International Journal For Technological Research In Engineering
Volume 5, Issue 8, April-2018 *ISSN (Online): 2347 - 4718*

MODELLING AND SIMULATION OF LOW VOLTAGE RIDE THROUGH CAPABILITY ENHANCEMENT OF DFIG WIND TURBINE

Chauhan Apeksha[1], Prof. Parashar Thaker[2]
[1]PG Scholar, [2]Assistant Professor, Electrical Department, HJD, Kera,Kutch, Gujarat, India

ABSTRACT: This paper is based on capability enhancement of doubly-fed induction generator for wind turbine using low voltage ride through. Wind power is currently one of the fastest growing renewable sources of electrical energy. The Low Voltage Ride Through (LVRT) capability of wind turbine during grid faults is one of the core requirements to ensure stability in the power grid during transients. Therefore, this study focuses on present status of the rotor over current and dc link over-voltage protection solution e.g. the crowbar and its related protection circuits, the reactive power injecting-devices such as the static synchronous compensators (STATCOM) and dynamic voltage restorer (DVR). The LVRT capability enhancement using reactive power injecting device methods are divided mainly three groups depending on the connection configuration like series connection, shunt connection and series-shunt (Hybrid) connection. This paper presents a study of the LVRT of grid connected DFIG-based wind turbine. DFIG-based wind turbines are sensitive to voltage sags during the grid faults. This paper presents, any one method to improve LVRT of DFIG wind turbine in WSCC 9-bus system.

I. INTRODUCTION

In recent years, there has been a huge increase in the global demand for energy because of not only the industrial development, but also the population growth. With such a trend towards the diversification of the energy market, wind power is one of the fastest growing sustainable renewable energy resources. These factors are driving the development of renewable energy technologies. Wind power is thought to be the most promising alternative energy soon. As renewable energy sources grow in popularity, wind power is currently one of the fastest growing renewable sources of electrical energy. Wind turbine has become an important source of renewable energy in several countries around the world. Therefore, connection of wind farms to the grid and their dynamic behavior under different grid conditions has become an important issue in recent years, and new grid codes have been introduced. The grid code technical specifications are divided into static and dynamic requirements. The static requirements discuss the steady state behavior and the power flow at the connection point to the transmission grid. While the dynamic requirements concern the desired wind turbine generator behavior during fault and disturbance periods. Generally, these requirements cover many topics such as, voltage operating range, power factor regulation, frequency operating range, grid support capability, and low fault ride-through capability. Indeed, grid codes dictate Fault Ride-Through (FRT) requirements. Low-Voltage Ride-Through (LVRT) capability is the biggest challenge in wind turbines design and manufacturing technology. LVRT requires wind turbines to remain connected to the grid in presence of grid voltage sags. Based on these code requirements, wind turbine generators must remain connected to the grid and actively contribute to the system stability during various grid fault scenarios that result in a decrease in the generator terminal voltage. Moreover, wind turbine generators should have the ability during the faults to supply reactive power, to increase voltage level. In addition, they should supply active and reactive power immediately after fault clearance to support the network frequency and voltage, respectively. Wind turbine can operate with either 1) fixed speed or 2) variable speed. For fixed speed wind turbines, the generator (induction generator) is directly connected to grid. Modern high-power wind turbines are capable of adjustable speed operation and use their doubly-fed-induction generator (DFIG) systems. DFIG based WTs widely used in wind power generation because of its capability of maximizing the energy capture during variable wind condition and controlling P and Q power for better grid integration. The doubly fed induction Generator (DFIGs) have been widely applied for wind farms (WFs) applications because of their advantages such as variable speed constant frequency operation capability and active/reactive power controllability.

II. WIND POWER

Wind is available in all over world and it is available or its existence is due to the unrequired heating on the earth surface and due to the earth’s rotation. The normally methods which is used for electricity generation is using oil, gas, coal etc. But, the main drawback of this system is this system is this type of conventional system of power plant produce pollution in environment. Due to these effects like pollution, temperature increase, greenhouse effect etc. The use and application of renewable energy sources are increased and mainly solar, wind, hydro power. Another best advantage of renewable energy source is that the overall cost of renewable energy sources is decreased day by day due to advancement in the new technologies.

