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LVRT Capability Assessment and Improvement of Grid Connected Wind Farm during Symmetrical Faults

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Abstract---**The increasing integration of wind power into the grid has become one of the most important challenges of wind industry. For this purpose, many countries have included requirements in their grid codes to ensure proper operation of wind turbines under grid disturbances.The connection of wind turbine into the grid causes number of power quality problems.In contrast, fault in the grid also affects the wind turbines.The wind turbines in transmission grids should not immediately disconnect from the grid when short circuits occur.This can be prevented by the addition of reactive power source.The reactive power source provide support to the turbine for defined period.In this paper STATCOM is used to enhance Low Voltage Ride Through (LVRT) capability of Doubly Fed Induction Generator (DFIG) generator. The main advantage of STATCOM is its capability to inject a controllable reactive current independently on grid voltage. The STATCOM along with PI controller is used for this purpose. Thus the performance of the STATCOM becomes much better by the robust control technique. Simulation result shows the better compensation to the grid connected to the wind farm.**

Keywords: symmetrical faults, DFIG, LVRT and STATCOM

I. INTRODUCTION

In the past decades wind energy has grown rapidly and become the most competitive form of renewable energy. Large scale generation of wind power is promising for many countries now a days. According to the world wind energy association (WWEA - 2014 report), the global installed capacity is 336.327 GW. The increasing penetration of wind energy in the power systems of many regions and countries require a development of a new grid code to maintain a stable and safe operation of the energy network[1]. The main elements in the grid codes include the requirements, active and reactive power controls, frequency and voltage regulations, power quality, and system protection. Large penetration levels of wind energy generation will have great impact on power systems stability. Possibility of partial blackouts, due to lack of reactive power support, is one of the risks associated with wind power integration into utility grids[2]. As a result, many countries pay more attention to overcome the possible negative impacts of the wind power integration, and hence interconnection requirements are developed in grid codes to mitigate those negative impacts.

LVRT capability is one of the most important requirements that have been identified in grid codes. This requirement usually differs from one country to another since it depends on the specific characteristics of each power system and the protection employed. In general, wind turbines (WTs), under LVRT requirement, are basically forced to remain connected to the grid during voltage interruptions or voltage dips with remaining voltage of almost 15% of the nominal voltage levels. Among different types of wind energy conversion systems (WECSs), the wind turbine equipped wind DFIG is most widely used all over the world.They are designed to operate at normal voltage levels and hence they suffer from excessive currents during low voltage disturbances[3].

Therefore, care should be taken in the form of passive or active techniques to limit the current and protect the converters during grid disturbances. Passive techniques apply resistive crowbar circuits that are usually connected in the rotor circuit in order to disable and protect the power converters during fault conditions. On the other hand, active techniques include design of new controllers that are capable of limiting high currents during low voltage conditions. Hybrid application of passive and active techniques has been used to efficiently enhance LVRT capability of DFIG and limits the dc-link voltage fluctuations. Technologies that can improve LVRT capability of induction generators by controllable reactive current injection, such as static compensator (STATCOM), have been reported in the literature. Alternatively, dynamic voltage restorer (DVR) has been used as one of the solutions to improve LVRT capability of SCIG and DFIG. DVR can be used to inject small portion of series voltage in order to fulfill LVRT requirement[5]. The main disadvantage of DVR is the complexity of controllers required to compensate the faulty voltage waveforms.

Newly, a control method to limit the torque and enhance the LVRT capability of grid-connected cage induction machines during the recovery period after grid faults by using a STATCOM is proposed in [6]. A novel damping control algorithm for a STATCOM in a series compensated wind park for mitigating sub-synchronous resonance (SSR) and damping power system oscillations. The existing control techniques are mainly aimed at maximising the output power, increasing the reactive current for the period of low-voltage, and reducing the peak rotor fault current. However, the non- linearity and interactions among wind farms is not considered. However, it is essential to consider the non-linearity and interconnection effects for designing controllers for multi-machine power systems, and also quantify the deviation of the operating point from the equilibrium point for which the system maintains closed-loop stability [7]. In recent years, the design of robust decentralised controllers for interconnected large power systems has been widely investigated and also presents large attention on guaranteeing the stability of the overall system model in the presence of interconnections terms. Although centralised controllers for such systems can often be designed using standard control design techniques, centralised control algorithms require a higher level of connectivity and higher communication costs compared with decentralised schemes[9]. Hence, much effort has been focused on the application of decentralised control in power systems. Results concerning robust decentralised control of interconnected power systems – based on approaches that explicitly take into account the interactions terms.

