

Dynamical Patterns of Synchronous Compensators connected to a Wind Power Plant

PS1: Changing Role of Electrical Machines in Power Generation

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As the use of wind power continues to increase, so do concerns about the stability of power grids. One potential solution to this problem is the installation of synchronous compensators, which can provide grid stability by regulating voltage and frequency. This paper examines the impact of synchronous compensators (SC) on wind power plant stability issues. The findings suggest that SCs can improve grid stability, particularly in high wind power penetration areas. They can also provide other benefits, such as reducing the need for curtailment and increasing the lifespan of wind turbines. However, installing SCs may only be cost-effective in some cases, and further research is needed to fully understand the optimal conditions for their use. Overall, this paper highlights the potential of SCs to address stability issues in wind power plants and provides a first approach to understanding the dynamical patterns and interactions in a modal analysis framework.

Renewable energy sources (RES) are widely deployed worldwide. RES, such as wind power and photovoltaic plants, are interfaced with the system through power converters. These technologies are unified under the name of inverter-based resources (IBRs). Moreover, the global tendency is to replace synchronous generation, in which physical rotational inertia is present, with IBR technologies, which provide a very small or even no inertia to the system. Removing too much inertia in the system can cause stability issues. The constant balance between generation and demand dictates the system frequency response. If the system exhibits high inertia, the frequency will not deviate significantly when there is an unbalance in the generation demand. However, if the system has low inertia, this frequency deviation can cause energy disruptions at the consumer end. It is studied in [1] how the loss of inertia can affect the stability of the African Network. Similar conclusions on the Italian Network case can be found in [2]. In conclusion, it is widely accepted that the loss of system inertia can cause stability issues. Possible solutions to tackle these stability issues come from installing virtual inertia or physical inertia in the system. Virtual inertia can be installed employing properly designed algorithms in which an IBR can emulate a physical mass inertia. This technology requires an energy storage system (ESS) to extract the needed power. On the other hand, physical inertia can be installed utilizing a SC (SC).

Furthermore, replacing synchronous generation with IBRs also affects the system's short-circuit ratio (SCR). The short-circuit ratio determines how often the device can provide its rated power in case of a short circuit at its terminals. A device with high SCR can contribute better to the system's restoration after a fault than if the SCR was low. The short-circuit ratio of an SC can be up to 10 times the rated power, whereas in IBRs, the short-circuit ratio is only 1.1-1.2 times the rated power.

A SC is an electrical machine where the shaft is left unloaded. The SC cannot provide active power in steady state, whereas active power flow is created when the shaft releases kinetic power to the grid in the form of electric energy, providing inertia to the system. On the other hand, the SC contributes to power factor correction by injecting or consuming reactive power. This is done via its Automatic Voltage Regulator (AVR).

Figure 1 shows the system under study, in which a Doubly Fed Induction Generator is connected to the grid through lines to which a SC is connected.

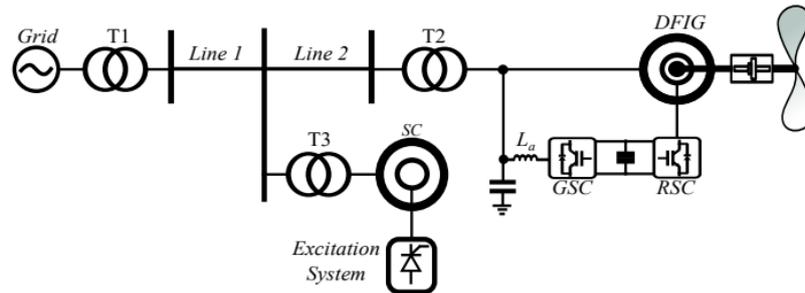


Fig. 1: System overview consisting of a WPP connected to an infinite grid through long lines and a SC in the middle

The final presentation will contain the experiment results in which different working points will be considered, how the SC affects the system's stability, and where it is the best point to connect the SC in terms of modal-analysis results.

One first simulation result is shown below. The system under study is the WPP connected to the grid without SC. Different active power generated by the WPP is considered. Further, it is studied how the distance between the WPP and the grid affects the eigenvalue location, i.e., increasing the impedance, meaning decreasing the SCR at the point of connection of the WPP.

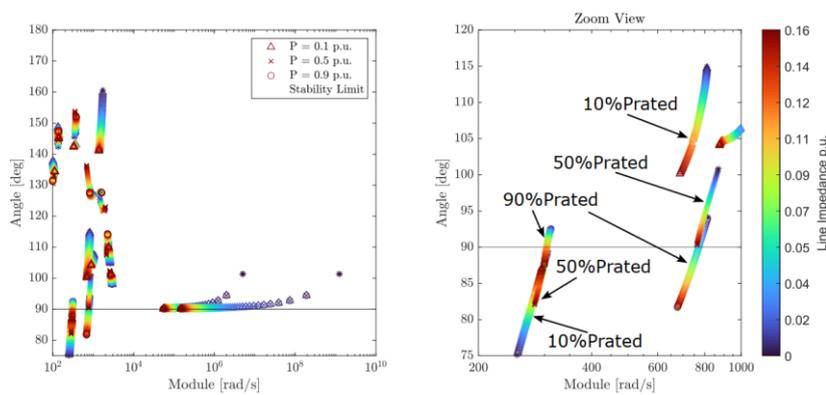


Fig. 2: Eigenvalues placement depending on active power injection from WPP and line impedance to the grid.

From Fig. 2 it can be concluded that the amount of active power delivered by the WPP and the connection impedance significantly impacts the location of the eigenvalues. Further, looking at the participation factors, it has been found that the phase-locked-loop control and the current control loops participate in unstable eigenvalues. Later experiments in which a SC is implemented show that the distance at which the system becomes unstable can be ten times greater than if no SC is installed. These results will be shown in the final manuscript.

The stability margins can be efficiently increased by including a SC in a wind-power plant system. Therefore, penetration of renewable energy sources and inverter-based resources can be increased by utilizing the well-known SC technology.

Keywords

Synchronous compensators, inverter-based resources, small-signal stability, modal analysis

References

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