Features of wind power SYSTEMS: -

These are so many advantages feature of use of wind power system. In most of the wind power plant site location is in rural area, island area and marine areas. The energy equipment in these kinds of places are simple and does not require high electrical power.

- The power system supplies cheap variable voltage for heating purpose and expensive higher voltage for motor and lights.
- The rural grid system is very weak up to 33 KV system. The grid integration of wind energy conversion system is very difficult, and problem occur for worker of the plant.
- These are some time duration is coming where wind energy is not available. That's storage system is necessary for continuous power supply.

Power from the WIND: -

The mechanical energy as kinetic energy is provided from the wind to rotate generator and produce electricity. These are so many factors are important for better efficiency and maximum power generation from the wind. The first and very important factor is wind speed to determine the capacity of wind to obtain maximum amount of power. So, the power produced from the wind turbine is equal to the cube of wind speed. So, it will double the value of wind speed than power produce is 8 times to original power. The relation between power generated and velocity of wind and diameter of rotor blades are given as below:

$$P_{wind} = \frac{\pi}{8} dD^2 v_{wind}^3$$

For selection of wind turbine available in market the best and efficient wind turbine is that which is capable of use of kinetic energy of wind.Wind power plant has the following advantages over the other conventional power plants:

- Improve the price complexity
- Easy installation of plant
- Fast and reliable construction
- Easy power generation
- Improve the system reliability
- Pollution free

Double fed inductionGENERATOR (dfig)

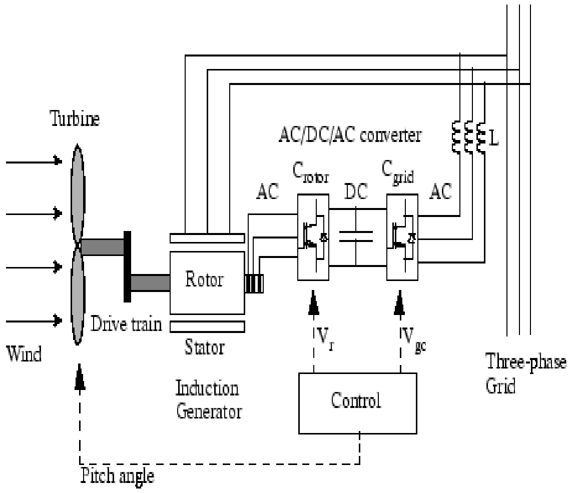
DFIG which is also known as Double feed induction generator which is mostly used in wind turbines. The DFIG is based on the working principle of an induction generator which is provided with multiphase wound rotor and slip ring design configurations.

The alternative of DFIG is brushless wound rotor doubly fees induction machine.

Principle of GRID CONNECTED Double FEed Induction Generator SYSTEM

The principle operation of DFIG is that the rotor windings are connected to the grid via slip rings and back to back VSC (voltage source converter) which provides the control of rotor side and grid side currents. The voltage source converter provides the control at rotor side current and provides the active and reactive power control feeding to the grid. The principle of control is provided using direct axis control or two axis control system.In the DFIG system the rotors are typically wound with number of turns of 2 to 3 multiple of stator turns. Due to this the rotor voltage value is higher and rotor current value is lower. So, in this configuration the operation speed of rotor is ±30% of the synchronous speed. The current rating of converter is lower due to that the cost of converter is low. The rotor voltage value is high due to that the controlled operation in operation speed range is not possible. Provide the protection against higher rotor voltage there are IGBT and diode configuration is used. Use of crowbar protection there are small currents and voltages are detected.

Fig: Operating Principle of the Wind Turbine Doubly-Fed Induction Generator



The double feed induction machine has several advantages over conventional induction machine for wind power application. The induction machine use power electronics converter the induction machine can import and export of reactive power in the system. Due to these kind of features the induction machine can provide power system stability and provide the support to grid during voltage disturbances.Another important feature is that induction machine is capable to synchronize with grid while wind turbine speed is variable. The variable speed wind turbine efficiently used during light wind conditions. Due to these kinds of several feature and advantages the efficiently of DFIG is very good.

