18th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2014, Budapest, Hungary 10-12 September, 2014

CONTROL SYSTEMS IN THE WIND TURBINES WITH DOUBLE FED INDUCTION GENERATOR

Nedzmija Demirovic
Faculty of Electrical Engineering,
Franjevacka 2, 75000 Tuzla
Bosnia and Herzegovina

Nerdina Mehinovic
Faculty of Electrical Engineering,
Franjevacka 2, 75000 Tuzla
Bosnia and Herzegovina

ABSTRACT
The possibility of voltage control in wind turbines installed in wind-farm of great strength is of utmost importance. Wind farms are typically connected over large distances so that voltage regulation is becoming more difficult outside the scope of the power plant. As a result of installed wind turbines, the scope of the current changes in the network becomes more important, and therefore the scope of voltage changes. It is possible to show that wind turbines with the possibility of voltage regulation can significantly contribute to reducing the voltage variation in the system nodes.
Wind-farm with variable speed of wind turbine is usually connected to the network via an interface based on power electronics. The electronic interface can have different configurations. Control systems can be designed with different levels of complexity. For version with double-fed induction generator, the stator is directly connected to the network while the rotor winding is connected to the network via slip rings, converters and transformer. The control system is installed on both the network and the side of the rotor which allows control of reactive power or voltage at the output of the plant. At the same time control system regulates the angle of the wind turbine blades, which regulates the power of wind turbines and protects it from mechanical damage.
In this paper the operation mode of control circuits in wind farm with doubly-fed induction generator will be presented. The paper will show the influence of a control mode on the output voltage as well as mode of individual control circuits.
Keywords: wind farm, induction generator, pitch control, voltage regulation, Var regulation.

1. INTRODUCTION
There are a variety of wind turbines with induction and synchronous generators. Induction generators can be used in wind turbines with constant and variable speed rotation. The network connection can be made directly or as often the case over the power electronics devices, i.e. AC/DC /AC inverter is designed for constant or variable speed rotation.
The doubly-fed induction generator is now frequently used option because of the ability to change speeds rotation in a wide range which again depends on the converter type used. Such a wide range of changes in operating speed contributes to the efficiency of wind turbines.
The doubly-fed induction generator can operate in inductive and capacitive regime of power chart and in this way it can generate reactive power into the network and thereby regulate voltage. This need is particularly important if the wind farms located at great distances where classic voltage regulation has effect only within the plant and does not affect the remote nodes in the system. If the wind turbine has

the ability to control the voltage, then the effect of the variation of voltage in the network as a result of variations in the current branch network can be significantly reduced.
In this paper the possibilities of regulatory systems in the concept of wind turbines with doubly-fed asynchronous generator will be explained. The effects of the regulatory system in the case of the voltage dip and short-circuit and their impacts on the quality of voltage and power at the outputs of the wind farm will be shown.

2. CONTROL SYSTEMS IN THE WIND TURBINE CONCPET WITH DOUBLE FED INDUCTION GENERATOR

Wind turbines use a doubly-fed induction generator (DFIG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the network of grid's frequency, while the rotor is fed at variable frequency through the AC/DC/AC converter. 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 (VSC) that uses forced-commutated power electronic devices to synthesize an AC voltage from a DC voltage source. The rotor-side converter is used to control the wind turbine output power and the voltage, Figure 1, (or reactive power) measured at the grid terminals. Rotor regulation block is given in the Figure 2.

