HydroFlex Public Workshop 3

April 2021

Summary

HydroFlex

Increasing the value of hydropower through increased flexibility

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1 Public workshop

Introduction

The third HydroFlex workshop took place on April 21, 2021. Due to covid-19 and travel restrictions, the event, which was planned to be arranged at Luleå Technical University (LTU), Sweden had to be converted to a digital workshop. More than 80 speakers and participants joined the 3.5 hours long workshop.

The theme of the workshop was "Flexibility needs in the Nordic power system towards 2030". More specifically, the workshop aimed at answering the following questions:

With emphasis on the changes towards 2030:

- How will Nordic hydropower as part of the European power supply system be operated?
- What are the main drivers for change in flexibility provision by hydropower plants in the Nordics?
- What benefits does an increased flexibilization of hydropower have in the Nordic power market?
- To what extent is flexibility provision from the Nordics possible for North- and Central Europe? What are the necessary conditions for this to happen?

The program of the workshop is listed below.

Time	Title	Presenter
08:30		Ole Gunnar Dahlhaug
Changing operating conditions		
08:40	The value of flexible hydropower – importance for the power system today and in the future	Lill Sandvik, Statnett
09:00	More variability with renewable electricity	Valentin Koestler, NVE
09:20	Nordic Balancing Model (NBM) – System services market in 2030	Erik Alexander Jansson, NBM
Changing market operators		
09:50	Long-term trends that can radically alter the flexibility needs of the Swedish power market	Anna Krook Riekkola, LTU
10:10	Hybrit Development AB	Mikael Nordlander, Vattenfall
Flexibility needs in 2030		
10:40	Key drivers, summary of Aachen simulations	Marius Siemonsmeier, RWTH
10:50	Key drivers, summary of SINTEF simulations	Michael Belsnes, SINTEF Energy
11:00	Industry comment (1)	Aslak Mæland, Statkraft
11:10	Industry comment (2)	Fredrik Engström, Vattenfall
11:20	Panel debate	

Review of content

In the following a brief summary of the talks during the workshop, highlighting the most salient conclusions is given.

In his opening of the workshop the coordinator for the Horizon 2020 project HydroFlex, professor Ole Gunnar Dahlhaug, NTNU summarized the overall challenge that the project is addressing: "Developing hydro turbine technology that permits 30 start-stops and faster ramping rates". Based on the market simulations from RWTH Aachen, it is not likely that this radical change of operation will be observed in the Nordic hydropower plants. However, this, possibly stretched goal has been an impetus to research new technology both for turbines and generators as well as environmental impact and social acceptance.

Changing operating conditions

The first session, denoted "*Changing operating conditions"* aimed at clarifying how the change in energy mix and changes in flexibility markets may impact the need and requirements for flexibility in the Nordic power system and how this impacts operating conditions for the hydropower fleet.

In the first talk "The value of flexible hydropower – importance for the power system today and in the future" Lill Sandvik, Statnett presented the main results from a report [1] recently issued by Statnett. Many Norwegian hydropower plants are undergoing or will in the near future undergo a relicensing process.

Changes is manoeuvring regulations may be the consequence of relicensing. These changes may include tighter restrictions on variations in water levels in reservoirs, specific requirements to ecological flow in the river or minimum discharge through the power plant. These are changes that may have significant impact on a plant's ability to supply flexibility services or ancillary services.

Statnett is asked to comment on the individual case, but an understanding and overview of the overall impact for the power system was lacking. In the report the need for flexibility services and types of services are outlined.

Some of the key takeaways from Lill Sandvik's presentation were:

Hydropower plants are distributed out throughout the country. This has permitted securing more of the supply regionally and thus has reduced the cost of development of transmission capacity. This frequently leads to bottle neck situations that requires acquiring regulation services locally rather than activating the lowest bidder.

In a previous study, The Norwegian Water Resources and Energy Directorate has identified a group powerplants where the expected potential for environmental gains in a relicensing process would be high while the loss in energy production would be low or moderate. This group is denoted category 1.1. The Statnett study concludes that 75% of the automatic frequency reserve regulation (AFFR) and 45% of the manual frequency reserve regulation (mFFR) is provided by plants in this category.

The study found that there is little or no correlation between energy production and contribution of balancing and flexibility services. Thus, loss of energy production alone, is not a good measure for evaluating the impact of changing manoeuvring regulations.

Change in the energy production mix as well as new power consumer pattern may increase the need for flexibility services. If current hydropower fleet is not able to support these changes, this may trigger significant additional development of transmission capacity. Otherwise, the security of supply may be reduced.

The impact of changes in the production mix was followed up by the second speaker, Valentin Koestler from NVE. His talk "*More variability with renewable electricity*" was based on the NVE report 44/2020 [2] investigating how a power system with more renewable may become increasingly weather sensitive. The study is using historical discharge series and weather data from the European Centre for Medium-Range Weather Forecasts (ECMWF) to simulate 41 different production and consumption series, based on the current Nordic and European power production mix. Key findings in their study are:

While the weather dependent variation in the power consumption was quite moderate (+4%/-3%), the difference in the hydropower production between a dry and wet year was substantial (+23%/-30%). The difference in solar power and wind power (approximately ± 12.5%) is less than hydropower but still significant.

