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Doubly fed induction generator in wind application

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Abstract - This paper is written on basis of power system under the title Doubly Fed Induction Generator Wind Applications. In this paper the review of DFIG along with back to back converters has been carried out to obtain the results. Owing to limited availability of fossil fuels, to think for alternatives for generating powers is must. It has been realized that wind has great potential and can be harnessed it to generate power for commercial as well as residential use. The use of DFIG in wind applications is gaining more importance among the researchers and engineers due to its ability to control power reliably.

***Keywords-component; doubly fed induction generator, variable speed wind turbine, fixed speed wind turbine, control schemes,* WECS**

1. INTRODUCTION

Industrial growth over last decade has tremendously increased, which resulted into more consumption of electricity. The need of generating electricity using renewable energy resources is gaining more importance due to limited abundance of non-renewable energy resources including coal. Among all renewable energy resources including solar, geothermal, hydro and wind energy, the wind is having huge hidden potential to generate electricity. The wind energy is superior to other renewable energy sources like solar energy as far as cost per kilowatt-hour of electrical power generation is concerned. Therefore, the energy conversion system called Wind Energy Conversion System (WECS) is used to harness wind energy.

Wind Energy Conversion System (WECS) is the overall system for converting wind energy into useful mechanical energy that can be used to drive an electrical generator for generating electricity. Basically three types of components consist of the WECS: aerodynamics, mechanical, and electrical.

2. INITIAL WIND GENERATORS DEVELOPEMENT

Industrial drive applications are broadly classified into constant and variable operations. The ac machines are generally being used for constant speed applications whereas the variable speed application makes use of dc machines. The dc machines suffer from commutation and brush problems; therefore ac machines are replacing dc machines in variable speed applications. Wind energy conversion system is gaining more importance among scientists and researchers owing to economical and environmental factors [4]. In the race of choosing best among the available sources of renewable energy, wind energy conversion system is superior to other renewable sources like solar energy which is having high cost per kilowatt-hour (kWh) of electrical power generated.

Cage rotor induction machines are widely used for constant speed constant frequency WECS owing to their design simplicity and low cost. The cage machines can also be used for variable speed applications when used with the drive. It has to be noted that the rating of the drive is 100% of the generator. Since the wind speed is not constant all the times, variable speed operation of electric generators is more advantageous compared to fixed speed operation. The broadly employed topologies being used for the variable speed operation includes conventional asynchronous generators with rated power converters, the permanent magnet synchronous generators (PMSG's) and the DFIG. The DFIG is having upper hand over PMSG since it is having partially rated converters compared to PMSG with fully rated power converters [1].

The generators are an integral component of wind energy generation system. They can be of squirrel cage induction type, wound rotor induction generator and permanent magnet synchronous generator. However, there are other types like field modulated or Roesel generators, which are rarely used in industry and therefore are not explained in present work.

3. DOUBLY FED INDUCTION GENERATOR

Wound rotor induction generators are provided with three phase windings on the rotor and on the stator. They may be supplied with energy at both rotor and stator terminals. This is why they are called doubly fed induction generators or double output induction generators [20] The power electronics converter that supplies the rotor circuits via sliprings and brushes is capable of handling power in both directions. Wind turbines use a DFIG consisting of a wound rotor induction generator and a back-back (AC/DC/AC) IGBT-based PWM converter. The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the back-back converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The best turbine speed producing maximum mechanical energy is proportional to the wind speed. Another advantage of the DFIG technology is the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator.

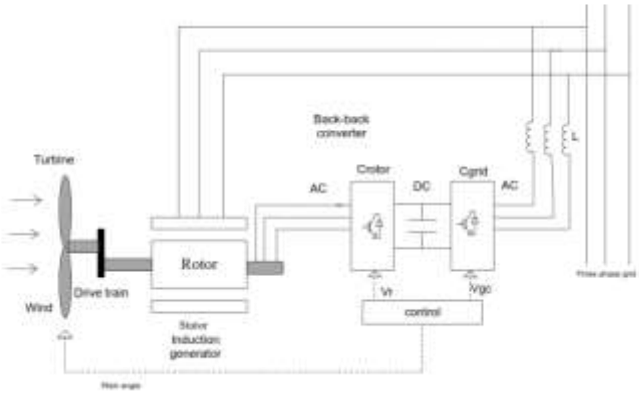

Figure 1. Basic diagram of doubly fed induction generator with converters

Where Vr is the rotor voltage and Vgc is grid side voltage. The back-back converter is basically a PWM converter which uses sinusoidal PWM technique to reduce the harmonics present in the wind turbine driven DFIG system. Here Crotor is rotor side converter and C grid is grid side converter. In this system, to control the speed of wind turbine gear boxes or electronic control can be used.