III. SYSTEM MODEL

The model of the system electrically is developed using phase of complex vectors in synchronous rotating reference frame theory. The calculation assumes + ve axis as real axis and – ve axis as imaginary axis. In different conditions the real and imaginary axis are align with vectors at different position and at different angles. The different assumption which are consider during development of electrical model of the system are:

- The losses like iron losses converter losses are neglected.
- The magnetic circuit of the machines can be represented by linear model in the system.
- The whole mechanical model of the system of the system can be modelled using lumped parameters of inertia like electrical angle and speed of induction generator.The power converter using inthe system are represented by state space representation for their low frequency values.
- It is assumed that the wind farm networks are

electrically stiff with respect to point of common coupling (PCC) and the conventional DFIG circuit is transformed into an equivalent circuit.

IV. DFIG CONTROL

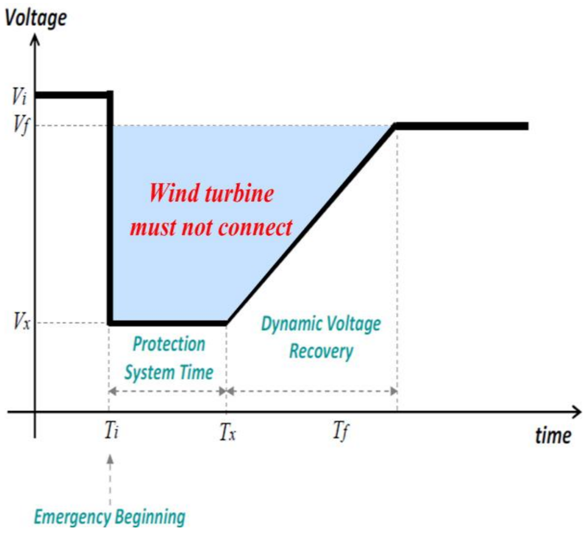
The DFIG is connected to the network is represented by three steps which has been represented as following steps. First step is regulating the stator voltage with respect to reference voltage.

Second step is the power control and regulation between stator and network.

V. MODELLING AND SIMULATION

The design configuration of DFIG based wind turbine connected with super capacitor bank-based energy storage system is shown in fig below. In the given system the low speed wind turbine drives the high speed DFIG using gearbox system. The DFIG is wound rotor type induction machine which is connected to the power grid at stator and rotor terminals. The stator is directly connected to the system while the rotor is connected through grid side converter and rotor side converter to the grid in the system. The DFIG based wind turbine generator rotates at the operational speed of 20-30% to the synchronous speed in the system and the active and reactive power is controlled independently in the system. In this design configuration the energy storage system is provided using super capacitor bank and two quadrant dc-dc converter. The ESS works as a source or sink to control the active power to the wind turbine generator system.

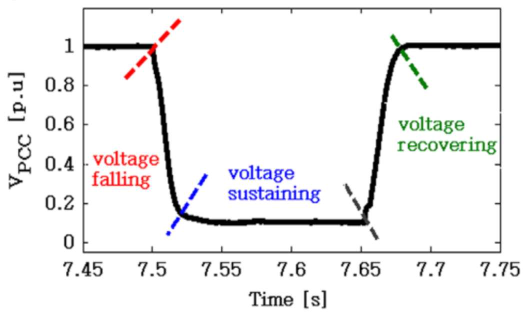
VI. VOLTAGE-TIME CHARACTERISTICS



Where,
Vi =initial voltage
Vf=recovering voltage
Vx =reduced voltage
Ti=at time when voltage falling
Tx=at time when voltage start to recover
Tf=dynamic voltage recover

