OPERATION OF DISTRIBUTED ENERGY SOURCES

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ABSTRACT

Renewable energy sources are becoming more prominent in securing the energy needs of mankind. Increasing share of renewable distributed electricity sources is one of possibilities how to cover growth of electricity consumption. So far, these sources have insignificant contribution in energy balance in Slovakia. Interest of investors in sources installing is very intensive and reaches some GW. This article is focused to possibilities of modelling of operation of distributed energy sources.

Keywords

Renewable energy sources, wind power plant, modelling

1. INTRODUCTION

Renewable energy sources (RES) are often applied as distributed energy sources (DES). They exist as small and dispersed sources of electricity. These sources are connected to lower voltage levels according to their location and size. Nowadays, the RES reach an installed power more than 300 GW and number of installed units is several ten thousand. Continual growth of prices and decreasing reserves of non-renewable energy sources causes the interest in utilisation of renewable energy sources. The aim is also to clear of dependency on oil, gas and other fuels.

For optimum operation of the DES, it is suitable to verify their operational characteristics by a computer modelling. The Eurostag software allows to simulate the operation of the different types of distributed electricity sources and their cooperation with the electric power system [1].

2. WIND POWER PLANTS

The high increase of installed power of wind power plants in the last two decades has caused also an acceleration of research and development bringing new construction solutions. These solutions are applied to design electric devices of the latest wind power plants. The most commonly used types of generators are described with possibilities of operation modelling [2].

2.1. Wind turbine with double fed induction generator

Variable speed induction machines and particularly Double Fed Induction Generator (DFIG) are preferred for wind energy conversion. This allows the turbine operation at variable speed enhancing the conversion efficiency at low wind speed. The main advantage of these types of generators is the gearless machine construction. It enables a weight and a noise decrease.

The model of the DFIG is composed of the following parts:

- Model of the doubly-fed machine and the converters;
- Aerodynamic model of the wind blades;
- Model of the wind turbine control (Pitch controller, Power controller and Main controller).

The mechanical power P_w extracted from the wind is expressed by the following well known formula:

$$P_w = \frac{1}{2} \cdot c_p(\lambda, \beta) \cdot \rho_a \cdot A_r \cdot v^3 \quad [\mathrm{W}] \tag{1}$$

with c_p – the performance coefficient, λ – the tip speed ratio, β – the pitch angle of the rotor blades [degrees], ρ_a – the air density [kg/m^3], A_r – the area covered by the rotor [m^2], v – the wind speed [m/s].

The model of this wind turbine in the Eurostag software includes stator protection with possibilities of a resynchronization (slow and fast reconnection modes).

2.2. Wind turbine with pitch control coupled with an asynchronous generator

This kind of wind turbine consists of fixed speed turbine (neglecting the 1 to 2 % fluctuation due to the slip of asynchronous generator) connected to an induction generator via a gearbox. The position of the blades of the wind turbine can be adjusted (pitch control).

The model of this type of wind turbine includes:

- The aerodynamic equation (wind speed → mechanical torque). This equation is identical to the one of the DFIG model (including pitch influence);
- Pitch control which is modelled by a PI controller followed by a time constant representing the actuator.

It is recommended to use for this wind turbine a speed protection in order to trip the asynchronous generator in case of overspeed (operation above fullout torque).

2.3. Wind turbine coupled with an asynchronous generator

This type of wind turbine consists of fixed speed turbine (neglecting the 1 to 2 % fluctuation due to the slip of asynchronous generator) connected via a gearbox to an induction generator.

Model includes the aerodynamic equation (wind speed → mechanical torque).

It is suitable to connect to this wind turbine a speed protection in order to trip the asynchronous generator in stalling conditions.

2.4. Variable-speed wind turbine with direct driven synchronous generator

A multi-pole synchronous generator (MPSG) is direct-driven and connected to the grid through a full load frequency converter. The wind turbine is gearless and the excitation system is replaced by permanent magnets. The permanent magnet generator (PMG) operates at variable speed (10.5 to 24.5 rpm) depending on the incoming wind. In high wind speeds conditions, the power extracted from the wind is limited by pitching the rotor blades. The grid-side converter operates reactive-neutral, because there is no exchange of reactive power between the grid-side converter and the AC grid.

The model of the MPSG includes:

- The aerodynamic equation (wind speed → mechanical torque). This equation is identical to the one of the DFIG model (including pitch influence);
- Pitch control which is modelled by a PI controller followed by a time constant representing the actuator;
- The mechanical equation of the permanent magnet generator. Its electrical torque is adjusted to obtain the optimal rotor speed in order to maximize the power from the wind;
- The purpose of the interface with the network is to maintain the DC bus voltage at a reference value and to inject into the grid a current in phase with the voltage on the network;
- The proposed model corresponds to a current injector. The electrical output is modelled by a negative consumption.

