MODELS OF RENEWABLE ENERGY SOURCES FOR GRID ANALYSIS

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ABSTRACT

This paper describes models of renewable sources suitable for studying theirs interactions with the power system. These models are used in simulation software, like PSLF, Neplan, Modes, or SimPower Systens.

2. INTRODUCTION

As the concern over global warming increases, renewable energy source become a more significant source of energy. Among these renewable energy sources, photovoltaic (PV) generation is attracting a growing amount of political and commercial interest. Also, wind power generation is promising renewable power generation technology. The growth of wind and photovoltaic (PV) power generation systems has exceeded the most optimistic estimations.

With opening of the power market and with larger number of renewable energy sources (RES) connected to the power system, some new advantages, but also new threats, appeared. Such a large penetration of distributed RES generation would have far reaching consequences not only on the distribution network but also on the transmission grid and the rest of the generators. The effect of a large penetration of renewable generation on the stability and security of the power system must therefore be considered carefully. In particular, the response of generators driven by renewable sources to disturbances could aggravate these incidents.

This paper aims to summarize different models of RES for grid studies, and their use in simulation software.

3. GRID STUDIES

Network analyses are necessary part of the approval process when connecting new resources to the power grid. This analysis is performed mainly by operators of distribution network, creating a mathematical model of part of the network using computer software. Once approved, the connection of renewable sources and their implementation are followed by verification tests and test operation period. Even after the fulfilling of all technical conditions and completing of test operation period, an undesirable impact of renewable source on the distribution network at the connection point (e.g. increased voltage, harmonics) can appear, observed by neighboring customers. These impacts should be reliably identified, using complex power quality analyzers, e.g. Elcom ENA 330. This measurement makes it possible to identify shortcomings and failures of installed equipment (inverter failure, improper operation of the harmonic filter). But usually is sufficient to use only software tools and simple measurements during verification tests.

2.1. Wind turbine models

The principle of wind turbine operation is based on two well-known processes. The first one involves the conversion of kinetic energy of moving air into mechanical energy. This is accomplished by using aerodynamic rotor blades and a variety of methodologies for mechanical power control. The second process is the electromechanical energy conversion through a generator that is transmitted to the electrical grid. Wind turbines can be classified by their mechanical power control, and further divided by their speed control. All turbine blades convert the motion of air across the air foils to torque, and then regulate that torque in an attempt to capture as much energy as possible, yet prevent damage. [3]

Beyond mechanical power regulation, turbines are further divided into fixed speed (Type 1), limited variable speed (Type 2), or variable speed with either partial (Type 3) or full (Type 4) power electronic conversion. The different speed control types are implemented via different rotating AC machines and the use of power electronics. As is the case with a synchronous machine, the stator windings of the induction machine are connected to the rest of the electric network. However, rather than having a dc field winding on the rotor, the ac rotor currents are induced by the relative motion between the rotating magnetic field setup by the stator currents, and the rotor. Both the Type 1 and 2 wind turbine models utilize induction generators, but whereas the Type 1 models have a conventional squirrel cage rotor with fixed rotor resistance, the Type 2 models are wound rotor induction machines that utilize a control system to vary the rotor resistance. The reason for this is to provide a more steady power output from the wind turbine during wind variation. [3]

Most new wind turbines are either Type 3 or Type 4. Type 3 wind turbines are used to represent doubly-fed synchronous generators (DFAGs), also sometimes referred to as doubly-fed induction generators (DFIGs). A DFAG consists of a traditional wound rotor induction machine, but with the rotor windings connected to the ac network through an ac-dc-ac converter—the machine is ‘‘doubly-fed’’ through both the stator and rotor windings. The advantages of this arrangement are that it allows for separate control of both the real and reactive power (like a synchronous machine), and the ability to transfer power both ways through the rotor converter allows for a much wider speed range. Because the stator is directly connected to the ac grid, the rotor circuit converter need only be sized to about 30% of the machines rated capacity. From a transient stability perspective the DFAG dynamics are driven by the converter, with the result that the machine can be well approximated as a voltage-source converter (VSC). A VSC can be modelled as a synthesized current injection in parallel with an effective reactance, in which the current in phase with the terminal voltage, and the reactive power current, can be controlled independently. Low and high voltage current management is used to limit these values during system disturbances. [3]

Type 4 wind turbines utilize a completely asynchronous design in which the full output of the machine is connected to the ac network through an ac-dc-ac converter (see Figure 1). Because the converter completely decouples the electric generator from the rest of the network, there is considerable freedom in selecting the electric machine type. For example, a conventional synchronous generator, a permanent magnet synchronous generator, or even a squirrel cage induction machine. [3]

