Literature Survey of Asymmetrical Fault Ride-Through As Ancillary Service by Constant Power Loads in Grid Connected Wind Farm

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Abstract ***This paper deals with literature survey on grid connected wind energy systems. This paper is on Wind Energy Conversion Systems with STATCOM and DFIG,PMSG and IG are collected and corresponding details are presented. Voltage stability is a key issue to achieve the uninterrupted operation of wind farms equipped with doubly fed induction generators (DFIGs) during grid faults. A Static Synchronous Compensator (STATCOM) is applied to a power network which includes a DFIG driven by a wind turbine, for steady state voltage regulation and transient voltage stability support. The control schemes of the DFIG rotor-side converter, grid-side converter and the STATCOM are suitably designed and coordinated. Recently, the grid codes require taking into account the reactive power of the wind farm in order to contribute to the network stability, thus operating the wind farm as active compensator devices. This paper presents a comparative study of stabilizing a wind farm using (Doubly Fed Induction Generators) DFIGs or using a (Static Synchronous Compensator) STATCOM during wind speed change and grid fault. Simulation results show that the wind farm could be effectively stabilized with both systems, but at a reduced cost with the DFIGs system because it can provide reactive power through its frequency converters without an external reactive power compensation unit like the STATCOM system significant. Voltage stability is a key issue to achieve the uninterrupted operation of wind farms equipped with doubly fed induction generators (DFIGs) during grid faults. To harness the wind power efficiently the most reliable system in the present era is grid connected doubly fed induction generator. This paper investigates the application of a static synchronous compensator (STATCOM) to assist with the uninterrupted operation of a wind turbine driving a DFIG, which is connected to a power network, during grid faults .After detailed literature survey it is decided to work on the Multi bus systems with wind farms and multiple STATCOMS. The studies will be performed using simulation of 8 bus system with and without multiple STATCOMS.***

Key Words: **Keywords**: *Wind Energy; Fault Ride-Through; Doubly-Fed induction Generator; Wind Farm,STATCOM*

1. 1.INTRODUCTION

Wind power has become the world's fastest growing renewable energy source. The many benefits of the wind energy are environmental protection, economic development, diversity of the supply, rapid spread, transference and technological innovation, industrial scale electricity in network and the fact is that the wind does not pollute, it is abundant, free and unlimited. The world-wide wind power installed capacity has exceeded 120 GW and the new installation in 2008 alone was more than 27 GW. More than thousands of wind turbines operating, with a total nameplate capacity of 121,188 MW of which wind power in Europe accounts for 55% (2008). World wind generation capacity more than quadrupled between 2000 and 2006, doubling about every three years. 81% of wind power installations are in the US and Europe. The share of the top five countries in terms of new installations fell from 71% in 2004 to 62% in 2006, but raised to 73% by 2008 as those countries—the United States, Germany, Spain, China, and India—have seen substantial capacity growth in the past two years By 2010, the World Wind Energy Association expects 160 GW of capacity to be installed worldwide, right from 73.9 GW at the end of 2006, implying an anticipated net growth rate of more than 21% per year. Wind power is often described as an "intermittent" energy source, and therefore unreliable. In fact, at power system level, wind energy does not start and stop at regular intervals, so the term "intermittent" is misleading. The output of aggregated wind capacity is variable, just as the power system itself is inherently variable. In the past, wind turbine generators were disconnected from the system during faults. Nowadays, there is an increasing requirement for wind farms to remain connected to the power system during faults, since the wind power lost might affect the system stability Therefore, the wind turbine behavior during system performance and its influence in the system protection must be analyzed. One of the most frequent irrelevant features about integrating wind energy into the electricity network is that it is treated in isolation. An electricity system in practice is modify like a massive bath tub, with hundreds of taps (power stations) providing the input and millions of plug holes (consumers) draining the output. The taps and plugs are opening and closing at all the time. For the grid operators, the task is to make sure there is enough water in the tub to maintain system security. It is therefore the combined effects of all technologies, as well as the demand patterns, that matters. The specific nature of wind power as a distributed and variable generation source requires specific infrastructure investments and the implementation of new technology and grid management concepts. High levels of wind energy in system can impact on grid stability, congestion management and transmission efficiency and transmission adequacy. A grid code covers all material technical aspects relating to connections to, and the operation and use of, a country's electricity transmission system. They lay down rules which define the ways in which generating stations connecting to the system must operate in order to maintain grid stability [1].

