Possibilities of Distributed Generation Simulations Using by MATLAB

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ABSTRACT

Distributed sources such as wind generators are becoming very imported part of power system in last few years. This paper deals about modeling possibilities of distributed sources connected to power systems using by MATLAB program. Simulations performed by MATLAB/Simulnik can have an important role in terms of evaluation of connecting conditions depended on small short-circuit power, which is usually in most places where distributed sources can be connected, very small. There will be five MATLAB/Simulink demo models introduced in this paper as examples of MATLAB/Simulink possibilities.

1. INTRODUCTION

In spite of increasing of interest of distributed sources in last few years the utilities have usually problems with connecting them to the network. Most of problems are power quality problems, such as flicker, harmonics, etc. which are often caused by small short-circuit power at the point of connection. Many problems can be solved using by simulation programs to find best solutions in network configuration and parameters setting before real connection of distributed source to power system. In the next chapters of this paper blocks from distributed resources library of MATLAB and few basic models which uses these bocks will be introduced.

2. DISTRIBUTED RESOURCES LIBRARY

There is a distributed resources library in the MATLAB 7 and higher, which contains tree models of wind turbines: Wind turbine, Wind Turbine Induction Generator (Phasor Type) and Wind Wind Turbine Doubly-Fed Induction Generator (Phasor Type).

2.1. Wind turbine

The model is based on the steady-state power characteristics of the turbine. The stiffness of the drive train is infinite and the friction factor and the inertia of the turbine must be combined with those of the generator coupled to the turbine. The output power of the turbine is given by the following equation [1]:

$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2}v_{wind}^3 \tag{2.1}$$

where P_m is mechanical output power of the turbine (W), c_p is performance coefficient of the turbine, ρ is air density (kg/m^3), A is turbine swept area (m^2), v_{wind} is wind speed (m/s), λ is tip speed ratio of the rotor blade tip speed to wind speed and β is Blade pitch angle (deg).

2.2 Wind Turbine Induction Generator (Phasor Type)

The wind turbine and the induction generator (WTIG) and their icon representation in Simulink are shown on figure 1. The stator winding is connected directly to the grid and the rotor is driven by the wind turbine. The power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding. The pitch angle is controlled in order to limit the generator output power to its nominal value for high wind speeds. In order to generate power the induction generator speed must be slightly above the synchronous speed. But the speed variation is typically so small that the WTIG is considered to be a fixed-speed wind generator. The reactive power absorbed by the induction generator is provided by the grid or by some devices like capacitor banks, SVC, STATCOM or synchronous condenser.

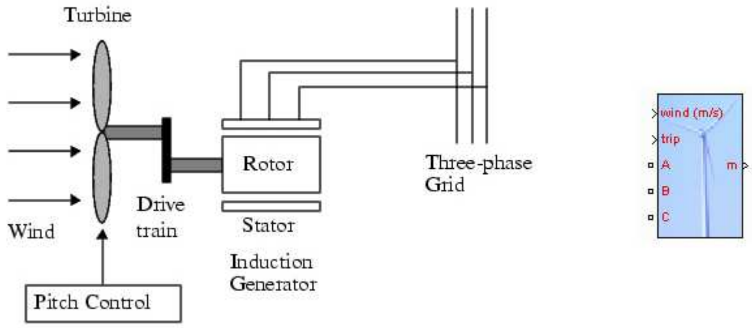

Fig. 1: Wind Turbine Induction Generator (Phasor Type)

2.2 Wind Wind Turbine Doubly-Fed Induction Generator (Phasor Type)

The wind turbine and the doubly-fed induction generator (WTDFIG) and their icon representation in Simulink are shown in the figure 2. The AC/DC/AC converter is divided into two components: the rotor-side converter (C_{rotor}) and the grid-side converter (C_{grid}). C_{rotor} and C_{grid} are Voltage-Sourced Converters that use forced-commutated power electronic devices (IGBTs) to synthesize an AC voltage from a DC voltage source. A capacitor connected on the DC side acts as the DC voltage source. A coupling inductor L is used to connect C_{grid} to the grid. The three-phase rotor winding is connected to C_{rotor} by slip rings and brushes and the three-phase stator winding is directly connected to the grid. The power captured by the wind turbine is converted into electrical power by the induction generator and it is transmitted to the grid by the stator and the rotor windings. The control system generates the pitch angle command and the voltage command signals V_r and V_{gc} for C_{rotor} and C_{grid} respectively in order to control the power of the wind turbine, the DC bus voltage and the reactive power or the voltage at the grid terminals.

