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Enhancement of Doubly-Fed Induction Generator Stability Using Bridge Type Fault Current Limiter

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Abstract - *Stability analysis is a major concern for Doubly Fed Induction Generator (DFIG) based Variable Speed Wind Turbine (VSWT) system during the fault, is directly affected by grid side as DFIG stator winding are directly connected to the grid. However, the during fault at the grid side the wind generator are connected and continue operation fault current overcome to using bridge type fault current limiter (BFCL)and series dynamic braking resistor (SDBR)using Grid code requirement. The proposed FCL not only limit the fault current level in acceptable level but also enhance transient stability of the DFIG by consuming excessive energy during grid fault. Simulation ware carried out in MATLAB/Simulink environment. Simulation results show that the BFCL is a very effective performance and batter stabilization of the DFIG and the SDBR in all aspects.*

Key Words*: Stability, doubly fed induction generator (DFIG), variable speed wind turbine (VSWT), wind turbine, grid code, bridge type fault current limiter (BFCL), series dynamic braking resistor (SDBR).

1. INTRODUCTION

Technology advancement and industrialization has increased in electrical power demand all around the world. Other thinks to limited reserved of oil, coal, gas, means fossil fuels. It urgent to seek for alternative energy sources and device improved methods of utilizes renewable energy sources. Among the available renewable energy sources, wind energy is the fastest growing and most prominent option to generate electrical power due to its zero fuel cost, pollution environment, lower maintenance, cheaper renewable nature. It is estimated future electricity demand 10% by the year 2020. The variable speed wind generator having full rated converter, the DFIG is directly connected to the grid, as its stator winding are directly connected to grid while rotor winding are interfaced to grid via the rotor side converter (GSC)and the Grid side converter (GSC) both are connected to back- to -back through DC-Link capacitor. Traditionally, to protection from fault indicates the generator is disconnected to the grid. At event the grid fault, the terminal voltage of the DFIG is very low and current is very high, and this high current flow through both RSC and GSC convertor. The convertor of the DFIG topology has the control to able to maintain stability at fault condition. Some Solution is to overcome the stability issue from different in the litterateur, to new control method. The superconducting fault current limiter is proposed to good performance. The bridge type fault current limiter is a new technique with good stability performance.

2. WIND TURBINE MODELING AND DFIG SCHEMES

In this paper, a 2 MW 690V DFIG variable speed wind generator system has been modeled to analyze the transient stability. The simple construction of DFIG is connected to the grid through step up transformer and double circuit transmission line as shown in Fig 1[ ]. Temporary symmetrical fault were applied at the most vulnerable point of the system. In order to see how much effective the proposed approach is, its performance is compared with that of the series dynamic resistor (SDBR) and bridge type fault current limiter (BFCL). Simulation was carried out using the MATLAB/Simulink software.

A.WIND TURBINE MODELING

The modeling of wind turbine depends on various physical and geometrical aspects. The commonly used mathematical relation for the mechanical power harnessed from the wind, can be expressed as following[ ].

$$Pw=\frac{1}{2}\rho ACp V_w^3 \tag{1}$$

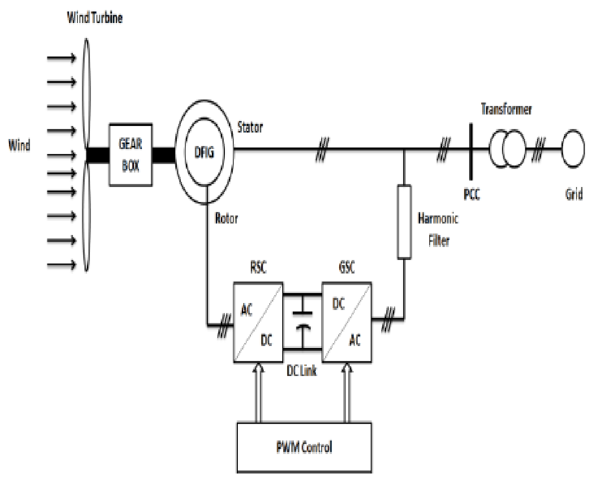

Figure: 1.Basic diagram of DFIG wind turbine

Where Pw is the extracted power from the wind, ρ is the air density, R is the blade radius, Vw is the wind velocity, and Cp is the power coefficient which is a function of both the tip speed ratio (λ), and the blade pitch angle (β), and is given by

