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Transient Stability Enhancement of Hybrid Power System by Using Bridge Type Fault Current Limiter

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ABSTRACT: This system proposes a controllable resistive type bridge type fault current limiter (CR-FCL) to enhance the transient stability of a hybrid power system consisting of a photovoltaic (PV) power generation source, a doubly-fed induction generator (DFIG)-based wind energy system, and a synchronous generator (SG).The CR-FCL is designed such a way that it can provide sufficient damping characteristics to the studied power system. Appropriate resistance generation of the BFCL during a grid fault to provide better transient stability is the main contribution of the work. The effectiveness of the proposed CR-FCL in improving the transient stability and enhancing the dynamic performance of the hybrid power system is verified by applying faults in the power network.. Simulation results obtained from the Matlab/Simulink software show that the proposed FCL is effective in maintaining stable operation of the PV, wind generator, and synchronous generator during the grid fault.

KEYWORDS: Doubly fed induction generator (DFIG), Controllable resistance bridge type fault current limiter (CR-FCL), photovoltaic (PV), Synchronous Generator (SG).

I. INTRODUCTION

Rapid depletion of the traditional sources of energy as well as the perpetual increase in energy demand in today's fast growing world has made the renewable energy as a hot research topic. The cost of the photovoltaic (PV) installation is gradually becoming low, and hence its growth is proliferating day by day. Among the renewable energy sources, the solar energy will attain the top position and full-fill almost 28% of world's total energy demand by 2040 [1]. On the other hand, the wind energy generating system (WEGS) today is an established source of renewable energy with its rapid growth. Due to their numerous advantages, such as maximum power extraction[2], more efficiency, decoupled active and reactive power control, and enhanced power quality, the variable speed wind generator(VSWG) systems are gaining more popularity over conventional induction machine-based fixed-speed wind-generators. Moreover, the simple and rugged construction, low cost, ability to capture the maximum energy from a wide range of wind velocities, and partially rated ac/dc/ac converter for generating variable frequency, make the doubly fed induction generator (DFIG) the preferred choice over other wind generating systems [3].

Transient stability is the property of a power system to regain its normal operating condition following sudden and severe faults in the system [4]. The transient stability study is extremely important for maintaining the continuity of the power flow and properly controlling the modern electrical power systems with multiple renewable energy sources integrated to it. Compared to the wind generators with full rated inverter/converters, the DFIG systems are extremely sensitive to the grid abnormalities, as their stators are directly connected to the grid. A grid side fault causes the terminal voltage of DFIG to go very low, which results in very high current through the stator and the rotor windings may hamper the stable operation and damage the machine. Several reports on minimizing the adverse effects of grid

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disturbances on the DFIG-based wind farms [5–11] are available in the literature, and the issues of enhancing the stability of the power networks including both wind synchronous generators (SGs)by flexible ac transmission system (FACTS) devices are addressed in [12–15]. On the other hand, the occurrence of the grid faults causes the imbalance between the PV generated power and power inserted by the voltage source inverter (VSI) to the grid.

Due to this power imbalance, there is a sharp rise in intermediate DC link voltage and also an over current at the AC side of the VSI, which may result in damaging of the power electronic interfaces [16]. The adverse effects of large-scale penetration of PV power to the grid on the power system stability have been reported in [17].The integration of a large scale hybrid renewable energy plant consisting of PV, wind, and marine-current to the grid is reported in[18–20]. Large scale penetration of these renewable energy sources into the power grid leads to an enhanced short-circuits power level. Moreover, the circuit breakers with their certain turn-off capability, cannot suppress the pick current.

Fault current limiters (FCLs)are extensively employed in the power system networks for sup-pressing the fault current. In the literature, various types of fault current limiter are proposed such as resistive-type FCLs, inductive-type FCLs, superconducting FCLs (SFCLs), flux-lock-type FCLs, DC reactor-type FCL, and resonance-type FCLs [21–26]. The application of the FCLs in the power systems is not only to suppress the peak of the short-circuit current, but also for other power system applications, such as power system transient stability augmentation, fault ride through (FRT) capability enhancement of wind generator, power quality improvement, and reliability improvement. Literature shows that coordinated operation of SFCL and SMES is employed at the PCC to enhance the FRT and the power fluctuation minimization purpose of DFIG-based wind farm [27].Switched-type FCL and high temperature superconducting fault current limiter (HTS-FCL) are employed in [28,13], respectively, for enhancing the FRT capability of the DFIG-based wind generator.