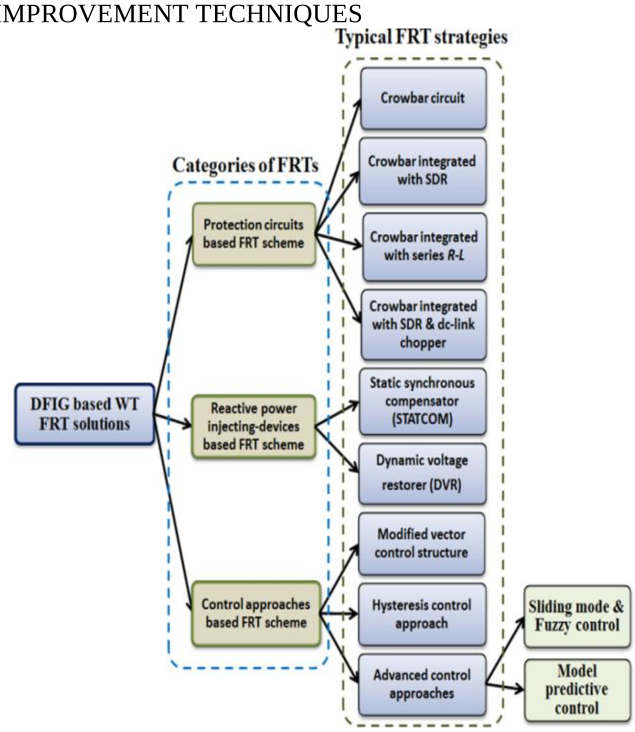
A typical LVRT characteristic is shown in Fig. According to the LVRT specification, wind turbines are required to stay connected to the grid and supply reactive power, when the PCC voltage drops and falls in the blue area, as illustrated by Fig Furthermore, wind turbines must be able to operate continuously at *Vf*% of the rated PCC line voltage *Vi*, as seen in Fig. The level of the voltage sag (*Vx*) and fault clearance time (*Tx*) are decided by the turbine protection system based on the location and type of fault, severity of the fault. The slope of the recovery depends on the strength of the interconnection and reactive power support. Stronger systems could afford a much steeper increase and thus minimize the ride-through requirements of the generators. When the stator voltage drops to a lower value. Now looking into the transient-state the response of the DFIG based WT can be classified into three transition periods as show in figure (a) and (b) which are named as: (i)the initial period(period 1)after the grid fault occurs 'voltage falling', (ii)the low voltage sustaining period(period2)also known as 'voltage sustaining' and (iii)the grid voltage recovery period(period 3)which represents 'voltage recovering' after the fault is cleared.

a



voltage response during transient–state

IMPROVEMENT TECHNIQUES



A crowbar circuit is a method of protection a circuit against high voltages in the event of a power supply malfunction.A crowbar circuit works by sensing a voltage that is above a certain threshold and shorting out the power supply. This causes a voltage drop in the rest of the circuit and current surge through the power supply that will trip a circuit-breaker or blow a fuse.

DFIG for Controlling the Grid Parameters

In this section the proposed DFIG system has been integrated with crowbar protection-based control for fault ride through enhancement and controlling the output parameters of the Grid.

