Voltage Control in a Medium Voltage System with Distributed Wind Power Generation

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ABSTRACT

In this thesis we investigate different methods to control the voltage in a system with distributed generation (DG). In this case we consider two wind power plants of 6 and 8 MW installed power. Lately the interest for DG is increasing. This technology is quite new and needs more investigation to develop cost-competitive alternatives.

The major advantage with DG is that the power is produced close to consumers. Therefore the losses are reduced in transmission and distribution systems. Also, DG gives the opportunity for autonomous island operation.

For conventional radial feeders, without any DG, the power flows only in one direction: from the feeding grid towards the loads. Therefore the voltages decrease towards the end of the feeder.

When DG is added in a system, we have to consider the situation when the DG exceed the local load and power flows in reverse direction, that is, towards the high voltage grid. Hence, the power flow can either be from the grid toward loads, or vice versa. Then we have two very different load flow situations to consider in the power system analysis. The opposite load flow conditions give totally different voltage distribution in the system. Hence, the conventional voltage control systems and protections might be inappropriate when we have DG.

When the DG is producing active power, the voltage at its connection point will increase which might lead to an overvoltage. On the other hand, when the DG is inactive and with heavy local load, the voltage might drop, giving low voltage. Therefore we have to avoid all abnormal voltage conditions, both undervoltage and also overvoltage.

This thesis starts with some background information of wind power and distributed generation. After that we simulated a 24-hour cycle of operation for a small system under different conditions. The simulation results are commented, and we try to make some general conclusions about the best options for each technology.

The simulated system is based in a real system located in Högseröd, Sweden. It is a 130kV/ 20kV system consisting of a transformer with on-load tap changer (OLTC). The transformer station has two 15 km feeders that connect to local buses with a combination of DG and local load. Due to variations in load and generation, it was suspected that this transformer could have problems with excessive wear of the taps. One objective was to minimize the number of tap operations per day.

We have studied two different wind turbine technologies, namely Doubly-fed Induction Generator (DFIG) and Squirrel cage induction generator (SCIG).
Another important aspect to study was the effect of reactive compensation. To do this, we simulated the DFIG without compensation (zero reactive power input and output) and in voltage control mode (to model this we used a STATCOM). For the compensation of the SCIG we used capacitors, either in three steps or one fixed value.
To get some insight of how the voltage control is affected by connection type, the simulation cases were run with underground cable and repeated for overhead line.
Inspired by the objective to reducing the number of tap changes, we also added a simulation case where the transformer OLTC was blocked.

An analysis of the simulations results can help to find a good control strategy for the system in Högseröd.
The number of tap changes is higher with SCIG because the reactive power through the transformer is higher than with DFIG.
DFIG technology gives better results in voltage control mode (with STATCOM) rather than with zero reactive power output.
SCIG technology works better with fixed capacitors instead of step capacitors. Step capacitors compensate 100% at full load causing a high overvoltage.
Using underground cables the number of tap changes is reduced and also the voltages are closer to nominal values. An exception is when DFIG is used in voltage control mode (with STATCOM). Then the node voltages are more sensitive to reactive power variations with an overhead line. The reason is that an overhead line gives the STATCOM more control authority.
Depending on the load location it could be a good solution in some cases to block the transformer.