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Enhanced wind farm modeling

For steady-state and dynamic analysis

At a glance

As wind farms become a larger part of the total generation of power systems worldwide, issues related to integration, stability effects, and voltage impacts become increasingly important. Adequate load-flow and dynamic simulation models (encompassing all significant aerodynamical, mechanical and electrical factors) are necessary to evaluate the impact of wind farms on power systems.

The challenge

Usually, a wind farm comprises a large number of individual turbine units that are interconnected in a radial or parallel arrangement. When studying the impact of a wind farm on the system, it is reasonable to construct an equivalent of the wind farm comprising a reduced number of aggregated units connected to the network. Such a lumped representation is advantageous since it saves the user time and effort in modeling the wind farm. This is the only possible approach for wind farm interconnection studies undertaken at the early phase of the project before a formal design is available.

Figure 1: Wind farm

The user may choose to represent the wind farm as a distributed system or a lumped system. A manual plan or the use of a “model builder” program can be applied for the necessary review of steady-state parameters and power flow review at “collector buses”. It is assumed that the user, prior to adding wind machines to a load flow case, has already correctly defined the configuration between these collector buses and the system interconnection points.

The model builder has the capability to either calculate MW-output based on a given wind speed or, as is more reasonable for system studies, to allow the user to directly dispatch the individual or equivalent units.

Reactive power injection or consumption of a wind turbine unit is determined by the type of the machine employed, its dispatch and AC voltage or power factor control. If available, additional shunt capacitors should be added to provide the desired power factor.

Model builder programs were developed for many vendor-specific wind turbine models to achieve a high level of automation in preparation for power flow and dynamic simulation data set-up. This relieves the user from having to obtain the information directly from the turbine manufacturers.

Currently, for users who have gained significant experience in wind-related system studies and dealing with wind technology manufacturers, Siemens Power Technologies International (Siemens PTI) recommends handling wind machines in load flow the same way as conventional machines.

The latest PSS®E release has expanded the machine data record by determining if a machine relates to the wind turbine and to its reactive power control objective. Careful engineering is necessary to ensure that all significant factors are included in dynamic models, and characteristics that are not relevant to the application of such models from a power system perspective are ignored

Similarly, there is also no need for detailed simulation of power converters because, in the frequency range typical for power system electromechanical transients, converters can be represented as controlled sources of real and reactive power.

Our solution

Numerous projects undertaken by Siemens PTI for utilities, manufacturers and consortia have concentrated on providing a suitable level of modeling for the required types of analysis.

Given the variety of commercially available wind turbine units, it can be concluded that a single generic dynamic model can neither be developed nor applied. However the following four types of generic wind models cover all currently available types of wind turbines:

- Type 1, directly connected induction machine
- Type 2, wound rotor induction machine with the external rotor resistance control
- Type 3, double-fed induction generator with the rotor winding controlled by a power converter
- Type 4, a machine decoupled from the grid by a full-size power converter

Siemens PTI is working vigorously on the development of these generic models. The idea is to create models that will be parametrically adjustable to any specific wind turbine of the same type available on the market.

Wind turbine manufacturers were invited to participate in this effort in terms of the model design and validation

The generic model of Type 3 (WT3) is included into the standard dynamic model library of the latest PSS®E release. Generic models Type 1, Type 2 and Type 4 are on the way.

The latest PSS®E dynamic interface provides more flexibility in terms of adding components of wind turbine modules to the dynamic setup and analyzing the results of the dynamic simulation.

Published by
Siemens AG 2016

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