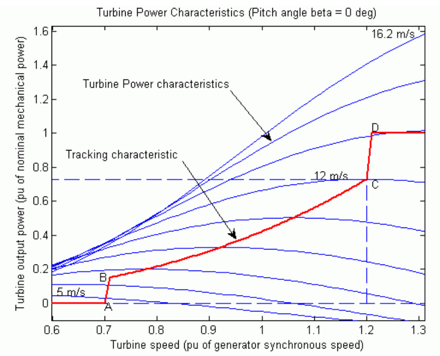

Figure 6 Wind turbine power characteristics

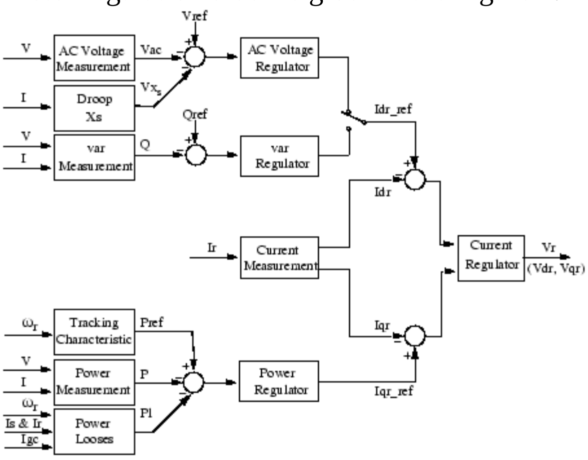

Figure 2 Rotor side control system

As can be seen, rotor-side control system consists of several PI regulators such as: power regulator, Var regulator, voltage regulator and current regulator. Each regulator operates on the principle of comparing the input and the reference values and accordingly gives the corresponding output.
Power controller compares the measured power at the output terminals of the wind farm, which is reduced by the amount of losses, and compared with a benchmark value of power which is defined by the wind turbine power characteristic..
The output of this regulator is the reference rotor current I_{qrref} that must be injected in the rotor by rotor side converter C_{rotor}. This is the current component which contributes in producing the electromagnetic torque T_{em}. The system must have a measurement of all sizes such as measurements of reactive and active power at the output terminals, the measurement of power losses, and measurement of AC current and AC voltage. Measurements allow proper operation of regulation system.
Voltage regulator compares the measured value of the alternating voltage reduced by the voltage drop across the reactance to the reference voltage. This means if the current is negative, i.e. in the case of capacitive operation, then the measured voltage is added to the reactance voltage drop, and the total value of the difference between the reference voltage and reduced AC voltage is such that the regulator raises voltage. In the inductive mode operation, the voltage drop at the reactance is at the right of the graph (positive) so that the total voltage slightly higher than in the previous case and PI controller lowers the voltage in the observed node. Since the voltage drop is usually between 1% and 4% at maximum reactive power output), the V-I characteristic has the slope indicated in the Figure 3,

called Wind Turbine V-I Characteristic. In the voltage regulation mode, the V-I characteristic is described by the following equation (1) :

$$V=V_{ref}+X_sI \qquad (1)$$

where are:

V- Positive sequence voltage (pu)

I- Reactive current (pu/P_{nom}) (I > 0 indicates an inductive current)

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X_s -Slope or droop reactance (pu/P_{nom})

P_{nom}–Three-phase nominal power of the converter specified in the block dialog box

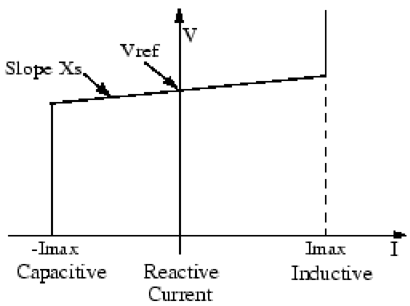

Figure 3 Wind turbine V-I characteristic

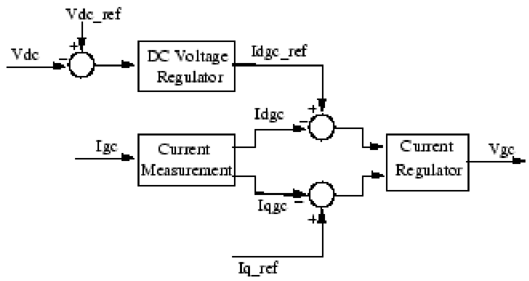

Figure 4 Network side control system

The output of the voltage regulator or the Var regulator is the reference d-axis current I_{dr_ref} that must be injected in the rotor by converter C_{rotor}. The same current regulator as for the power control is used to regulate the actual I_{dr} component of positive-sequence current to its reference value. The output of this regulator is the d-axis voltage V_{dr} generated by C_{rotor}. The current regulator is assisted by feed forward terms which predict V_{dr}. V_{dr} and V_{qr} are respectively the d-axis and q-axis of the voltage V_r.

