Analysis of grid frequency data to quantify the effect of the provision of synthetic inertia on the mechanical loads of a wind turbine

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Abstract

Power systems world-wide see an ongoing replacement of conventional power plants by renewable energy sources (RES). Unlike conventional power plants RES are typically connected to the power systems by inverters and therefore do not inherently provide inertia to the system. This causes a decline of the system inertia and can therefore facilitate higher variations of the grid frequency. In order to ensure a reliable control of the grid frequency some system operator require the provision of synthetic inertia (SI) from RES and especially from wind turbines (WTs), i.e. the WT has to change its power output depending on the change of the grid frequency. Today, these requirements are still limited to severe problems in the power systems, so called frequency events. However, with an ongoing decline of the system inertia grid operators may require continuous provision of SI in the future.
WTs usually provide SI either by derating its power prior to a frequency event or by using the kinetic energy stored the drive train to temporarily increase the electrical power when the frequency event occurs. Derating the WTs for continuous provision of SI obviously leads to a high decrease of the energy yield and is therefore not recommended. However, using kinetic energy stored in the drive train can also cause problems as the reaction of the WT to a frequency event highly depends on its operating point at the time of the event. In order to reduce such unforeseeable reactions the use of variable inertia constants have been proposed by the authors. A WT equipped with such a controller varies its inertia contribution with its operating point and therefore provides a reliable reaction to a frequency event.

Providing SI may have a significant effect on the mechanical loads of the WT, especially when it has to be done continuously. As the results of a load analysis highly depend on the inputs, the simulated scenarios for the grid frequency behaviour must be chosen carefully. First load simulations show two scenarios which are potentially harmful for the WT:

- Frequency events lead to abrupt changes of the grid frequency and hence to abrupt changes of the power output of the WT: this causes strong singular excitations of WT components.

- Sub-synchronous oscillations or period changes of the grid frequency: this causes periodic excitations of WT components.

In order to thoroughly define scenarios for the load calculations and thereby to quantify the effects of SI provision on the mechanical loads additional information are needed for both scenarios:

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- Frequency events: Number of events in time interval and magnitude of frequency change/magnitude of rate of change of frequency.

- Frequency oscillations: Number of events in time interval, magnitude of frequency change/magnitude of rate of change of frequency, period of oscillation, and duration of oscillation.

The characteristics of the scenarios highly depend on the electrical grid to which a WT is connected. Hence, time traces of the grid frequency have to be analysed to estimate the situation in a certain grid. The authors currently work with an exemplary high resolution data set of the Indian grid frequency. Based on these results scenarios for the load simulations shall be proposed which reflect the expected effect of continuous SI provision on the WT mechanical loads for the analysed grid. Furthermore, it may show a method how to the effects of continuous SI provision can be implemented in the load simulation.

Keywords: Frequency support, Mechanical loads, Synthetic Inertia