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Balancing of variable wind and solar production in Continental Europe with Nordic hydropower – A review of simulation studies

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Abstract

The objective of this paper is to identify the state-of-the-art related to use of Nordic hydropower for balancing and storage of variable wind and solar based power production in the future Northern European system. The following topics are studied: 1) The need for balancing and storage; 2) Possible further development of the Nordic power system; 3) Consequences of different market solutions and 4) Changes in operation patterns of the Nordic system. Twelve scientific papers are reviewed. None of the studies have modelled the future variability in both wind and solar power sufficiently realistic. Further research should start with establishing such a model.

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1. Introduction

Based on EU targets and ambitions the share of power production from wind and solar resources is expected to continue to grow. In 2050 wind and solar may be as much as 65 % of gross electricity generation in EU [1] (High RES scenario). These resources are variable in its nature and may also be hard to predict. The need for balancing

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and storage is therefore expected to increase with increasing shares of production from wind and solar resources in the power system.

The future solution to the need for balancing and storage may be a combination of several technologies such as more flexible thermal production, local storage in terms of e.g. batteries or flywheels and also to some degree flexibility in demand. In Europe, hydro power can also be an important part of the solution, and the large hydro reservoirs and production facilities in the Nordic region is often mentioned as a one of the main contributions to balancing and storage of variable new renewable production in Continental Europe and UK. Norway alone has approximately half of the reservoir capacity in Europe with possibilities to store about 85 TWh. The production can be regulated up and down in very short time frames and to very low cost.

Norway is considered as a possible battery for Europe based on the idea that water could be pumped up to higher levels when there are surplus from wind and solar production and that the hydropower production could be increased in periods with low production from the wind turbines and solar cells.

Use of the flexibility of the Norwegian hydropower system may benefit several actors in the power market: power suppliers in Northern Europe may sell surplus in wind and solar production to Norway in low price periods and avoid dumping of the energy. In periods with low power production from wind and solar resources, they can buy power to fulfil delivery obligations. Norwegian power suppliers can buy cheap wind and solar power production in low price periods and store the water in the reservoirs until periods with higher prices. The impact on the power prices in other countries than Norway will be limited because the volume of the exchanged power will be small compared to the total system in Northern Europe. The impact on the power prices in Norway will depend on the prices differences between Norway/the Nordic region and Northern Europe.

There is hardly any physical pumping in the Nordic system today, but the hydropower system already works as a kind of a battery because production is increased in daytime when power prices are high in neighboring countries. Furthermore, the production is decreased below domestic load in the night when prices are lower than in the countries Norway, which the highest storage capacity and pumping potential, is presently connected by subsea HVDC cables to Denmark (1700 MW) and the Netherlands (700 MW). Connections to UK (1400 MW) and Germany (1400 MW) are under development and possibly an additional cable to the Netherlands after 2020. Today's exchange pattern is related to the production pattern of the thermal based power system in Continental Europe. The future exchange pattern will most likely be more variable and uncertain due to increase in wind and solar production.

2. The objective of this study

The objective of this paper is to identify the state-of-the-art related to the need for balancing and storage for scenarios of large shares of wind and solar production in the Northern Europe, and the possibility for using the Nordic hydropower for balancing the variability and uncertainty. Based on the state-of-the-art overview, the research gap is identified. Variability shall be understood as the expected or foreseen variation in production from wind and solar resources, i.e. it can be scheduled how to balance the variability. The uncertainty shall be understood as the unexpected variation in the production, which has to be reacted to in short times frames and typically through reserves markets.

To assess the capability of Nordic hydropower for balancing wind and solar power, increased knowledge is necessary related to several fields of research: The need for balancing and storage in the future power system; the future prices for power production flexibility; consequences of different market solution; economic impacts for different actors; risk in investments; possibilities for further development of the Nordic hydropower system; changes in operation patterns of the hydropower system; alternative storage technologies; impact on greenhouse gas emission and impacts on local environment. This review paper investigates state-of-art related to a selection of these research questions/topics.

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