II. LVRT

Normally, the LVRT process for DFIG-based WECS can be divided into three continuous periods according to the LVRT grid codes, the initial period after the grid fault occurs (the first period), the low voltage-sustaining period (the second period) and the grid voltage recovery period after fault clearance (the third period). To achieve complete LVRT, the control objectives for DFIG-based WECS for each period is different. In the initial period after a grid fault occurs, a large electromotive force (EMF) is induced in the rotor circuit of the DFIG by the transient decay component of the stator flux, which produces stator voltage dip. To ensure the safe operation of the rotor-side converter (RSC), the main objective for DFIG-based WECS in this period is to restrain the rotor surge current caused by the large EMF. The rotor crowbar protection is a simple but effective measure. When a grid fault occurs, the active crowbar is connected to short the rotor circuit of the DFIG, which can accelerate the decay of the transient stator flux while protecting the RSC. When the transient stator flux is almost damped out, it enters the low voltage-sustaining period. The crowbar is disconnected, and the RSC recovers the control of the DFIG. The control objective for DFIG-based WECS in this period is to bear the grid voltage by providing reactive current into the network[10].

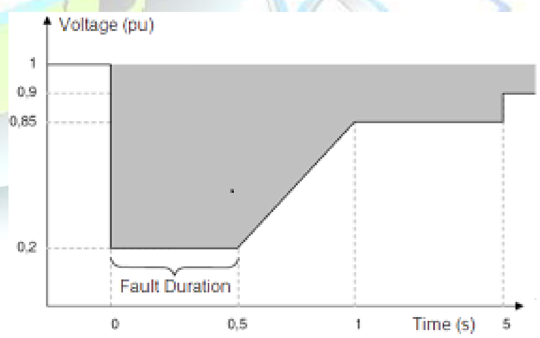

Fig.1.LVRT capability

III. DFIG

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 attached directly to the 50 Hz grid while the rotor is fed at variable frequency through the

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AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind during low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The optimum turbine speed produce maximum mechanical energy for a given wind speed 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.

