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Analysis of Dynamic Behaviour of a DFIG Based Wind Turbine during Symmetrical Three Phase Fault at Grid End Using Crowbar Protection

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ABSTRACT:Wind power isincreasing by leaps and bounds in the world and installed capacity is amplified rapidly. Doubly fed induction generator (DFIG) generally used to convert mechanical energy of air into electrical energy because of its many benefits. When fault occurs at the grid end, stator voltage drops, a crowbar circuit between rotor of generator and rotor side converter (RSC) is activated. Crowbar is used to limit rotor current and dc-link voltage. MATLAB-SimPowerSystem software is used for analysis and study of dynamic behavior of the system.

KEYWORDS: Crowbar protection, Doubly fed induction generator (DFIG), Low voltage ride through (LVRT), Wind turbine (WT)

I.INTRODUCTION

As electrical power demand is increasing day-by-day, new generating units must be installed to the grid. Renewable energy resources are connected to grid because this form of energy is pollution free. Among all the available renewable energy resources wind energy is fastest growing and developing. There are several types of generator that can be coupled to the shaft of the rotor of WT for converting mechanical energy of the wind into electrical energy. DFIG is the most popular for variable speed application because it is effective and inexpensive. Variable speed application can be achieved by bi-directional transfer of slip energy through the back-to-back voltage source converters (VSC). In DFIG stator circuit is supplied via grid and rotor circuit is connected to grid via back-to-back VSC. Capacity utilization factor increased and cost per kWh power is reduced because of variable speed operation thus total energy output is 20% to 30% more in case of DFIG based WT [1].

Due to increased demand of electricity wind energy penetrate more into the power system. So grid codes are revised to regulate and control the operation of DFIG based WT and reduce effect on the grid. In the past WT disconnected during the grid fault because of this a large portion of grid power is lost. According to new grid code requirement a WT should remain connected to the grid during grid fault so they can provide voltage support after and during the fault. This phenomenon of DFIG based WT to remain connected to gird during fault is known as low voltage ride through (LVRT) capability. Stator and rotor circuit is electromagnetically coupled so when stator voltage decreases due to grid fault a large amount of rotor current flow to the rotor circuit and overvoltage occur in the rotor circuit. Due to this a large amount of current is flowing through rotor side converter (RSC), because of this converter and dc-link can be damaged. DC-link capacitor voltage rises above its nominal value. So special protection techniques are required to improve LVRT capability of DFIG based WT.

A DFIG based WT model is considered using MATLAB-SimPowerSystem is taken for the study [2], [3]. A crowbar protection technique is used to limit the current from reaching to RSC thus converter can be protected. At steady state condition a three phase fault is simulated at grid and dynamic behavior of proposed system is studied with and without crowbar protection circuit.

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II. A CASE STUDY

A pitch controlled WT of 1.5MW is considered for the study. A 575 V/ 25 kV transformer is used to connect DFIG based WT to bus B25. Then grid is connected to wind energy conversion system (WECS) through 25 kV/120 kV transformer. Main parameter used in the simulation are given in [2], [3].

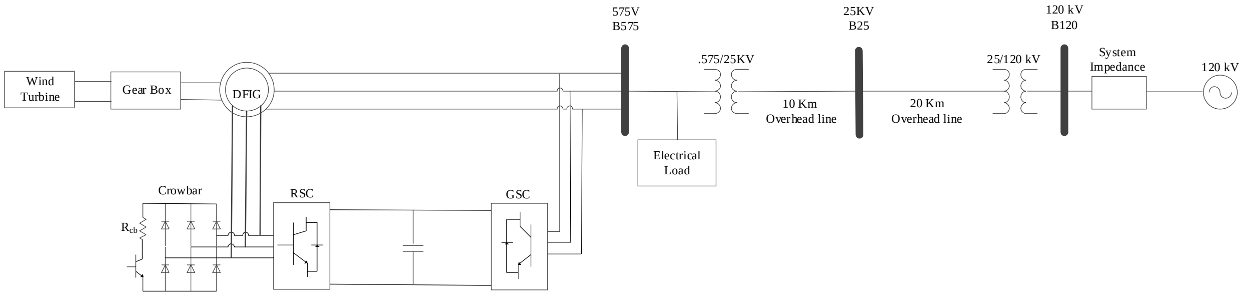

Fig. 1. DFIG-based WECS

A crowbar circuit is composed of switched bridge connected in series with the power resistor as shown in Fig. 2. A crowbar circuit is connected between rotor of the generator and RSC. When a fault occur at the grid end, high transient rotor current flow through the crowbar resistance due to voltage dip in the rotor circuit and RSC pulses are blocked [4].