3. MICROTURBINES FOR LOCAL GENERATION

The model of the microturbine includes the representation of both the mechanical and electrical part. The mechanical part including the turbine is viewed as a lumped moment of inertia, a delay and a time constant. Its output is the torque applied to the permanent magnet generator. The generator feeds a converter that includes a rectifier, a DC capacitor and a voltage source inverter.

The control part of the model includes a primary frequency control, a voltage regulator and a speed regulator.

The DC link voltage is indirectly controlled to allow satisfactory operation of the inverter. The microturbine can be operated in grid-connected or disconnected modes.

4. PHOTOVOLTAIC SYSTEMS

The model includes a solar array feeding, a DC capacitor and a power conditioner formed by a chopper, a DC capacitor and an inverter that converts DC power to AC power output (Figure 1). It includes current, voltage and frequency control.

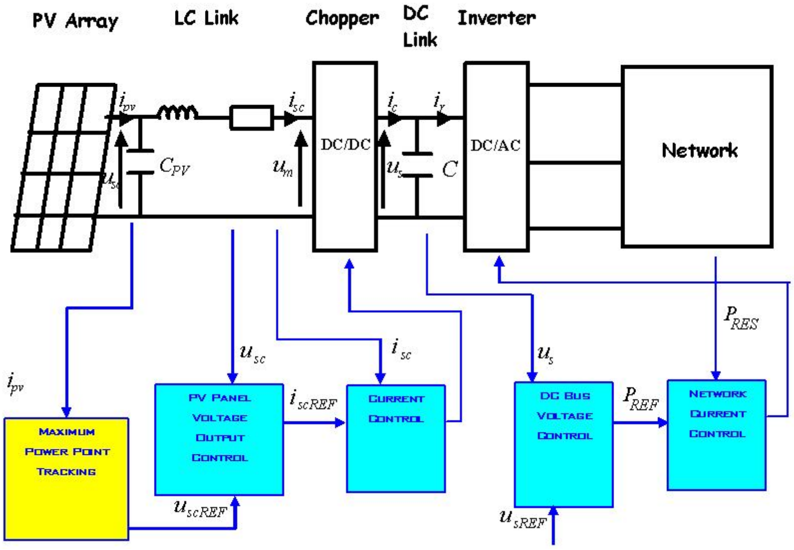

Figure 1 – Photovoltaic system model [1]

The output current and voltage of the photovoltaic (PV) panel are set to match the maximum power point that depends on irradiation and temperature. The method used is maximum power point tracking (MPPT) control which continuously tracks and matches the output characteristics of the solar array to the input characteristics of the converter.

The model takes into account the following features:

- The purpose of the interface with the network is to maintain the DC bus voltage at a reference value and to inject into the grid a current in phase with the voltage on the network;
- The proposed model corresponds to a current injector. The electrical output is modelled by a negative consumption.

5. FUEL CELL SYSTEMS

The model represents a SOFC system (Solid Oxide Fuel Cell). It is assumed that the response time of other types of cells is similar.

A power generation fuel cell system has the three main parts:

- Fuel processor that converts fuels such as natural gas into hydrogen and by-product gases;
- Power section (fuel cells) that generates the electrical power. There are numerous individual electrochemical fuel cells in the power section;
- Power conditioner that converts DC power to AC power output. It includes current, voltage and frequency control.

The model takes into account the following features:

- The purpose of the interface with the network is to maintain the DC bus voltage at a reference value and to inject into the grid a current in phase with the voltage on the network;
- The proposed model corresponds to a current injector. The electrical output is modelled by a negative consumption.

6. CONCLUSIONS

Renewable energy sources, especially as distributed energy sources, are important contribution for solution of world energy and ecology problems. Number of the DES applications has significantly increased and therefore it is necessary to exam impact of all distributed sources on system before their connection to the network to preserve reliability of EPS and quality of electricity.

For this purpose it is very suitable to use the Eurostag software which enables various studies, e.g.:

- Checking the keeping up of synchronism after various disturbances.
- Behaviour of the power system in emergency or in extreme conditions (voltage collapse, loss of synchronism, resynchronisation, etc...).
- Dynamic stability of the machines, regulations, transmission system around an operating point of the power system.
- Design, co-ordination and adjustment of protection systems for power plants and transmission networks.

Moreover, all those possibilities are available for balanced or unbalanced network conditions.

REFERENCES

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