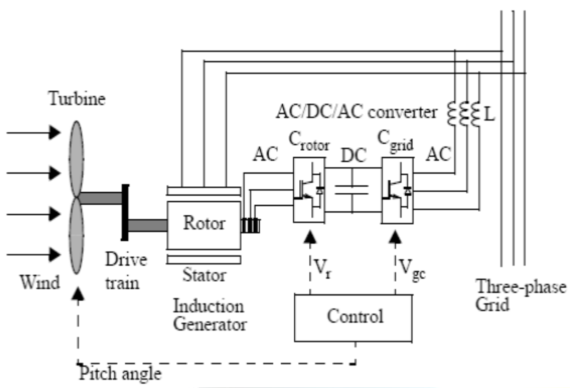

Fig.2. Basic diagram of Doubly Fed Induction Generators with converters

IV. STATCOM

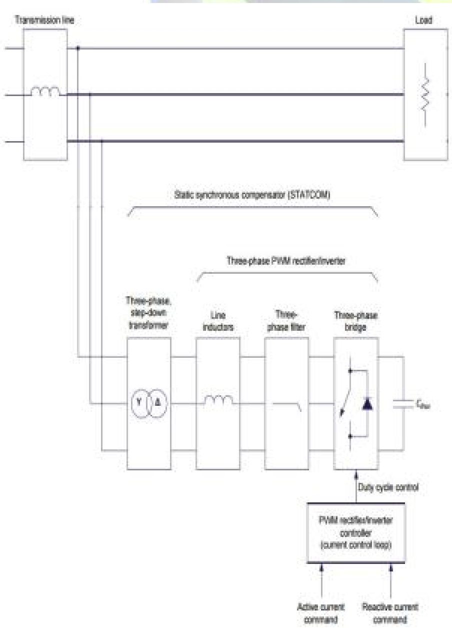

Fig.3. Block diagram of a typical STATCOM

Fig 3 shows that a STATCOM primarily consists of a three-phase step-down transformer and a three-phase PWM rectifier/inverter (i.e., a three-phase bridge, a three-phase filter, line inductors, and a controller). A large capacitor (c_{BUS})is used as a dc power source for the three-phase PWM rectifier/inverter. As seen in the last section, STATCOMs are used to supply reactive power to the ac power system to which they are connected, either for voltage compensation or for dynamic power factor correction (i.e., dynamic reactive power compensation). This is achieved by controlling the amplitude and phase angle of the three-phase current flowing through the ac side of the STATCOM. When the current flowing through the ac side of the STATCOM leads the voltage across its ac side by 90°, the STATCOM acts as an inductor and absorbs reactive power from the ac power system. Christo Ananth et al.[4] discussed about principles of Electronic Devices which forms the basis of the project. Conversely, when the current flowing through the ac side of the STATCOM lags behind the voltage across its ac side by 90°, the STATCOM acts as a capacitor and supplies reactive power to the ac power system. The magnitude of the current flowing through the ac side of the STATCOM determines the amount of reactive power the STATCOM exchanges with the ac power system. This enables the STATCOM to supply or absorb precisely the right amount of reactive power required in order to compensate the reactive power requirement of the ac power system. a large capacitor (c_{BUS}) is used to supply dc power to the three-phase PWM rectifier/inverter. The voltage across this capacitor must be maintained to a value that is high enough for the STATCOM to be able to exchange reactive power with the ac power network (i.e., to a value high enough for the STATCOM to be able to produce ac voltage at the value required). The voltage across the capacitor is maintained at the required value by continually adjusting the magnitude and polarity of the active component of the current at the ac side of the STATCOM. Christo Ananth et al.[8] presented a brief outline on Electronic Devices and Circuits which forms the basis of the project. When the voltage across the capacitor needs to be increased, the STATCOM adjusts the magnitude and polarity of the active component of the current flowing through its ac side so that active power is drawn from the ac power system and converted to dc power in order to charge the capacitor. Conversely, when the voltage across the capacitor needs to be decreased, the STATCOM adjusts the magnitude and polarity of the active component of the current flowing through its ac side so that active power is

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returned to the ac power system, thereby discharging the capacitor.

a) VI Characteristics of Statcom

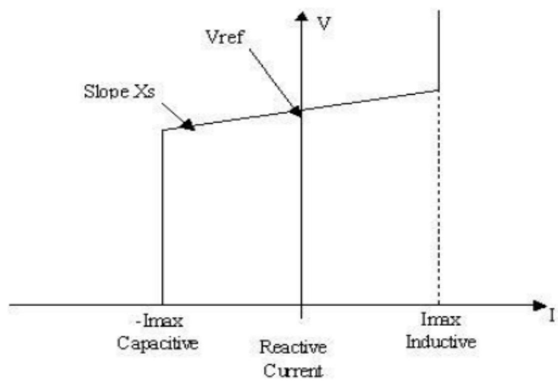

Fig.4. VI characteristics of STATCOM

Modes of the STATCOM operation:

1) Voltage regulation mode

2) VAR control mode

The V-I characteristic is depicted by the following equation:

V = Vref + XS.I ----------- (1)

Where V = Positive sequence voltage (pu) I = Reactive current (pu/Pnom) (I > 0 indicates an inductive current and I< 0 indicates capacitive current) XS=Slope (pu/Pnom: usually between 1% and 5%) Pnom=Converter rating in MVA This plots the ac bus voltage at the point where the STATCOM is connected against variation in STATCOM current (Istatcom). It can be seen that ac system voltage varies linearly with slope Xs from the reference setting Vref. This characteristic is also called the droop characteristic as it indicates the drop in voltage due to current drawn. The middle characteristic represents nominal system condition, and is assumed to intersect the STATCOM characteristic at point A where V = Vref and Istatcom is zero. If the bus voltage falls below Vref due to increase in system load level, the STATCOM holds the voltage at V3 that would otherwise drop to V2 without STATCOM. In this case the STATCOM must become more capacitive to raise the voltage. If, on the other hand, the voltage rises above Vref possibly due to a decrease in system loading, the system voltage will increase to V1 without STATCOM. With STATCOM operating point moves to point B. The STATCOM regulates the system voltage to V4 by absorbing inductive current I1. In this case the STATCOM becomes inductive to lower the voltage to the desired value. Outside the control range the STATCOM acts like a fixed current source (capacitive or inductive).

V. SIMULATION AND RESULT

The simulation is performed using MATLAB Simulink software.The fault examined here is 3LG fault. There is dip in stator voltage due to fault occurring in grid.The STATCOM is connected to compensate the voltage in the grid. The value of gain in PI controller is changed dynamically depending on the reactive power compensation needed to the grid. Therefore, stability of the grid is maintained. The dip in stator voltage and raise of post fault current are shown in Fig5 and Fig6 respectively. Eventhough there is fault the voltage is compensated in Fig7 and the post fault current is minimized in Fig8.

