Wind power – a resourceful power source

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With an increased penetration of wind power in the system, a higher controllability is needed to help maintain the network balance. Modern wind turbines have advanced control capabilities, the challenge is to find the best ways to use them. When generating electricity the produced amount need to match the consumed amount at all times. The reason for this is that the ability of the power system to store electricity is very limited. Both the power flow and the voltage level need to be controlled at certain levels in order for the system to work. This is a challenge for wind power, since the power output is strongly connected to the wind speed. Therefore, wind power has traditionally not been doing much to support the network. The share of wind power in the system is increasing and this means that wind power plants (WPPs) also need to help in maintaining the network balance. To achieve this, ways of improving wind power controllability are being developed. It is hard for wind turbines to help out when the level of production in the system is too low, since the turbines usually run at full power. On the other hand when the level of production in the system is too high, WPPs can help out by curtailing its power output. In order to find out more about how the control of WPPs can be improved, I performed two studies. One considering curtailment strategies with the goal of avoiding unnecessary losses of revenues and increased turbine fatigue, and one considering how wind power can help in maintaining the local voltage balance.

Coordination strategies for wind turbines within a WPP during curtailment

The turbines within a WPP affect each other through wake effects. These wake effects can be explained as follows; if one turbine is situated upstream of another turbine, the upstream turbine will capture a part of the wind. This results in a reduced wind speed hitting the downstream located turbine, giving this turbine a reduced power output. When a WPP is curtailed, some main priorities to consider are; avoiding unplanned turbine stoppages, avoiding increased fatigue on the turbines and providing a fast and accurate control.

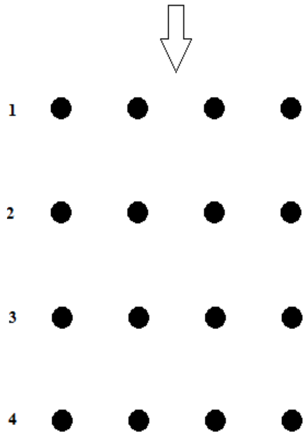

Figure 1. WPP model used for coordination strategies.

These goals can be reached using different coordination strategies, see figure 1 for example of a WPP model. There are two main strategies; low wind speed and high wind speed strategies. At low wind speed the main concern is avoiding unplanned turbine stoppages. The approach is to start the curtailment at the first row, since this row is not affected by wake effects. This means that it has a larger available power output then the other rows, meaning more room for curtailment. At high wind speed the strategy is the opposite. The WPP should be curtailed starting at the last row, reducing the impact of the curtailment on the other rows. If the curtailment is started at the first row instead, the turbines in the back rows will suffer from this. In order to curtail the first row, the blades of the turbines are “pitched” meaning that they are rotated, which reduce their ability to capture the wind. This causes increased turbulence which will result in increased fatigue on the turbines in the back rows and a slower acting control. The strategies where tested though simulations, one of the cases is shown in figure 2 and explained in table 1. All graphs show maintained production for all rows except the yellow graph. This graph shows a case when only rows 3 and 4 where curtailed during low wind speed and indeed it can be seen that row 4 will stop, which is what we want to avoid. This supports the theory that the WPP should be curtailed staring at the first row during low wind speed.

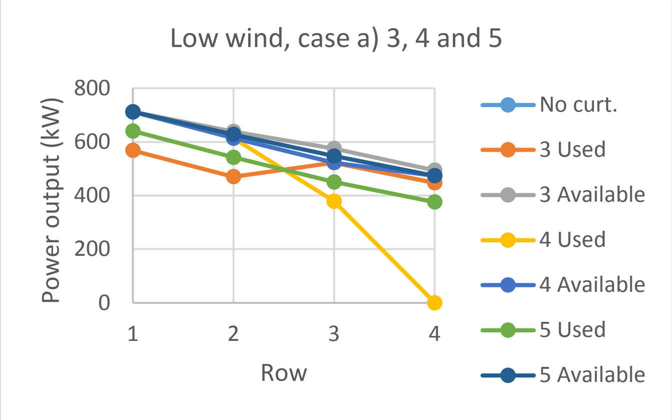

Figure 2. Result of simulations of the curtailment strategies during a case of low wind speed.

Table 1. Actions displayed in figure 2.

a.	WPP curtailed 12.5 %, i.e. 1.15 MW
	Action
3.	Curtail row 1 and 2 equally
4.	Curtail row 3 and 4 equally
5.	Curtail entire WPP equally

Reactive power control contributing to maintaining local voltage balance

In power systems the power is transferred in two different shapes, active and reactive power. The active power is the power that we need, that powers our light and allows us to charge our cell phones. The reactive power on the other hand is only necessary at some points in the network to for example magnetize electrical motors. This leads us to an important aspect of the system balance; the voltage level. This level can be adjusted by injecting or extracting reactive power in the network. Traditionally wind turbines has not been able to do this, but modern wind turbines have extensive reactive power capabilities. I tested some of these reactive power capabilities through computer simulations. The result was successful, the tested WPP was able to maintain the voltage balance in the network through injecting/extracting reactive power. These capabilities can be used to comply with national grid codes, which are requirements that dictate the rules of the power network. Another way of using the capabilities is to help network operators in adjusting the local voltage balance. The later example could be a future grid code requirement, or a reactive power service that can be traded between the WPP owner and network operator. Which option to be realised can be discussed, but it can be argued that the market option would be more profitable for all involved parties. The reason for this is that both the WPP owner and the network operator can benefit from this solution.

Control strategies in the future power system

Both the reactive power control and coordination strategies presented above can be implemented and used with current technology. If the reactive power control shall be sold as a service, WPP owners and network operators need to work together. This is a perfect example of a feature of a smart future power system, using its assets in an efficient way. Another example of such a feature is introducing wind power on the regulating power market in Sweden (this is already a reality in some countries). This will provide an incitement for WPPs to curtail during situations when the network is overloaded and prices are low. A step towards adapting to future grid codes and power market changes can be to introduce the types of control presented in this work. The sooner all participants of the energy system start using the different services that modern wind turbines can provide, the sooner it will become evident that wind power interaction in the transmission system is not a problem to be solved, but a solution to the problem.