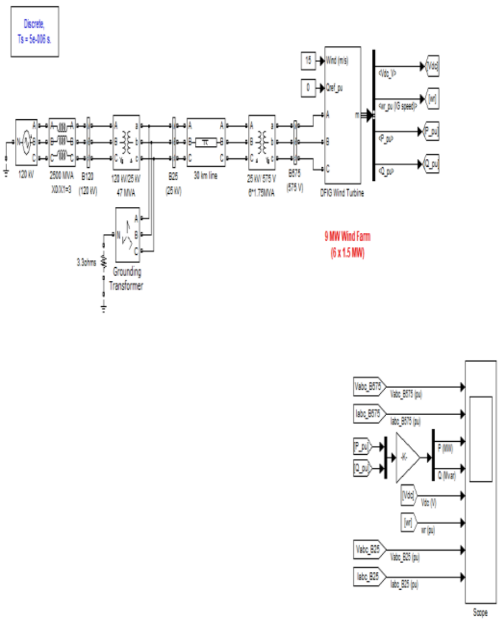


Fig DFIG Controlled System

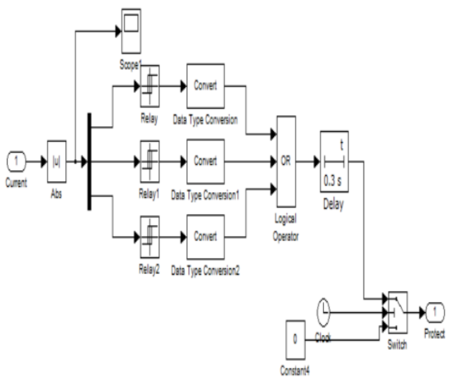


Fig Crowbar Protection subsystem for fault ride through

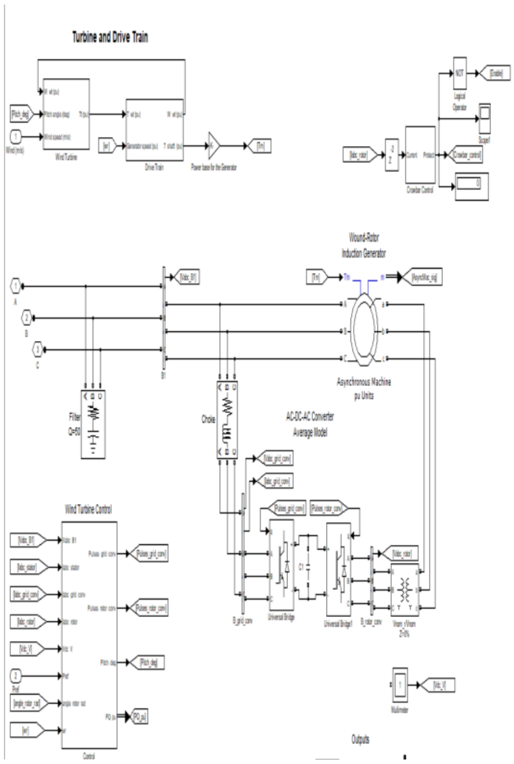


Fig DFIG integrated with Crowbar Protection

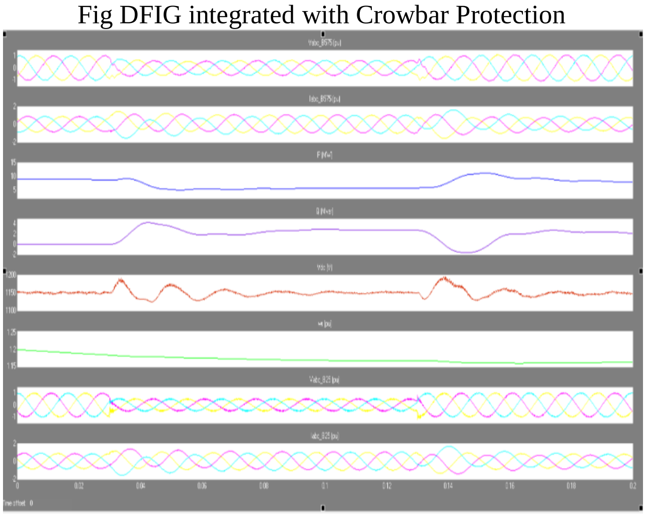


Fig: Controlled output parameters (Voltage, Current, Active & Reactive Power)

