

# A Superior Control Technique in Wind Generation System under grid faults

K.Keerthi, P.B.Chennaiah, S.Sagar Reddy

**Abstract:** During disturbances, the wind energy generation apparatus are connected for stability improvement, to the grid. Distributed generation Grid failure, a major challenge particularly for PM synchronous wind turbines connected, back-to-back to converters and generator. The need of generated wind power grid integration protocol in terms of active and, reactive power control and failure travel (FRT) capacity needs to be discussed. Here a solution is presented which while fulfilling requirements of LVRT on grid failures, over voltage at dc – link suppression through improved BTB controllers, having a limit on active power, keeps the grid inverter peak current under safe limits during various asymmetric grid defect. By using the proportional and integral control loops, the inertia moment in the wind turbines will be reduced and dynamic performance can be improved. However, during the problem, the calculation time is more. Computational time is reduced by considering a proportional resonant controller and is implemented in the system, where by the active grid oscillation and dc - link voltage ripples are reduced. The validity and effectiveness of the proposed control approach were demonstrated in various conditions through simulation.

**Index Terms:** Back to back converter, Reactive power control, Low-voltage ride-through, asymmetrical faults, symmetrical faults, voltage sag, active power control, peak current limitation.

## I. INTRODUCTION

Wind energy is rapidly developing energy source in the world over, in light of fast depletion of fossil fuels [1]. The directly driven PMSG Wind Energy System (WES) having benefits of high precision, large power density, simple and easy control systems, is handicapped by high initial costs [2]-[4]. The WECS with variety of benefits is more importantly preferred to be grid connected. A few countries have recently published the protocols to connect the WES to the utility grid [3]. For efficiency, in the analysis of smart grid, micro grid, it was noticed that the micro grid voltage varies more than that of the utility grid. Improved control in the WES provides grid stability conditions. Solutions for the faults in the grid have been stated [4]. For low voltage ride through (LVRT), on DFIG, an external resistor is placed in the circuit to absorb active power during the grid fault. The turbine operates continuously generating active energy while the reactive power is GSC controlled at the grid. [5]. However, GSC alone does mitigate the fault and in the case of a weak grid there is a danger of voltage instability [3]-[6]. A static synchronous compensator (STATCOM) was used for reactive power injection, and is installed at a common coupling point (PCC) grid facilitating uninterrupted functioning of the wind turbine.

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[7]. The rotor - side converter (RSC) is used only for ride - throwing DFIG capability, to protect against the rotor over current [7]-[9].

An alternate control strategy for PMSG wind turbine, with direct driven MW of high inertia is proposed. MPPT implemented through GSC and dc - link voltage, is controlled by MSC which eliminates active crowbar in dc - link. For positive and negative sequence components effects the dual current controller is designed. A new maximum current levels of all phases within the safety limit is proposed, for appropriate reactive current injection into the grid. In the grid voltage sag conditions, the limits for active and reactive GSC power refers are calculated with the PMSG excluded from MPPT while GSC is operated as STATCOM. The turbine - generator acts as energy storage. The increase in speed of the wind turbine is monitored through the pitch angle control, a strategy which is compatible with various grid protocols. The ripples on the grid side are suppressed using the proposed controller with the active power vibration and dc - link voltage.

## II. SYSTEM MODELING

### (A) Back-to Back Converter

In figure 1, the generator side converter works as a corrector and the grid side converter as an inverter [10]-[12]. the power flow is bi - directional.

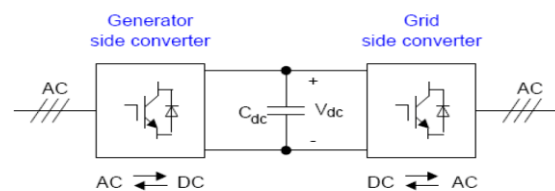


Fig: 1. Back to Back converter

The grid side considered only in simulations, and hence back to back converter is not modelled. VSC grid side model to perform the simulations is adequate. The VSC includes a mechanical system making the time longer than the converter's switching time. Its logical scheme, one for voltage calculation and one for currents, have been implemented in two sub-blocks. The various BTB converters used in commercial WECS execute a conversion of the generator's variable voltage/frequency output to dc, dc to ac, with fixed voltage/frequency of the grid. As the power flow is bidirectional, SCIG, PMSG and WRSG can use the BTB converters. The BTB



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converters, grouped according to the IEC 60038 standard - low voltage (< 1 kV) and medium voltage (1– 35 kV) converters, the classification is shown in figure 2. The popular voltages by many commercial wind turbine equipment manufacturers are 690 V and 575 V.