There is a clear tendency of correlation between hydropower and wind power such that dry years may coincide with years with less wind than average.

Even if the onshore wind energy profile is more similar to the actual consumption profile over the year, winter periods with very low temperature, no wind and no rainfall is a recurrent pattern. Such periods will be important in determining necessary energy storage and transmission capacity.

The Nordic Balancing Model, a joint program by the Nordic TSOs to develop a common solution and market place for balancing services in the Nordic grid. The program was presented by Erik Alexander Jansson, NBM in his talk "Nordic Balancing Model (NBM) – System services market in 2030". Through NBM the TSOs will develop a digital market platform for joint Nordic market for automatic and manual frequency restoration reserves (FRR). Introducing a 15-minute resolution in the market compared to the current 1 hour is part of the change introduced by NBM. Despite the development towards a joint Nordic and in longer term joint European balancing market, physical constraints (e.g. transmission capacities and bottlenecks) must be incorporated into the model. The activation optimisation function (AOF) is an important aspect of this work.

According to the current roadmap the Nordic balancing market will be integrated with European balancing markets sometime in 2024.

Changing market operators

In the second session, denoted "*Changing market operators*" the focus was on changes happening on the consumer side. The first presentation was made by Anna Krook Riekkola, LTU with a talk entitled "Long-term trends that can radically alter the flexibility needs of the Swedish power market". The point of departure was a long term energy transition analysis showing how electrification of industrial processes to reduce CO_2 emissions will potentially lead to radical increase in the power consumption from industry. In the most radical scenario, the industry consumption may double in the next couple of decades. A significant shear of the increase in the industrial consumption may be located in the northern part of Sweden. This is the region with the most hydropower resources as well as good onshore wind resources.

An important part of the Swedish discussion regarding the energy transition, is the need for base load production. Analysing different time series from 2002 to 2019 it is concluded that the need for base load power plants has been reduced. Energy storage of the order weeks and months may be needed. Possibilities to increase hydro storage in North of Sweden should be discussed. Finally, Anna observed that many of the industries, such as steel and other metallurgical industries are highly exothermic and the surplus heat can be used district heating network, thus creating a coupling between the heat market and electricity market.

One example of new power consumption due to electrification was presented by Mikael Nordlander, Vattenfall presenting Hybrit Development AB. Hybrit is a joint endeavour between SSAB, LKAB and Vattenfall. Considering the whole process from iron ore to finished steel, the aim is to reduce CO_2 emissions by rethinking the whole process. As an example, he compared the traditional iron reduction process, where iron ore is reduced in a blast furnace using coke, producing large amounts of CO_2, with a hydrogen reduction process producing water – H_2O as byproduct. Green hydrogen can be produced locally by wind power. However, while the industrial process needs to be continuous and predictable, wind power production and accordingly also the hydrogen production depends on the metrological conditions. This has lead to the development of underground storage concept for hydrogen. Using lined, underground caverns surplus hydrogen can be stored in periods with high wind conditions. This reservoir can draw down during less windy periods. Pilot installations both for the hydrogen reduction of iron ore and hydrogen storage is already under development or in operation in Luleå, Sweden. One interesting fact presented by Mikael was that even if the green steel, e.g. steel without CO2 emissions is expected, at least initially to be more expensive than traditionally manufactured steel, the general trend in many industries to reduce the carbon footprint of their products is driving the demand and willingness to pay the premium price.

Flexibility needs in 2030

In the last session, entitled "*Flexibility needs in 2030*" the specific questions raised in the introduction were addressed head on.

Marius Siemonsmeier, RWTH and work package leader for WP2, "Definition of Scenarios and Reference Cases", together with his colleagues Peter Wirtz and Maik Schönefeld presented the results of the market simulation developed by Institute of Power Systems and Power Economics (IAEW), RWTH Aachen. In their work, the IAEW market model was extended to include a detailed description of Nordic hydropower plants with a rule based commitment model. Three different scenarios for development of consumption and production mix towards 2030 and 2040 was simulated. In addition, as a sensitivity analysis, a simulation with extreme wind installation in the Nordic region was also tested. The team have also studied the impact of a future power mix on the grid stability. The dynamic model is based on the NORDEL grid model of TYNDP2030 grid, and includes approximately 560 synchronously coupled power plants and around 250 loads. The primary control reserve (PCR) is set to 2050 MW. The fault considered was the outage of three thermal power plants with a total load 2113 MW.

Some of the key conclusions from their analysis was the following.

The simulation showed only a moderate increase in start/stop for the reference plants.

The diurnal variation of power production on the Germany and Central Europe leads to a situation where the cross border interconnections are fully utilized for either import or export. Thus the export of flexibility between the Nordic frequency region and the Central European frequency region will be limited.

The main driver for increased demand for flexibility in the Nordic grid is the development of intermittent renewable power production and in particular onshore wind.

The stability calculations showed that the specified PCR was adequate and that the hydro power plants were able to restore the frequency.