Renewable sources often produce power and voltage varying with natural conditions (wind speed, sun light etc.,) and grid connection of these sources is essential if they are ever to realize their potential to significantly alleviate the present day problems of atmospheric pollution and global warming. The micro wind power generation system with battery energy storage is becoming more prominent with the increasing demand of power generation. It also reduces the environment pollution. However the output power of micro- wind generator is fluctuating and will affect the operation in the distribution network. The utility system cannot accept new generation without strict condition of voltage regulation due to real power fluctuation and reactive power generation/absorption. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. However the wind generator introduces disturbances in to the distribution network .One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent advantages of cost effectiveness and robust- ness. However; induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine. It used for sensitive load applications as it supplies the power for a short period of time. The wind energy generation system is response for either charging/discharging the battery and also acts as a constant voltage output for the critical load in the distribution system [2].

In recent years the penetration of electric vehicles has increased tremendously. New battery technologies and power electronic power converter have resulted in highly efficient vehicles. Electric vehicles are used only for small amount of time for transportation, for the remaining time they are parked in parking space. These vehicles while they are not used for transportation can provide many grid services. They can act as storage devices, and with suitable interconnections it can feed power back to grid especially during peak hours. Another service that can be provided by electric vehicle is that they can act as external storage devices for renewable sources. Electric vehicles have the potential of supplying both real and reactive power with the grid, inverter and dc to dc converter in vehicle can control the amount of real and reactive power exchanged with a vehicle side proper controller.

Electric vehicle's real power capability has been studied previously, but same vehicle can provide reactive power support, which in effect will not reducevehicle's battery's state of charge(SOC) when compared to real power exchange. Thereby electric vehicle can give voltage support for integration of renewable energy like wind and act as a virtual STATCOM. Utilization of Solar farm as a STATCOM during night time has been studied previously. Most of the wind energy systems uses doubly fed induction generator(DFIG).DFIG has the inherent capacity to provide necessary reactive power for its operation during normal operating conditions. During fault conditions it is a common practice to short the rotor side converter of DFIG using crow bars.DFIG with shorted rotor will act as simple induction generator. Reactive power for the induction generator has to be supplied by some external means. STATCOM is used for fast and reliable reactive power compensation and voltage support in doubly fed induction generator based wind farms, but their major drawback is their high cost. Electric vehicle connected to grid by bidirectional power converter can support DFIG based wind farms by supplying necessary reactive power. Decrease in the battery state of charge(SOC) is very less in this reactive power transfer. The vehicle charger can supply reactive power during charging and discharging. Other than reactive power compensation, major problem associated with wind power integration is due to intermittency in wind power generations. Stability of grid gets affected due to transmission line outflows and power oscillations due to variations in wind velocity. Wind farms equipped with energy storage devices can effectively reduce stability issue. Super capacitors acting as energy storage devices for wind farm. But when the wind farm is large, huge no of storage devices and converters are required, making entire structure and control complex. Electric vehicle can involve in active power transfer with the grid by making use of battery and bidirectional converter. Battery can store energy when there is excess wind power, and it can discharge sufficient amount power, when wind velocity is low, making grid power always constant [3].