3. OPERATING PRINCIPLE OF DFIG

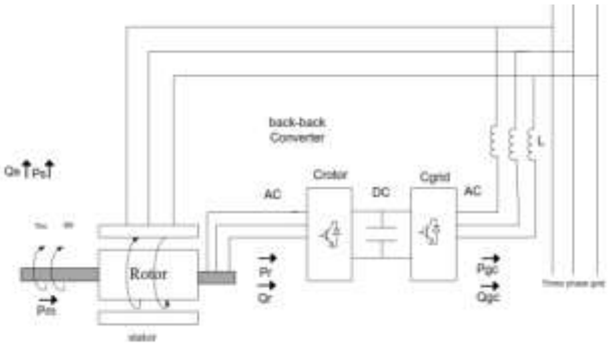

Figure 2. Power flow diagram of DFIG

The stator is directly connected to the AC mains, at the same time as the wound rotor is fed from the Power Electronics Converter via slip rings to allow DFIG to operate at a variety of speeds in response to changing wind speed. Indeed, the basic concept is to interpose a frequency converter between the variable frequency induction generator and fixed frequency grid. The DC capacitor linking stator- and rotor-side converters allows the storage of power from induction generator. To achieve full control of grid current, the DC-link voltage must be boosted to a level higher than the amplitude of grid line-to-line voltage. The slip power can flow in both directions, i.e. to the rotor from the supply and from supply to the rotor and hence the speed of the machine can be controlled from either rotor- or stator-side converter in both super and sub-synchronous speed ranges. As a result, the machine can be controlled as a generator or a motor in both super and sub synchronous operating modes realizing four operating modes. Below the synchronous speed in the motoring mode and above the synchronous speed in the generating mode and rotor-side converter operates as a rectifier and stator-side converter as an inverter, where slip power is returned to the stator. Below the synchronous speed in the generating mode and above the synchronous speed in the motoring mode, rotor-side converter operates as an inverter and stator side converter as a rectifier, where slip power is supplied to the and the speed of the wind turbine is determined by the power Pr absorbed or generated by Crotor. The phase-sequence of the AC voltage generated by Crotor is positive for sub synchronous speed and negative for super synchronous speed. The frequency of this voltage is equal to the product of the grid frequency and the absolute value of the slip. Crotor and Cgrid have the capability for generating or absorbing reactive power and could be used to control the reactive power or the voltage at the grid terminals

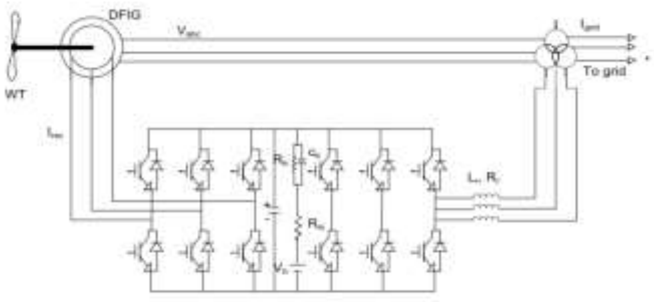

Figure 3 DFIG based WECS with a BESS in dc link for grid power leveling

In DFIG based Wind Energy Conversion System employing BESS, Incorporating a battery or any other energy storage device in the dc link enables temporary storage of energy and, therefore, the ability to provide constant output active power, which is both deterministic and resistant to wind fluctuations.

4. ROTOR –SIDE CONVERTER (RSC)

The rotor-side converter (RSC) applies the voltage to the rotor windings of the doubly-fed induction generator. The chief role of rotor side converter is to control the rotor currents such that the orientation of rotor flux with respect to stator flux is such that the desired torque is developed at the shaft of the machine. It uses torque controller for regulation reactive power and wind turbine output power. The power is controlled in order to track maximum power at pre-defined turbine power-speed characteristic. It compares actual electrical output power from the generator terminals with the reference power obtained from the wind turbine characteristic. It usually makes use of Proportional- Integral regulator at the outer control loop to reduce rotor speed error to zero. The output of the regulator is the reference rotor current that must be injected in the rotor winding by rotor side converter. This q-axis component controls the electromagnetic torque $T_{e.}$ The actual q-axis component of rotor current is compared with reference rotor current and the error is reduced to zero by a current PI regulator at the inner control loop. The output of this current controller is the voltage of q-axis component generated by rotor-side converter [6].

5. GRID-SIDE CONVERTER (GSC)

The grid-side converter aims to regulate the voltage of the dc bus capacitor. It is allowed to absorb or generate reactive power from or to the grid. This converter works at the grid frequency (leading or lagging in order to generate or absorb a controllable magnitude of reactive power) [6]. A transformer may be connected between the grid side inverter or the stator, and the grid. The rotor side converter work at different frequency depending on the wind speed.

5. CONCLUSION:

Present work gives a configuration of a DFIG-based WECS with a BESS in the dc link has been proposed with a control strategy to maintain grid power. The effectiveness of the proposed control strategy on a DFIG-based WECS with BESS has been demonstrated under different wind speeds. In the present work, it can be seen that DFIG-based WECS with BESS gives satisfactory performance under various wind speeds. The proposed configuration and control strategy, however, mitigates a need for supplying a constant flow of energy to the grid irrespective of wind speed variations. Placement of BESS in the dc link of a DFIG –based WECS proves to be satisfactory implementation in terms of maintaining a constant power at the grid.

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