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Study of DFIG based Wind Turbine for Reactive Power Generation Capability

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Abstract: In this paper to enhance the ability of reactive power support of a doubly fed induction generator (DFIG) based wind turbine during serious voltage dips. the proposed strategy is an advanced low voltage ride through(LVRT) control scheme, with which a part of the captured wind energy during grid faults is stored temporarily in the rotor's inertia energy and the remaining energy is available the grid while the DC-link voltage and rotor current are kept below the dangerous levels. our objective is to develop the grid connected DFIG based wind turbine, to analyse the reactive power capacity on the stator and the grid side converter during various fault conditions. Simulation studies are presented and discussed, with the help of MATLAB software.
Keywords: Doubly fed induction generator (DFIG), low voltage ride through (LVRT), power system fault, reactive power.

I. INTRODUCTION

In recent years, wind energy has become one of the most important and promising sources of renewable energy, which demands additional transmission capacity and better means of maintaining system reliability. The evolution of technology related to wind systems industry leaded to the development of a generation of variable speed wind turbines that present many advantages compared to the fixed speed wind turbines. These wind energy conversion systems are connected to the grid through Voltage Source Converters (VSC) to make variable speed operation possible. The studied system here is a variable speed wind generation system based on Doubly Fed Induction Generator (DFIG). The stator of the generator is directly connected to the grid while the rotor is connected through a back-to-back converter which is dimensioned to stand only a fraction of the generator rated power. To harness the wind power efficiently the most reliable system in the present era is grid connected doubly fed induction generator.

The DFIG brings the advantage of utilizing the turns ratio of the machine, so the converter does not need to be rated for the machine's full rated power. The rotor side converter (RSC) usually provides active and reactive power control of the machine while the grid-side converter (GSC) keeps the voltage of the DC-link constant. The additional freedom of reactive power generation by the GSC is usually not used due to the fact that it is more preferable to do so using the RSC. However, within the available current capacity the GSC can be controlled to participate in reactive power generation in steady state as well as during low voltage periods. The GSC can supply the required reactive current very quickly while the RSC passes the current through the machine resulting in a delay. Both converters can be temporarily overloaded, so the DFIG is able to provide a considerable contribution to grid voltage support during short circuit periods.

The Doubly Fed Induction Generator (DFIG) based wind turbine with variable-speed variable-pitch control scheme is the most popular wind power generator in the wind power industry. This machine can be operated either in grid connected or standalone mode. Doubly fed induction generator (DFIG) based WTs are widely used because of high efficiency, variable speed operation,as well as the use of converters with partial capacity that enables independent control on active and reactive power. To realize LVRT for DFIGs, several technical concerns arisen due to the grid faults must be properly addressed including the over-current in the stator and rotor circuits, the overvoltage of the DC-link connecting the rotor side converter (RSC) and the grid side converter (GSC), and the overloading of these converters. To meet the challenging requirements of reactive power support during voltage dips, the reactive power output from DFIGs needs to be increased as much as possible.

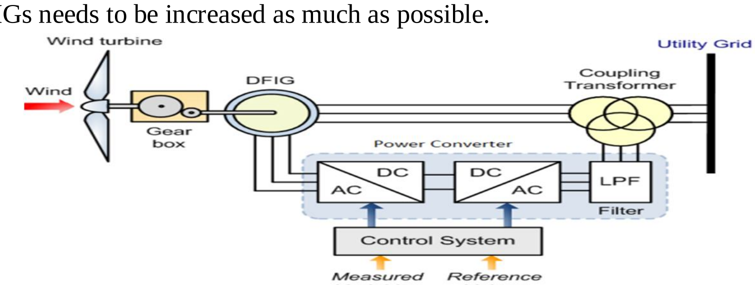

Fig 1.Block diagram of DFIG

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II. DOUBLY FED INDUCTION GENERATOR