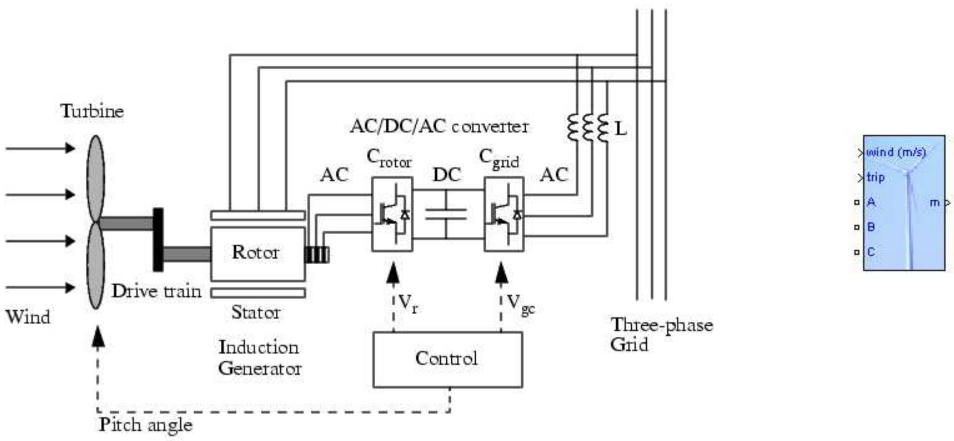

Fig. 2: The Wind Turbine and the Doubly-Fed Induction Generator System and its icon representation

3. DISTRIBUTED RESOURCES MODELS

There are five demonstration models included in Distributed Resources Models section, which is a part of Silmulink SimPowerSystems demo section. Three basic types of these models will be discussed below.

3.1 Wind farm (IG) model

A wind farm consisting of six 1.5-MW wind turbines is connected to a 25-kV distribution system exports power to a 120-kV grid through a 25-km 25-kV feeder. The 9-MW wind farm is simulated by three pairs of 1.5 MW wind-turbines. Wind turbines use squirrel-cage induction generators (IG). The stator winding is connected directly to the 60 Hz grid and the rotor is driven by a variable-pitch wind turbine. The pitch angle is controlled in order to limit the generator output power at its nominal value for winds exceeding the nominal speed (9 m/s). In order to generate power the IG speed must be slightly above the synchronous speed. Speed varies approximately between 1 pu at no load and 1.005 pu at full load. Each wind turbine has a protection system monitoring voltage, current and machine speed.

Reactive power absorbed by the IGs is partly compensated by capacitor banks connected at each wind turbine low voltage bus (400 kvar for each pair of 1.5 MW turbine). The rest of reactive power required to maintain the 25-kV voltage at bus B25 close to 1 pu is provided by a 3-Mvar STATCOM with a 3% droop setting. The model and its wind farm subsystems are shown on figures 3 and 4.

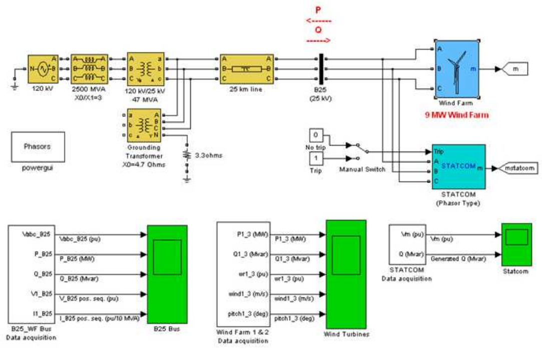

Fig. 3: The Wind farm (IG) model

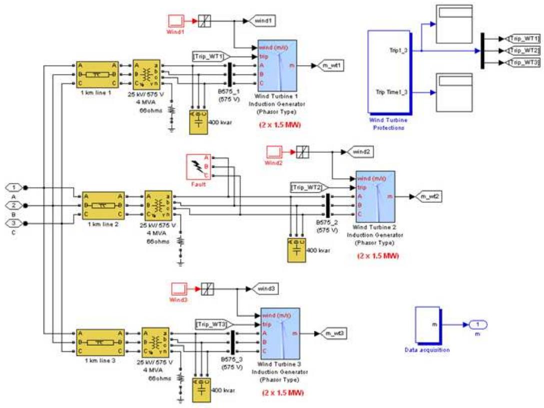

Fig. 4: Wind farm subsystem of the wind farm (IG) model

3.2 Wind Turbine Asynchronous Generator in Isolated Network model

A generic model of the High-Penetration, No Storage, Wind-Diesel (HPNSWD) system is presented in this demo [2]. This technology was developed by Hydro-Quebec to reduce the cost of supplying electricity in remote northern communities [3]. The optimal wind penetration (installed wind capacity/peak electrical demand) for this system depends on the site delivery cost of fuel and available wind resource. The first commercial application of HPNSWD technology was commissioned in 1999 by Northern Power Systems (Vermont, USA) on St. Paul Island, Alaska [4]. The HPNSWD system presented in this demo uses a 480 V, 300 kVA synchronous machine, a wind turbine driving a 480 V, 275 kVA induction generator, a 50 kW customer load and a variable secondary load (0 to 446.25 kW).

At low wind speeds both the induction generator and the diesel-driven synchronous generator are required to feed the load. When the wind power exceeds the load demand, it is possible to shut down the diesel generator. In this all-wind mode, the synchronous machine is used as a synchronous condenser and its excitation system controls the grid voltage at its nominal value. A secondary load bank is used to regulate the system frequency by absorbing the wind power exceeding consumer demand. A Wind Turbine Asynchronous Generator in Isolated Network model is shown on figure 5.

