Performance Evaluation of Wind Turbine Primary Frequency Regulation Methods under Inertial Support Action

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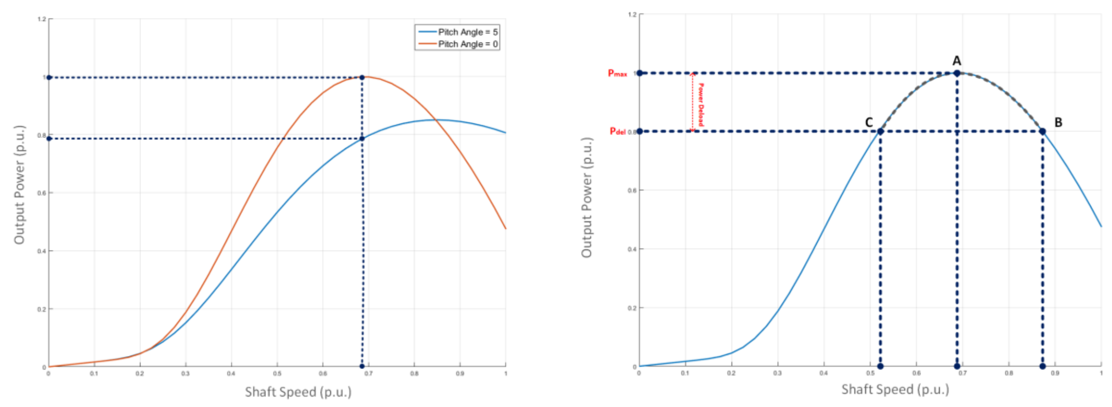
Abstract/synopsis:

Objectives and context

The share of renewable sources in the installed capacity continues to raise each passing day. Renewables bring promising results in the environmental issues. However, they cause operational problems in the electricity grid. This is why grid operators require additional services from renewables such as inertial support from wind turbines. Due to power electronics in the wind turbines, grid frequency has no influence on rotational speed of the turbine. Therefore, inertia existing in the turbine blades and generator is not reflected to grid side. Frequency deviations on the grid can be reflected to turbine speed by emulating the synchronous generator behaviour. Hence, the turbine output power can be increased or decreased by extracting or storing the kinetic energy in turbine inertia depending on the direction of the grid frequency deviation. Another additional service is the primary frequency control. Most of the conventional generation units are utilized below the rated power. In this way, output power can be increased if the frequency decreases. Nevertheless, wind turbines are operated in Maximum Power Production Point for maximum efficiency. Instead, conventional power plants are utilized for primary frequency control. However, this increases the responsibility of these conventional generation units in the frequency support mechanisms. In the future, all generation units including the renewable sources are expected to participate primary frequency control action which does not extract whole available wind power.

Methods/approach

Wind turbines are operated in a point which captures maximum power from wind. This maximum power value can be found from Power Coefficient curve depending on the wind speed, pitch angle and shaft speed. In order to participate primary frequency control action, wind turbines are required to operate below maximum power. In this way, active power output can be increased if the grid frequency decreases. Wind turbines can reach such operation by either changing pitch angle or turbine speed. In normal operation, pitch angle is used for curtailing the captured power in high wind speeds. Therefore, changing the pitch angle is one way of curtailing the turbine active power. In Fig. 1.a, power curtailment by changing pitch angle is shown. By using this method, power can be curtailed without changing the turbine speed. However, the rate of change of pitch angle is limited due to long response time of pitch angle controller.



a-) b-)

Figure 1:Turbine Output Power a-) changed pitch angle b-) changed turbine speed

Another way to curtail active power is either decreasing or increasing the speed of the turbine. Note that in Figure 1.b, there are two different speeds corresponding to a defined power value. Due to fact that the lower speed would store less kinetic energy, high speed is more appropriate for primary frequency control. Therefore, primary reserve in a wind turbine can be achieved by either increasing the pitch angle or shaft speed. In this study, these primary control methods will be compared for inertial support performance.

Outcomes

Inertial support methods allow wind turbines to increase its power output for small time intervals by making use of the kinetic energy stored in the total turbine inertia. As a result, turbine operation deviates from the maximum power point and turbine speed decreases. One disadvantage is that the turbine speed should be recovered by decreasing the power output at the end of the support period. However, both primary control methods will not experience speed recovery period resulting no power reduction after frequency support. Moreover, primary control with over-speeding action would have more kinetic energy than primary control with increased pitch angle. Therefore, the over-speeding action is expected to exhibit better performance. Furthermore, it is another fact that high speed operation for same active power rating machines would results less copper losses due to less torque. Therefore, another expectation is that over-speeding action is expected to be more efficient.

Conclusions

At the end of this study, the simulation results for the comparison of primary control methods will be presented in terms of inertial support performance. A wind turbine active power can be decreased by either increasing pitch angle or turbine speed. The performance of these methods with inertial support will be evaluated at the end of the study. Primary frequency control methods will be implemented for GE 2.75-103 wind turbine model. However, over-speeding method is expected to demonstrate better performance due to higher kinetic energy storage and better efficiency.