Doubly fed induction generator the AC/DC/AC converter is basically a PWM converter which uses sinusoidal PWM technique to reduce the harmonics present in the wind turbine driven DFIG system. Here Crotor is rotor side converter and Cgrid is grid side converter. DFIG stator windings directly connected to the grid and its rotor windings connected to the grid through an AC/DC/AC frequency converter (Fig.1). This kind of machine has to be fed from both the rotor and stator sides. The frequency converter is built by two self commutated PWM converters, a rotor-side converter and a grid-side converter, with an intermediate DC voltage link.By controlling the converters on both sides, the DFIG characteristics can be adjusted so as to achieve maximum of effective power conversion or capturing capability for a wind turbine and to control its power generation with less voltage/power fluctuation. Many control algorithms have been proposed and used for controlling the DFIG rotor- and grid-side converters for certain dynamic and transient performance achievements of DFIGs. The rotor-side converter controls the active and reactive power of the DFIG independently, and the grid-side converter controls DC link capacitor voltage in a set value and maintains the converter operation with a desired power factor.

III. OPERATION PRINCIPLE OF DFIG

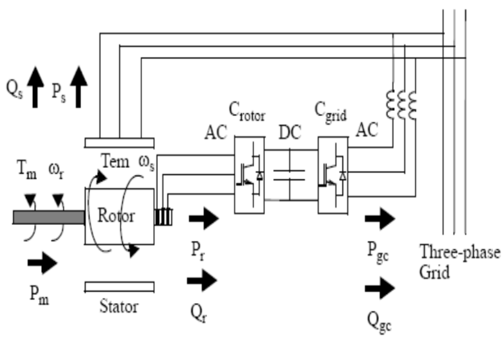

Fig. 2 Power flow diagram of DFIG

The stator is directly connected to the AC mains, whilst the rotor is fed from the Power Electronics Converter via slip rings to allow DIFG to operate at a variety of speeds in response to changing wind speed. Indeed, the basic concept is to interpose a frequency converter between the variable frequency induction generator and fixed frequency grid. The DC capacitor linking stator- and rotor-side converters allows the storage of power from induction generator for further generation. To achieve full control of grid current, the DC-link voltage must be boosted to a level higher than the amplitude of grid line-to-line voltage. The slip power can flow in both directions and hence the speed of the machine can be controlled from either rotor- or stator-side converter in both super and sub-synchronous speed ranges. As a result, the machine can be controlled as a generator or a motor in both super and sub-synchronous operating modes realizing four operating modes. Below the synchronous speed in the motoring mode and above the synchronous speed in the generating mode, rotor-side converter operates as a rectifier and stator-side converter as an inverter, where slip power is returned to the stator. where slip power is supplied to the rotor. At the synchronous speed, slip power is taken from supply to excite the rotor windings and in this case machine behaves as a synchronous machine.

$Pr = -SPs$

Where $S = Ws – Wr / Ws$

Generally the absolute value of slip is much lower than 1 and, consequently, Pr is only a fraction of Ps. Since Tm is positive for power generation and since ωs is positive and constant for a constant frequency grid voltage, the sign of Pr is a function of the slip sign. Pr is positive for negative slip and it is negative for positive slip For super-synchronous speed operation, Pr is transmitted to DC bus capacitor and tends to rise the DC voltage. For sub-synchronous speed operation, Pr is taken out of DC bus capacitor and tends to decrease the DC voltage. Cgrid is used to generate or absorb the power Pgc in order to keep the DC voltage constant. In steady-state for a lossless AC/DC/AC converter Pgc is equal to Pr and the speed of the wind turbine is determined by the power Pr absorbed or generated by Crotor. The phase sequence of the AC voltage generated by Crotor is positive for sub-synchronous speed and negative for super-synchronous speed. The frequency of this voltage is equal to the product of the grid frequency and the absolute value of the slip. Crotor and Cgrid have the capability for generating or absorbing reactive power and could be used to control the reactive power or the voltage at the grid terminals.

