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# A Modified Bridge-Type Fault Current Limiter for Fault Ride Through Capacity Enhancement of Doubly Fed Induction Machine (DFIM)-Based Wind Generator

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***Abstract—*** ***Transient stability a crucial aspect for doubly fed induction machine (DFIM). A DFIM-based arrangement is adversely operated due to faults, as the stator of generator is linked with the power grid. Even so, there is a obligation for the wind generator to be allied even during fault conditions. Hence , it is much crucial to increase the short-lived stability of the DFIM. For getting better stability of the DFIM, a R- type solid state fault current limiter is suggested in work. Here grounded faults were performed on test system to verify the upshot of the BFCL in transient stability enhancement. Simulations were done in SIMULINK domain. To illustrate the presentation of the proposed modified BFCL(R-SSFCL), its performance is compared with that of the SDBR & conventional BFCL. Simulation results gives the information that the modified R-SSFCL is a good efficient device rather than series dynamic braking resistor(SDBR).***

***Index Terms—*** ***R-type solid state fault current limiter(R-SSFCL), Bridge-type fault current limiter (BFCL), series dynamic braking resistor (SDBR).***

## I. INTRODUCTION

The advancement of technology and industries are raising world-wide increment in electrical demand By concerning green issues and limited resources of fossil fuels leads to non-conventional energy sources. Among the accessible renewable sources, wind is the fastest mounting and most protruding possibility to turn out electric power. It is expected that roughly 10% electricity of global demand will be delivered from the wind energy by the year 2020.

. owed to tractability in operation and enriched features greater improvement in power quality, and efficiency. Decoupled mechanism of reactive and active power, the flexible speed wind alternator are drawing higher devotion than the classical induction machine-based fixed speed wind generators. DFIM is considered as a ultimate option over the other choices due to its lower cost, partially rated converter, structure, durability, low losses and wide range control of wind speed. In view of stability, DFIM is more sensitive to disturbances because the stator windings are coupled to grid and the windings of rotor are interfaced to grid via the RSC and of grid side converter via a dc link capacitor. If grid fault occurs, there is a much decrement in voltage and severe current flows in windings of the stator & rotor which leads to instability and eventually it may damage the converters and the machine. Classically to defend such faults, wind generators were discoupled. But it is necessary that wind turbines are to be coupled to the grid due to the amalgamation of much more wind power. So for these reasons, there is a need of improved stabilization and fault-ride through facility for the DFIM.

During faults, DFIM topology has the ability to maintain stability. As the converters have partial rating, their capacity is insufficient to ensure stability so there is a constraint of auxiliary devices with small capacity. In order to defend the stability criteria, an auxiliary device like synchronous capacitor is proposed. But it needs a coupling transformer, an additional compensator and harmonic filters. For storage of energy a flywheel energy storage system, and SMES are also proposed which increments the cost and performance.

A new technique called BFCL is proposed, however the BFCL is never used to enhance the transient stability of DFIM. In this report BFCL performance on enhancing the stability of DFIM is being investigated.

The BFCL effectiveness is being demonstrated via test-drive wind energy translation scheme which has of a transformer, the double circuit transmission lines attached to the in-finite bus and wind turbine furnished with a DFIM. To verify the efficacy of proposed approach a temporary unsymmetrical and balanced faults were smeared at the utmost vulnerable end of the system and its feat is paralleled with SDBR.

This tabloid is systematized as follows. The DFIM modeling, the wind turbines are discussed in Section II. The intending, operation and controlling of SDBR, BFCL are illuminated in Sections IV and III respectively.

## II. TURBINE OF WIND AND DFIM MODELING

The intend of the turbine is done by considering a single mass system. Basically DFIM it-self is an induction generator with the windings of stator coupled directly to the grid and via ac/dc/ac converter manageable windings of the rotor are coupled to the grid as shown in Fig. 1 which also shows the assessment system model along with the parameters of line. Through a step-up transformer at the PCC which is coupled through line, 2-MW DFIM is coupled. In akin trend SDBR is coupled. sculpt of the converter controllers, the DFIM, and the turbine are exemplified in the succeeding sections.

### A. Design of Wind Turbine

A simple method modeling of a turbine is generally used by ignoring various geometric and physical concerns. The mechanical power yoked from the wind, can be expressed with help of known scientific equations.

