

Improving Power Quality of Wind Power Grid-Connected System

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Abstract- This paper proposes to improve power quality and reliable operation of wind power grid connected system. It consists of Superconducting Magnetic Energy Storage (SMES) based excitation system for doubly-fed induction generator (DFIG). The excitation system is composed of the rotor-side converter, the grid-side converter, the dc chopper and the superconducting magnet. The superconducting magnet is connected with the dc side of the two converters; Superconducting Magnetic Energy Storage (SMES) is a promising alternative for active power compensation. Having high efficiency, very fast response time and high power capability it is ideal for leveling fast fluctuations. and it handle the active power transfer with the rotor of DFIG and the power grid independently alleviate the influence on power quality, and improve fault ride-through capability for the grid-connected wind farms. According to the system control objective, the system can contribute to the stability and reliability of the wind power grid-connected system.

Index Terms- Converter, Doubly-fed induction generator (DFIG), super conducting magnetic energy storage (SMES), and Wind power generation.

1. INTRODUCTION

Electricity plays a huge important role in our everyday lives. Whether it is at home, at school, the local shopping centre or industrial area or our daily routines rely heavily on the use of electricity. Generally, there are various way to generate electricity such as thermal power, hydro power, nuclear power, solar power or wind power. Presently almost all the electricity generation takes place at central power station which utilizes coal, oil, gas, water or fissile nuclear material as the primary fuel source. There are many problems facing for further development of generating methods based on any of these conventional fuels. Hydro-power generation is restricted to geographically suitable areas, and reserves of coal, although presently plentiful, are not renewable. The possible hazards of nuclear power have been much publicized, particularly those concerning the storage and military use of nuclear waste material. Nevertheless, to assist in maintaining electrical supply in many of our societies it seems likely that an increasing nuclear power presence, involving breeder and possibly fusion reactors, will be tolerated. To achieve this and also to aid in management of the existing fossil-fuel resources, it is essential that some part and an increasing part, of future electrical energy research and development be concerned with so called nonconventional methods of generation. Wind power generations are visible options for future power generation. But focusing on an effective way to solve the global problems such as the environmental pollution and energy shortage is the large scale development of wind power.

Many large wind turbines operate at variable speed which has improved the efficiency of energy transfer from the wind. But in this paper by using the doubly fed induction generator (DFIGs) improves the efficiency of wind power. Doubly fed electric machine fed ac currents to both stator and rotor winding. Doubly fed induction generators (DFIGs) are by far the most widely used type of the Doubly fed electric machine, and are one of the most common type of generator used to produce electricity in wind turbines. Doubly fed induction generators have number of advantage over other type of generator when used in wind turbines.

2. METHODOLOGY

The DFIG plays very important role, but there is some problem regarding to the wind farms when it is connected to the power grid. The first problem is because of variations in wind speed. Due to that variations power quality problems arises, means power quality induced by fluctuant power. The second problem is when fault occurs in power grid which is far away from wind turbine. Due to that problem the voltage drop will affect at the stator winding which will result in an increase in current of the stator winding, which will induce the over current in the rotor circuit and the power electronic converter. To overcome the above problems, many devices and control strategies are suggested for wind power. For that first of all by regulating the reactive power output which can be directly control the wind power. And another one is by regulating the power output of external energy

storage devices which can be indirectly control the wind power but the best way is by using the small capacity Superconducting Magnetic Energy Storage system (SMES) to improve power quality.

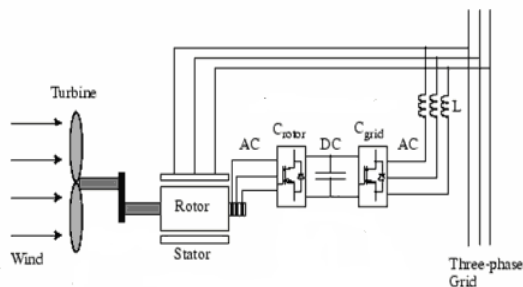


Fig. 2: DFIG based on SMES wind turbine system

The energy storage unit is a preferred way to handle the energy transfer caused by power fluctuation or grid fault. The doubly-fed induction generator based on SMES wind turbine system is as shown in Fig.2. It consists of rotor-side converter, grid-side converter, DC chopper, and superconducting magnet. The SMES device has a very high energy storage efficiency and quick power response.