IV. CONVERTER CONTROL

The back to back PWM converter has two converters, one is connected to rotor side and another is connected to grid side. Control by both converters has been discussed here.

A. Rotor Side Converter Control System

The rotor-side converter is used to control the wind turbine output power and the voltage measured at the grid terminals. The power is controlled in order to follow a pre-defined power-speed characteristic, named tracking characteristic. This characteristic is illustrated by the ABCD curve superimposed to the mechanical power characteristics of the turbine obtained at different wind speeds. The actual speed of the turbine ωr is measured and the corresponding mechanical power is used as the reference power for the power control loop. The tracking characteristic is defined by four points: A, B, C and D. From zero speed to speed of point A the reference power is zero. Between point A and point B the tracking characteristic is a straight line. Between point B and point C the tracking characteristic is the locus of the maximum power of the turbine. The tracking characteristic is a straight line from point C and point D. The power at point D is one per unit. Beyond point D the reference power is a constant equal to one per unit.

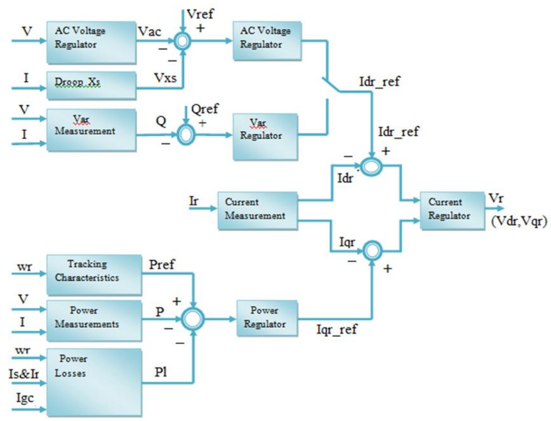

Fig 2. Rotor side converer

For the rotor-side controller the d-axis of the rotating reference frame used for d-q transformation is aligned with air-gap flux. The actual electrical output power, measured at the grid terminals of the wind turbine, is added to the total power losses and is compared with the reference power obtained from the tracking characteristic. A Proportional-Integral (PI) regulator is used to reduce the power error to zero. The output of this regulator is the reference rotor current Iqr_ref that must be injected in the rotor by converter Crotor. This is the current component that produces the electromagnetic torque Tem. The actual Iqr component is compared to Iqr_ref and the error is reduced to zero by a current regulator (PI). The output of this current controller is the voltage Vqr generated by Crotor. The current regulator is assisted by feed forward terms which predict Vqr. The voltage at grid terminals is controlled by the reactive power generated or absorbed by the converter Crotor. The reactive power is exchanged between Crotor and the grid, through the generator. The excess of reactive power is sent to the grid.

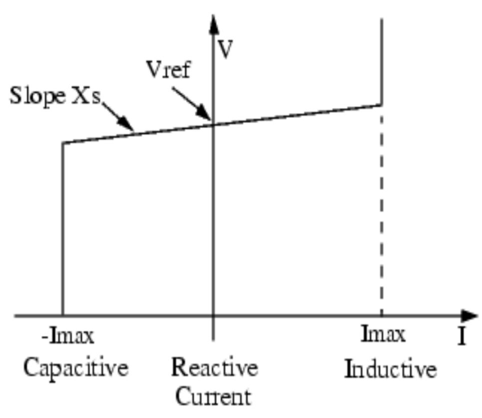

Fig 3.V-I characteristics of turbine

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The wind turbine control implements the V-I characteristic illustrated in Fig..3 As long as the reactive current stays within the maximum current values (- Imax, Imax) imposed by the converter rating, the voltage is regulated at the reference voltage Vref. When the wind turbine is operated in var regulation mode the reactive power at grid terminals is kept constant by a var regulator. The output of the voltage regulator or the var regulator is the reference d-axis current Idr_ref that must be injected in the rotor by converter Crotor. The same current regulator as for the power control is used to regulate the actual Idr component of positive-sequence current to its reference value. The output of this regulator is the d-axis voltage Vdr generated by Crotor. The current regulator is assisted by feed forward terms which predict Vdr. Vdr and Vqr are respectively the d-axis and q-axis of the voltage Vr.