When crowbar is active, DFIG is behaving as fixed speed induction generator with increased rotor resistance. Due to insertion of rotor resistance shifts the rotor speed at which pull-out torque occurs into higher speeds and reactive power absorption is reduced.

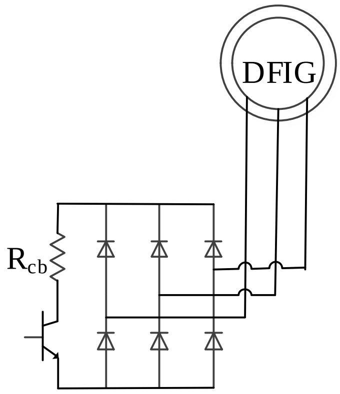

Fig. 2. Crowbar circuit

The value of crowbar resistance is very important. It should be low enough so that it can protect the converter terminal form the overvoltage and it should be high enough to limit rotor current. Thus a crowbar circuit is used to protect the DFIG based WT from dc-link overvoltage and rotor overcurrent.

Fig. 3 shows the proposed control of crowbar protection circuit. An enable signal is fed to power electronic switch when rotor current, i_r, exceeds the threshold value of i_{rt}, or if dc bus voltage, V_{dc} exceeds the threshold value of V_{dct}.

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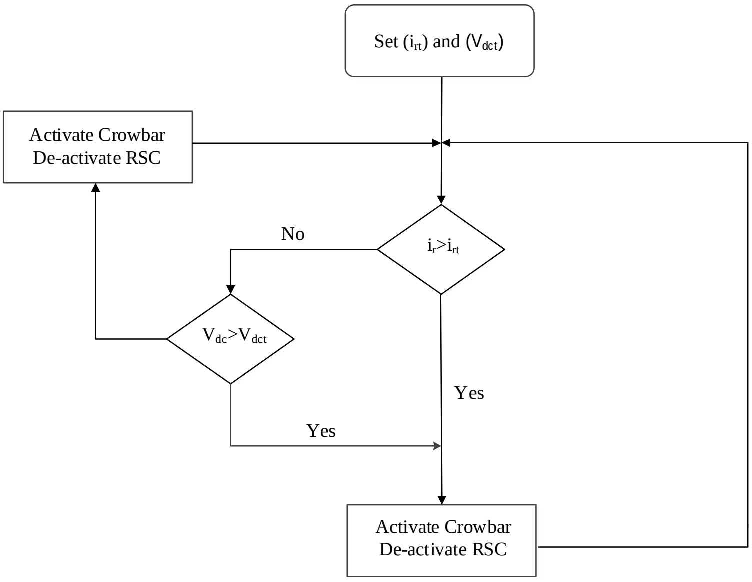

Fig. 3. Flowchart of proposed control scheme for crowbar

III. SIMULATION RESULT AND DISCUSSION

The projected method is simulated on MATLAB-SimPowerSystem. A symmetrical three phase fault is simulated at bus B25, which is known as point of common coupling (PCC). Fault is initiated at t= 12 s and cleared at t= 12.1 s. The dc bus voltage is set at 1150 V. Threshold value for rotor current and dc bus voltage is set at 1.5 p.u. and 1800 V respectively. Two studies are carried out, first one is for without protection and second one is with crowbar protection. For both the studies wind speed is taken as 13m/s.

Without Crowbar Circuit

A symmetrical three phase fault is initiated at 12 s for 100ms at the PCC without crowbar protection. Back-to-back VSC are controlled to feed reactive power during grid fault until fault recovery. Due to fault at bus B25, PCC voltage is reduced to zero during fault as shown in Fig. 4. Value of the stator voltage is corresponding to the reactive power fed to grid through DFIG as illustrated in Fig. 5. DC bus voltage is discharging during fault as shown in Fig. 6. During fault real power transmitted to grid is zero and DFIG is controlled to feed reactive power to grid as shown in Fig. 7, 8. Maximum value of rotor current is more than the double the threshold value as portrayed in Fig. 9. Fig. 10 and 11 shows that electromagnetic torque and generator rotor speed respectively, during fault.

