



NATIONAL GRID

Grid Code Modification Proposal Discussion Document

Requirement for Provision of Dynamic Modelling Data
from Wind Turbine Generators

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1. Introduction

This document sets out to explain the basis for the recent Grid Code modification proposal dealing with the requirement to provide dynamic modelling data for wind turbine generators. This modification proposes adding section PCA 4.10.1 to the Planning Code Appendix of the Grid Code. It has been assigned the identification number MPID 126. It should be noted that it is not intended that this justification document should form part of the Grid Code. The proposed text is available in a separate document.

2. Background

As part of its responsibility to ensure the development of a reliable and secure transmission system, the Transmission System Operator (TSO) must assess the impact of the changing patterns of generation on the dynamic performance and security and stability of the power system. The TSO carries out these stability assessments using the dynamic simulation modules of the power system analysis package PSS/E. PSS/E dynamic simulation uses a single-phase (positive sequence) representation of the power system. Only fundamental frequency (50 Hz) phenomena are represented. To assess stability, simulations are typically run for up to 1s before a disturbance, the duration of the disturbance (which could be several seconds) and for up to one minute after a disturbance.

To run the PSS/E dynamic simulations, the TSO requires suitable and accurate dynamic models for all generators connected to, or applying for a connection to the transmission system. The models must be valid for the type of simulation described above.

Modelling requirements for thermal and hydro generators have been processed on the identification by the applicant of the relevant PSS/E library model and the provision of the applicable data parameters in the current, appropriate application form.

At present (September 2004) there are no suitable PSS/E library models for Wind Turbine Generators. As a result the TSO requires applicants with wind farm schemes greater than 5 MW to provide a specially written model (termed a PSS/E user-written model) and associated data parameters specific to the wind turbine generators and any associated controls and reactive compensation equipment to be used in the applicant's wind farm scheme, in the same way as such models are required for conventional plants.

The CER Direction 04/245 of 9th July requires the TSO to “*define the model requirements and what shall be deemed ‘an appropriate model’ in conjunction with the industry, subject to approval by the Commission*”. These modelling requirements are to be detailed in the Planning Code Appendix of the Grid Code and in the Distribution Code. Given that the science of modelling wind turbine generators for power system stability studies is continuing to evolve, it is not practical to set out final detailed criteria for these models. The standards for modelling will depend on developments at the research level, and also in developments by the developers of power system simulation packages. The standards will also be informed by experience gained in using the early models. Therefore, the TSO proposes that the high-level requirements for simulation models be included in the two codes. (The

modelling requirements for remaining in the Connection Offer Process are dealt with separately.)

3. Dynamic Model Requirements

3.1 Functionality

The models for wind turbine generators must be able to calculate how quantities such as power output, reactive power output, turbine speed etc. vary as factors such as the voltage at the connection point change. They must take account of the inherent characteristics of the machines and the actions of the WTG control systems.

The model must represent the wind turbine generator to be installed in the relevant wind farm and must include representation of features added to the WTG to comply with the Grid Code. The model must be appropriate for a 50 Hz system.

The models should represent the features and phenomena likely to be relevant to angular and voltage stability. These include

Electrical characteristics

The electrical characteristics of the generator are necessary for the calculation of voltages and currents at each time step in the simulation.

Mechanical characteristics

The separate mechanical characteristics of the turbine and generator, and the drive train between them are essential for torque and speed calculations. Wind turbine generators have relatively “soft” shafts that tend to twist when torque is applied. This twist will affect the acceleration of the turbine and generator under fault conditions. Therefore separate representation of the turbine and generator (“two-mass representation”) is essential.

Blade pitch control and C_p , λ , β curves

The power co-efficient C_p of a wind turbine relates the power extracted by the turbine to the wind speed. The power co-efficient depends on the blade pitch angle β which may be altered by blade pitch control and the ratio λ between the blade tip speed and wind speed. Since both blade pitch and tip speed ratio may vary during a simulation, these dependencies must be represented, along with the blade pitch control.

Converter controls

For variable speed machines the converter controls may be used control generator speed and generator power factor. They also play a key role in low-voltage ride through. These controls are therefore fundamental to any dynamic simulation. However, it should be noted that very short time constants in the converter controls need not be represented, as these would require an excessively short integration time step.

Reactive compensation

Any reactive compensation devices, together with their controls, must be represented if they will be active in the time scales relevant to system stability studies.

Protection relays

Protection relays such as under-voltage, over-voltage, under –frequency and over-frequency must be represented, along with the appropriate settings.