B. Grid Side Converter Control System

The Grid side converter is used to regulate the voltage of the DC bus capacitor. For the grid-side controller the d-axis of the rotating reference frame used for d-q transformation is aligned with the positive sequence of grid voltage. This controller consists of :

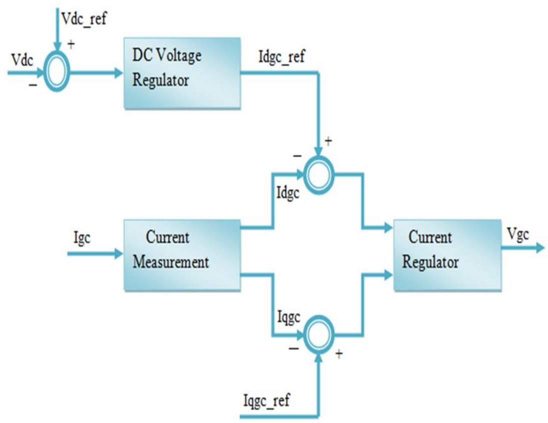

Fig 4. Grid side converter control

1) A measurement system measuring the d and q components of AC currents to be controlled as well as the DC voltage Vdc.
2) An outer regulation loop consisting of a DC voltage Regulator.
3) An inner current regulation loop consisting of a current Regulator.

The current regulator controls the magnitude and phase of the voltage generated by converter Cgrid (Vgc) from the Idgc_ref produced by the DC voltage regulator and specified Iq_ref reference. The current regulator is assisted by feed forward terms which predict the Cgrid output voltage.

V. FAULT ANALYSIS OF DFIG

Analysis of DFIG for reactive power support during with fault and without fault conditions are carried out.

A. Without fault

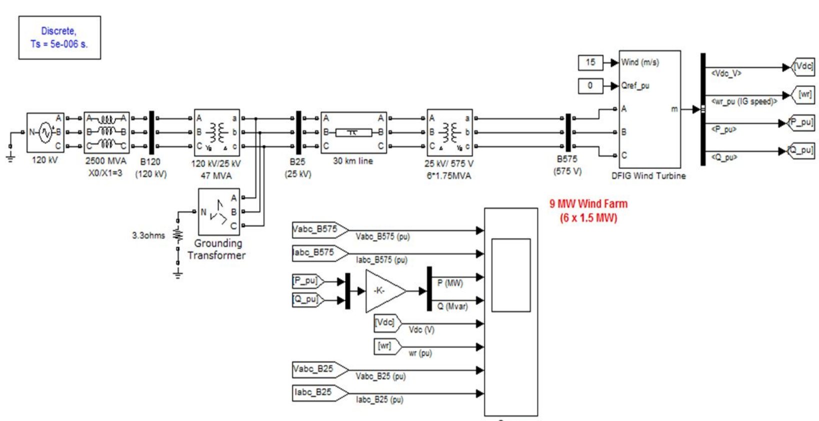

Fig 5. Simulation block diagram without fault condition

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Detailed simulation studies carried out on MATLAB/Simulink platform to verify the reactive power support during normal operating conditions to improve the voltage Level at the grid terminal here detailed model DFIG wind turbine is used.And operating behavior of the scheme as shown in fig.5 modeled in Simulink. Machine parameters chosen for carried out the simulation study are provided in Table .