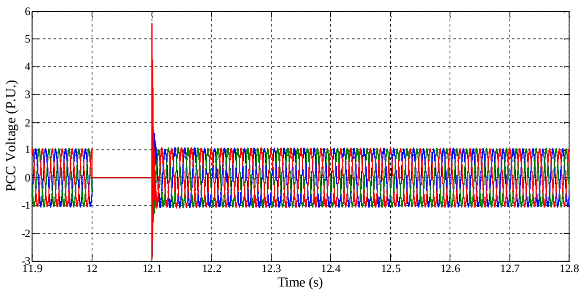

Fig. 4. PCC Voltage

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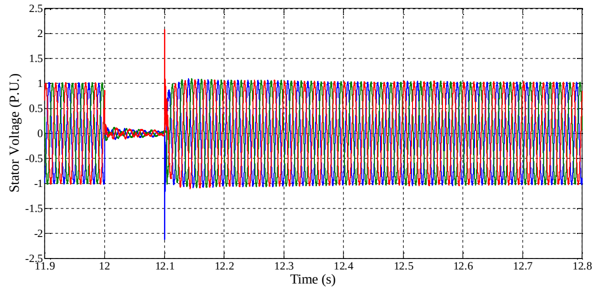

Fig. 5. Stator Voltage

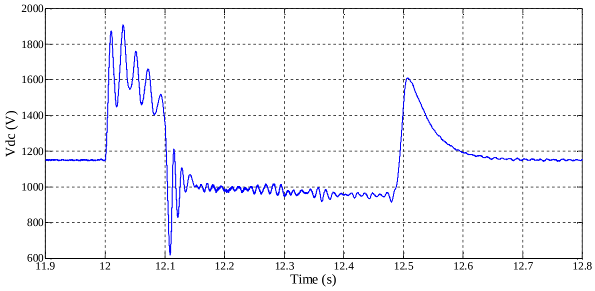

Fig. 6. DC bus Voltage

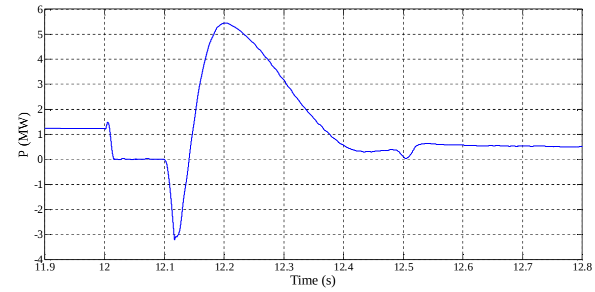

Fig. 7. Active Power fed to PCC from WECS

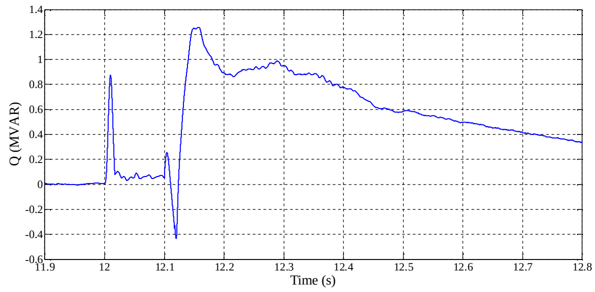

Fig. 8. Reactive Power fed to PCC from WECS

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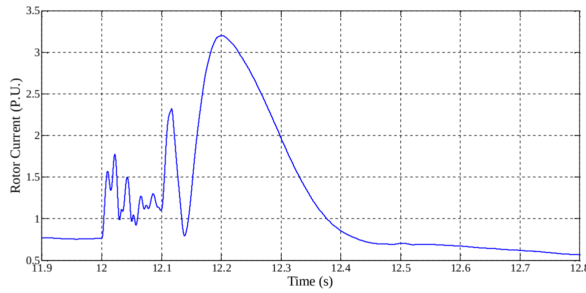

