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Enhancement of Low Voltage Ride through Capability for DFIG Based Wind Turbine with STFCL, DVR and Energy Storage System

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Abstract*: A Switch type fault current limiter in coordination with DVR is presented in this paper for Wind turbine generators that consist of doubly fed induction generators in order to full fill Low voltage ride through requirements in grid systems. The position of in-statement, the simulation and the methods for enhancement of LVRT functioning are represented. Collaborative control between the STFCL and a combination of Reactive power control and Inductance emulating control are used to enable the doubly fed induction generator to generate reactive power and ensure that the system remains safe even during faults in the grid. A different type of fault conditions are examined under both normal conditions and while the proposed system is attached.

***Index Terms*: DFIG, DVR, LVRT, STFCL.**

I. INTRODUCTION

Doubly fed induction generators which are the most commonly used generators in wind power system; generally have the drawback of poor low voltage ride through capability. The system is often unable to check over currents that occur in the system in times of voltage sag conditions and ends up harming the rotor side converter [1]. This frequently happens with tripping the particular circuit and hence there is a high risk of rotor voltage surpassing the allowed value.

The existing methods of enhancing the Low voltage ride through capability only address cases where the voltage sag is average but in situations [2] where the condition is high, an inductance emulation plan is used to repress rotor current that arises after the fault has occurred. In this method, the rotor side converted is used to act as an inductance [3]. Even so, the results obtained only showed a breakthrough in low voltage ride through within 80 %0voltage sag situations [4].

In such a case, Reactive power control cannot be carried out because it is insufficient to maintain voltage at the power control centre. Thus changes need to be implemented in the exciting methods and further development of hardware is required to boost capabilities in low voltage circumstances. Hardware improvements such as STATCOM, DVR, Crowbars can be used to give better performance in cases of high rotor current or when the voltage at the extremities need to be improved [5,6].

The downside of using crowbars is that they consume a high amount of reactive power and in addition are unable to prevent electromagnetic torque oscillations [7]. The STATCOM and DVR on the other hand may prove to be high cost when used in combination with the existing transformer and converters setup.

In a resistive type STFCL, the current passes directly through the superconductor. When it is extinguished, the fault current is reduced by an increase in resistance. A resistive FCL can be DC or AC. An AC FCL is usually made from wire wound non-inductively or else additional power loss would occur because of the inductance in the system. STFCL also exhibit excellent qualities in self starting, faster responses and quick recoveries [8]. The liability in such a situation is that often the STFCL alone cannot give adequate reactive power to grid to maintain grid voltage [10].

Consequently this paper aims to explore collaborative methods to give solutions.

In this technique, an advanced method for rotor side control which includes Inductance emulating control (IEC) and Reactive power control (RPC) [11] are used to restrict rotor current, ensure high reactive power yield and repress electromagnetic torque oscillations and are used in coordination with STFCL's which in turn also improves terminal voltage.

In cases of voltage swell and sag, the efficiency of the system is compromised. To prevent such an occurrence, DVR's are used to inject voltage so that the load side voltage amplitude and waveform is maintained to be as demanded by the system.

In other words, the DVR can inject or absorb independently controllable real and reactive power at the load side. Thus it is a solid state DC to AC switching power converter which injects a set of three-phase AC output voltages in series and synchronicity with the distribution and transmission line voltages [12].

II. PRINCIPLE AND TOPOLOGY

The purpose of including the IEC and RPC is to maintain the steady supply of reactive power.

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In instances where there is found to be a fault current which leads to a potential drop across the stator, that is far beyond the tolerable limit of the STFCL, the impedance progressively rises and causes a large voltage drop across the STFCL and thus acts as a passive voltage compensator.

When the grid fault does not exist, the impedance across the STFCL is zero because the current value is within the tolerable limit [13]. In the occurrence of an over-current the STFCL [9] goes into normal operation, thus suspending its super-conducting capability until the fault is resolved.