Table 1 Simulation Parameters

Symbol	Quantity	Values
Pn	Nominal power	1.5MVA
Fn	Frequency	50Hz
Vs	Nominal Stator voltage	575Vrms
R_s	Stator resistance	0.023p.u
Lls	Stator leakage inductance	0.18p.u
Vr	Nominal Rotor voltage	1975Vrms
Rr	Rotor resistance	0.016p.u
Llr	Rotor leakage inductance	0.16p.u
Lm	Magnetizing inductance	2.9p.u
H(s)	Inertia constant	0.685
F(pu)	Friction factor	0.01
P	Pairs of poles	3

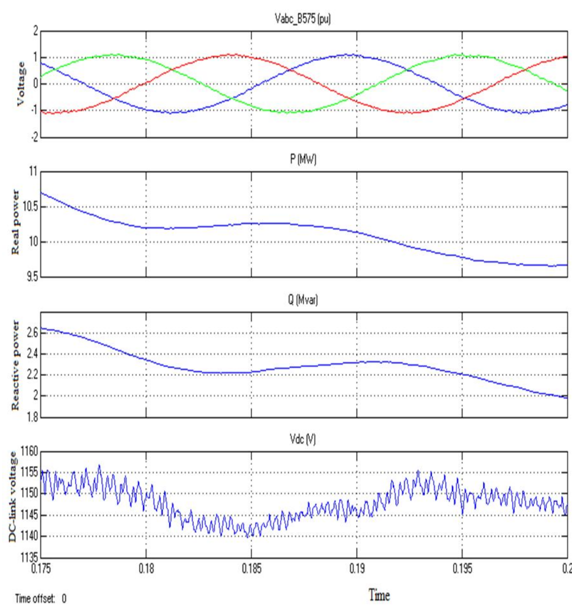

Fig.6. Simulation of DFIG performance during without fault.

(a)voltage (b) Real power (c) Reactive power (d)DC-link voltage.

The system performance of the DFIG is shown in Fig. 6, converters are continuously in operation to generate(or)absorb the reactive power to maintain the constant voltage at grid terminal in normal operating condition by means of maintaining the constant DC-link voltage at DC-link capacitors.

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B. With fault

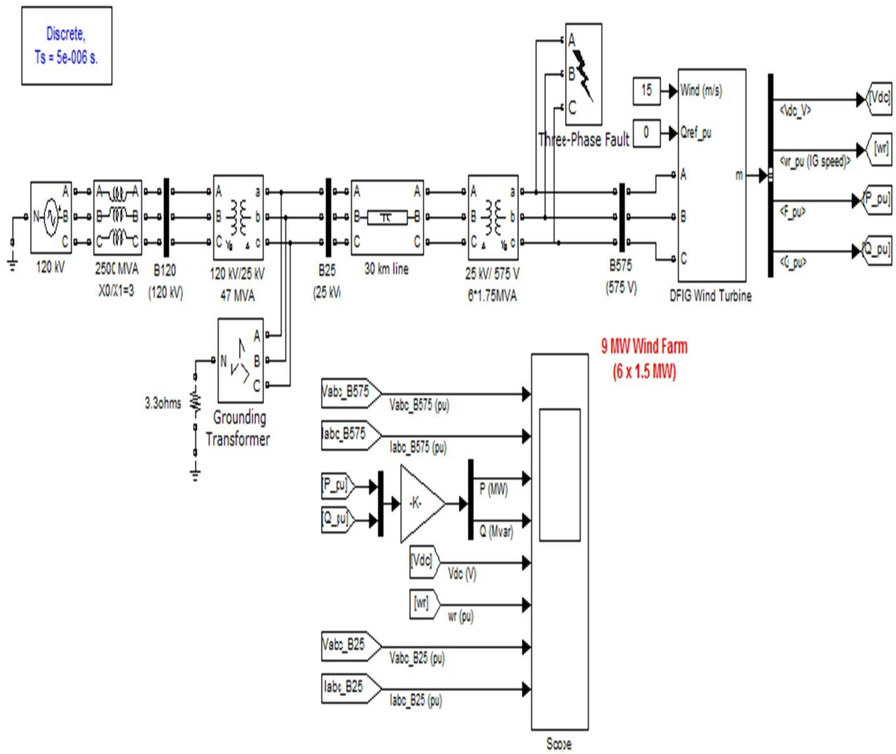

Fig.7 Simulation block diagram with fault condition.