Resistor-based superconducting fault current limiter (SFCL) [25,29]and HTS-FCL [30] are placed at the PCC point in order to enhance the transient stability of synchronous generator (SG)-based single-machine-infinite-bus (SMIB) power system. Dangjin power plant, operating under utility company Korean Power Exchange (KPX),has multiple thermal power generating units connected to a common bus (PCC), and SFCL is placed at the PCC to enhance the power system stability [31].Besides the above mentioned applications of FCLs for the stability purposes, the high-voltage direct-current (HVDC) link joined with a damping controller based on adaptive-network-based fuzzy inference system (ANFIS) utilized in [18], for enhancing the transient stability of a hybrid system consisting of PV, wind, and marine current energy generator.

The static synchronous series compensator (SSSC) [32], series dynamic braking resistor (SDBR) [33], static var compensator (SVC) [34], and static synchronous compensator(STATCOM) [12] are employed for enhancing the stability of the hybrid power system consisting of DFIG, permanent magnet synchronous generator (PMSG), and SG-based power systems. Applications of SMES for enhancing the dynamic performance of grid-connected wind and PV generating systems are reported in [35].Some of the above mentioned FCLs and other auxiliary means of enhancing the stability incur additional cost due to the use of converters, coupling transformers, and filters. SFCL employs superconducting inductor and some of the bridge-FCLs use trans-former for the coupling purpose incurs high manufacturing cost.

Because of the high cost of SFCLs, they are not commercially avail-able in the markets. It is important to investigate a cost-effective and new method for transient stability improvement of hybrid power systems. Due to its simplicity and low cost, the non-super-conducting fault current limiter [26] is a promising technique for enhancing the transient stability of the power system [36] and improving the fault ride through capability of the wind generators[37]. Resonance-type FCLs suppress the fault current by exploiting various configurations of series or parallel LC resonant circuits [38]. However, the impedance imposed during the fault event for PRBFCL has more impact than the BFCL, because of the presence of capacitor and multiple resistors for the power evacuation. In this work, in order to augment the transient stability capability enhancement of a hybrid power system consisting of a DFIG-based wind generator, a PV generator, and conventional synchronous generator (SG), a controllable type fault current limiter (CR-FCL) is proposed. So far, the CR-FCL has not been investigated as an auxiliary means for improving the transient stability of the power systems. During the severe voltage dips, volt-age source inverter (VSI) of the PV and grid side converter

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(GSC) of the DFIG is utilized for the reactive current injection according to the E.ON grid code [40]. FRT scheme of PV which includes DC-link voltage suppression by controlling DC/DC boost converter of the PV system is also implemented and analyzed. Bridge type fault current limiters have been utilized to enhance the transient stability during fault. Fixed impedance has entered the fault line which is not appropriate in providing maximum stability of the power system. Controllable resistive type fault current limiter will be presented to improve the stability.

The effectiveness of the proposed scheme for enhancing the transient stability is verified by considering a test system consisting of one synchronous generator-based single machine infinite-bus system, to which one DFIG-based wind farm and a PV farm are integrated through a short transmission line. By limiting the fault current and improving the voltage sag at the point of common coupling (PCC), the proposed method makes the power sources of the hybrid system stable during the grid fault Extensive simulations were carried by using the Matlab/Simulink software.

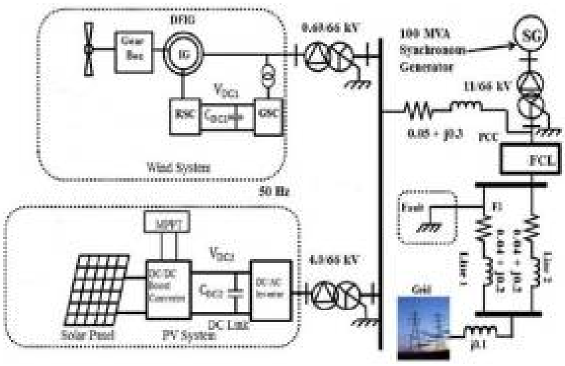

Fig.1 Hybrid Power System Model

II. PROPOSED SYSTEM

The power system model as shown in fig.1 for transient stability enhancement. It consists of one synchronous generator(2MVA),DFIG based wind system(1.5MW) and PV system(1MW) are integrated through a short transmission line. PV modules connected in series-parallel combination to attain desired power. The CR-FCL placed at the grid point as shown in fig.1.