2. DOUBLY FED INDUCTION GENERATOR

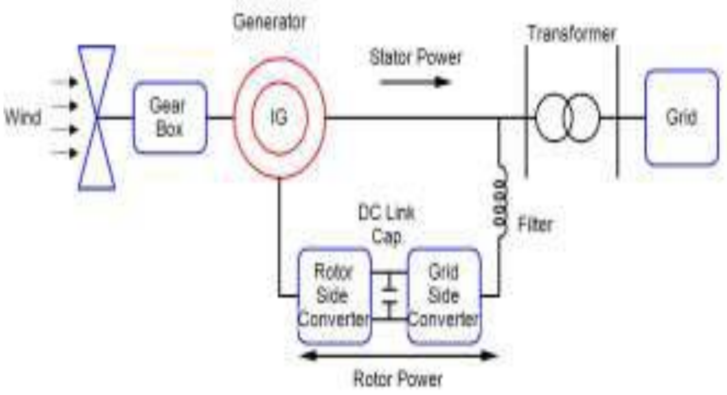


Figure 1 Doubly fed Induction Generator

Conventional wound-rotor induction machine in which the stator is directly connected to the grid through a transformer and the connection of the rotor to the stator (and grid) is via a back-to-back voltage source convertor. The rotor converter system consists of a grid side converter (GSC)and rotor side converter (RSC) connected via a DC link. A simplified schematic diagram of a DFIG based wind energy generation system is shown in Fig.1.The generator is called DFIG because the power is fed from both stator and the rotor circuits to the grid. The rotor circuit handles typically about 25-30% of the generator rated power, this percentage allows the DFIG to have about 30 ± % operational speed range around the synchronous speed and reduces the rating and the cost of the rotor converter. The size of the converter is not related to the total generator power but to the selected speed range and, hence, to the slip‖ power, thus the cost of the converter increases when the speed range becomes wider. The selection of the speed range, therefore, is based on the economic optimization of investment costs and on increased efficiency. Since the DFIG is connected to the grid, the high transient currents due to the grid disturbances may destroy the power electronic devices of the rotor converter. A protection system called ―crowbars‖ is being used in which the rotor winding can be short circuited during the fault period via a small resistance and released when the fault is cleared.

2.1 Design of GSC Controller of DFIG

Rotor-side converter is used to control the machine speed and the reactive power supplied through the machine stator, while the grid-side converter is used to maintain the dc bus voltage constant. The reactive power of this converter can be controlled, and The one strategy is to maintain the power factor of this converter at unity. This minimizes the current flowing in the grid side converter.

2.2 Design of RSC Controller of DFIG

The purpose of the rotor inverter is to control the generator speed to achieve maximum power from the wind over a range of wind velocities. The rotor side inverter control scheme is based on a multitier structure that comprises a speed, active power, reactive power and current control loop. It should be noted that omission of the power control loop is possible by implementing decoupled current control.

2.3 Fault-ride-through performance

DER systems must possess LVRT and HVRT capabilities as laid out in section IV-C. A key consequence for microgrids is that any intended transition due to faults from the grid-connected to autonomous modes of operation must be suppressed until disconnection is permitted, either according to the LVRT curve in Fig. 4. or HVRT minimum trip times. Otherwise, the fundamental objective of FRT (prevention of a sudden significant loss of generation) is defeated. The transition process from grid-connected to autonomous modes of operation may only be initiated once a disturbance persists long enough. Developers must assure the micro grid controller responsible for islanding associated functions is designed to respect these transition constraints.

Another key consequence of FRT requirements for micro grids is the impact on chosen architecture. FRT requirements, specifically LVRT, may heavily influence the design of a micro grid's internal bus configuration (e.g., dc, ac or hybrid dc-ac). For example, implementing a common dc bus fixed by a (stiff) battery energy storage system can improve the LVRT performance of dc-ac converter based DER units. Thus, developers should take FRT requirements into perspective when designing a preferred micro grid architecture. Doing so may greatly reduce any re-engineering efforts invested to attain FRT compliance, especially when compared with other architectures that were devised without any foresight for FRT.

2.4 Power quality issues

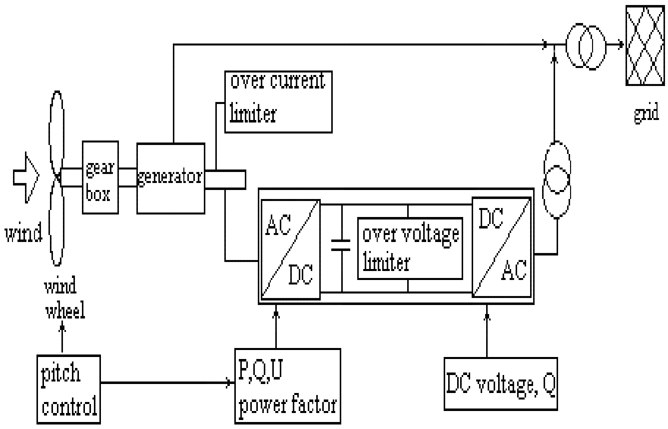


Figure.2

Power quality issues are considered for new construction or connection of generation systems to the existing ones. This paper shows a thorough analysis of voltage sag and swell ride through capacity of DFIG. A voltage sag can be defined as the drop of 0.1 to 0.9 pu in the rms value of voltage at a power frequency for time durations ranging from a half 5 cycles to a minute. They are caused due to system faults, heavy loads injected in the system, turning on large motors.

