ENHANCEMENT OF STABILITY AND LVRT CAPABILITY IN DFIG BASED WIND FARM USING SMES AND SFCL

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***ABSTRACT**- In this paper performance analysis of Doubly Fed Induction Generator under abnormal condition is analysed. In recent years, this series compensated transmission system will produce unwanted effect of sub synchronous resonance. Super Conducting Magnetic Energy Storage (SMES) provides an efficient damping for sub synchronous resonance that will enhance power system stability in addition to real and reactive power compensation. Superconducting Fault Current Limiter (SFCL) which has the competence to limit the fault current and protect the equipments from damage. Simulation results are analysed with help of SMES and SFCL by means of MATLAB/SIMULINK.*

Keywords-Doubly-Fed Induction Generator (DFIG), Superconducting Magnetic Energy Storage (SMES), Superconducting Fault Current Limiter (SFCL), Sub Synchronous Resonance (SSR).

I. INTRODUCTION

In recent years more attention has been given to induction machines because they are used for low and medium power application. Attractive advantages over conventional generators are lower unit cost, less maintenance and robust construction etc. Doubly-Fed Induction Generators (DFIG) is particularly suitable for isolated operation like hydro and wind developments [1].

Doubly fed induction generators (DFIGs) are currently dominating the renewable energy market. Over the last decades, DFIG-based wind turbines have been most preferred option for the high capacity wind farms because it has the ability to control the active and reactive power exchange within the network. DFIGs have the capability to operate in variable speed regions so we have to achieve a smoothened and twice the power than any other conventional generator will produce. In the development of wind turbine techniques, DFIG is becoming more popular because of its unique characteristics such as high efficiency, low cost and flexible control [2].

Most of the wind turbines face a problem of LVRT. One common LVRT solution is to install a crowbar circuit across the rotor terminals. When the rotor over current is detected, the crowbar circuit short circuits the rotor terminals and isolates the converters from the rotor. And thus Rotor Side Converter triggering is blocked.

This provides conservative protection to the rotor circuit and the RSC changes the DFIG to a squirrel cage induction machine, which absorbs reactive power from the grid. As a result dynamic VAR compensators, such as static VAR compensators or static synchronous compensators are sometimes installed at the DFIG terminals to provide reactive power support during a grid fault [3].

Unbalanced grid faults degrade the performance of DFIG-based wind turbines. In fact, if voltage unbalance is not taken into account the stator and rotor currents will be highly unbalanced even with a small unbalanced stator voltage.

The unbalanced currents will create unequal heating on stator and rotor windings which will produce a complete change in torque and power pulsations of the generator which is twice the line frequency [4].

Several control approaches have been presented for DFIG systems operating with unbalanced grid faults. The rotor-side system is decomposed in two separate models which are represented with positive and negative-sequence components respectively. Two parallel controllers which are expressed in the positive and negative synchronous reference frame are also presented. The goal of the positive-sequence controller is to regulate the rotor side converter as in the case of normal operating conditions [5].

II.DFIG BASED POWER GENERATION

Now-a-days, the majority of wind turbines are equipped with Doubly Fed Induction Generators (DFIGs). In the DFIG concept, the wound rotor induction generator is grid-connected at the stator terminals as well as at the rotor mains via a partially rated variable frequency AC/DC/AC converter (VFC). This only needs to handle a fraction (25%-30%) of the total power to achieve full control of the generator.

The VFC consists of a Rotor side Converter (RSC) and a Grid-Side Converter (GSC) connected back-to-back by a dc-link capacitor. In order to meet power factor requirement (e.g. −0.95 to 0.95) at the connection point. Most wind farms are equipped with switched shunt capacitors for static reactive power compensation. Moreover because many wind farms are connected to electrically weak power networks characterized by low short circuit ratios and under-voltage conditions.