Detailed simulation studies carried out on MATLAB/Simulink platform here DFIG wind turbine can be subjected to various faults such as single phase-ground fault , Two phase-ground fault and Three phase-ground fault to verify the reactive power suppoimprove the voltage Level at grid.

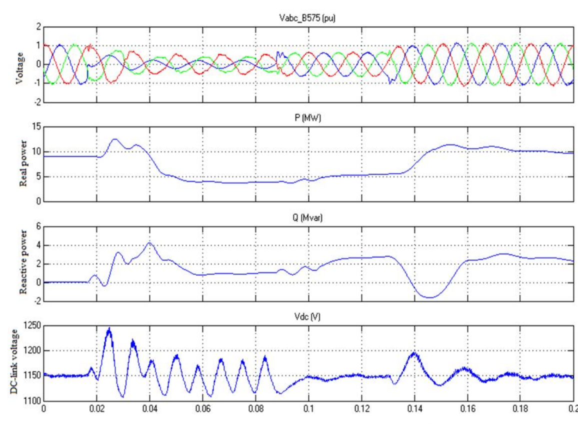

Fig.8. Simulation of DFIG performance during single phase-ground fault.

(a)voltage (b) Real power (c) Reactive power (d)DC-link voltage

The fig,8 shows single phase to ground fault here Voltage sag occurs from 0.016sec to 0.084sec during the time active power generation in DFIG is very high (13MW) due to that quadrature current increased and voltage becomes to decrease. So, we can absorb the excessive energy by accelerate rotor speed temporarily then reduce the fault current and increase the voltage by improving the reactive power support upto 4.2Mvar with the help of maintain the DC-link voltage with in the limit. And the Most severe fault occurs in this single phase-ground fault.

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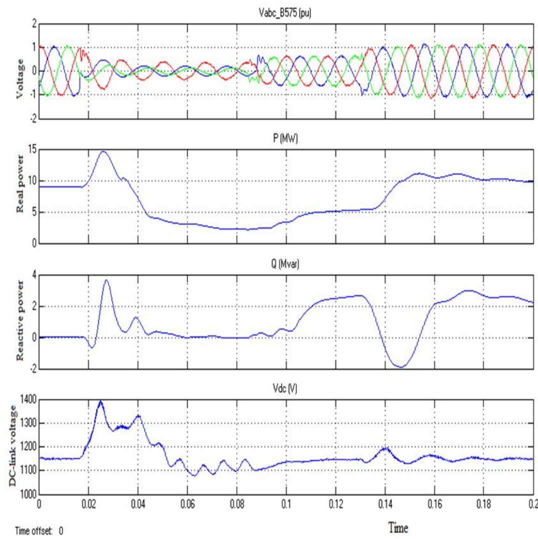

Fig.9. Simulation of DFIG performance during Two phase-ground fault.

(a)voltage (b) Real power (c) Reactive power (d)DC-link voltage

The fig 9. shows Two phase to ground fault here Voltage sag occurs from 0.016sec to 0.098sec that time active power generation in DFIG is very high (15MW) due to that quadrature current increased and voltage becomes to decrease So, we can absorb the excessive energy by accelerate rotor speed temporarily then reduce the fault current and increase the voltage by improving the reactive power support upto 3.8Mvar with the help of of maintain the DC-link voltage with in the limit.