$$C_p(\lambda, \beta)=0.73[151/(\lambda i)-0.58\,\beta-0.02\,\beta^{2}2.14-13.2]e^{18.4/\lambda i} \quad (2)$$

$$\lambda=\frac{\omega r R}{Vw} \quad (3)$$

Where, ωr is the angular mechanical speed. The wind turbine parameter used in this study, are given in table [ ].

TABLE I. WIND TURBINE DATA

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

B. DFIM MODELING

The Doubly fed induction generator (DFIG) is stator directly connected with grid, but rotor winding is connected to the grid through AC-DC-AC back to back converter. The Rotor side converter (RSC) and Grid side converter (GSC) and both are connected to DC-Link capacitor. In this research, to control the RSC and GSC both converter of the DFIG, the vector control method is used [ ].

TABLE II. DFIG PARAMETERS

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

A. ROTOR SIDE CONVERTER (RSC)

In DFIG, the rotor side converter (RSC) is connected with the generator rotor side as shown in Fig. 2. The RSC is a two level, six pulse based IGBT full bridge AC-DC converter that controls both active and reactive power at the stator DFIG. And other side end of RSC, it is coupled to a D.C link capacitor to balance the energy both the sides of RSC and GSC. The generator speed ω_g and the reactive power Q_t, and the terminal voltage of the generator V_t, are taken as input to RSC such the output are controlled active and reactive powers. The park's transformation is used to convert the three phase quantities, direct (d) and quadrature (q) components and vice versa. The PI controller along with park's transformation produces a three- phase output is given to the PWM signal block generator. So it can generate the pulse to the RSC controller.

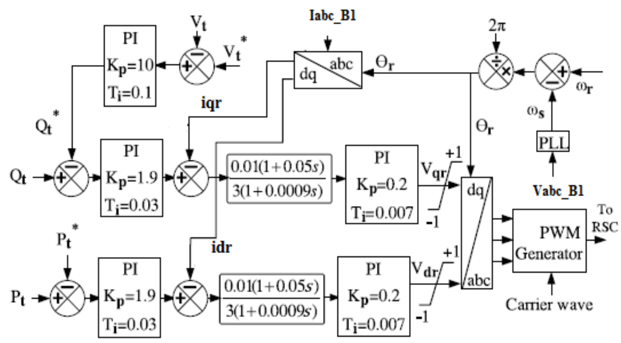

Figure: 2.RSC Controller

B. GRID SIDE CONVERTOR (GSC)

The GSC also contains a two-level, six pulses, IGBT based full bridge power electronic DC/AC converter with DC side connected to the DC-link and the ac side interface to the grid. This converter is maintaining a constant power factor at the connection point. It is important to choose an appropriate switching frequency to keep the harmonics to the minimum level. The GSC controller scheme is given Fig. 3. It take the dc link voltage (E_{dc}) and the grid side current (I_{dg}) and generates output pulses by means of PWM generator via PI controller. Also, maintain a constant dc-link voltage, the controller ensure the energy balance on the both side of the dc-link. The dc-link capacitor 10000μF is choosing to smooth out the ripple of the D.C voltage and keep it constant voltage.