The discharge capabilities of SMES compared to several other energy storage technologies is less. So here SMES is prefers for energy storage which is the most effective device.

This device consists of two converter of the DC side. The DC chopper is used to control the charging and discharging of super conducting magnet. And converter controls the power transfer between the superconducting magnet and DFIG rotor and the power grid.

The SMES based excitation system for doubly-fed induction generator can fulfill the following functions:

- 1) Super conducting magnet which can store very large amount of energy can also and handle power transfer during the operation of variable speed constant frequency (VSCF). During the operation period less power fluctuation is obtained and improves the power quality.
- 2) At the time of system operation, the rotor-side converter and the grid-side converter is mutually independent. Therefore, system helps to control the power grid and improve the stability of power system.
- 3) If the grid fault is occurring, then the over current in the rotor can be extinguished using the energy storage of SMES. Additionally, the SMES

and the grid-side converter are impermeable to the grid fault, which can supply the power compensation to the grid.

2.1. The equipment level

As per the requirement of power from the system level, the rotor side converter, the grid side converter and the DC chopper are controlled to regulate the power flow. For the rotor-side and the grid-side converter, the pulse-width modulated (PWM) voltage source converter is adopted. In this by using vector control method improves the dynamic power response. The DC chopper deals with the active power transfer of the DFIG rotor and the grid, and the integrated energy control should be considered.

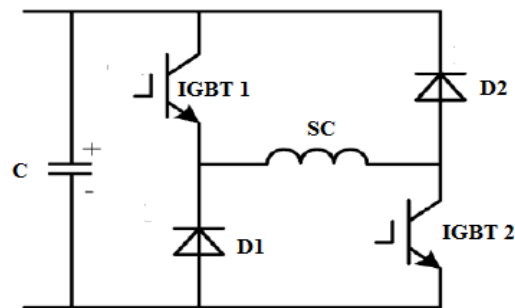


Fig.2.1: The topology of DC chopper

The circuit description of DC chopper is as shown in the Fig.2.1 This DC chopper consists of two IGBTs and two diodes. The DC chopper can control the magnitude and the polarity of the voltage across the superconducting magnet (SC) complying with the energy flow of the system. It also can maintain the DC voltage to be essentially constant. Based on the direction of energy transfer, the DC chopper has two operating modes.

- 1) Charging mode. G1 is ON at all times, and G2 is alternately ON and OFF during each chopper cycle.
- 2) Discharging mode. G1 keeps OFF at all times, and G2 is alternately ON and OFF during each chopper cycle. Considering the operation life of the switching device, the switch motion of G1 and G2 can be reciprocated.

3. DOUBLY-FED INDUCTION GENERATOR (DFIG)

Doubly-Fed Induction Generator (DFIG) is widely used in large wind power generation. A typical DFIG system is shown in the below fig.3. The AC/DC/AC converter consists of two components: the rotor side converter C_{rotor} and Grid side converter C_{grid} . These converters are voltage source converters that use forced

commutation power electronic devices (IGBTs) to synthesize AC voltage from DC voltage source. A capacitor connected on DC side acts as a DC voltage source. The generator slip rings are connected to the rotor side converter, which shares a DC link with the grid side converter in a so called back-to-back configuration. The wind power captured by the turbine is converted into electric power by the IG and is transferred to grid by stator and rotor windings. The control system gives the pitch angle command and the voltage commands for C_{rotor} and C_{grid} to control the power of the wind turbine, DC bus voltage and reactive power or voltage at grid terminals.