On the other hand a swell or rise in voltage swell can be defined as increase in the rms value of the voltage at the power frequency for a time durations ranging from a half cycle to a minute. During voltage swell the magnitude of voltage may lie in the range of 1.1 and 1.8 pu. They are less common than dips. They are observed while disconnection of large load or bringing large capacitor banks into operation. Also in a three phase system the voltage on the healthy phases during a single line to ground fault is more than the faulted phase.

Energy storage devices can effectively improve the competitiveness of renewable energy generators but they are very volatile and complicates the operation. This issue can be smoothed through energy storage systems. The time response of energy storage systems depends on the physical principle on which they are based. The paper discusses the operation of an SMES systems to enhance the sag and swell ride through caliber of WECS during voltage sags and swells

3. FAULT RIDE-THROUGH CAPABILITY-TOPOLOGIES

Even though DFIG wind turbine has several advantages, it faces two major problems. Firstly, it is very sensitive tovoltage disturbances especially voltage dips (sag). If any fault occurs in the grid, there will be a very large voltage disturbance which leads to uncontrollable current in the rotor side converter that results in the damage of the power electronic switches. Secondly DFIG suffers from output power fluctuations.

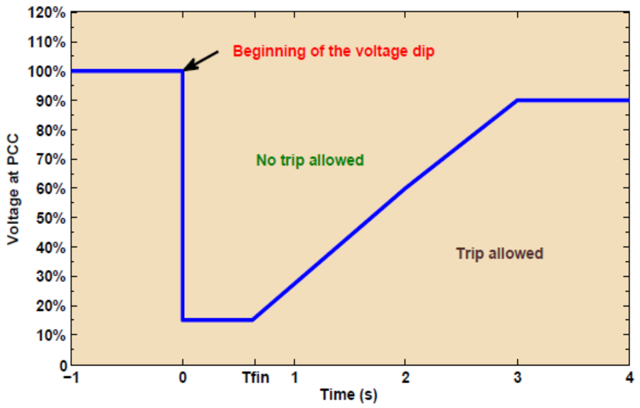


Fig.3. Typical LVRT curve

To protect the rotor circuit during fault conditions, usually the DFIG wind turbine is disconnected and remains unoperated until the fault is cleared which decreases its operational efficiency. So for the wind turbines to remain connected to the grid during the faults, various technologies have been developed to withstand the voltage dips. This withstanding capability of DFIG against voltage sags is called as Low Voltage Ride-Through (LVRT) or Fault Ride-Through (FRT) capability . The typical Low

Voltage Ride-Through (LVRT) curve is shown in Fig.3. The LVRT capability approaches can be divided mainly into two categories: (i) *Passive Methods:* they use additional components such as crowbar, blade-pitch angle control, energy capacitor system and DC bus energy storage circuit. (ii) *Active Methods:* includes several converter controls.

3.1 Passive Methods(DC Chopper)

A braking resistor (DC chopper) is connected in parallel with the dc-link capacitor to limit the overcharge during the fault condition. A DFIG dc-link brake chopper is shown schematically in Fig.6. The dc-link brake chopper shorts the dc-link through a power resistor when the dc-link voltage exceeds a fixed threshold level. The brake is used to maintain the dc-link voltage when transient rotor over current occurs. There are six anti parallel diodes in the rotor-side converter that are highly rated to withstand short-circuit currents. The brake chopper works on a hysteresis band, i.e., the turn-OFF