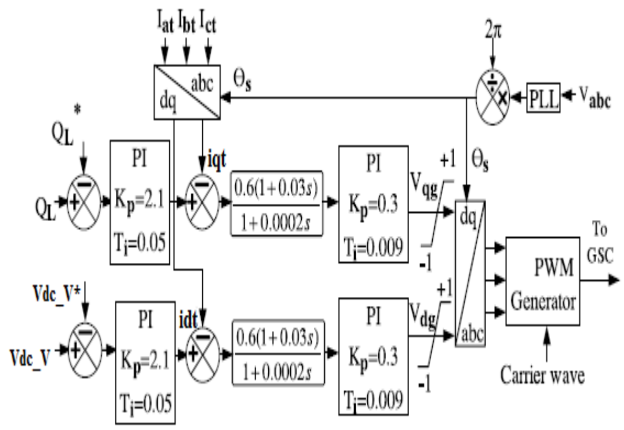

Figure: 3.GSC Controller

I. BRIDGE TYPE FAULT CURRENT LIMITER (BFCL)

The detail modeling of the proposed BFCL is given below. The BFCL is composed of two sections: (a) the bridge part and (b) shunt part. The bridge part is composed of diodes D1-D4, a small valued dc reactor Ldc and small value resistor Rdc are connecting with a parallel diode D5 placed in series with IGBT switch arranged as shown in Fig. 4. The IGBT switches normally come in a package with free- wheeling diode which is not shown here. The shunt part composed of a resister Rsh and inductor Lsh, are connected in series and it is in parallel to the bridge part.

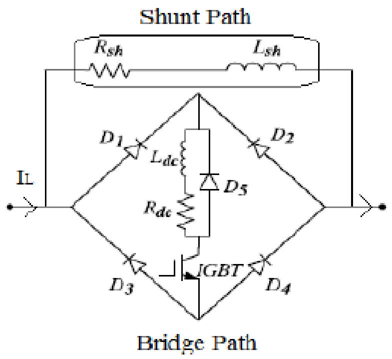

Figure: 4.Bridge Type Fault Current Limiter

A. BFCL OPERATION

During normal operating condition, IGBT switch in the bridge part remain close. During the positive one half cycle of electrical frequency, the line current flow from D1- Ldc-Rdc- IGBT-D4 and for the negative half cycle, the line current flows from D2-Ldc-Rdc-IGBT-D3. So, the current through Ldc, flow in same direction and this current is dc current idc. Ldc is charge to peak current and offers no impedance to idc. In normal operation, the IGBT turn on resistance and the diode forward voltage drop cause some voltage drop, but is quit negligible camper to line drop and this ignorable significant Fig.5.

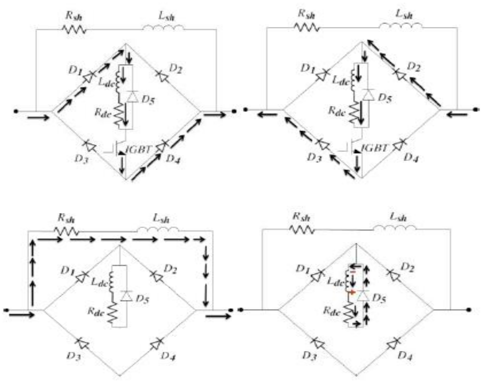

Figure: 5.Bridge Type Fault Current Limiter Operation

The shunt path inductance is chose high enough, complete line current to flow through the bridge the bridge except a very small leakage current. When a fault occurs, initially the line current tens to increase suddenly, but the inductor (Ldc) limits the increasing rate of the line current. The safe operation is maintained because the IGBT switch is saved from high value of $\frac{di}{dt}$. During the open circuited period of the bridge, the free-wheeling diode of the dc reactor and IGBT provides path to discharge the stored energy in them.

B. BFCL CONTROL STRATEGY

The BFCL controller is shown in Fig. 6. It is composed of a two comparator and one pulse generator. Both cooperator signal are compare and pulse generator to generate appropriate pulse for IGBT gate signal.