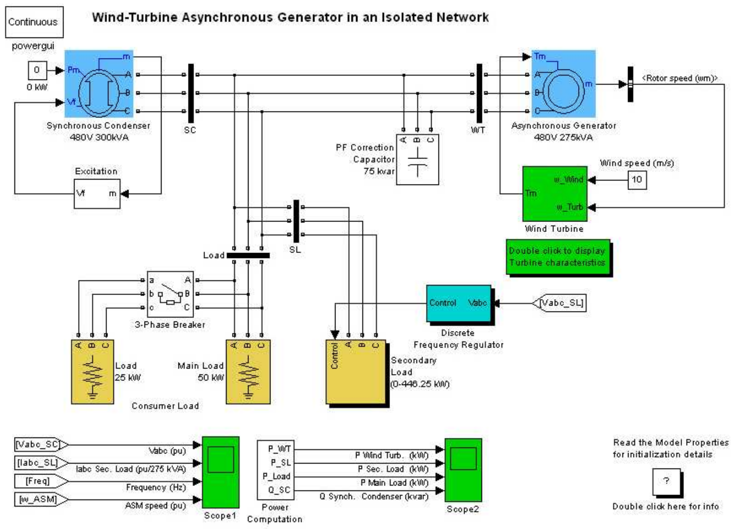

Fig. 5: Wind Turbine Asynchronous Generator in Isolated Network model

3.3 Doubly-Fed Induction Generator (DFIG) Driven by a Wind Turbine model

A 9-MW wind farm consisting of six 1.5 MW wind turbines connected to a 25-kV distribution system exports power to a 120-kV grid through a 30-km, 25-kV feeder. A 2300V, 2-MVA plant consisting of a motor load (1.68 MW induction motor at 0.93 PF) and of a 200-kW resistive load is connected on the same feeder at bus B25. Both the wind turbine and the motor load have a protection system monitoring voltage, current and machine speed. The DC link voltage of the DFIG is also monitored. A -Fed Induction Generator (DFIG) Driven by a Wind Turbine model is shown on figure 6.

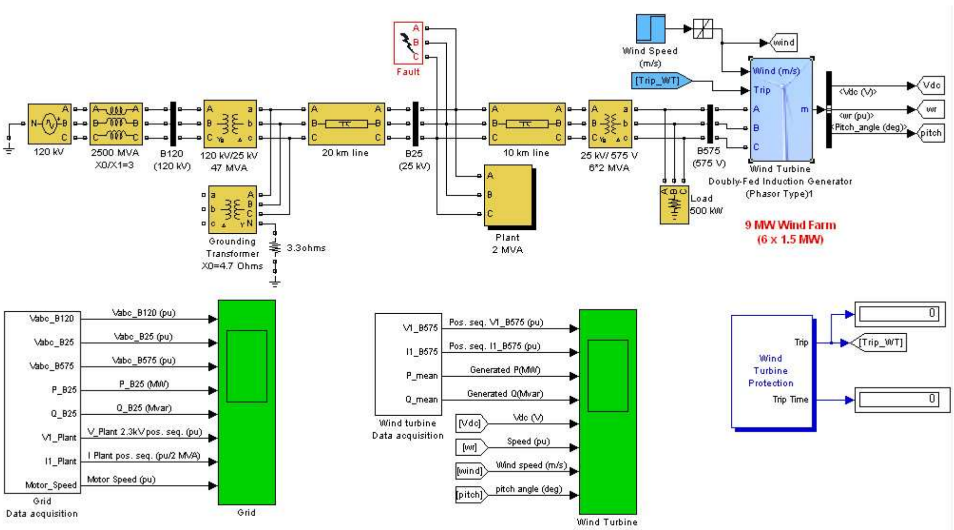

Fig. 6: Doubly-Fed Induction Generator (DFIG) Driven by a Wind Turbine model

4. CONCLUSSION

Basic models introduced in this paper can be used as examples for creating and developing special network connections including wind turbines for power quality evaluation purposes, in case of projection of wind turbines connections to the power systems. MATLAB/Simulink provides many possibilities for engineers to create different network models, which can be useful to prevent bad solutions leading to worse power quality.

5. REFERENCES

[1] http://www.mathworks.com

[2] R. Gagnon, B. Saulnier, G. Sybille, P. Giroux; "Modeling of a Generic High-Penetration No-Storage Wind-Diesel System Using Matlab/Power System Blockset" 2002 Global Windpower Conference, April 2002, Paris, France.

[3] B. Saulnier, A.O. Barry, B. Dube, R. Reid; "Design and Development of a Regulation and Control System for the High-Penetration No-Storage Wind/Diesel Scheme" European Community Wind Energy Conference 88, 6-10 june 1988, Herning, Denmark

[4] L. Mott (NPS), B. Saulnier (IREQ) " Commercial Wind-Diesel Project, St. Paul Island, Alaska" 14th Prime Power Diesel Inter-Utility Conference, May 28-June 2, Winnipeg, Manitoba, Canada

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