3.2 Platform

PSS/E is continually developed and by Shaw-Power Technologies Inc. Major new revisions are released approximately annually. In addition, PSS/E is available in different versions depending on the computer hardware and operating system being used. Shaw-PTI does not update “user-written” models to keep pace with computer environment changes. The TSO may decide from time to time to update its current version of PSS/E in order to benefit from the enhancements introduced with each new version. On request, the TSO will provide information regarding its current version of PSS/E, operating system etc. Whenever the TSO decides to move to a newer version of PSS/E, it will allow a reasonable time for models supplied by users to be updated.

3.3 Simulation time step

Dynamic simulation is based on a process of numeric integration. In PSS/E the user specifies a simulation time step. An excessively short time step will make the time required to run simulations unacceptably long. A simulation time step of not less than 5 millisecond should be adequate to represent accurately all phenomena that are of interest as far as power system stability is concerned. This will mean that processes with very short time constants will have to be represented in the model as algebraic relationships ignoring the very short time delays.

3.4 Model initialisation

PSS/E dynamic simulation uses a loadflow study as a starting point. The PSS/E models for wind turbine generators should incorporate an initialisation routine to calculate initial conditions of machine slip, machine power factor, status of reactive compensation devices etc. taking account of terminal voltage. This will enable the models to be added to the loadflow with the correct power factor.

3.5 Aggregation

Aggregation refers to the ability to use a single machine model to represent a number of wind turbine generators, or perhaps a complete wind farm. Aggregation results in some loss of accuracy, as in reality all wind turbines face slightly different conditions – different wind speed and direction and different terminal voltage. On the other hand, aggregation can greatly reduce the computational effort in a total system simulation. One of the objectives of the TSO’s global system dynamic studies is to develop an understanding of the extent to which wind turbines may be aggregated in system stability studies. However, some level of aggregation will be essential. The models should therefore be capable of aggregation into single models, each representing a number of wind turbine generators.

3.6 Standard architecture

The models should be based on a standard architecture. The joint development of proposals for standard architectures for each WTG technology is being discussed by the five transmission system operators in the UK and Ireland.

Ultimately, standard library models for wind turbine generators should be provided for PSS/E. The wind turbine generator industry and Shaw Power Technologies Inc, the developers of PSS/E should work together to achieve this.

3.7 Documentation

The model should be fully documented. The documentation should describe in detail the model structure, inputs, outputs and how to set up and use the model. The standard of documentation should correspond to that provided for PSS/E standard library models

3.8 Source Code

The source code of standard PSS/E library models is available to the TSO. However, manufacturers of wind turbine generators are anxious to protect their technical secrets, and are therefore concerned to keep the source code of the dynamic models for wind turbine generators confidential.

Circumstances do arise from time to time when it would be helpful for the TSO study engineers to have access to the source code in order to investigate problems encountered in running simulations or develop a better understanding of simulation results. It is therefore proposed that the source code of the dynamic models should be made available to the TSO in response to a specific request. The TSO undertakes to ensure that the source code is kept confidential and that it is not disclosed to any other party.

4. Model Validation

The results of any simulation study can only be valid if the models used in the study are valid, i.e. the behaviour shown by the model under simulated conditions is representative of the behaviour of the real equipment under equivalent conditions.

Validation of wind turbine generator models is problematic for a number of reasons:

- Wind turbine generators are being developed continually. In particular, developments have taken place to ensure compliance with Grid Codes in various countries. Therefore in many cases there are no examples of the wind turbines to be installed in Ireland already in service elsewhere.
- Wind farm development and power systems vary from one country to another. Measurements on a small wind farm connected to a distribution system in one country may not be relevant to a large wind farm connected to a transmission system in another country.
- It may be some time before a particular wind farm encounters the appropriate combinations of disturbance types and wind conditions.

For validation purposes the applicant should provide the TSO with whatever information is available showing how the predicted behaviour of the PSS/E model to be verified compares with the actual observed behaviour of a prototype or production wind turbine generator under laboratory conditions and/or actual observed behaviour of the real wind turbine generator as installed and connected to a transmission or distribution network.

The conditions validated should as far as possible be similar to those of interest, e.g. low short circuit level at connection point, close up, severe faults, nearby moderate faults, remote faults, voltage excursions, frequency excursions, large wind speed variations.

Where appropriate measurements to confirm the validity of the PSS/E model for conditions likely to be encountered in Ireland are not available from the wind turbine generator manufacturers or other sources, on-site measurements will be required to

demonstrate the validity of the model. If necessary the model shall be modified to ensure reasonable correspondence between the behaviour predicted by the model and the measured behaviour.