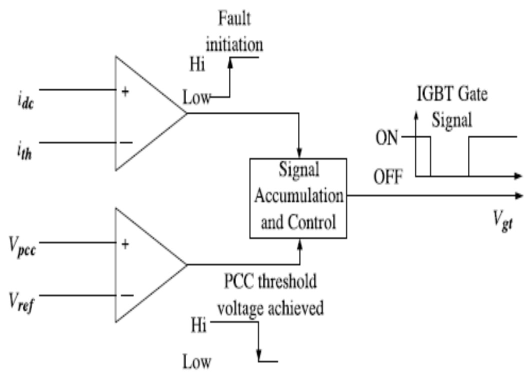

Figure: 6. BFCL Controller

The PCC voltage of the wind generator (Vpcc) is compared with the threshold reference value (Vref). At the event fault, idc current is very high and Vpcc goes low and becomes lower than Vref, and idc is higher than iref. The IGBT switch opens and current is bypassed to the shunt having high impedance and suppresses the fault current. When Vpcc is restored due to fault isolation and becomes greater than threshold value Vref. The IGBT switch is closed to normal operation. In this paper, to get the good performance of the consider system. The value of Rdc and Ldc are 0.3Ω, 1mH respectively. Also Rsh and Lsh value 0.48 and 0.04p.u.

II. SERIES DYNAMIC BRAKING RESISTOR (SDBR)

The SDBR is modeled by arranging a resistor with a parallel switch as shown in Fig. 7. This study considers this IGBT switch based, due to its modular design. The freewheeling diode of the IGBT is not shown.

A. SDBR OPERATION

During the normal operating condition, the IGBT switch remains closed and the line current flows through IGBT. At event of fault, the IGBT switch will open and the line current flow through braking resistor until the desired condition will be satisfied. The same control strategy is used for BFCL and SDBR. To make the comparison, the same value of 0.48p.u resistance as SDBR and BFCL Fig.9.

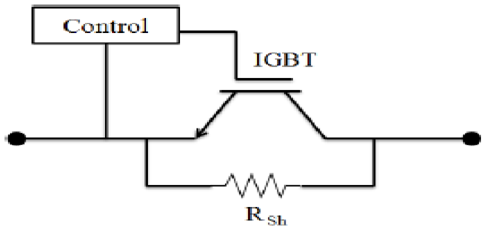

Figure: 7. SDBR Controller

III. SIMULATION CONSIDERATION

The simulation is modelled in MATLAB software with comparison of results for different cases. The first case is with no auxiliary device connected to the test system. The second case is using SDBR and the third case is connecting BFCL in series between DFIG wind farm and 66kV line. The protection devices reduce the current injected through the DFIG wind farm during fault conditions on the transmission line. In previous sections modelling of the protection devices is shown along with the controller part which controls the IGBT switch operation during fault conditions with respect to time. The below is the Simulink model of the proposed test system with protection devices attached at the 66kV bus.