Single machine Circuit of DFIG

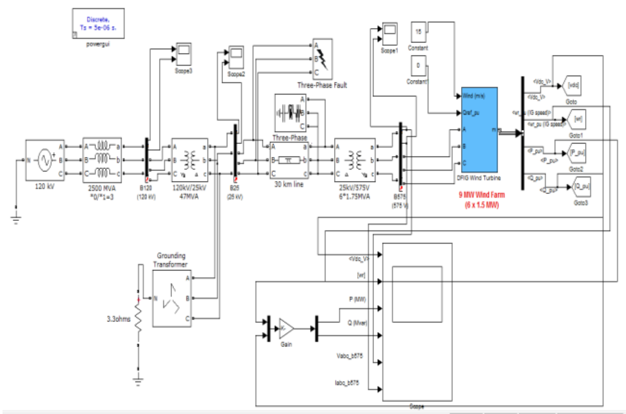


Fig Single Machine Circuit of DFIG

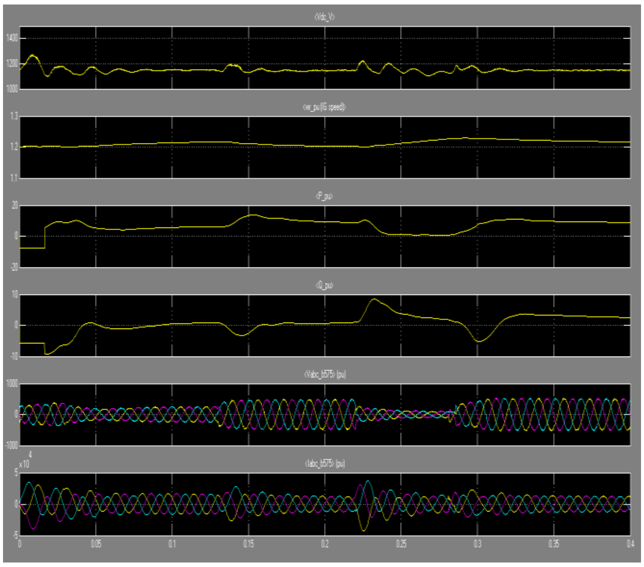


Fig Single Machine Circuit based DFIG output waveforms 3-machine 9-bus system

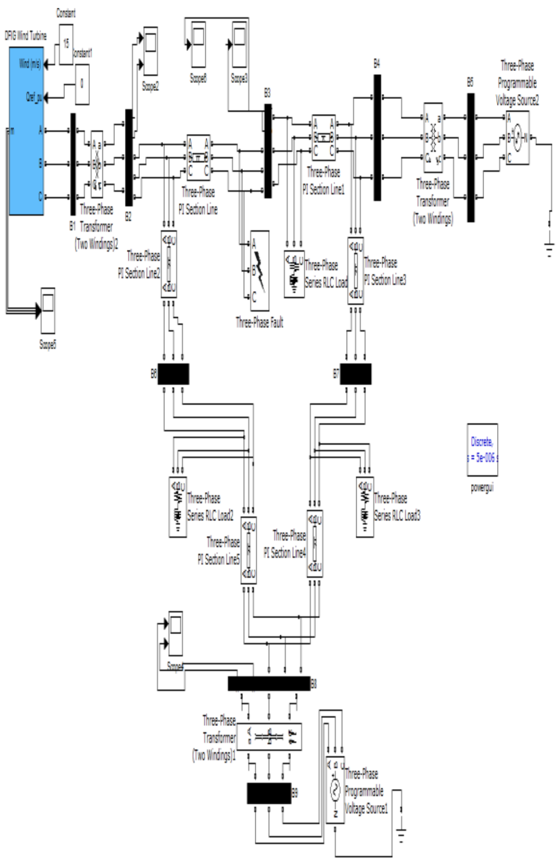


Fig 3-machine 9-bus system

- If grid fault occurs at that time large voltage and current flow in the rotor circuit, which may damage the power electronic converters.
- The voltage recovery or voltage sag recover used many techniques.