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### B. Design of DFIM

In order to model the DFIM an approach called Park's transformation model i.e., a fifth-order two-axis exemplification is proposed. A synchronously rotating d-q frame of reference in which d—axis allied with the flux of stator with the equivalent speed as the stator flux.

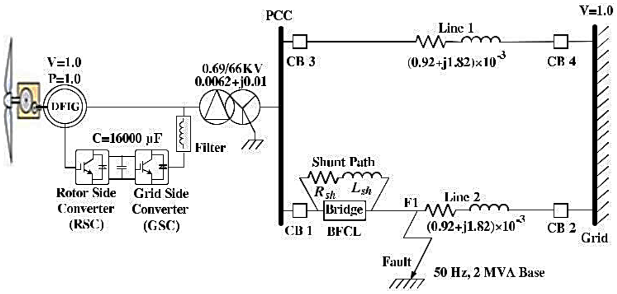

*Fig.1Basic diagram of DFIG with grid connection.*

TABLE I
WIND TURBINE DATA

| Characteristic | Value |
|---|---|
| Turbine type | Three blade horizontal axis |
| Radius | 46 m |
| Rotor speed | 18 r/min |
| Air density | 1.225 kg/m$^3$ |
| Cut in wind speed | 4 m/s |
| Rated wind speed | 12 m/s |
| Tower height | About 100 m |

TABLE II
WIND GENERATOR DATA

| Generator characteristic | Value |
|---|---|
| Nominal power (P) | 2 MW |
| Rated voltage (V) | 690 V |
| Stator to rotor turns ratio | 0.3 |
| Rated frequency | 50 Hz |
| Stator resistance (Rs) | 0.0108 p.u. |
| Stator inductance (Ls) | 0.102 p.u. (referred to stator) |
| Rotor resistance (Rr) | 0.0121 p.u. |
| Rotor reactance (Lr) | 0.11 p.u. (referred to stator) |
| Mutual inductance (Lm) | 3.362 p.u. |
| Lumped inertia constant (H) | 0.5 s |

### *C. RSC – controller*

It is a two-leveled IGBT based six pulses full bridge ac-dc converter, which couples the side of rotor to dc link. It takes input as a V_t,P_t,(Qt), and monitors outputs input pulses are generated by SVPWM. By Park's transformation 3-phase quantities are converted to equivalent d—q components and vice-versa. With the help of PLL a slip angle is produced by paralleling the rotor position and voltage angle which is used in Park's block.

### *D. GSC- Controller*

It is also has a two-leveled IGBT based six-pulse full bridge ac-dc converter with the side of ac interfaced to grid and dc-dc link .At the connection point to keep a constant power factor this converter is employed by selecting an proper switching frequency i.e., 1650 Hz so as the harmonics falls to minimum. It takes input as rotor line reactive power(QL) the dc-link voltage(Edc) and yields the required outputs which generates a requisite pulses by SVPWM for the GSC converter., the constraints of PI controllers parameters which uses a transfer function are preferred in same way that they offer the greatest possible performance for the structure under concern. Need of regulation of the RSC and GSC controller parameters is vital whilst the parameters of DFIM differs from that of Table II.

## III. BFCL

The thorough intend of the anticipated BFCL is as follows.

### *A. Arrangement of BFCL*

The BFCL is categorized of two units, namely the shunt path and the bridge part .The first part the bridge part which is equipped by a few diodes D1 -D4, and a small-valued dc reactor Ldc paralleled with a free-wheeling diode D5 coupled in series with an IGBT switch organized as revealed in Fig. Rdcis the inherited resistance of inductor considered which is of small value.

The latter is a shunt path comprises of Rsh and Lsh sited in parallel to the former part as in Fig.2

### *B. Operation of BFCL*

Bridge part residue bunged in normal action. For one half cycle the path is D1 -Ld c -Rd c -D4 , carries the current and for the remain half it chooses a path of D2 -Ld c -Rd c -D3 .Ldc charges to the maximum current and bids no impedance to idc . Switching wastes are minor, so the bridge has zero effect on steady state. High impedence should be offered to shunt path so that the whole current is flown through the bridge. During fault there is an abrupt increment in the line current. A safe operation is achieved by an dc reactor which limits the increasing current, id c is paralleled with reference value of maximum current ith which makes IGBT turns off. Optimal rate of ith is preferred because lower value causes un-wanted engaging and higher causes delay in reaction. ith is supposed to be 1.3 times the nominal rate of idc. When idc exceeds ith IGBT turns off, bridge gets open circuited, current gets bypassed through shunt path which has a high impedance therefore fault current gets limited and consumes excess energy from DFIM. When bridge gets open circuited free-wheeling diodes afford a path to discharge the accumulated energy.