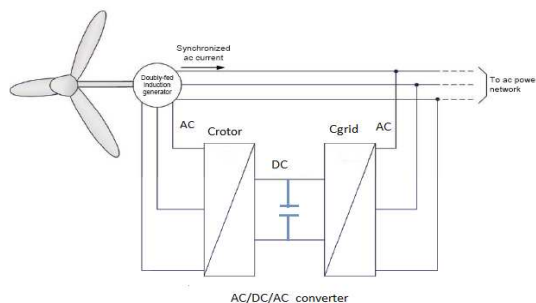


Fig. 3: Doubly-fed induction generator (DFIG)

Operation:

When the rotor speed is greater than the rotating magnetic field from stator, the stator induces a strong current in the rotor. The faster the rotor rotates, the more power will be transferred as an electromagnetic force to the stator, and in turn converted to electricity which is fed to the electric grid. The speed of asynchronous generator will vary with the rotational force applied to it. Its difference from synchronous speed in percent is called generator's slip. With rotor winding short circuited, the generator at full load is only a few percent. With the DFIG, slip control is provided by the rotor and grid side converters. At high rotor speeds, the slip power is recovered and delivered to the grid, resulting in high overall system efficiency. If the rotor speed range is limited, the ratings of the frequency converters will be small compared with the generator rating, which helps in reducing converter losses and the system cost. Since the mechanical torque applied to the rotor is positive for power generation and since the rotational speed of the magnetic flux in the air gap of the generator is positive and constant for a constant frequency grid voltage, the sign of the rotor electric power output is a function of the slip sign. C_{rotor} and C_{grid} have the capability of generating or

absorbing reactive power and can be used for controlling the reactive power or the grid terminal voltage. The pitch angle is controlled to limit the generator output power to its normal value for high wind speeds. The grid provides the necessary reactive power to the generator.

4. SUPERCONDUCTINGMAGNETIC ENERGY STORAGE (SMES)

Energy stored in a normal inductor will fade out rather quickly due to the ohm resistance in the coil when the power supply is disconnected. Obviously this will not be acceptable energy storage for use in a power system. The ohm resistance has to be removed before an inductor can work for this purpose. This is possible by lowering the temperature of the conductors, and by this making the conductors superconducting. A superconducting wire is in a state where the resistance in the material is zero. In this state the current in a coil can flow for infinite time. This can also be seen from the time constant of a coil $\tau = L/R$ where R goes to zero and τ then goes to infinity. There are constraints for a superconducting wire to stay superconducting. The conductor has to be operated below a critical temperature T_c , below a critical current I_c and below a critical magnetic field H_c . There should also be some safety margin between the critical values and the operating conditions there are several types of superconducting material. They can be divided into two groups. High Temperature Superconductors (HTS) and Low Temperature Superconductors (LTS). The HTS types are cooled to 77 K using liquid nitrogen. A LTS is generally cooled using liquid helium to 4.2 K. SMES is together with capacitors the only energy storage form which is a pure electrical.

5. ADVANTAGES AND DISADVANTAGES

5.1. Advantages:

- 1) Wind power systems typically include both, which can simultaneously improve the quality and availability of power.
- 2) Resulting in a system with lower emissions than traditional fossil-fueled technologies.
- 3) It help in avoiding the high costs of extending utility power lines to remote locations, prevent power interruptions, and provide a non-polluting source of electricity.
- 4) The major advantage of wind energy system is that the reliability of the system is enhanced. v. Efficiency is more.

- 5) Easy to maintained. vii. The wind energy system gives continuous power supply.

5.2. Disadvantages:

- 1) Initial Cost is more.
- 2) If SMES systems will failure then we are not fed the constant power to grid.

6. CONCLUSION

This paper proposes to improve the power quality of the wind power grid-connected system. To evaluate the dynamic response of the SMES based excitation system for DFIG, The excitation system can respond very quickly to the active and reactive power demands and the power fluctuation of DFIG can be smoothen effectively.

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