One interesting observation was that while the most critical case in the European grid is considered to be the high load cases, in the Nordic grid, the low load situation in summer time is considered the most critical. This is due to the fact that during this time the fraction of wind and run of river hydropower plants are the highest.

Michael Belsnes presented the results from the SINTEF Energy simulation. He started his talk by formulating the question "What does this variability from solar and wind actually mean?" How much storage is actually needed in the power system to ensure security of supply? Based on European weather data and models for expected European grid in 2050. Spatially the model was dividing Europe and the Nordic region into 1300 climate areas and the time divided into 12 periods (e.g. monthly resolution). For each month the hourly consumption and production is calculated, and the deviation is assumed to be covered by storage facilities. The cumulative charging and discharge will give a measure of the total storage capacity needed.

In order to check the ability of the model to reproduce the actual variability, the simulations were compared with historical hour by hour data. This confirmed that the model quite accurately was able to predict the actual variability observed in the grid. Based on the production mix defined by the eHigway2050 project, the key takeaways from the simulations were:

The maximum energy storage needed was 25 TWh. This is significantly less than the storage capacity is the Norwegian hydropower reservoirs.

However, the peak storage discharge power required was about 200 GW and the required charging power to avoid curtailment was more than 300 GW.

There are periods with very low production from wind and solar (20% of the hours in the year with less than 10% of the installed capacity)

Each winter there will be several periods of about 100 hours duration with very low solar and wind production in West Central Europe

Grids have some capacity to smooth deficits but periods with low production remains a risk.

As an introduction to the panel debate, two power companies were invited to give their perspective. Aslak Mæland, Statkraft started his introduction entitled “How will Nordic hydropower be operated in the future?” with looking into the recent historical usage of some of Statkraft’s hydropower fleet. Using as an example, the year 2016 which hydrologically and price wise could be considered a quite regular year with for the most part quite stable power prices. One exception was short, cold period with little wind power production early in the year that led to a significant price peak. Likewise, hydrological deficit in the autumn led to gradual increase in the power price. He then showed the historical production records for three different installations. Mår HPP (180 MW, 1.1 TWh) is a typical industrial plant with very high utilisation factor (70%). With 5 Pelton turbines, it has technical capacity to deliver more flexibility but that was not part of the planned usage. Saurdal HPP (640 MW, 1.4 TWh) is part of the Ulla-Førre group and was from the start designed for much more flexible usage. This includes 2 reversible pump turbines that can be used to top up the Blåsjø reservoir (8TWh) during the spring flooding season. The utilization factor (25%) is much lower and the plant has frequent starts and stops and with the large storage it represents multi-year flexibility. Lang-Sima HPP (500 MW, 1.1 TWh) has quite high flexibility, but limited storage capacity in the reservoirs and thus the operating pattern is more strongly driven by the hydrological conditions. As Aslak concluded, seen from the outside, hydropower is flexible, but the degree of flexibility is different for the individual plants. With the large storage Saurdal has the highest flexibility value, but the marginal value of the flexibility is higher in Sima HPP. Thus, planning the optimal usage if reservoir capacity where it is limited or restricted becomes crucial. Zooming out and looking on the Nordic power production mix for one week in 2017 with the typical diurnal variation of electricity consumption – high in daytime and low in night time. With high wind production in the night time, possibly with high run of the river power production, prices will collapse. Extrapolating the same weather pattern to a 2030 scenario the situation will be even more strongly accentuated, requiring more flexibility in the system. Raising the rhetorical question “What type of flexibility is important?” he concluded that most likely the seasonal complementarity of hydropower and wind power most likely will solve the yearly variations. And while batteries may solve some of the short term or daily imbalances, hydropower reservoirs will be crucial to solve the monthly and weekly imbalances. It is expected to see more starts and stops in 2030. This will not be 10 times but maybe 1-2 times more than today.

Fredrik Engström, Vattenfall gave a few reflections seen from Vattenfall, the largest Swedish hydropower producers.Vattenfall runs the Lule river, which represents about 10% of Swedens hydropower production. When the Swedish wind power developer, Svevind, launched the Markbygden development (4GW) there was concern how this was going to impact the power balance and prices. With the recent plans to develop green steel and other power intensive industries in the north of Sweden, the question again becomes “do we have power enough?”. Thus, the picture is changing quite rapidly. Industries are attracted to northern Sweden due to low power prices, but this may on a longer time scale push up the prices again. In sum he concluded that the exact future scenario is uncertain, but he predicted that the role of hydropower also in the future will be as the flexible renewable power source in the system.

Due to time constraint the closing panel discussion became a bit shorter than originally planned. In general, most of the participants agreed that at least for the next two decades the development of more intermittent renewable energy in the Nordic region will be the most important driver for the flexibility needs in the Nordic power system. Based on the current foresight this implies a moderate increase in flexibility of operation and number of start-stops. In closing it was argued that demand response and battery will be the most important solution on short time scale and also on smaller geographic scale (smaller scale than the price areas).

References

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2 Det svinger mer med fornybar strøm. NVE rapport 44/220. https://publikasjoner.nve.no/rapport/2020/rapport2020_44.pdf