NEPP
north european power perspectives

April 2011

Hydro power as a balance resource

- for increasing amounts of wind power: possibilities and limitations

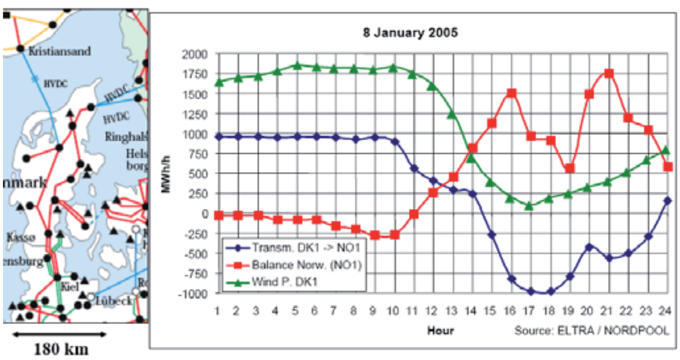
In a power system with larger amounts of wind power the controllable part of the system has to change its production in order to keep the continuous second-to-second exact balance between consumption and production.

In this context a hydro power station can, compared to thermal power stations, rather easily be controlled with a high ramp-rate. To obtain an economical balancing one has to study large areas. Experience shows that during normal conditions, hydrological constraints and court decisions allow hydro power to be used for balancing of hourly variations even for large amounts of wind power. Lack of balancing resources has historically not been a problem in the Nordic system; therefore, not many studies have been made to determine the balancing capacity of the hydro system.

Experience shows that wind power variation in Western Denmark in an efficient way can be balanced with hydro power in Norway. Studies have shown that it is technically possible to balance large amounts of wind power using hydro power in Northern Sweden.

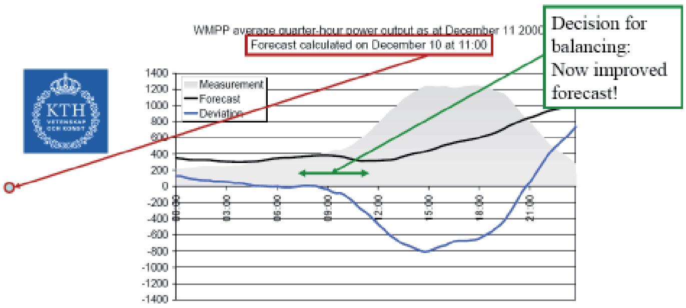
Danish experience concerning balancing

Concerning longer time frames an example is shown in the figure below. The figure shows an example from Denmark, when a storm front hit the country. The storm front caused the wind power plants to shut down from maximum production to zero. The total result was -1800 MW in 6 hours. The example illustrates the time frame of larger changes. The figure also illustrates that the changes in Denmark were balanced in Norway, i.e., in hydro power. It can also be noted that one can follow the storm front which means that it is possible to forecast this change.



Example of forecasting

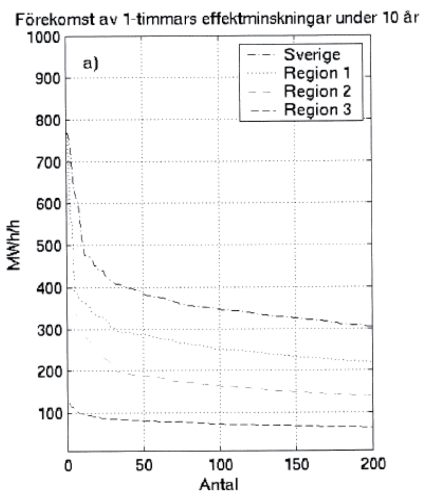
Concerning wind power forecast, which has an impact on hydro power planning, the figure illustrates a situation with comparatively bad forecast, a deviation of up to 800 MW in a situation with maximum production of 1200 MW.



It must though be noted that here this deviation concerns a forecast which is made 27 hours earlier. In most systems, shorter forecasts are needed for the physical operation of the system. Most hydro power plants can start up in 15 minutes, but there may be hydrological restrictions in the form of flowing water in the rivers which may be a limiting factor for a faster response.

Wind power changes in Sweden

In the report "Production variation from wind power, Elforsk report 04:34", a possible installation of 4000 MW of wind power in Sweden has been studied. In the report it is shown, e.g., that a loss of capacity of 50 per cent during a six-hour period happens once a year on average. This is valid for the total installed wind power capacity for the whole of Sweden. The correspondent number for a one-hour period is a loss of capacity of 10 per cent. The figure shows how common (nr of occasions in 10 years) 1-hour decrease was during the studied period.



Technical possibilities to balance wind power with Swedish hydro power

The balancing capacity of the hydro power system in Northern Sweden has been studied in Elforsk report 09:88. The model used in this study considered 154 hydro power plants with a total installed capacity of 13 200 MW (i.e., about 80% of the Swedish hydro power). Hydrological couplings and court decisions were explicitly included in the model. The transmission limitations between Northern and Southern Sweden were also considered, as well as the export limitations to Norway and Finland respectively. (The remaining restrictions mentioned below were not considered.) The model was used to test if hydro power could balance load and wind variations without being forced to spill water. The data were based on historical data series, which were scaled to match scenarios with increased amounts of wind power.