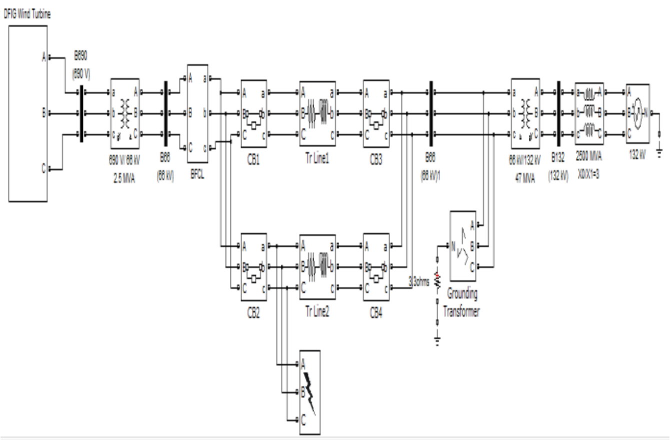

Figure: 8. Test system with protection device

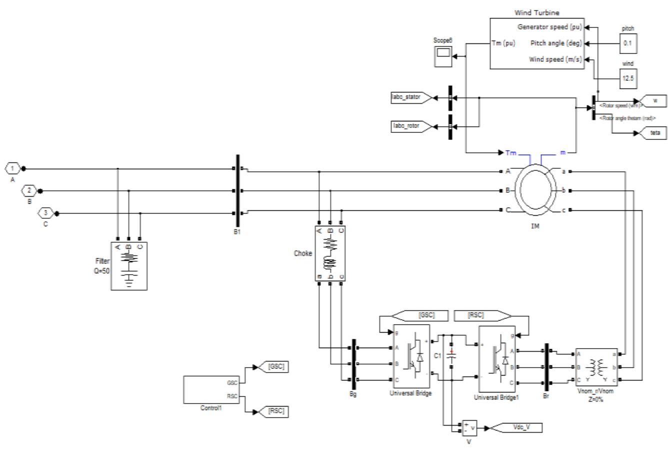

Figure: 9. DFIG modeling for 2MW wind farm

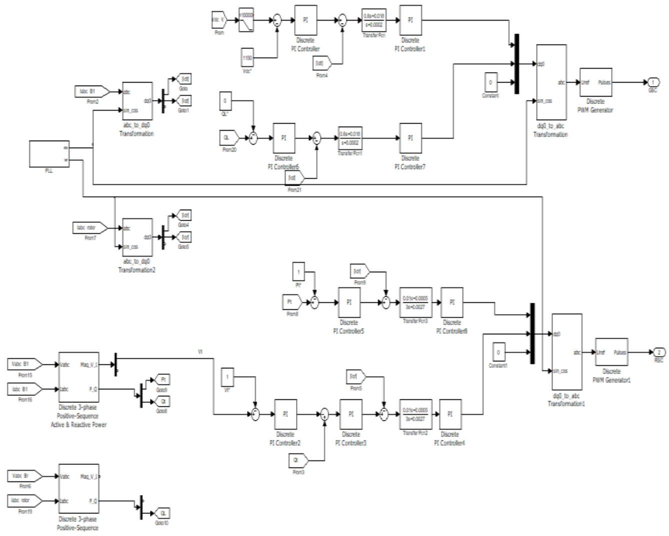

Figure: 10. Controller of DFIG wind farm

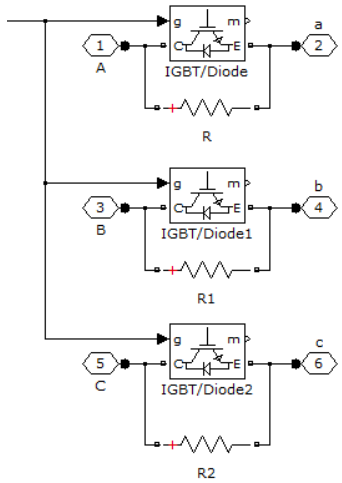

Figure: 11. Modeling of SDBR

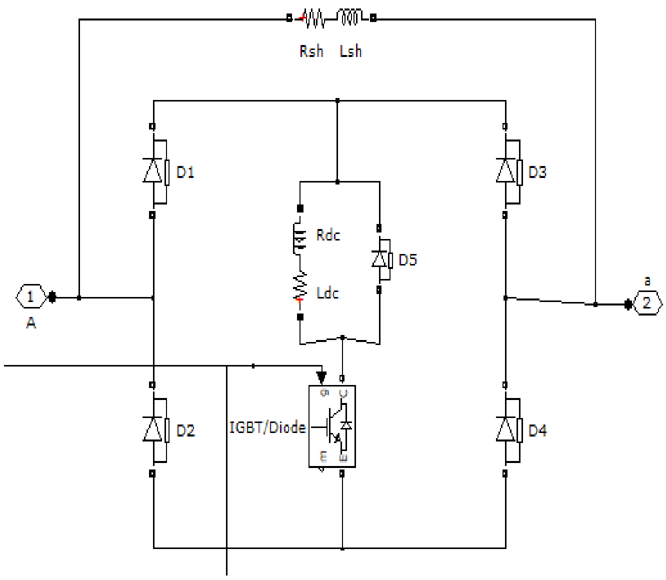

Figure: 12.modeling of BFCL

In the above figures the schematics of the protection devices are controlled by IGBT power electronic device. The pulse for the power electronic switch is given from the controller which generates a trip signal using a relay set point. The relay switching is controlled by comparison of voltage measured with a threshold value. When the resultant value is going beyond the threshold value the relay activates and the IGBT is turned OFF. The below are the result comparisons of the test system with different auxiliary protection devices.