Fig. 9. Rotor Current

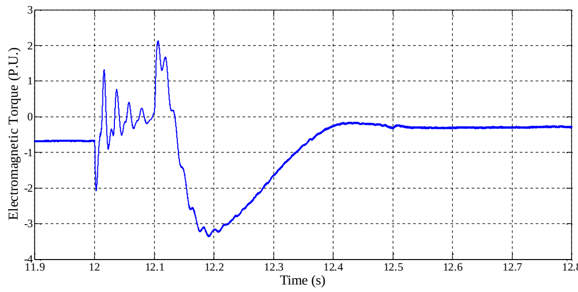

Fig. 10. Electromagnetic Torque

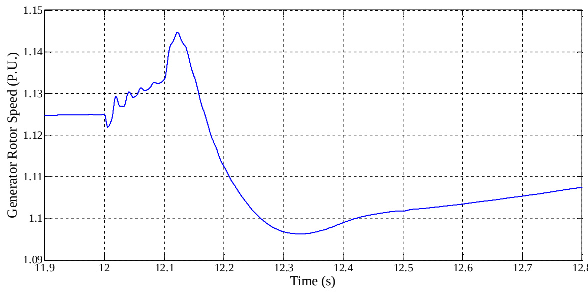

Fig. 11. Generator Rotor Speed

With Crowbar Circuit

A symmetrical three phase fault is initiated to the system for the same duration as for without crowbar protection. When dc bus voltage or rotor current value is more than the set threshold value, an enable signal is generated for the fraction of second as shown in Fig. 12. This enable signal is fed to power switch which is connected in series with the crowbar resistance and RSC is deactivated. A huge current is flowing through the crowbar resistance as portrayed in Fig. 13. DIFG is now working as squirrel cage machine. When rotor current and dc bus voltage is within limits RSC reconnected to system.

Comparing Fig. 7, 8 and 14, 15 shows that recovery period of the system increases in case of crowbar circuit because of increased reactive power drawn from the WECS to limit the dc bus voltage with in prescribed limit. Fig. 16 shows that shape of dc bus voltage is improved for crowbar circuit. Rotor current peak value is decreased by using the crowbar circuit as illustrated in Fig. 17. The activation of crowbar controls the transient in electromagnetic torque and generator rotor speed as portrayed in Fig. 18 and 19 respectively.

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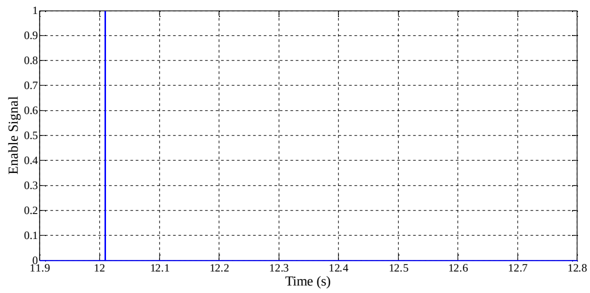