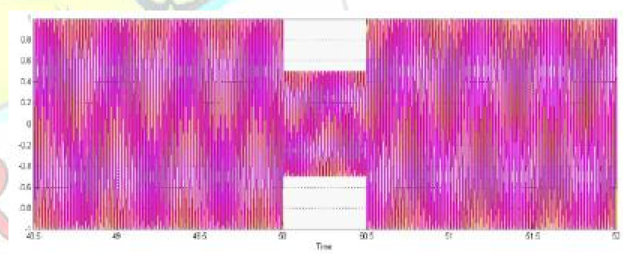

Fig.5. stator voltage

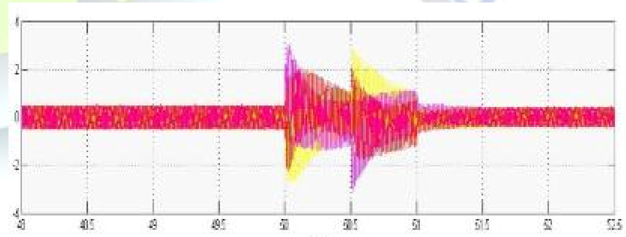

Fig.6. stator current

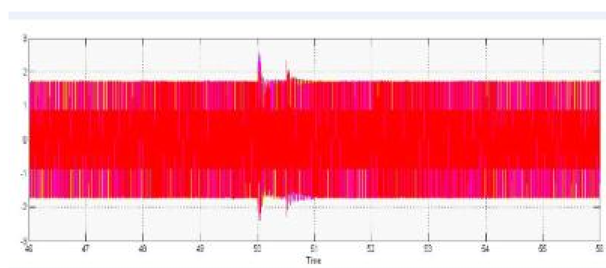

Fig.7. grid voltage

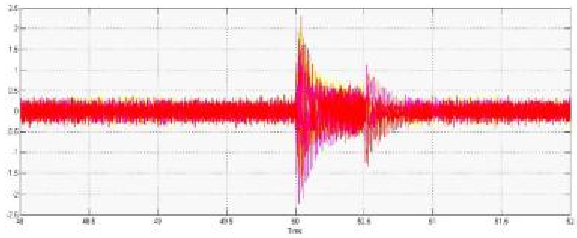

Fig.8. grid current

VI. CONCLUSION

The grid-connected windfarms is rapidly growing in large-scale during the last years. The stability of the power system is very much disturbed due to disconnection of wind farms during voltage sags.The refinement in the grid code states that wind turbine should remain connected to grid when voltage sag is sensed.In this paper, a STATCOM is used to improve the LVRT capability of wind turbine during voltage dip.Finally, a detail simulation model is built in MATLAB and the simulation results verify the feasibility and usefulness of the proposed device and control strategies.In this the LVRT capability improvement after connecting STATCOM with PI controller is simulated and examined.

VII. REFERENCES

[1] M.Tsili ,S.Papathanassiou, “A review of grid code technical requirements for wind farms”,IET Renewable Power Generation, 2009, Vol. 3, Iss. 3, pp. 308–332.

[2] Antonio Camacho, Miguel Castilla, JaumeMiret,Angel Borrell, and Luis García de Vicuña,“Active and Reactive Power Strategies With Peak Current Limitation for Distributed Generation Inverters During Unbalanced Grid Faults”, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 62, NO. 3, MARCH 2015, pp.1515-1525.

[3] Hua Geng, Cong Liu, and Geng Yang, “LVRT Capability of DFIG-Based WECS Under Asymmetrical Grid Fault Condition”, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 60, NO. 6, JUNE 2013,pp.2495-2509.

[4] Christo Ananth, S.Esakki Rajavel, S.Allwin Devaraj, P.Kannan. "Electronic Devices." (2014): 300.

[5] Kyung-Min Jin, Quach Ngoc Thinh, Eel-Hwan Kim, “DVR Control of DFIG for Compensating Fault Ride-Through Based on Stationary and Synchronous Reference Frame”,2012 IEEE 7th International Power Electronics and Motion Control Conference, pp.3004-3009.

[6] M.M.A Mahfouz, Mohamed A.H. El-Sayed, “Static synchronous compensator sizing for enhancement of fault ride-through capability and voltage stabilisation of fixed speed wind farms”, IET Renew. Power Gener., 2014, Vol. 8, Iss. 1, pp. 1–9.

[7] Lucheng Hong, Qirong Jiang, Liang Wang, “A New Topology and Control Strategy for Centralized Ride-Through Capability of Wind Farm”, 38th Annual Conference on IEEE Industrial Electronics Society DOI:10.1109/IECON.2012.6389334,pp. 3516 – 3520.

[8] Christo Ananth,W.Stalin Jacob,P.Jenifer Darling Rosita. "A Brief Outline On ELECTRONIC DEVICES & CIRCUITS." (2016): 300.

[9] M.J. Hossain,H.R. Pota,R.A. Ramos, “Improved low-voltage-ride-through capability of fixed speedWind turbines using decentralised control of STATCOM with energy storage system”,IET Gener. Transm. Distrib., 2012, Vol. 6, Iss. 8, pp. 719–730.

[10] Massimo Bongiorno and TorbjornThiringer, “A Generic DFIG Model for Voltage Dip Ride-Through Analysis”,IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 28, NO. 1, MARCH 2013,pp.76-85.