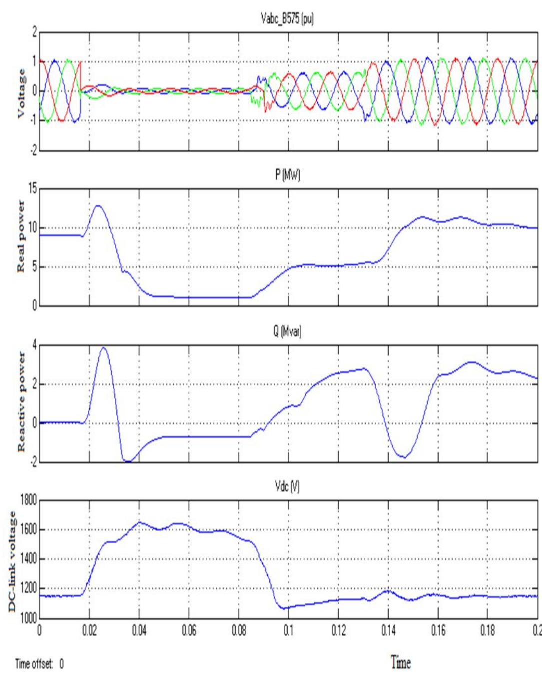

Fig.10. Simulation of DFIG performance during Three phase-ground fault.

(a) voltage (b) Real power (c) Reactive power (d) DC-link voltage.

The Fig,10 shows the Three phase to ground fault here voltage sag occurs from 0.016sec to 0.084sec that the time active power generation in DFIG is very high (14MW) due to that quadrature current increased and voltage becomes to decrease. So, we can absorb the excessive energy by accelerate rotor speed temporarily and we can reduce the fault current and increase the voltage by improving the reactive power support upto 3.9Mvar with the help of maintain the DC-link voltage with in the limit.

VI. CONCLUSION

High penetration of wind turbines imposes a significant challenge to the safe operation of power systems. to ensure the security of electricity supply with substantial wind power, the wind turbines must ride through and even contribute the grid operation under the fault requirements. This project proposes a new and efficient control strategy for both the rotor and grid side converters to improve the LVRT capability of the DFIG wind turbine. this new control strategy enables the DFIG to continue the electricity production, and absorb the excessive energy by increasing the generator rotor speed temporarily when a fault occurs at, example the PCC.The new strategy also introduces a compensation item to the grid side controller in order to suppress the DC-link over-voltage during the faults. The simulation results shows that the proposed control strategy can enable a safe LVRT of DFIG based wind turbine as a continuously operating resource of active and reactive power and fullfill the grid code requirements during various low voltage events.

REFERENCES

[1] Dongliang Xie, Zhao Xu,"A comprehensive LVRT control strategy for DFIG wind turbine with enchanced reactive power support".IEEE transactions on power system,vol.28,No.3,August 2013.

[2] A. H. Kasem, E. F. EI-Saadany,H. H. EI-Tamaly, andM. A. A.Wahab,"An improved fault ride-through strategy for doubly fed induction generator-based wind turbines," IET Renew. Power Gener., vol. 2, no. 4,pp. 201–214, Dec. 2008.

[3] J. López, E. Gubía, E. Olea, J. Ruiz, and L. Marroyo, "Ride through of wind turbines with doubly fed induction generator under symmetrical voltage dips," IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4246–4254, Oct. 2009.

[4] M. Kayikçi and J. V. Milanović, "Assessing transient response of DFIG-based wind plants-the influence of model simplifications and parameters," IEEE Trans. Power Syst., vol. 23, no. 2, pp. 545–554, May 2008.

[5] J. Liang, W. Qiao, and R. G. Harley, "Feed-forward transient current control for low-voltage ride-through enhancement of DFIG wind turbines,"IEEE Trans. Energy Convers., vol. 25, no. 3, pp. 836–843, Sep 2010.

[6] D. Xiang, L. Ran, P. J. Tavner, and S. Yang, "Control of a doubly fed induction generator in a wind turbine during grid fault ride-through," IEEE Trans. Energy Convers., vol. 21, no. 3, pp. 652–662, Sep. 2006.