Fig. 12. Enable Signal

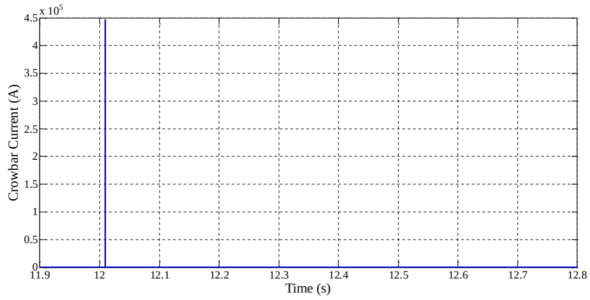

Fig. 13. Crowbar Current

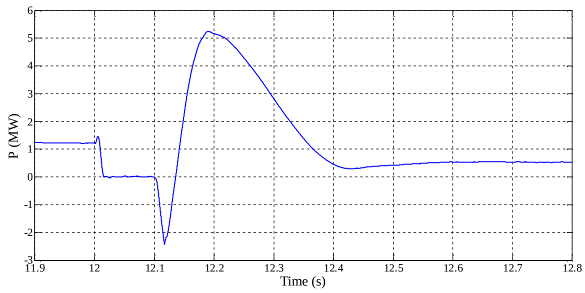

Fig. 14. Active power fed to PCC form WECS

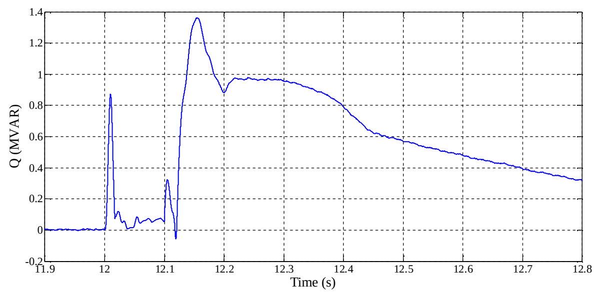

Fig. 15. Reactive power fed to PCC form WECS

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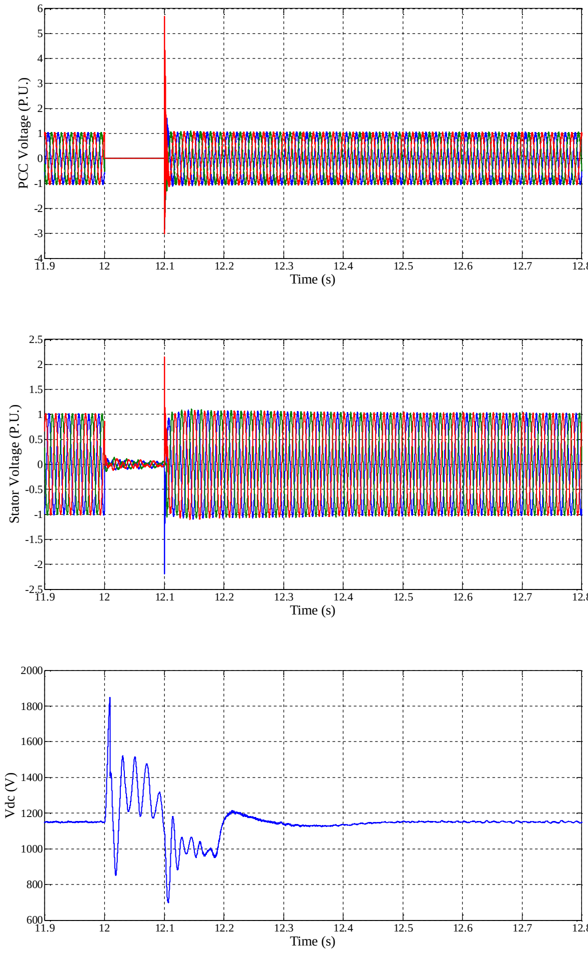

Fig. 16. The PCC Voltage, the Stator Voltage and dc-link voltage

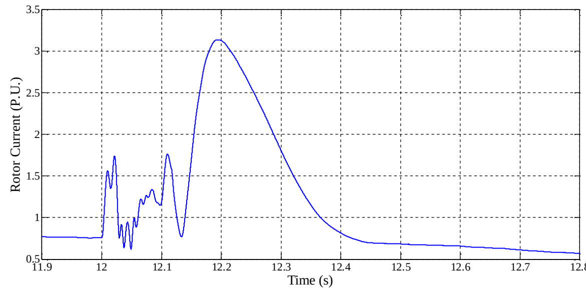

Fig. 17. Rotor Current

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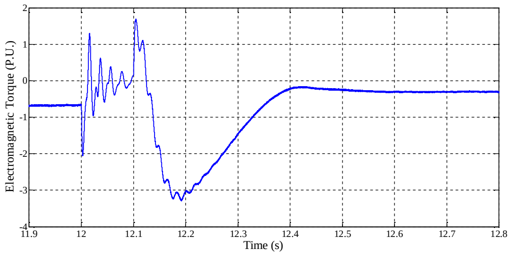

Fig. 18. Electromagnetic Torque

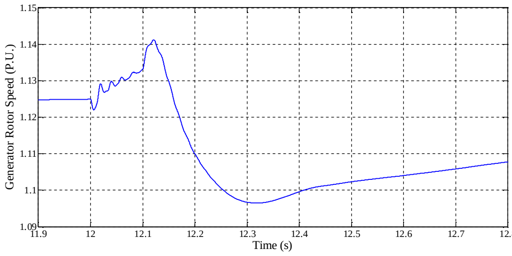

Fig. 19. Generator Rotor Speed

VI.CONCLUSION

This paper is mainly about protection scheme for the DFIG based WT system. A DFIG model is developed in MATLAB-SimPowerSystem, and crowbar protection scheme is verified. By the use of crowbar circuit, over current in rotor circuit and over voltage in the dc-link voltage is restricted within limits. In this paper symmetrical three phase fault at PCC is simulated to examine the system behaviour with and without crowbar protection.

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BIOGRAPHY

Nagendra Singh is a student of Masters of Engineering in Electrical and Instrumentation Engineering Department of Thapar University, Punjab, India. His research interest is in the area of renewable energy resources, microgrid (analysis and simulation).

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