CONTROL STRATERGIES FOR DFIG BASED WIND TURBINE FOR ENHANCING LOW VOLTAGE RIDE THROUGH CAPABILITY

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Abstract—*Wind energy is the most preferable renewable energy for the generation of electric power. Initially the fixed speed wind turbines were used for the generation of power, but now a day the variable speed wind turbines has become popular because of its advantages over fixed speed wind turbines. DFIG which is a variable speed wind turbine, has been used widely because of its low cost, higher energy output, and independent control of real and reactive power. However the DFIG wind turbines are facing the problems of power fluctuation during normal operation in the system and this leads to Low Voltage Ride Through [LVRT] during the fault occurrence. At the initial stages, WTG's are allowed to disconnect from the grid during fault. But due to increasing trend in WTG's, it is necessary for the wind turbine to be connected with the grid, even when fault occurs in the system. According to the Grid code requirements the wind farms should contribute to power system control like frequency and voltage and make the wind turbine to be connected to grid and support it by injecting the reactive power to the grid. This can be achieved by using hardware or software implementation for the rotor side and grid side converter, so that it can prevent the converter from tripping and provide uninterruptible operation to the DFIG when severe fault occurs. The different LVRT control strategies have been analyzed in this paper.*

Keywords—Doubly Fed Induction Generator (DFIG), Low Voltage Ride Through (LVRT), Dynamic voltage restorer (DVR), Static compensator (STATCOM), Unified power flow controller (UPFC), Crowbar

1. INTRODUCTION

Now a days, the renewable energy sources has becoming very popular when compared to other conventional energy sources [1]. Wind energy is the most preferable renewable energy for the electric power generation. In earlier times, a simple Squirrel Cage Induction Generators were used which is a fixed speed wind turbines, but due to the better performance they are replaced by the Doubly Fed Induction generators which are variable speed wind turbines [2]. These wind turbines has less mechanical stress, has independent control of real and reactive power. The DFIG can give steady output voltage and can be directly connected to grid. Therefore DFIG is very sensitive to grid disturbances such as Voltage sag, Voltage swell, Flickers and also Voltage stability problems, Fault ride through. In order to reduce all these issues, Grid Code requirements has to be considered [3]. The DFIG is an induction machine with a wound rotor in which the rotor and stator are connected to electrical sources, hence they are named as "doubly fed". Here, the stator is directly connected to the grid, while rotor is connected through a back to back converter [4] [5].

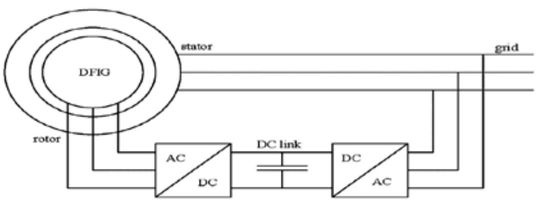

Figure. 1 Configuration of DFIG based WECS

Low voltage ride through, is one of the major issues in power system and it is the capability of the wind turbine to stay connected to the grid, even when a severe fault occurs. This may lead to some undesired characteristics on machines, such as real and reactive power problems and falling grid code requirements [6]. A large EMF will be induced in the rotor circuit when a fault occurs in the system, and there will be a large inrush current due to the magnetizing effect, in both stator and rotor. So, the continuous operation of DFIG wind system is essential for the reliable operation of the power system. Various control and protection techniques for the DFIG have been analyzed in this paper.

2. GRID CODE REQUIREMENTS

Grid codes are used to specify that wind farms must contribute to power system control, and should have withstanding capability of wind system during abnormal condition. The Indian Electricity Grid Code (IEGC) provides the major technical rules to enable safe operation, maintenance, development and planning of electricity grid. The main objectives of IEGC is to maintain safe and reliable operation of power system. The IEGC guidelines and standards are suggested to be followed by various participants of the power grid. Indian Wind Grid Code (IWGC) has been developed only to enhance the secure operation of the wind farms and also their integration into the Indian electrical system.

IWGC structure includes (1). Roles and responsibility of various organizations (2). Suggestion of Planning code for transmission of wind power (3). Wind farm connection code (4). Operating codes for wind farm (5). Fault Ride Through is an important feature. To improve the withstanding capability of wind turbines, to remain connected to the grid during the faults, various technologies have been developed [7]. This capability of

DFIG to withstand against voltage sags is called Low Voltage Ride-Through (LVRT) or Fault Ride-Through (FRT) capability. If Fault Ride Through capability is not installed , generation would be susceptible to tripping when subject to a voltage dip even when connected to a healthy circuit for less than normal protection operating times. The typical LVRT curve as per IWGC is shown in figure 2.