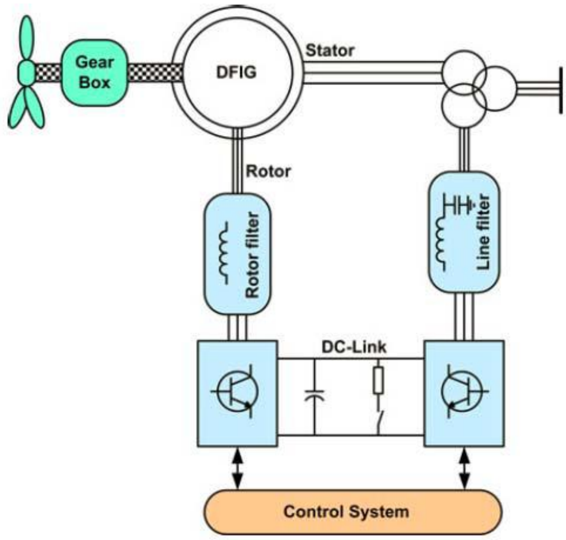


Fig.4.

3.2. Active Methods

With the control strategies of the rotor-side converter, the impact of fault on the DFIG wind turbine can be controlled. Maximum power tracking is used in all variable-speed wind turbines to increase their power conversion efficiency. Therefore, the converters used in wind turbines are designed in such a way that they should handle the maximum possible power that could be generated before reaching the cut-out wind speed.

4. CONSTANT POWER LOADS IN GRID CONNECTED WIND FARM

The introduction of distributed generation (DG) into low voltage (LV) systems demands that the generation system remain grid connected during voltage sags to ensure the operational stability. The DG consisting of fixed speed squirrel cage induction generator (SCIG)-based wind turbines is unable to provide reactive power control and needs a dedicated compensating device. Under asymmetrical grid faults the negative sequence flux circulation in the airgap introduces the torque oscillations that lead to the reduction of lifetime of the generation system. This paper proposes the use of distributed constant power loads (CPLs) for asymmetrical fault ride through (FRT) instead of using a centralized STATCOM.

It has also been observed that the compensation of negative sequence voltage improves the performance of SCIG by eliminating the torque ripples. The compensation of positive sequence voltage avoids a possible voltage collapse at the LV distribution level and improves the reliability and stability of the wind farm. Centralized compensation of the asymmetrical grid fault by a STATCOM is compared with the distributed compensation by CPLs. The results suggest that each individual CPL injects lower current for maximum FRT enhancement compared to a dedicated STATCOM.

The principle of a STATCOM is based on a power electronic converter based voltage source as in Figure 6. The basic principle of a voltage source behind a reactance is the same as for the synchronous condenser. However a STATCOM provides faster and more flexible control.

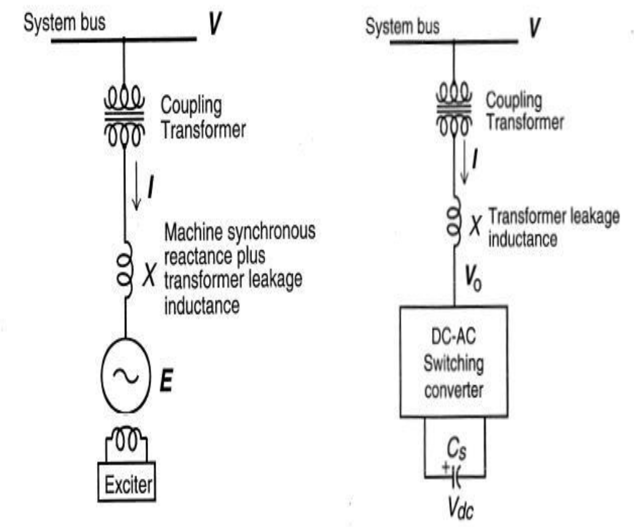


Figure 6. Condenser and STATCOM Based on the voltage source, the current or reactive power output from a STATCOM is controlled by the voltage difference over the inductance. Thus, its current can be kept constant and reactive power is proportion to the voltage as in Figure 6. Figure 7 V-I and V-Q characteristics of STATCOM. Any of the FACT devices or combination of them could be a solution to reactive power compensation for wind parks.

