Scheme of Integration of Wind Power to Electric Power Grid

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Abstract

Integration of large wind farms into bulk power systems presents multiple challenges to system operation and security. Wind generators may have to be disconnected from the grid once the system has a disturbance. The presence of wind farms in such weak systems raises serious concerns about system stability, voltage regulation, and post-fault power swings. WFMS and LVRT technology for wind turbine generators can provide much improved system performance compared to more traditional wind generation equipment. This chapter presents dynamic performance of GE wind turbine-generators with LVRT and WFMS technology. The information presented includes dynamic simulation results from existing power systems with large wind farm interconnections, and actual field measurements from operating systems. This paper also presents control design philosophy, innovative control designs and relevant control diagrams.

Key words: LVRT-Low voltage ride through; WFMS-wind farm management system.

1.Introduction

At present a vast majority of the generating power plants are thermal, hydro or nuclear power stations with large synchronous generators. These plants have a very controllable generation capability of both the active and reactive powers within their capability limits. Moreover, the power system network has evolved around these machines; hence they go together very well. The characteristics and capabilities of wind WPPs are very different from the conventional power plants. Their operational behavior, dynamics, controllability and capability are dependent upon the type of wind turbine generators used, farm control architecture as well as instantaneous wind availability. In the past, wind power penetration in the power grid network was relatively small and grid operators treated them as negative load, rather than a power generation source. They were not expected to provide grid support. The conventional power houses were required to provide controlling power to make up for the lost wind power generation and support grid recovery. With increasing wind penetration, grid operators are now imposing grid code requirements to specify the steady and dynamic requirements that wind farms must comply with for getting connected to the grid. Wind farms need to participate in the frequency and voltage regulation by continuously controlling their active and reactive power outputs. They are expected to exhibit low voltage fault ride through capability and support the grid recovery[1]. E.ON Netz Grid Code states that every generating plant with a rated capacity of over 100MW must be capable of supplying the control power[2].

These requirements are being addressed by the latest generation of wind turbine-generator (WTG) equipment. WFMS and LVRT technology for wind turbine generators can provide much improved system performance compared to more traditional wind generation equipment. LVRT technology is now able to eliminate most concerns about tripping during system voltage events and allows for the rapid and well-behaved recovery of the wind farm and the grid when system faults are removed. Wind farms controlled by WFMS can provide extremely fast initial response to system events and wind induced perturbations, and voltage and reactive power response similar to that of conventional synchronous generation.

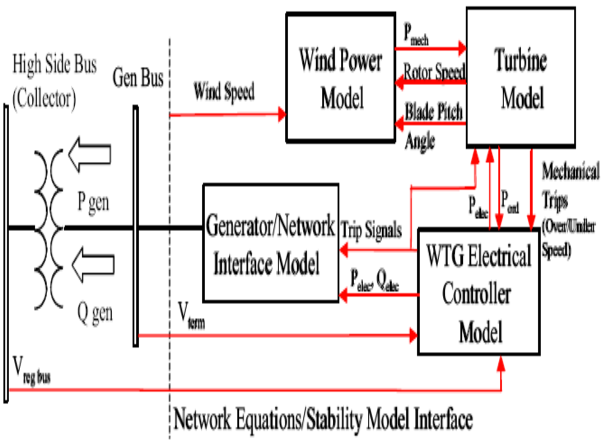
2.Theory

The distinction is that TWGs equipped with a solid-state AC excitation system. The AC excitation is supplied through an ac-dc-ac converter. The fundamental frequency electrical dynamic performance of the WTG is completely dominated by the field converter. In practice, the electrical behaviour of the generator and converter is that of a current-regulated voltage source inverter[6]. The converter will make the WTG behave like a voltage behind a reactance that results in the desired active and reactive current being delivered to the device terminals. Conventional aspects of generator performance related to internal angle, excitation voltage, and synchronism are largely irrelevant. These characteristics have significant implications from the standpoint of power-swing performance and modal interactions[5]. This model was developed specifically for the GE 1.5 and 3.6 MW WTGs. This model is not designed for, or intended to be used as, a general purpose WTG. There are substantial variations between models and manufacturers.

The overall WTG model consists of four major elements, as shown in Figure. Generator/Network Interface, Electrical Control,Wind Turbine, and Wind Power Model.

3.Modeling of WTG

Figure 1. Generator network interface



The wind turbine model provides a simplified representation of a very complex electro-mechanical system. The turbine control is designed to deliver power over a range of wind conditions, taking advantage of the variable speed capability of the machine. The controller enforces the power speed relationship shown in Figure 2. Above about 75% rated power, the power levels of primary interest for stability studies, the controller works in two distinct regions. When the available wind power is above the equipment rating, the blades are pitched to reduce the mechanical power (Pmech) delivered to the shaft down to the equipment rating (1.0 p.u.), thereby returning the machine to the reference speed for full power operation, 120% of synchronous speed. When the available wind power is less than rated, the blades are fixed to maximize the mechanical power, and speed control is accomplished by adjusting the generator electrical power. The dynamics of the pitch control are moderately fast, and can have significant impact on dynamic simulation results. The block diagram for the model is shown in Figure 2.