The results from the study showed that during normal conditions (there might be extreme situations that are not represented in the historical data series), hydrological constraints and court decisions allow hydro power to be used for balancing of hourly variations even for large amounts of wind power. The conclusion is that in order to utilise this potential it is very important to study efficient tools for short-term and seasonal planning. It is also important to study how much of this balancing capacity that will be made available to the electricity market under different regulatory frameworks.

Balancing capacity

Hydro power is a very flexible generation source. In theory, a hydro turbine can increase its generation from zero to its maximum level (or vice versa) within minutes. However, in practice there are several factors that limit the balancing capacity of the hydro power system:

- **Hydrological coupling.** Hydro power plants in the same river system cannot be operated independently, since water that is released from one reservoir will eventually reach the downstream reservoir, and there must then be sufficient space in that reservoir in order to avoid spilling water.
- **Court decisions.** Each hydro power plant has a court decision which is setting limits for upper and lower reservoir levels, minimum and maximum water flow, etc.
- **Transmission limitations.** The transmission capacity of the grid might put a cap on the total generation of the hydro power plants and other generating units in an area.
- **Forecast uncertainty.** There are many uncertainties (inflow, load and wind power generation) that needs to be considered in the operation planning of hydro power. The uncertainty will force the hydro power producers to keep larger margins, which consequently will reduce the flexibility.
- **Goodwill.** Although the hydro power plants in a river have enough flexibility to be used for balancing, the resulting variations in water flow might cause complaints from the locals. Hydro power plants might therefore prefer not to utilize the available flexibility.
- **The electricity market.** The objective of a hydro power producer is to maximize the profits, not to maximize the balancing capacity of the hydro power plants. Hence, the existing flexibility will only be put to use if it is profitable.

For further information: Lennart Söder, Mikael Amelin, KTH

RERSERVE TERMINOLOGY

In a power system there are continuous production and consumption changes so the balance between production and consumption has to be kept by use of actively controlled changed production as an answer to the deviation. This means that there has to be capacity to follow both scheduled and unscheduled changes in production and consumption. From the system point of view it is the total changes that have to be considered, e.g. the total changes in the Nordic system or in sub-systems. The balancing resources can be outside the studied area if there is available transmission capacity to the other areas. Some terms are the following:

- *Net load changes* are changes in load - wind power + outages
- *Net load forecasts* are the forecasts for total net load
- The net load changes put a requirement on *available flexibility*, i.e., the controllable part of the system must be able to follow the net load changes.
- *Reserve capacity* is the share of available flexibility that will meet *unscheduled* net load changes, i.e. the difference between real net load and the net load forecast
- All the above terms can be estimated for different time frames, e.g., 2h net load changes, 4h available flexibility, 24 hour forecast, 15 min reserve capacity etc.

Some general conclusions are

- The *need of flexibility* is **not** the same as *need of reserves*, since a part of the net load variation can be forecasted.
- The *need of reserves* and *available flexibility* for different time frames can **not** be easily added. If a certain reserve capacity is needed for net load changes within 4 hours, then this will **include** the requirement for reserve capacity that meet net load changes within 2 hours. It is only if the reserves are kept in different units that one can add them.
- The *need of reserves* is always less than the *need of flexibility* for the same time frame since some part of the wind and load changes normally can be forecasted.
- The *need of reserves* is connected to the time frame and the ramp rate of existing power plants. If all power plants can start up in four hours, then *need of 8h reserves* does not have a large relevance since maximum 4 hour net *load forecast errors* have to be considered to allocate units to keep enough reserves.
- Wind power can only decrease when there is a production level and only decrease largely when there is a large production. It is also clear that the more wind power, the lower production in other units, i.e. the other units can act as reserve plants when wind power decreases. This means that there is a strong negative correlation between the available amount of reserves/flexibility and the wind power production level. This means that *flexibility* and *reserve keeping* in a system with wind power is often more an issue of ramp rates and start-up times, than a need of more capacity. More fast ramping and starting capacity can be needed, if the forecast errors are large than the slow units can follow.
- In a situation with no wind power, there is no need to include wind power when determining downward reserves/flexibility in the power system.
- There is a strong interaction between *reserves* and *market arrangements*. If the *net load forecasts* are relatively accurate for a certain time frame (e.g. 24 hours) then only a 24 hour market is needed. If, on the other hand, the 24 hour forecasts have low quality, then there has to be a market for changed production within that period. It is **not** the variability that requires updated markets but more the net *load forecast errors*. It must also be noted that, e.g., *24 hour reserves* is not a physical but mainly a market need. Most power plants need maximum 4-6 hours to start up so they do not need this information 24 hour in advance. In e.g. Spain where 16% of the energy came from wind power during 2010, there are six intra-day markets with comparatively large volumes since wind power forecasts are not so accurate.