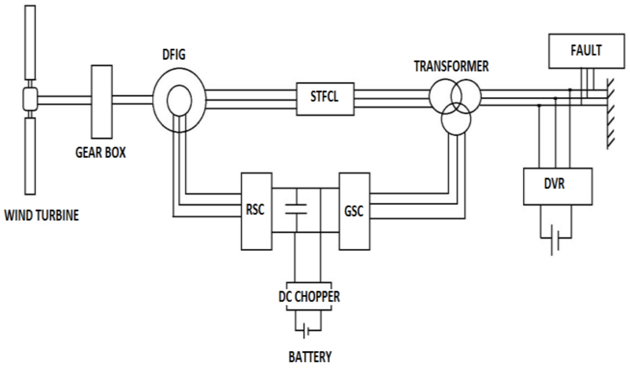

Fig 1. Block diagram of DFIG

III. CONTROL SCHEME

A chopper is connected to the RSC and GSC control and the output is fed to a battery [14]. When the excessive energy is generated, the surplus energy is stored within the battery for future use. The chopper is connected so as to obtain efficacious output.

IV. SIMULATION

The simulation is done in MATLAB 2013a. The whole system is divided into two parts, one is the main system and other is the sub system. The DFIG along with storage system and STFCL are provided in the sub system while the DVR and grid connection are provided in the main system [15]. When the fault occurs the system mustn't stop working, for this the STFCL is provided. But the STFCL and the storage system can't work at the same time. Either the STFCL works or the storage system is used to store the extra energy for future use.

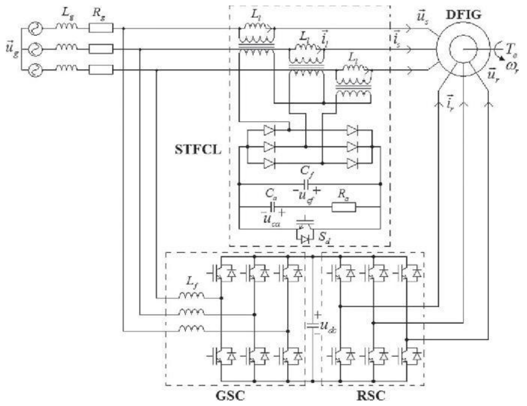

Fig 2. Schematic diagram of STFCL

The system is capable of handling several types of fault. The types of fault examined are: LG, LLG, LLLG, LL and LLL. All these faults are examined under two conditions first when the STFCL is switched off and second when the STFCL is switched on. The DVR calculates the voltage required by the grid and provides the voltage to the system when any fault

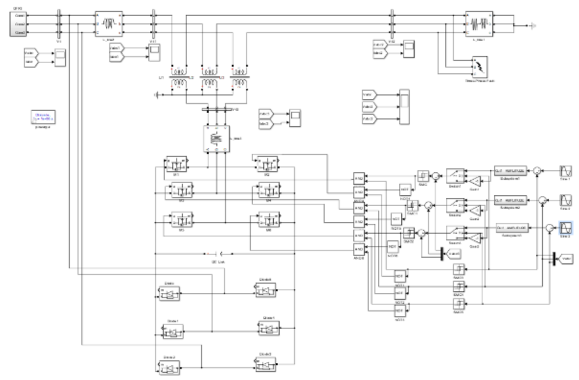

Fig 3. Simulation diagram of DFIG with DVR and grid connected systems

occurs. During normal level of supply voltage, the DVR is controlled so that the losses are reduced to minimum. When voltage sag is detected due to Fault, the DVR acts immediately and injects AC voltage into the grid. The DVR generally calculates the difference between the reference voltage and the injected voltage and produces load rated voltage.

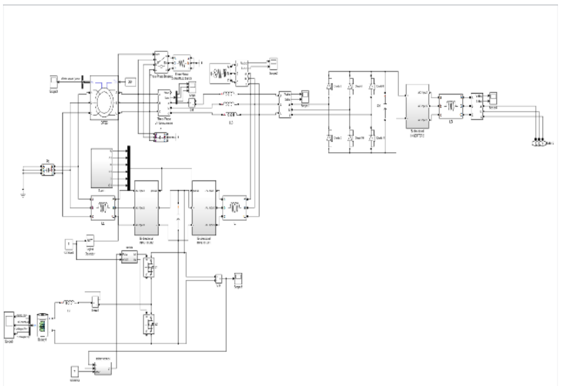

Fig 4. Simulation diagram of DFIG with energy storage system and STFCL

V. SIMULATION RESULTS

From fig 5. to fig 9. Indicates the various faults occurred in DFIG without STFCL and fig 10. to fig 14. Indicates the various faults occurred in DFIG with DVR and STFCL

All the possible outputs from the system are provided. When fault occurs, the compensation is done by DVR at the moment. In the meantime either STFCL will work or the battery will get charged according to the need. At 0.058s the Fault occurs and it is cleared at 0.063s. The compensated output in the grid is shown and that is the final output. The DVR compensates the voltage for the line in which the fault has occurred while the STFCL protects the system from over current.