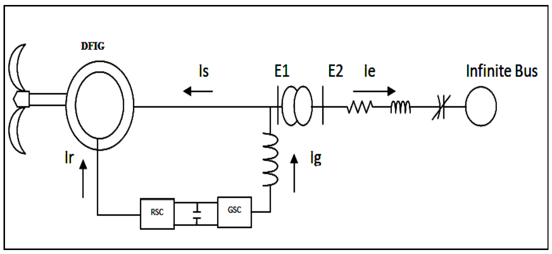

Figure.1 Schematic Diagram of DFIG

CONTROL OF ROTOR SIDE CONVERTER AND GRID SIDE CONVERTER:

The stator power under an unbalanced grid voltage condition can be obtained. This model provides a basis for system optimization, such as the minimization of the torque or power oscillations using RSC. The objective of the RSC is to govern both the stator-side active and reactive powers independently.

In order to achieve independent control of the stator active power Ps and reactive power Qs by means of rotor current regulation, the instantaneous three-phase rotor currents Ir_{abc} are sampled and transformed to d-q components i_{dr} and i_{qr} in the stator-flux oriented reference frame. Subsequently, Qs and Ps (thus the generator rotor speed d_r) can be represented as functions of the individual current components. Therefore, the reference values of i_{dr} and i_{qr} can be determined directly from the Qs and d_r commands.

The actual d-q current signals (i_{dr} and i_{qr}) are then compared with their reference signals (i_{dr} and i_{qr}) to generate the error signals, which are passed through two PI controllers to form the voltage signals v_{dr1} and v_{qr1}. The two voltage signals (v_{dr1} and v_{qr1}) are compensated by the corresponding cross coupling terms (v_{dr2} and v_{qr2}) to form the d-q voltage signals v_{dr} and v_{qr}. They are then used by the PWM module to generate the IGBT gate control signals to drive the IGBT converter.

III. SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES)

A SMES device is a dc current controlled device that stores energy in the magnetic field. The dc current flowing through a superconducting coil in a large magnet creates the magnetic field. The inductively stored energy (E in Joule) and the rated power (P in Watt) are commonly given in specifications for SMES devices and they can be expressed as follows:

$E= (1/2)LI2$

$P=dE/dt=LI\ di/dt=VI$

where L is the inductance of the coil, I is the dc current flowing through the coil and V is the voltage across the coil.

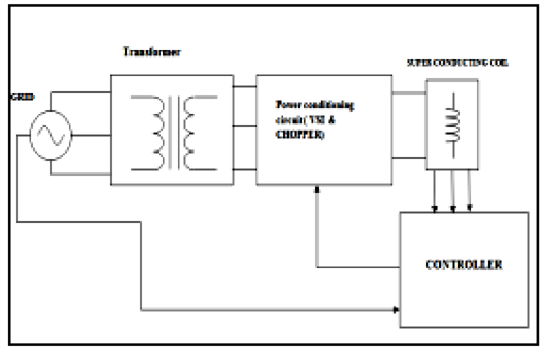

Figure.2 Components of a typical SMES system

A SMES system consists of a superconducting coil, cryogenic system and the power conversion or conditioning system (PCS) used for control and protection functions. SMES consists of

1. Power Conditioning System (PCS)
2. SMES Coil.

PROPOSED CONTROL SCHEME OF THE SMES SYSTEM

The proposed hierarchical control schemes of the SMES unit consist of an external, middle and internal level. Its design based on concepts of instantaneous power on the synchronous rotating d-q reference frame. This structure has the goal of rapidly and simultaneously controlling the active and reactive power flow provided by the SMES. For this aim the controller must ensure the instantaneous energy balance among all the SMES components. In this way the stored energy is regulated through the PCS in a controlled manner for achieving the charging and discharging of the SC coil.

IV. SUPER CONDUCTING FAULT CURRENT LIMITER

SFCLs utilize superconducting materials to limit the current directly or to supply a DC bias current that affects the level of magnetization of a saturable iron core. While many FCL design concepts are being evaluated for commercial use and improvements in superconducting materials over the last 3 years have driven the technology to the forefront.

This improvement is due to the ability of HTS materials to operate at temperatures around 70K instead of near 4K which is required by conventional superconductors. The advantage is that the refrigeration overhead associated with operating at the higher temperature is about 20 times less costly than the initial capital cost. SFCLs use the transition of superconductors from zero to finite resistance to limit the fault currents that result from short circuits in electric power systems.