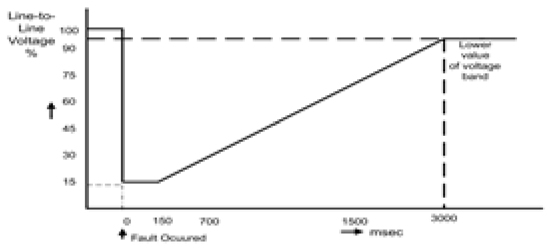

Figure. 2 LVRT curve in IWGC

3. ISSUES IN DFIG CONNECTED TO GRID

A. Poor grid stability

A reliable grid is as important for the economic exploitation of wind energy as availability of strong winds. The stable grid can be have loss generation of 10% to 20% and this deficiency is the main reasons for actual energy output of WEGs compared to the predicted output in known windy areas.

B. Low-frequency operation

Low frequency operation surely affects the output of WEGs mainly in two ways. When frequency is less than 48 Hz , then many WEGs do not get cut-in, (for standard frequency of Hz) though the wind conditions are favorable. This deficiency will make the output of WEGs at low frequency operation and it is reduced, due to reduced speed of the rotor. The loss in output could be about 5 to 10% on the account of low frequency operation.

C. Impact of low power factor

Power factor can be major issue that has to be considered in grid code requirements. For magnetizing purpose, WEGs are fitted with the induction generators need reactive power. Normally in conventional energy systems, generators will be supplying a reactive power along with the real power. But the WEGs fitted with induction generators will absorb reactive power from grid, which will create a strain on the grid. Suitable reactive power compensation may be required to reduce the reactive power burden on the grid.

D. Power flow

The interconnection of transmission or distribution lines should be ensured that it will not be over-loaded. This analysis is needed to ensure that the introduction of additional generation should not overload the lines and other electrical equipment. Both active and reactive power requirements should be investigated.

E. Short circuit

The impact of additional generation sources to the grid should be determined in order to ensure the short circuit current ratings of existing electrical equipment on the network.

F. Power Quality

Power quality is a major issue that has to be considered, the fluctuations in the wind power may have direct impact on the quality of power supply. Therefore large voltage fluctuations will result in voltage variations outside the regulation limits, and on flicker and other power quality standards.

4. LITERATURE REVIEW

A. CROWBAR METHOD :

Crowbar protection method is one of the main and typical protection scheme to achieve the Low voltage ride-through ability of wind turbines. There are different crowbar technologies available such as Passive crowbar, Active crowbar, Stator crowbar. Among these Passive crowbar technique has an outstanding performance. When the magnetic coupling between the stator and rotor occurs, the voltage drop in the stator side will result in overvoltage of rotor, this leads to overcurrent on the RSC and this will damage the converter. When the crowbar comes into action, the RSC is bypassed by the resistor and the problem of inrush current and overvoltage is overcome [7]. But if the voltage dip occurs for long time the crowbar protection cannot provide the reactive power to the grid and so the situation will become much more severe.

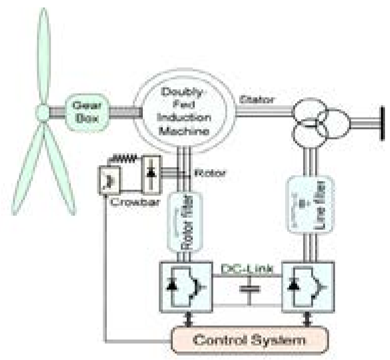

Figure.3 Crowbar Circuit

B. Non Linear Control :

In order to improve the LVRT characteristics, the nonlinear control strategies will not effectively mitigate the severe voltage variations. The effect of stator dynamics and rotor dynamics can be identified by the model analysis of DFIG. This may improve the LVRT capability [8].

C. Using different storage technologies:

1) Super capacitor storage :

The LVRT improvement can also be achieved by using storage elements. Super capacitor uses the nickel chromium battery that has been used for small wind power generation. By using this, the DC link capacitor voltage of DFIG can be controlled and the limit of over current can be reduced [9].

2) SMES :

SMES is Super Conducting Magnetic Energy Storage which is a DC current device, that stores energy in magnetic domain. The energy is stored in circulating current, so the energy can be pulled from the SMES unit. During the cryogenic temperature (Critical Temperature) the current carrying conductor behaves like a super conductor i.e Resistance of the coil becomes zero. Whenever , a fault occurs in the system SMES will provide the stored energy. The main advantage of using SMES is that the number of charging and discharging time will be high and also enhances the transmission line capability. This will improve the transient stability of the system by using different control techniques like PI and FUZZY controllers. But the main disadvantage is that the stress in the SMES coil increases when overvoltage occurs.

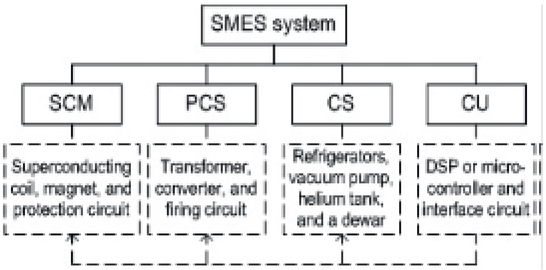

Figure.4 Block diagram of SMES

D. Using FACTS devices :

The interconnection of wind farm to a power grid can be concerned with many issues such as dynamic stability on the power system, Voltage variation problems and because of this they cannot be able to meet the reactive power demand during faults and heavy loading conditions. Flexible AC Transmission Devices [FACTS] plays major role in the power system as the have many advantages over other devices that has been used for control purposes. These devices can be used for improving power system stability and to damp power system oscillations. Many FACTS devices are available and in practice that are related with wind power generation.