3. NETWORK SIDE CONTROL SYSTEM

The network–side control system consists of measurement systems, an outer regulation loop and an inner current regulation loop, Figure 4. Measurement systems measured AC positive-sequence currents to be controlled as well as the DC voltage V_{dc}. The current regulator controls the magnitude and phase of the voltage generated by converter C_{grid} (V_{gc}) from the I_{dgcref} produced by the DC voltage regulator and specified I_{qref} reference. The current regulator is assisted by feed forward terms which predict the C_{grid} output voltage. The converter C_{grid} is used to regulate the voltage of the DC bus capacitor. In addition, this model allows using C_{grid} converter to generate or absorb reactive power.

4. PITCH CONTROL SYSTEM

Change the angle of blades is used for controlling the rotor torque and power that occurs under the influence of wind, and also allows a match of strength and speed limit at high wind speeds. Blade rotation mechanism is powered by hydraulic or electric drive. Thus controlled rotors are prevalent in all major systems. The rotors are equipped with this mechanism depends on the angle of rotation of the blades corresponding outputs from the controller. This mechanism is then used to limit the power and value provided to limit the speed of rotation of the blades depending on the speed and angle of wind blades corresponding outputs from the controller.

The pitch angle is kept constant at zero degree until the speed reaches point D speed of the tracking characteristic. Beyond point D the pitch angle is proportional to the speed deviation from point D speed.

5. SIMULATION RESULTS AND COMENTS

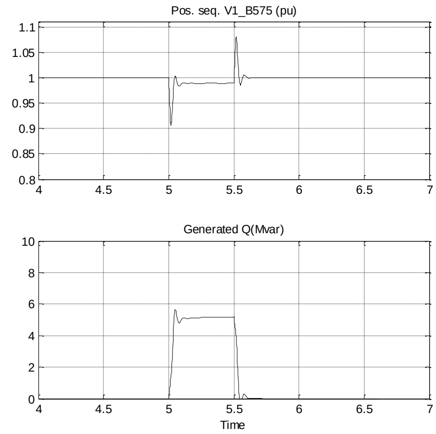

Figure 5 Output voltage and generated reactive power when control parameter is voltage

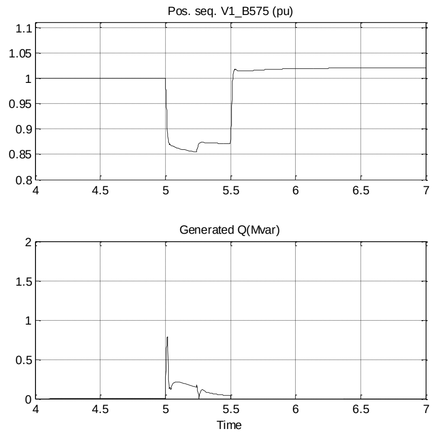

Figure 6 Output voltage and generated reactive power when control parameter is reactive power

Simulation of voltage drop in the network as a phenomenon that may contribute to power quality parameters was performed. If parameter of control is voltage, Figure 5, it can be seen that at the beginning and end of the transient phenomena, voltage variations are within tolerable values.

If parameter control is reactive power, Figure 6, then voltage at the output terminals decreases to 85% of rated voltage, and then returns to the normal value. Reactive power is only slightly increased to approximately 0.9 MVAr and then rapidly decreases, i.e. the machine continues to work at cos phi = 0, i.e. neither generated or consumed reactive power.

The difference in the sizes mentioned origins primarily due to the mode of regulation circuits. In both of cases, the voltage conditions have been improved by generating reactive power, and value of reactive power is smaller in reactive operation mode. On the other hand, the voltage drop is slightly higher. It could be conclude the choice of control depends of strength of the network. So, if the network is weak, voltage variations will be evident and one should choose such a way of regulation to keep voltage inside satisfactory limits.

6. CONCLUSION

In this paper the operation mode of control circuits in wind farm with doubly-fed induction generator is presented. The power flow control in the DFIG is performed by connecting AC/DCAC converters between rotor and utility grid. The rotor-side converter is used to control the wind turbine output power and the voltage measured at the grid terminals. The grid converter is used to regulate the DC voltage at bus capacitor, and allows generating or absorbing reactive power. It is observed that control systems of DFIG turbine concept shows satisfactory performance under different wind speed conditions and system events. The proposed control strategy mitigates voltage variation in the system nodes and maintains the grid power constant under different wind speeds.

7. REFERENCES

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