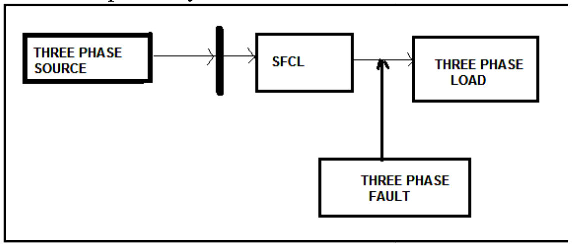

Figure.3 Block Diagram of Superconducting Fault Current Limiter

IMPROVING LOW VOLTAGE RIDE THROUGH CAPABILITY

Such short circuits can be caused by aged or accidentally damaged insulation by lightning striking an overhead line or by other unforeseen faults. If not deliberately checked, the subsequent fault current is limited only by the impedance of the system between the location of the fault and the power sources. The power grid holds some requirements for large-scale wind power to ensure its stability and to minimize the negative effects on the reliability of power grids, different countries have defined different low voltage ride through (LVRT) requirements for wind turbines (WT) in their grid codes.

To ensure the above requirement, the power grid requires the DFIG based wind turbine power system being connected to the power grid for a while in the lower voltage condition during the grid fault, which means that DFIG system should have fault ride through (FRT) capability for low voltage faults on the grid (LVRT) to prevent tripping of DFIG from the grid to assure reliability and without any damage to the DFIG system. In order to fulfil these LVRT requirements, the standard of LVRT requirement also included in grid code of different countries. The LVRT standard for American grid code is established as shown in Figure 4.