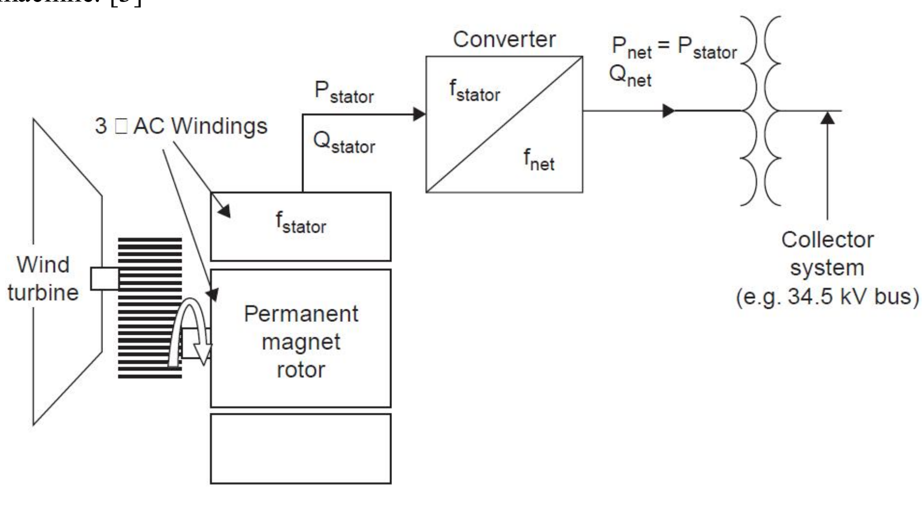

Figure 1 – Type 4 wind generator model [3]

2.2. *Photovoltaic generator models*

Principle of electrical energy photoelectric conversion is quite well known. Photovoltaic panels of various types, connections and arrangements are used, arranged into arrays and connected through the invertors mostly to the distribution network.

Figure 2 is the diagram of the grid-connected three-phase PV model, and the model can be viewed as a composition of DC part, inverter part and three-phase AC part, in which only one phase is shown. The DC part includes PV arrays, the cable resistance R_{DC} and the capacitance C. The three-phase half bridge inverter circuit and sinusoidal pulse width modulation (SPWM) are applied in inverter part, and M and α represent the amplitude modulation ratio and the phase shift angle, respectively. The resistance R is used to approximately calculate power loss of inverter. The AC part includes a step-up transformer and a filter, of which L_f and C_f represent the inductance and the capacitance of the filter, respectively. The step-up transformer is figured as Γ- equivalent circuit, and R_T, X_T, G_T and B_T represent the resistance, the reactance, the conductance and the susceptance, respectively. The voltage amplitude of the point of common coupling (PCC), U_g, is counted into low voltage side of transformer. [5]

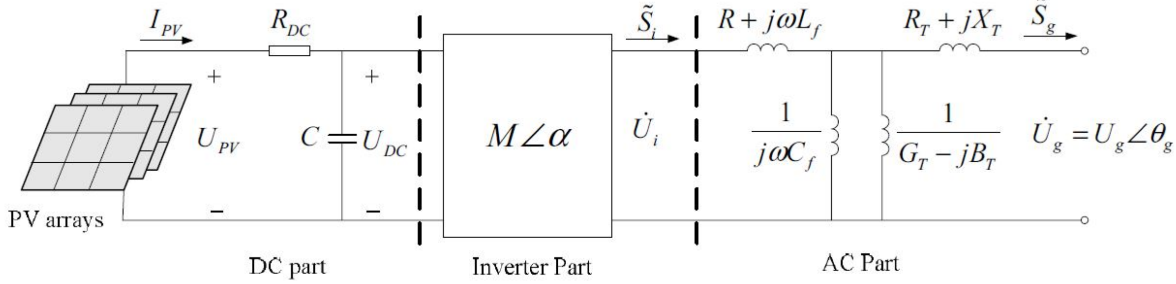

Figure 2 – Grid-connected photovoltaic generation system [5]

2.3. *Biomass generators models*

Biomass power plants are used to convert chemical energy contained in biomass to mechanical energy using different principles, depending mainly on the kind of biomass used. Biomass is used as wood chips, and thus as an ingredient to conventional coal thermal power plants, or in the form of ethanol or biogas extracted from biomass. The power plant configuration especially depends on the fuel choice for prime mover of generator and the generator itself. Mainly are used combustion engines or steam turbines. As power generators are used according to the output power either induction or synchronous generators. Models of these machines for power system analysis are the same as those used for conventional sources.

4. CONCLUSIONS

Renewable energy sources are nowadays rapidly developing energy sector. There are different views on the extent of their use, but their research cannot wait.

Thanks to unpredictability of photovoltaic power plants, which are the most common renewable sources in the Slovak Republic, it is necessary to intense study the impact of renewables on our electrical power system. The basic requirement, which must be maintained, is efficiency of obtaining energy from these sources, along with stability and security of power system operation.

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