After the fault gets isolated, the structure recovers and there will be a rise in bus voltages. The insertion of shunt path in string to the line is decided by paralleling PCC voltage Vpcc with a predefined reference value Vref.. Optimal value of Vref. is chosen i.e., 90% of nominal because lower value may results in high currents and higher value delays the reaction of BFCL and there is a rise in voltage beyond 1.1 times of the nominal. The controller of BFCL forces the IGBT gate voltage Vgt to high when Vpcc sets to Vref after 1.5 cycles.. To guard the controller from the oscillations of current this delay is must. The controller of BFCL comprises of signal accumulator and both comparators. The collection of signals from two comparators is done, and an applicable IGBT gate control signal Vgt is sent with help of accumulator.

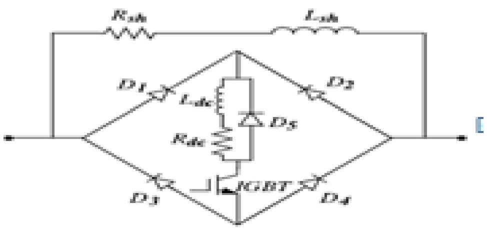

*Fig .2 BFCL arrangement*

### C. Intend Considerations of BFCL

The equivalent diagram of test-drive system bearing in mind scenario of fault along with the DFIM is illustrated in Fig. 1 .Equal amount of power is being carried by each double circuit line during normal operation. To guarantee the least interruption near the machine at fault, the BFCL should ingest least power i.e the same to the quantity of current carried in faulted line at pre-fault. The Post-fault power consumption Pbfcl is expressed by (1) and (2)

$$P_{bfcl} \leq \frac{P_g}{2} \qquad (1)$$

$$P_{bfcl} = \frac{V^2{}_{pcc}}{R^2{}_{sh}+X^2{}_{sh}} \qquad (2)$$

Where $P_g, X_{sh}$ and $V_{pcc}$ are the power , shunt inductance and voltage of system .By solving them can catch the values needed.

### D. Control Strategy of BFCL

There are some constraints which are used in control methodology such as the line voltage, the generator terminal current, the line current, the reactive and the active powers. idc has a fast rate of rise than any other parameters with much sensitive is used to regulate mainly turnoff the IGBT. Another control parameter is essential for turning on the IGBT to do so Vpcc is compared to the reference if it crosses nominal, breaker opens and IGBT turns on norm al operation endures.

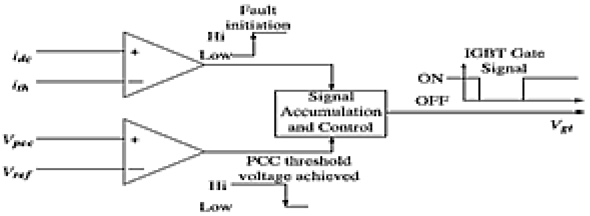

*Fig.3 control scheme*

## IV.PROPOSED R-TYPE SSFCL:

### A. R-type SSFCL configuration and operation

The proposed R-SSFCL has revealed in Fig 4. The bridge is prepared of the 4 Diodes , and a few value of dc reactor in series with a fast reaction self-turn-off IGBT. The shunt branch is made of a bypass resistance and a ZnO arrester. In normal action, the self-turn-off device IGBT closed and current pass through it. For first half cycles, the line current outdo through and via IGBT switch, and second half cycle current flows through IGBT. The impedance of shunt pat must be high. During fault, the IGBT switch is open and high fault current will pass via the large impedance of the shunt resistance branch and limits the fault current. In this paper, over voltages will be censored by ZnO. in the fault, more current may pass to the circuit and this sudden disturbance of elevated current can origin an ended voltage into the circuit, which can dent the circuit. By using ZnO arrester elevated voltage can prevent and protect the circuit. The fault is isolated after opening the circuit breaker, and then the system starts to recover and try to bring its normal condition.