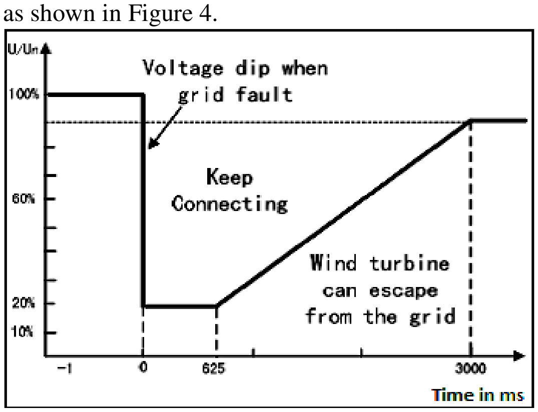

Figure.4 LVRT Standard of Grid code

IV. SIMULATION AND RESULTS

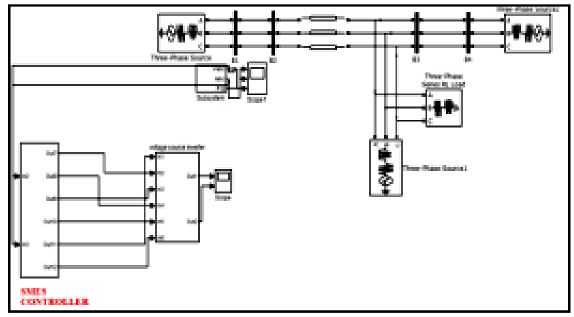

Figure.5 Simulation diagram of SMES with STATCOM controller

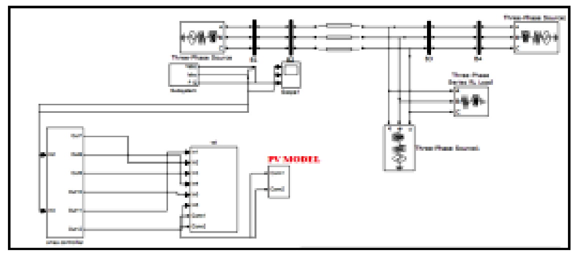

Figure.6 Simulation diagram of SMES based STATCOM with PV Cell input

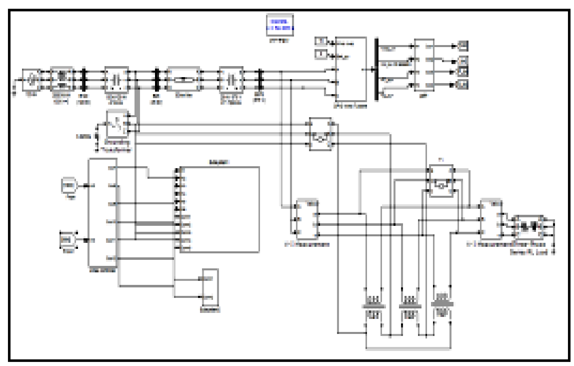

Figure.7 wind farm system with SMES and STATCOM

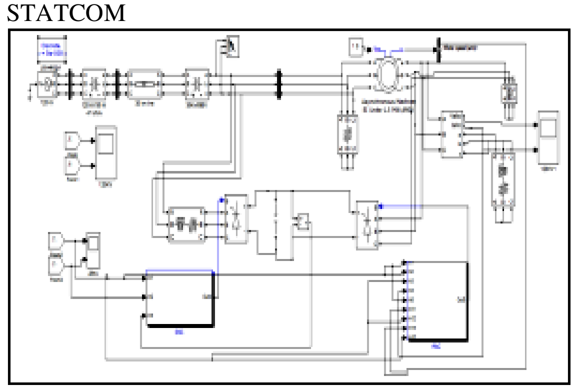

Figure.8 Modelling of DFIG based wind power generation under fault

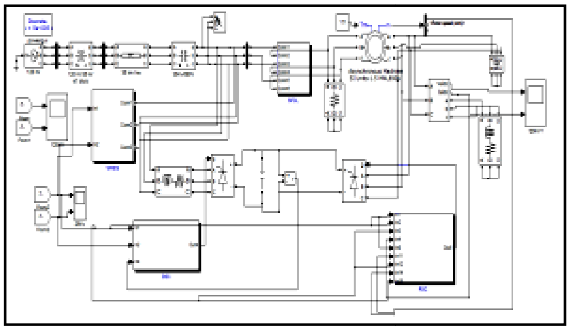

Figure.9 Coordinated operation of SMES-SFCL

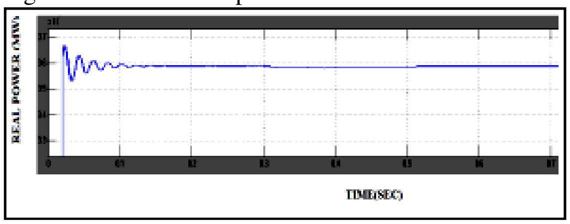

Figure.10 Real power variations in a Transmission Line

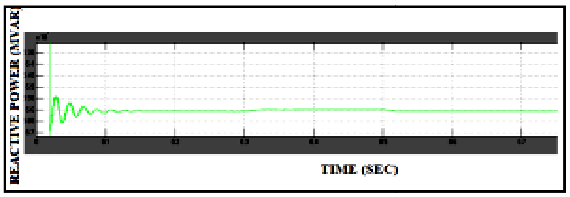

Figure.11 Reactive power variations in a Transmission Line

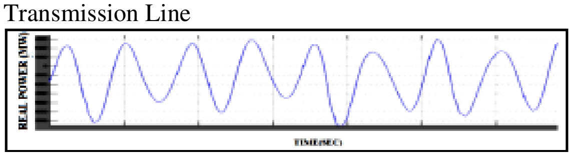

Figure.12 Real power variation

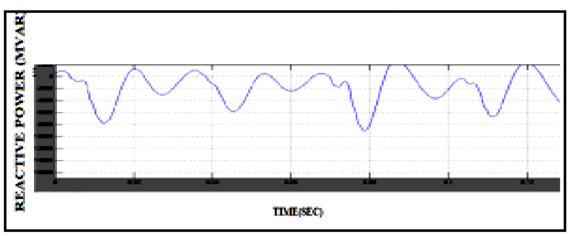

Figure.13 Reactive power variation

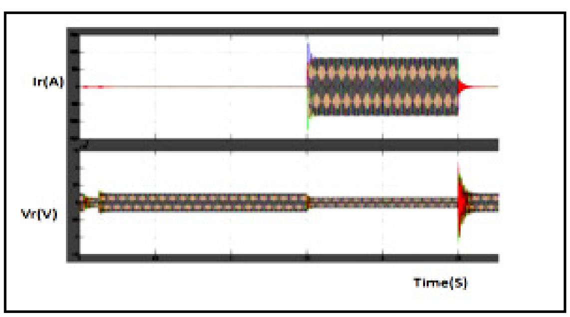

Figure.14 Rotor Voltage and Current

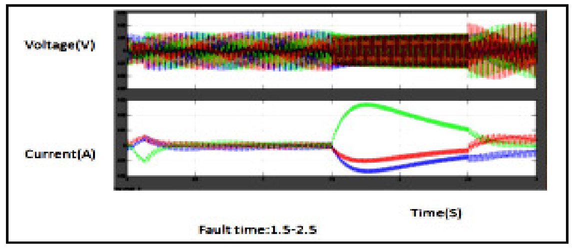

Figure.15 Voltage and Current in Stator and Grid

CONVENTIONAL CONTROL (CROW BAR)