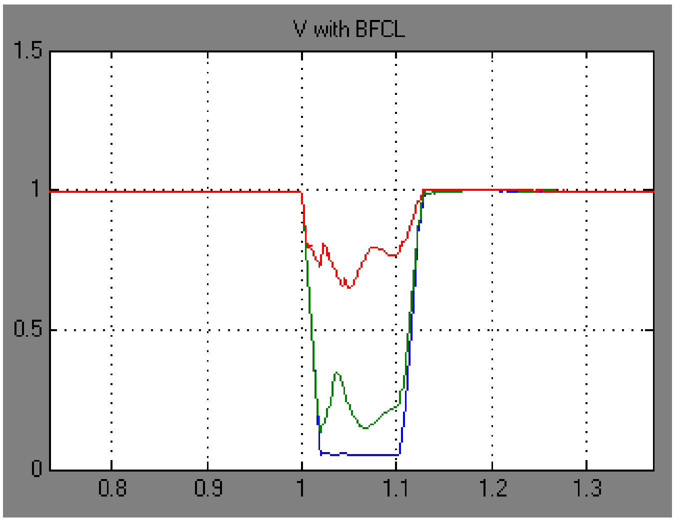

Figure: 13. Voltage pu comparison

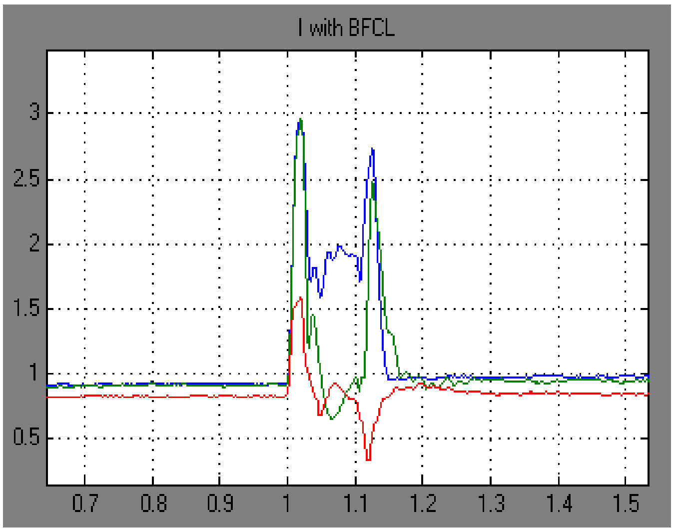

Figure: 14. Current pu comparison

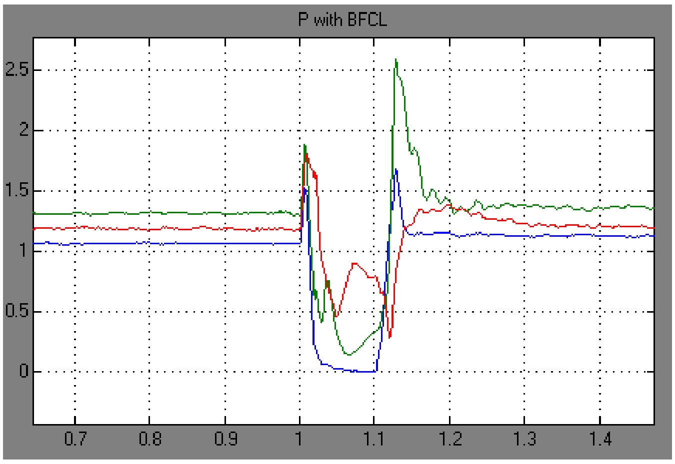

Figure: 15. Active power pu comparison

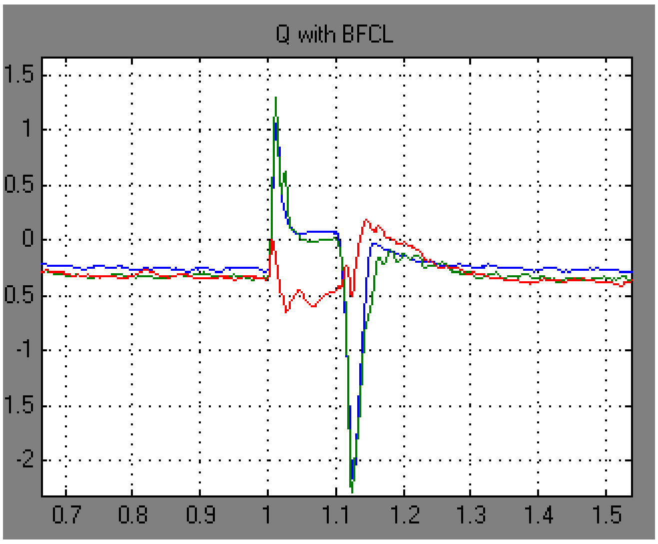

Figure: 16. Reactive power pu comparison

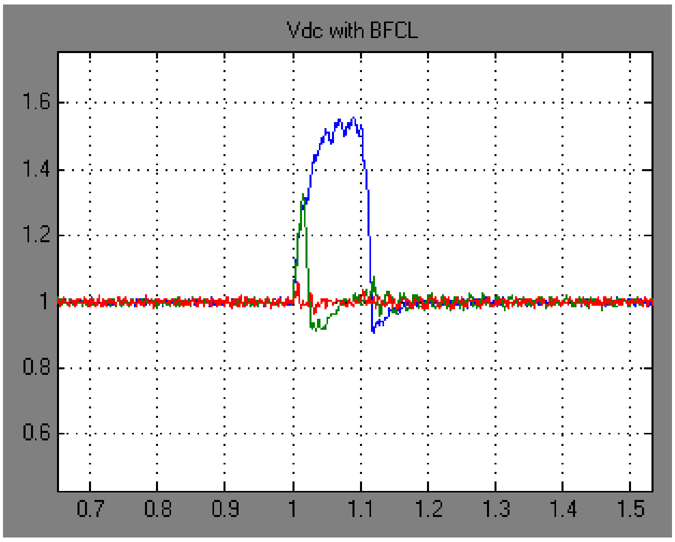

Figure: 17. DC voltage pu comparison

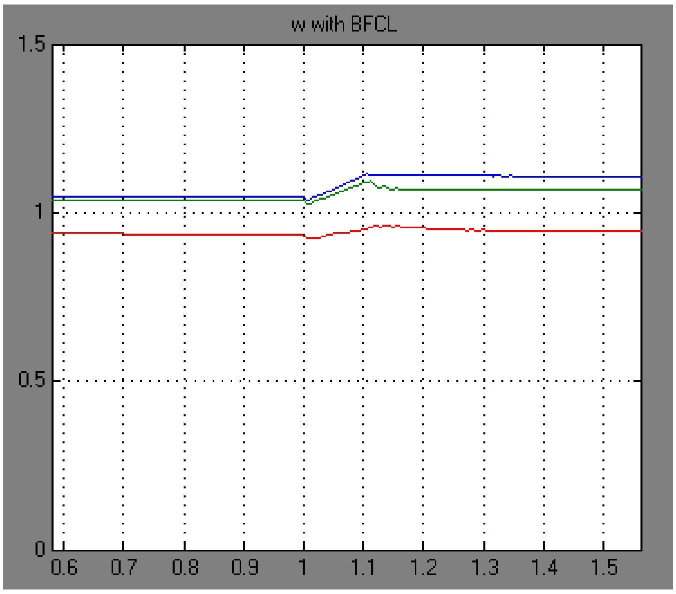

Figure: 18. DFIG speed pu comparison

In all the above comparison graphs the blue signal is no auxiallry device, green signal is with SDBR and red signal is with BFCL.

2. CONCLUSIONS

With the above results and comparison of the parameters of the DFIG wind farm voltage, current, Active power, Reactive power, DC voltage and speed the values are stabilized with minute disturbance when BFCL is used as auxiliary device. The current is completely maintained at 1 pu during the fault and the voltage drop is also reduced with no change in DC voltage across the capacitor.

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