III. THE PROPOSED CR-FCL

The three phase power circuit topology of the proposed CR-FCL shown in fig.2. The three phase transformer is known as isolation transformer is located in series with the power system. In addition a three phase diode rectifier bridge is used to insert dc resistance into the ac side of the proposed CR-FCL. The resistance placed in parallel with a self-turnoff switch,

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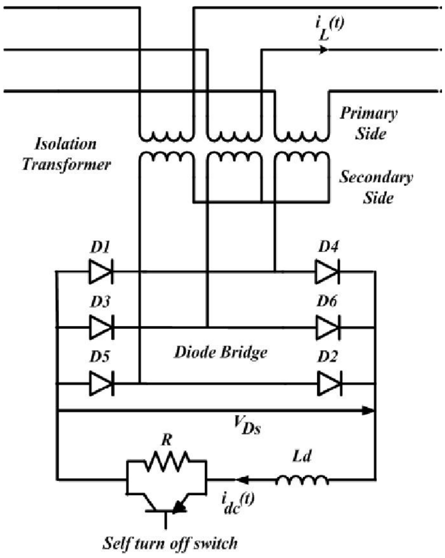

Fig.2. Proposed CR-FCL

plays the main role in limiting the line current during the fault. It is obvious that the line current will increase intensely in the first moments of the fault. So, to protect the self-turnoff switch against the severe line current variation, a small value of dc reactor, is placed
in series with the switch.

The proposed structure does not affect the normal operation of the power system because is bypassed by the self-turnoff switch. When a fault occurs, the current of the induction generator increases immediately. When this current reaches pre-specified value, the proposed control method is employed to the CR-FCL. Therefore, the self-turnoff switch starts switching with a pre-defined frequency, and a duty cycle, By using this special switching pattern, the proposed CR-FCL is able to insert a controllable value of the resistance to the fault line. So, the fault current is limited to the desired value which makes the maximum stability of the proposed system. After the fault removals, the CR-FCL returns to the pre-fault condition.

IV.FCL CONTROL STRTEGY

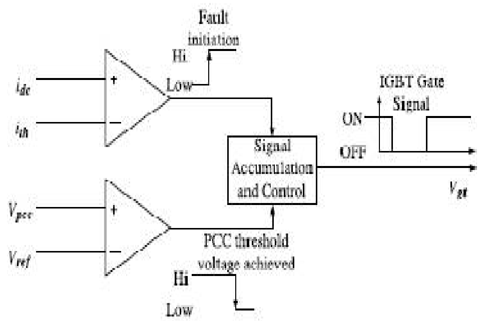

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Fig.3. FCL Controller

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There are some parameters, such as the line current, the line voltage, the generator terminal current, the active and the reactive powers that can be used in the BFCL control strategy. Here,
the dc current *i*dc, through the dc reactor is used to control the IGBT switch. The dc reactor current is very sensitive to current through the line and its rate of rise is faster than the line current or other parameters. So, by using *i*dc as a control parameter, faster control is achieved. This is only used to turn off the IGBT, as *i*dc becomes almost zero after IGBT opening. So, to turn on the IGBT, choosing another control parameter becomes necessary. Maintaining the voltage at the machine terminal is important to
retain the transient stability, so the voltage at the PCC, *V*pcc is the best choice. As the voltage at the PCC, *V*pcc crosses some predefined reference value *V*ref , the IGBT is closed after a preset delay period, provided that the circuit breaker is opened. As the IGBT is turned on, current flows through the bridge and the normal operation continues.

V. SIMULATION RESULTS

Hybrid power system is subjected to balanced and unbalanced faults. Simulation results are as shown below.