This energy can be stored in the battery and thus can be used later. The battery is connected through a chopper for protection and quality output.

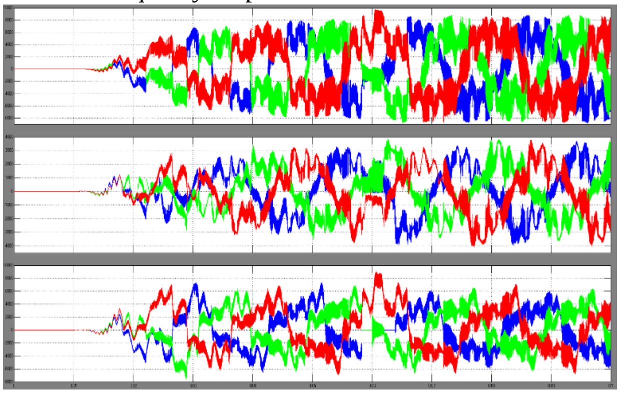

Fig 5. LLG Fault with DVR without STFCL

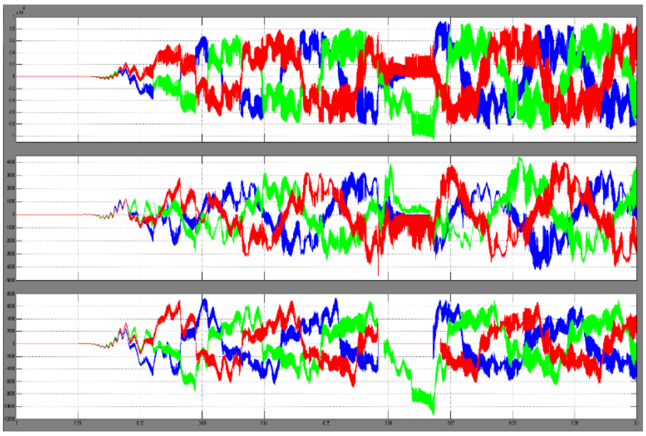

Fig 6. LLLG Fault with DVR without STFCL

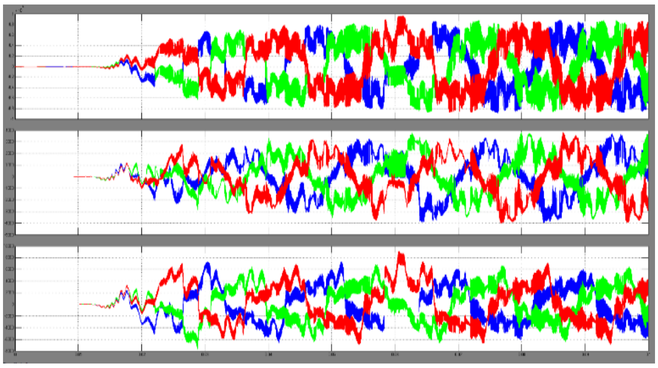

Fig 7. LG Fault with DVR without STFCL

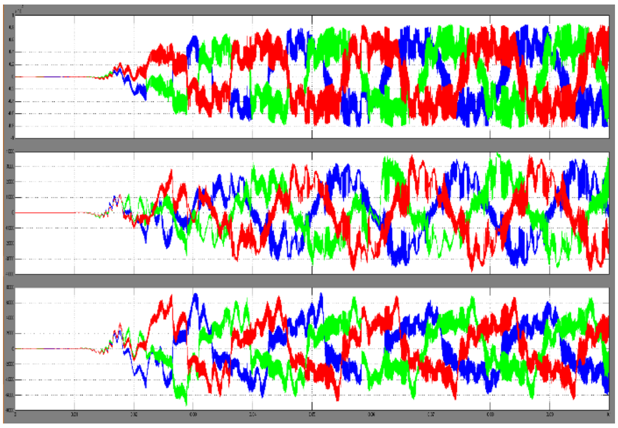

Fig 8. LL Fault with DVR without STFCL

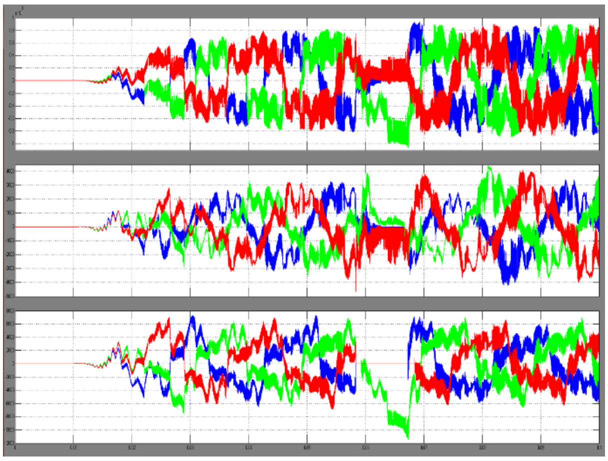

Fig 9. LLL Fault with DVR without STFCL

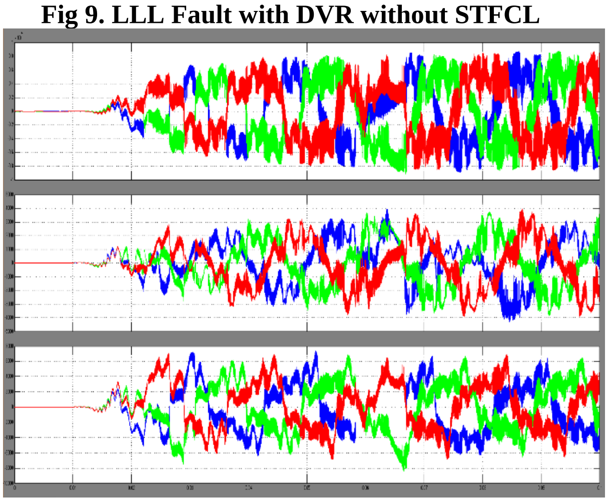

Fig 10. LLL Fault with DVR and STFCL

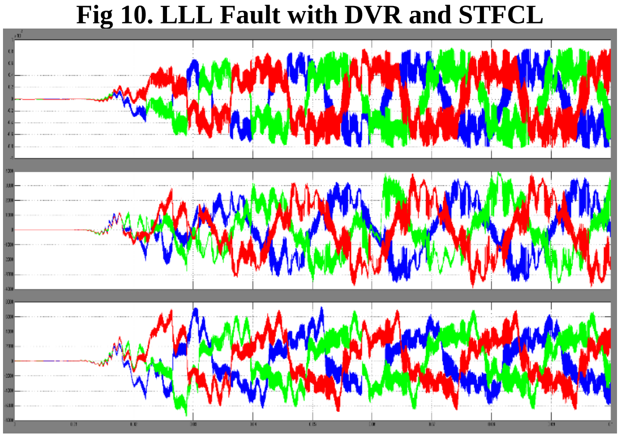

Fig 11. LL Fault with DVR and STFCL

VI. CONCLUSION

An all inclusive Low Voltage Ride Through strategy which uses STFCL, DVR and energy storage has been proposed and simulation has been conducted to evaluate the increase in efficiency in comparison with existing systems. The system has been tested under various fault conditions such as LG, LLG, LLLG, LL and LLL. The working of the proposed system is distinguished in conditions when the DVR only is present and when both DVR and STFCL are present. Consequently, improvement in low voltage ride through is observed and electromagnetic torque oscillations were reduced. Also energy decimation was reduced.