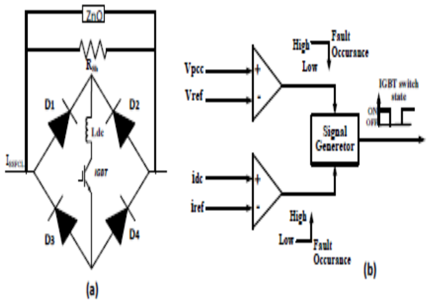

*Fig 4.proposed single phase R-type SSFCL*

## V.SIMULATION AND RESULTS

### *A. Simulation Consideration*

In this work, at the time of a fault the wind speed of 12m/s is considered and the power factor is unity for fault analysis. For evaluating the structure transient stability, a momentary LLLG, and LG faults are given at one line at 0.1s. The faulted line circuit breakers will open at 0.2 s successfully just after applying the fault and reclose two CBs at 1.2 s. The simulation time span is considered here from 0 to 1.5s and simulation step reaction is used 10 Four different cases (without any auxiliary controller, with BFCL, SDBR and with the R-type SSFCL) are considered in this work. the below figures from 1-5 for LLLG fault (a)with No controller (b) with SDBR (c) with BFCL.

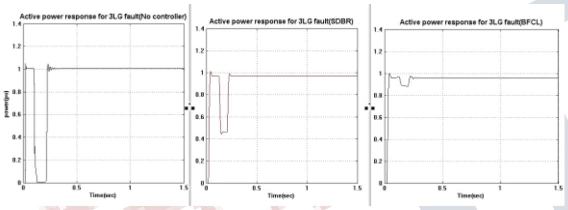

*Fig.1 Machine output active power reaction for LLLG fault*

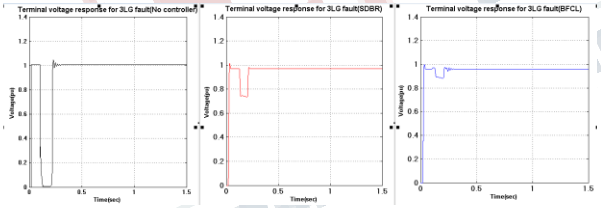

*Fig.2 Terminal voltage reaction for LLLG fault*

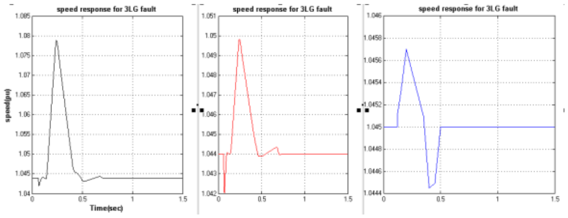

*Fig.3 Machine speed reaction for LLLG fault*

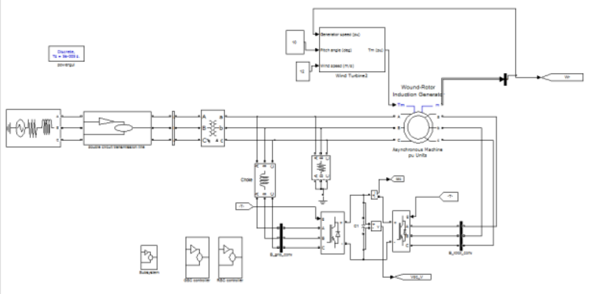

*Fig.4 Simulation diagram of DFIG*

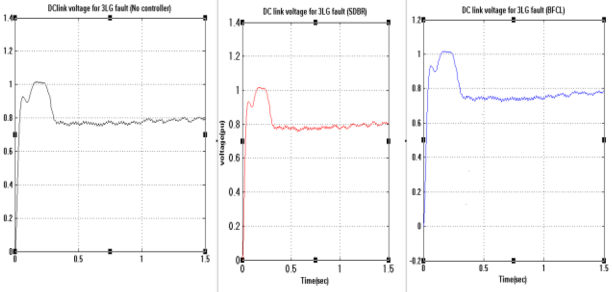

*Fig.5 dc link voltage reaction for LLLG fault*

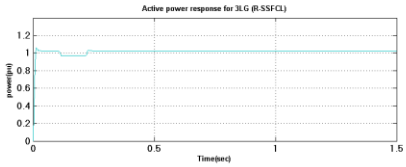