1) STATCOM

A STATCOM is a shunt-connected device that is capable of generating and/or absorbing reactive power and using this device the output can be varied to control the parameters of the power system. The STATCOM is a static compensator and is used to regulate voltage and to improve dynamic stability. It can supply the required reactive power under various operating conditions, and to improve the steady state stability of the system. It can be employed to regulate the voltage at the bus, and helps to maintain constant DC link voltages at individual wind turbine inverters during disturbances. This will enable the continuous operation of each wind turbine during fault or disturbances occur in the system. Also, the reactive power imbalances, will seriously affect the power system, and can be minimized by reactive power compensation devices such as the STATCOM. Therefore, the STATCOM can contribute to the LVRT capability as it can operate at full capacity even at lower voltages [10].

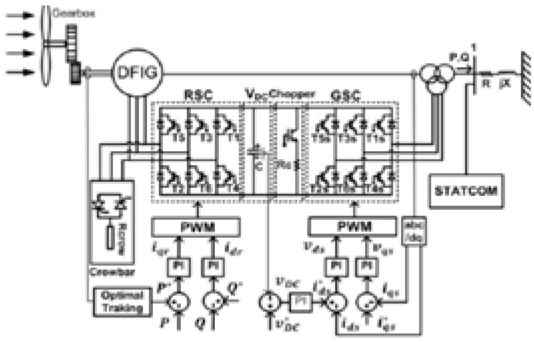

Figure.4 Protection for STATCOM

2) DVR :

DVR employs a IGBT solid-state power electronic switches in a pulse-width modulated (PWM) inverter structure. The DVR is capable of generating or absorbing independently controllable real and reactive power at its ac output terminal. Like in a DSTATCOM, the DVR is made of a solid-state dc to ac switching power converter that injects a set of three-phase ac output voltages in series and synchronism with the distribution feeder voltages. The DVR is used to compensate the voltage, when a fault occurs in the system and it helps to maintain the desired grid voltage. Even though it reduces the complexity in DFIG system, it is more costly [11].

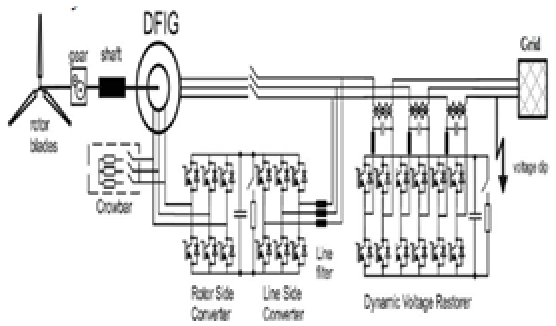

Figure.6 Protection for DVR

3) UPFC

UPFC is Unified Power Flow Controller which is a combination of shunt and series compensators which are connected to the grid through shunt and series transformers respectively. The two Voltage Source Converters (VSC) are connected via DC link capacitor. The Shunt converter is responsible for Voltage regulation at the point of common coupling. It injects reactive power to the transmission line and will balance the real power flow exchanged between series converter. The Series converter is responsible for the control of real and reactive power flow. It is done by inserting a appropriate voltage with controllable magnitude and phase angle in series with the transmission line. This will exchange active and reactive power with the transmission line. Therefore the stability of the system can be improved and also the Low Voltage Ride Through capability can also be improved by using UPFC [12].

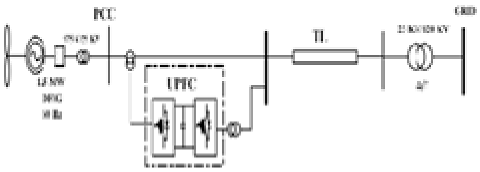

Figure.7 UPFC with grid connected DFIG

5. CONCLUSION

Low Voltage Ride Through is one of the major issues that has to fulfill the Grid Code requirements. The DFIG is very sensitive to grid disturbances, so a proper control strategy must be implemented on the grid side to overcome these problems. Various control methods has been discussed in this paper. Crowbar method is a conventional method, but it draws more reactive power from grid during severe voltage fault. Energy storage systems also helps to improve the system stability but they are not able to support the grid during fault condition in a complete manner. Also the FACTS devices are much more advantageous as they has the ability to damp system oscillations and can provide voltage and reactive power compensation during fault conditions but these devices are used very costly and common now a days. So, the concentration can be made on current feedback and Voltage control techniques as they give good performance and less costly to improve the LVRT capability.

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