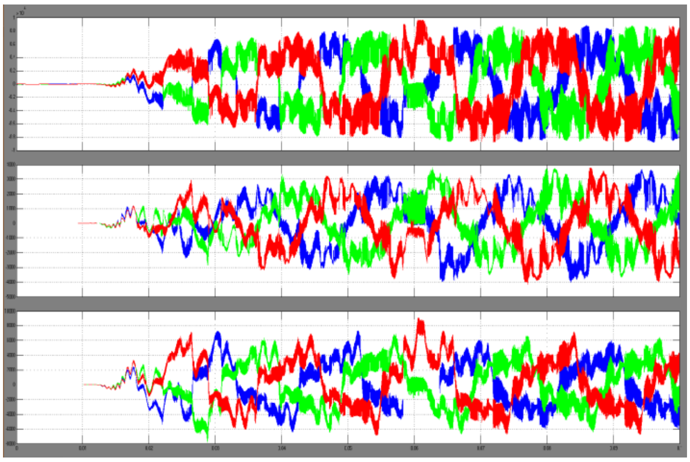

Fig 12. LG Fault with DVR and STFCL

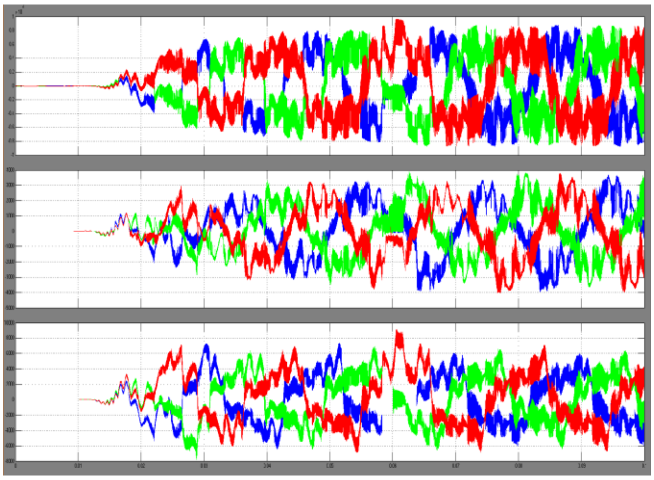

Fig 13. LLG Fault with DVR and STFCL

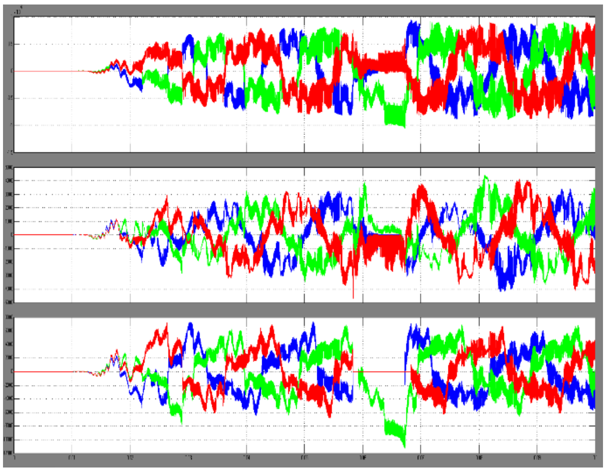

Fig 14. LLLG Fault with DVR and STFCL

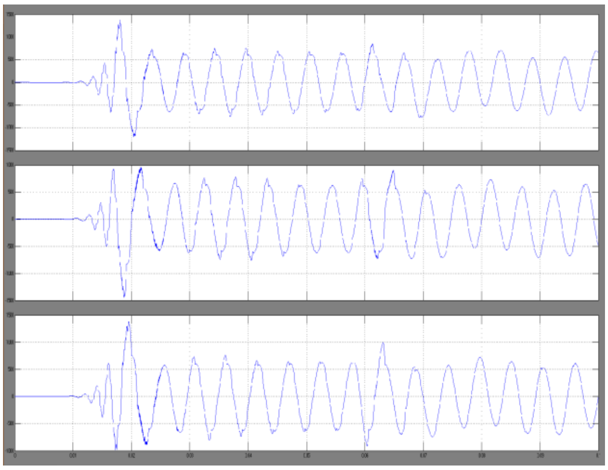

Fig 15. Current in three phases through STFCL during fault

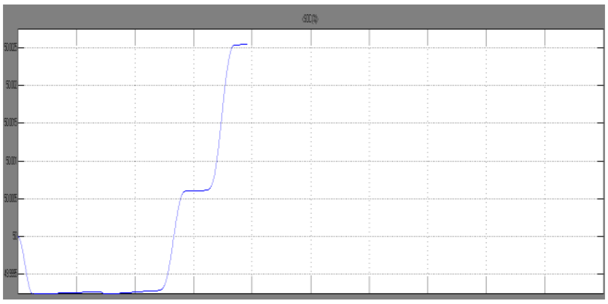

Fig 16. Charging of Battery

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