*Fig.6 Machine output active power reaction for LLLG fault(R-SSFCL)*

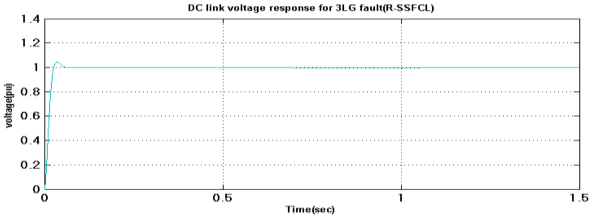

*Fig.7 dc- link voltage reaction for LLLG fault(R-SSFCL)*

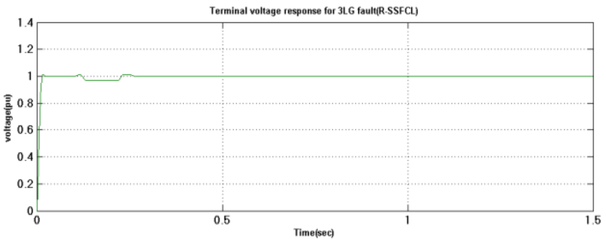

*Fig.8 dc link voltage reaction for LLLG fault(R-SSFCL)*

### *5.2.2 PERFORMANCE INDEX CALCULATION FOR 3LG FAULT*

For clear insight of performance comparison below performance indices are considered.

| Index parameter (%) | NO controller | SDBR | BFCL | R-SSFCL |
|---|---|---|---|---|
| Volts(pu) | 10 | 2.1 | 0.8 | 0.2 |
| Speed(pu) | 1.75 | 0.25 | 0.04 | 0.02 |

Below shows LG faults reactions of DFIG from figure 9-12 (a) with No controller (b) with SDBR (c) with BFCL.

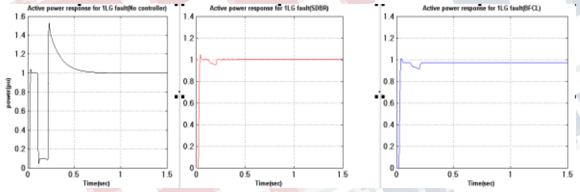

*Fig.9 Machine output active power reaction for LG fault*

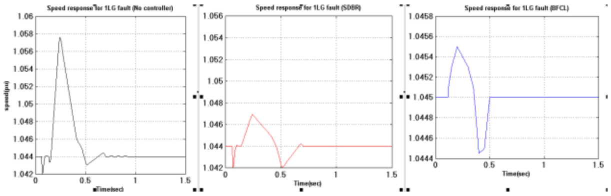

*Fig.10 Machine speed reaction for LG fault*

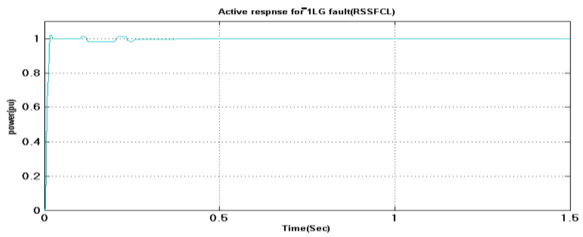

*Fig.11 Machine output active power reaction for LG fault(R-SSFCL)*

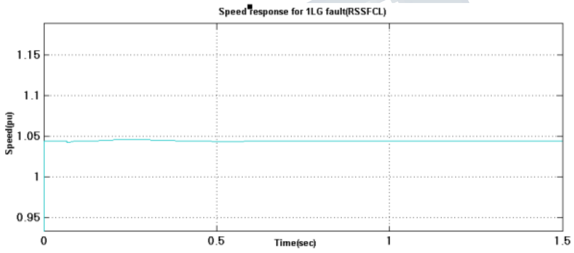

*Fig.12 Machine speed reaction for LG fault(RSSFCL).*

## VI.CONCUSION

By the presentation of all type of controllers it is understood that R –Type Solid State fault current limiter(R-SSFCL) is having better control over BFCL and SDBR.

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