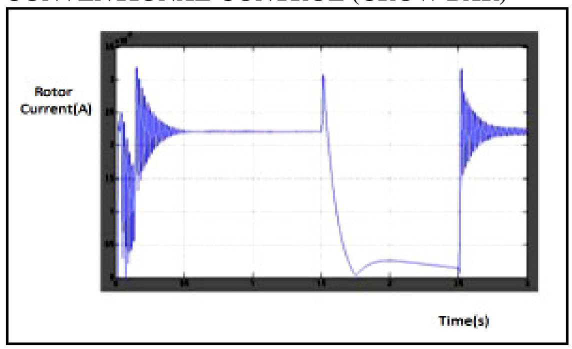

Figure.16 Rotor Fault current under crow bar method

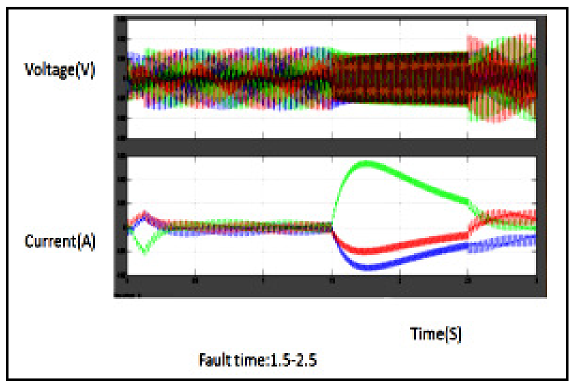

Figure.17 Limited Rotor voltage and current by the effect of SFCL

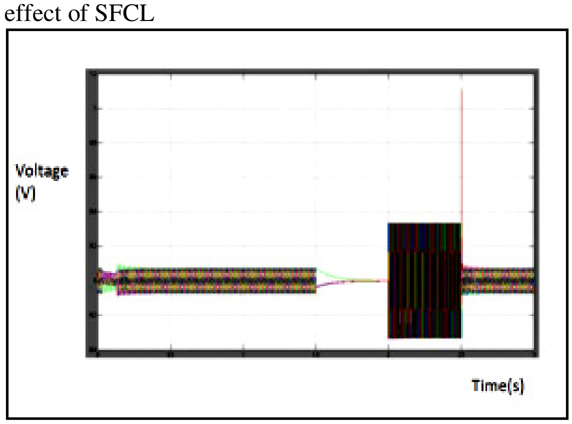

Figure.18 Stator Voltage by the action of SMES

V CONCLUSION

This proposed system has an effective SMES controller and SFCL for the stabilization and LVRT improvement in DFIG based wind power systems. SMES controller has an ability to control both active and reactive power in the line in addition to damp power system oscillation in a power system so it will provide power system stability. Superconducting Fault Current Limiter which has the competence to limit the fault current and protect the equipments from damage. It is used to improve the voltage unbalance in a transmission system.

Co-ordinated operation of SMES and SFCL is used to improve the overall performance. This new model is able to provide full ride through to the generator and power system capability can be improved. Simulation results are analysed using MATLAB/SIMULINK

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