variety of likely development scenarios [8].
- Standardised requirements for the DG units should be stated in the standard contract for grid connection, as recommended in [14,15]. Examples include:
  - Generator specifications (capability, stability)
  - Voltage response (voltage stability)
  - Frequency response according to ENTSO-E requirements (not included in [14,15])
  - Communications for remote meter readings and breaker operation with a reasonable maximum response time
  - Remote set-point configuration control from the DSO should be considered.

Alternatives to grid upgrades should always be considered in order to postpone or minimise the need for large investments. Some of the solutions for DG connection in Figure 3 are not yet commercially ready, and more development is needed, if necessary in coordination with regulators, in order to obtain an optimal infrastructure in a socio-economic sense.

ACKNOWLEDGMENTS

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