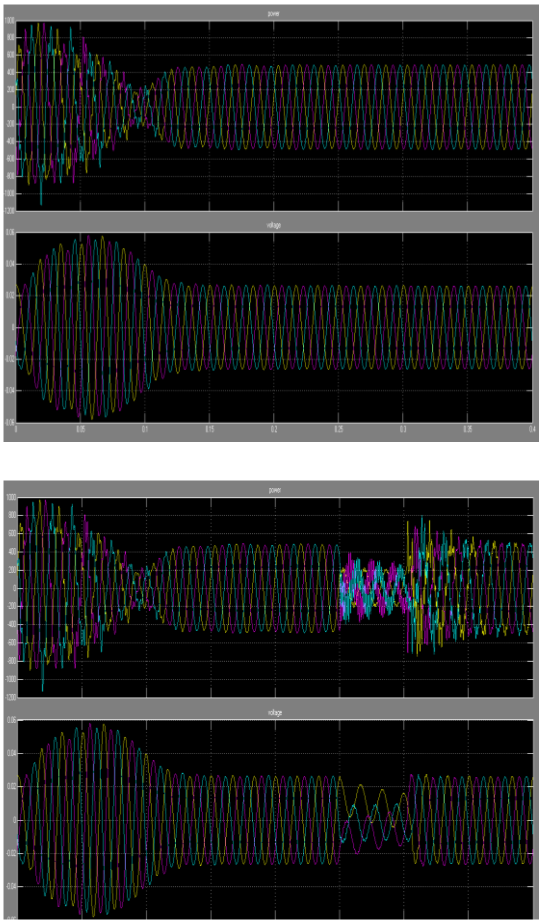


Fig: Low voltage ride through waveform improvement in DFIG using Crowbar system

VII. CONCLUSION

With the increasing penetration of wind power, it is necessary to participate of WTG in the grid power supply as well as supply active power for control power flow. We can see from some output of WTG without any control strategies, there are fluctuations in speed of rotor and output power. After applying the PLL control Strategy and rotor and grid side converter control, we can generate the constant output power at the DFIG generation side. The value of active and reactive power will become constant using DFIG control and the value of D.C voltage at converter control side also become constant.

REFERENCES

[1] SajjadTohidi, Hashem Oraee, Mohammad Reza Zolghadri, ShiyiShao,and Peter Tavner:" Analysis and Enhancement of Low-Voltage Ride-Through Capability of Brushless Doubly Fed Induction Generator", IEEE transactions on industrial electronics, vol. 60, no. 3, march 2013

[2] Jiabing Hu, Bo Wang, Weisheng Wang, Haiyan Tang, Yongning Chi, and Qi Hu:" Small Signal Dynamics of DFIG-based Wind Turbines during Riding Through Symmetrical Faults in Weak AC Grid ", DOI 10.1109/TEC.2017.2655540, IEEE

[3] Jaime Rodríguez Arribas, Adrián Fernández Rodríguez, ÁngelHermoso Muñoz and Carlos Veganzones Nicolás:" Low Voltage Ride-through in DFIG Wind Generators by Controlling the Rotor Current without Crowbars ", Energies 2014, 7, 498-519; doi:10.3390/en7020498

[4] YounessBoukhris, Aboubakr EL Makrini, Hassane EL Markhi:"low voltage ride through capability improvement of dfig based wind turbine using statcom", IJATESvol.no:3,August-2015

[5] Marwa Ezzat, Mohamed Benbouzid, S.M. Muyeen and Lennart Harnefors:" Low-Voltage Ride-Through Techniques for DFIG-Based Wind Turbines: State-of-the-Art Review and Future Trends" , IEEE -IECON 2013, Nov 2013, Vienne, Austria. pp.7681-7686, 2013.

[6] YiZhou,Paul Bauer, Jan A. Ferreira and Jan Pierik:" Operation of Grid-Connected DFIG UnderUnbalanced Grid Voltage Condition", IEEE transactions on energy conversion, vol. 24, no. 1, march 2009.

[7] A. D. Hansen, P. Sorensen, F. Iov, and F. Blaabjerg, "Control of variable speed wind turbines with doubly-fed induction generators," WindEngineering, vol. 28, no. 4, pp. 411–434, 2004

[8] Amirhasan Moghadasi, Arif Sarwat, Josep M. Guerrero:" A comprehensive review of low-voltage-ride-through methods for fixed-speed wind power generators", Renewable and Sustainable Energy Reviews 55(2016)823–839.

[9] Jackson John Justo, Francis Mwasilu, Jin-Woo Jung:" Doubly-fed induction generator based wind turbines: A comprehensive review of fault ride-through strategies" Renewable and Sustainable Energy Reviews 45(2015)447–467.