Figure 2. Power and Speed control

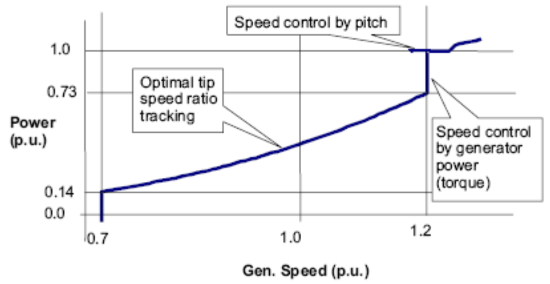
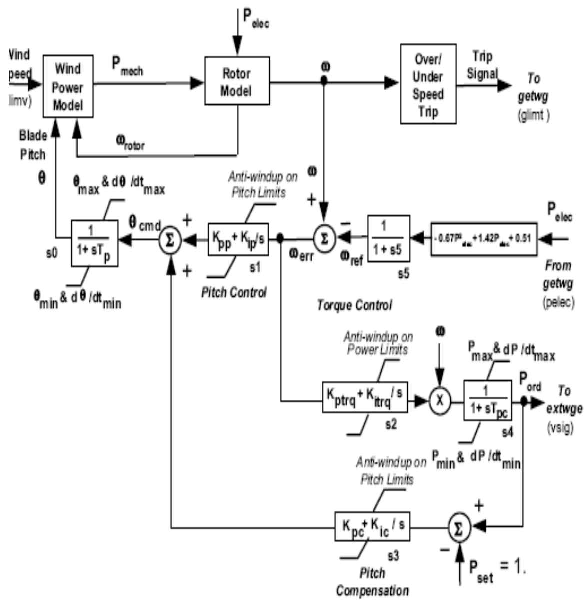


Figure 3.Wind Power Model



The wind turbine model represents all of the relevant controls and mechanical dynamics of the wind turbine. The model accepts the machine terminal active power from the WTG Electrical Control Model and the mechanical power calculated by the Wind Power Model. The turbine control model sends a power order to the electrical control for the converter to deliver the requested power to the grid. The electric power actually delivered to the grid is returned to the turbine model, for use in the calculation of rotor speed. The speed controller does not differentiate between shaft acceleration due to increase in wind speed or due to system faults. In either case, the response is appropriate and relatively slow compared to the electrical control. The turbine control acts so as to smooth out electrical power fluctuations due variations in shaft power. By allowing the machine speed to vary around its rated value (120%), the inertia of the machine functions as a buffer to mechanical power variations. The function of the wind power module is to compute the wind turbine mechanical power (shaft power) from the energy contained in the wind. [8].

4.Simulation results

Figure 4. shows the simulated response of a wind farm of 108 GE 1.5 MW wind turbine generators (WTGs) to ten minutes of highly variable wind near rated wind speed. The red traces show the system response with WFMS, and the black traces show the system response with conventional fixed power factor control. The fixed power factor control is local to each individual WTG. The utility bus (the point of interconnection), the system voltage with conventional power factor (pf) control exhibits unacceptably high variation.

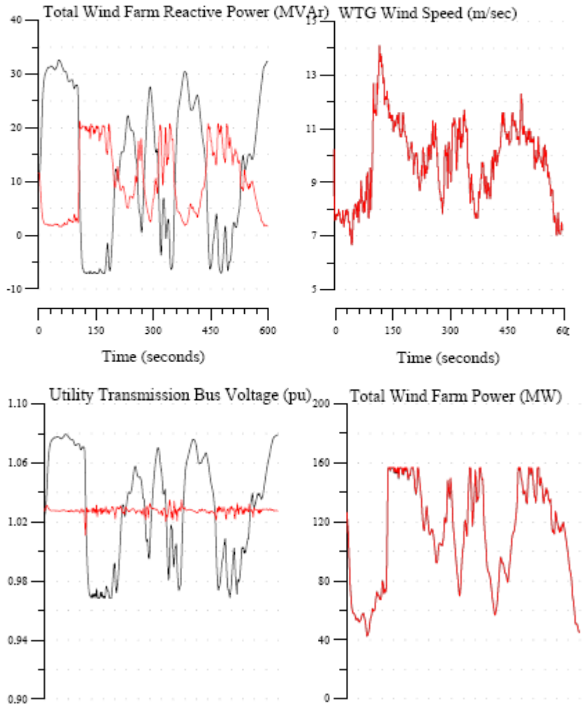
The fixed power factor control is local to each individual WTG. The utility bus (the point of interconnection), the system voltage with conventional power factor (pf) control exhibits unacceptably high variation. By comparison, the WFMS controlled system voltage exhibits very small variations. The voltage flicker index, Pst, is less than 0.02 for this high stress condition – well within industry requirements.

The results demonstrate the capability of LVRT to handle unbalanced faults and a high level of fidelity in the digital simulations and models. Voltage and reactive power control performed by WFMS minimizes voltage flicker, improves system stability, provides voltage regulation, reduces the risk of voltage collapse, and minimizes the impact of system disruptions. WFMS provides tight closed loop control of utility system voltages. The impact of active power fluctuations from wind variation on the grid voltages are minimized and the fast and precise voltage control effectively strengthens the grid, improving the overall power system's resilience to large disruptions.

5.Conclusion

Voltage and reactive power control performed by WFMS minimizes voltage flicker, improves system stability, provides voltage regulation, reduces the risk of voltage collapse, and minimizes the impact of system disruptions.

Figure 4. Effects of various variables



WFMS provides tight closed loop control of utility system voltages. This provides two major benefits: First, the impact of active power fluctuations from wind variation on the grid voltages are minimized; second, the fast and precise voltage control effectively strengthens the grid, improving the overall power system's resilience to large disruptions.

LVRT feature renders this over-sensitive response obsolete by improving generator and control system design. Before LVRT technology, wind turbines would trip off-line on any voltage sag below 70%. Now they are designed to ride through severe grid disturbances. LVRT technology enables wind farms to continue operation during and after severe faults or voltage depressions on the power grid. Power-electronic conversion and control technology incorporated into the generating system enables variable speed operation, while eliminating electromechanical power swing interaction with the grid. The combination of these features enable wind power plants to achieve stability performance that can exceed that of conventional synchronous generations of the same rating, installed at the same locations.

6.Referances

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