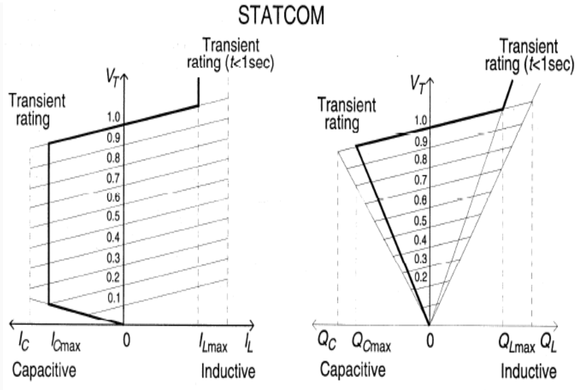


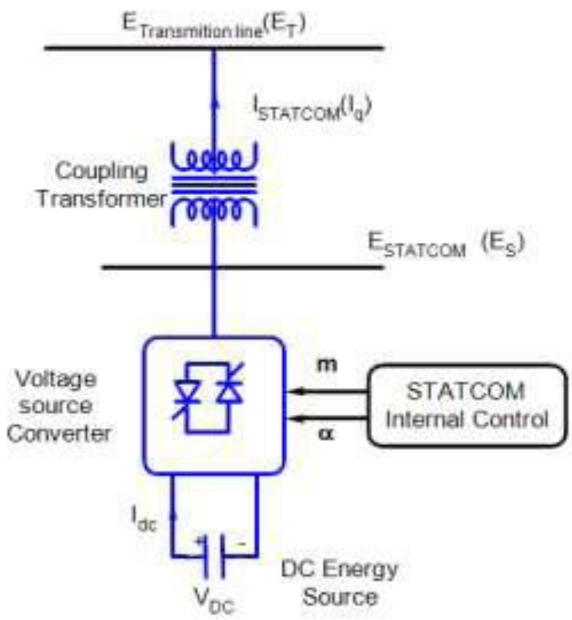
Fig.7

5. FACTS DEVICES OVERVIEW

FACTS are defined as ―Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability‖ One of the major causes of voltage instability is the reactive power limit of the system. The voltage fluctuation limit of a bus in the power system depends on the reactive power support (and control) that the bus can receive from the system. When the system approaches the Maximum Loading Point (MLP) or voltage collapse point, both real and reactive power losses increase rapidly. Therefore, the reactive power supports have to be local and adequate. In terms of wind energy applications, there are times when wind farms are subjected to short duration disturbances due to short circuits. During these disturbances the system voltage rapidly collapses. Smaller scale wind turbines are normally disconnected from the system until healthy conditions have been restored. For larger wind farms, it is often a requirement that they remain connected to the system during such disturbances and also provide support to the system to aid recovery to a pre-disturbance state.

6. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

STATCOM is another very popularly used Flexible AC Transmission System (FACTS)device that is capable of generating and/or absorbing reactive power and is applied to voltage support at a given bus It consists of a Voltage Source converter (VSC) and a DC energy storage device connected in shunt to the distribution network through a coupling transformer. The VSC converts the DC voltage across the storage device into a set of three phase AC output voltages. It can continuously generate or absorb reactive power by varying the amplitude of the converter voltage with respect to the line bus voltage so that a When system voltage is high, it absorbs reactive power. The VSC uses forced-commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize its terminal voltage from a DC voltage source. . The major features of STATCOM are quick response time, less space requirement, optimum voltage platform, higher operational flexibility and excellent dynamic characteristics under various operating conditions With the large installed capacity of 1.5MW wind turbines, LVRT capability enhancement is becoming one of the most important grid connection issues. This paper demonstrates how network voltage dips affect the LVRT capability of DFIG wind turbines by having destructive effects on the power electronic converters and the electrical generator.



The application of STATCOM connected to a wind-turbine driven DFIG to allow uninterruptible Low Voltage ride-through of grid voltage faults is investigated. The STATCOM can compensate the faulty line voltage, while the DFIG wind turbine can continue its nominal operation and fulfill any grid code requirement without the need for additional protection methods.

7. CONCLUSION

The above literature survey does not deal with modeling of eight bus system with wind farms and STATCOMS. This work deals with modeling and simulation of eight bus system with multiple STATCOMS. This work proposes multiple STATCOMS for power quality improvement. Voltage stability will be investigated under fault condition

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Real-Time Implementation of a STATCOM on

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