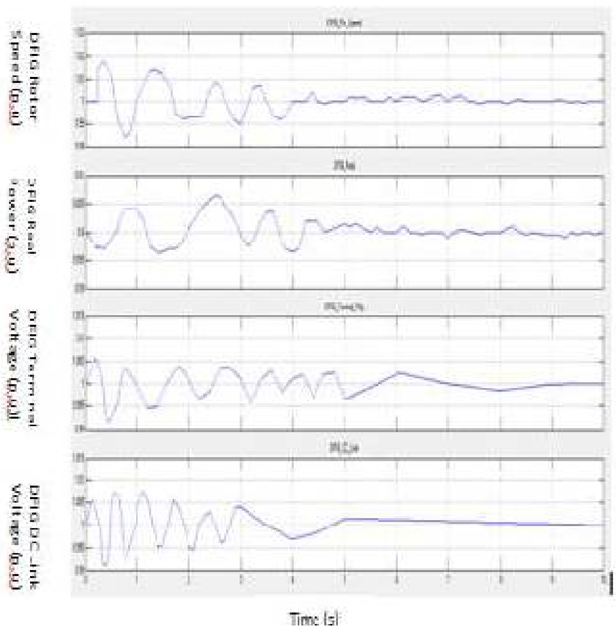

Fig.1 DFIG without FCL

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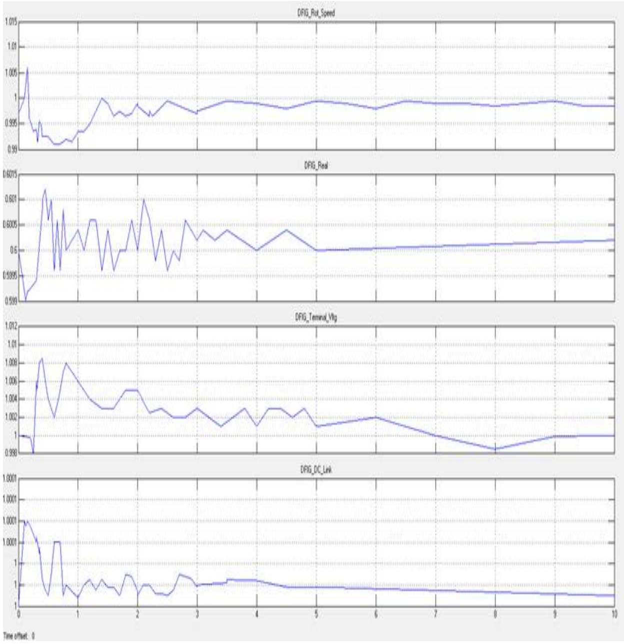

Fig 2 DFIG with FCL

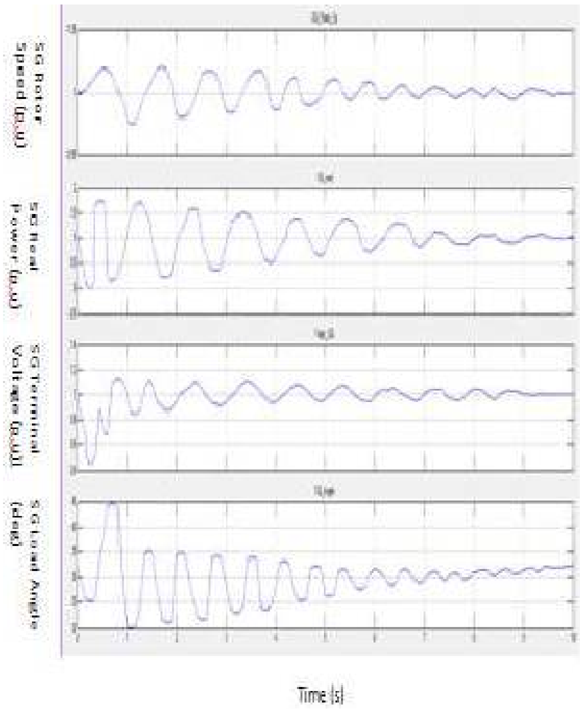

Fig .3 SG with out FCL

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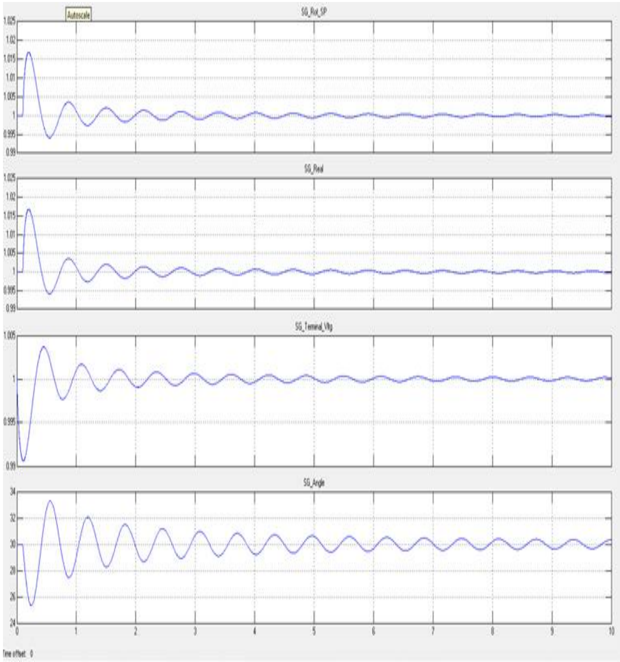

Fig 4.SG with FCL

From the results It is clear that the transient stability of the system is improved with the proposed FCL.

VI.CONCLUSION

This system proposes the application of a FCL to enhance the transient stability of a hybrid system consisting of a wind generator, a PV system, and a synchronous generator. Effectiveness of proposed method is verified by simulating the output in Matlab simulink software

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