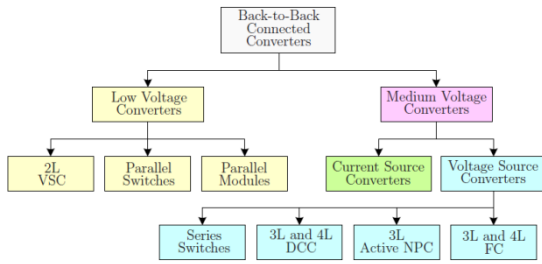


Fig. 2. Classification of back-to-back connected converters.

### (B) Wind Energy Conversion System

Figure 3. gives the wind energy system consisting of a wind turbine to extracts wind energy, a PMSG, a BTB converter to transform variable frequency signals into grid frequencies as per the grid model.

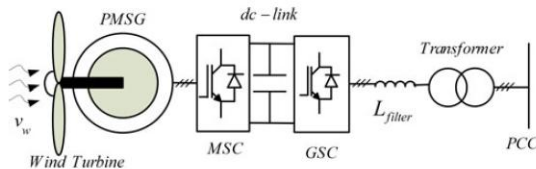


Fig. 3. Simplified scheme of WECS.

GSC is joined to the common connection point (PCC) as shown above. A new strategy for control of PMSG - based direct - driven wind turbines, operating under various conditions is proposed. MPPT through GSC is implemented. The Dual Strom Controller deals with asymmetrical failures for GSC's positive and negative sequence components. An upper limit for the maximum currents of all phases within the safety limit is proposed, which deviates from other studies, while allowing the reactive current flow into the grid during symmetrical and asymmetrical grid failures, in line with the requirements of grid protocols.

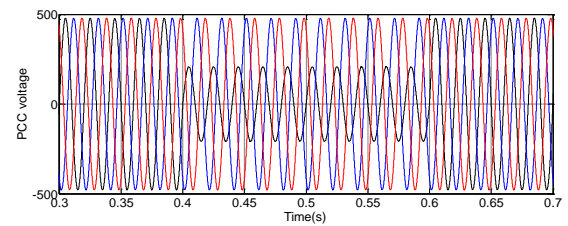
### III. SIMULATION RESULTS

In Matlab / Simulink software many simulations have been performed and compared with the real conditions which demonstrate the good performance of the proposed method.

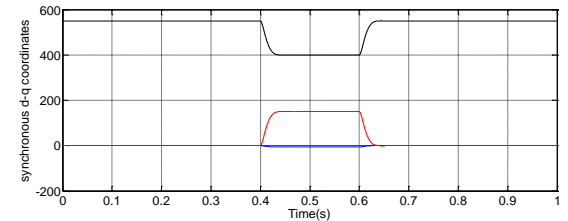
#### CASE A: UNSYMMETRICAL FAULT(L-G)

A L-G fault applied to PCC in 0.4 s. as in Fig. 4(a), resulted in voltage sag.. The PCC voltage was converted to d-q components, with positive- and negative-sequences separated as shown in Fig. 4(b). Fig. 4(c) shows the MPPT controller input as  $P_{lim}$ ,  $P_0^{ref}$  and  $P_{grid}^{ref}$  i.e. active power limitation, active power reference, and applied active power reference respectively. In Fig. 4(e) the d-q components of positive- and negative-sequences of GSC current with the active power limiter, Fig. 4(f) showing the voltage unbalance factor

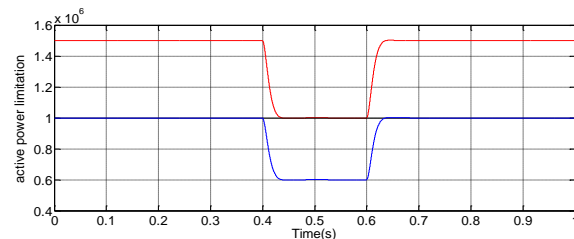
equivalent to 0.3205 during voltage sag, Fig. 4(g), indicating the reactive current injection as per Danish grid code, Fig. 4(g) gives the ratio of  $Iq^+$  to  $I_{max}$  greater than rated GSC current ratio ( $\alpha$ ), are depicted. Finally, dc-link voltage is shown in Fig. 4(h). New control strategy, demonstrates the dc-link voltage in safety range without any external devices, the amplitude of second-order harmonic fluctuations decreases. Fig. 4(i) shows the grid side current of the GSC. As shown, the peak of each phase current is kept within the safety limit. As mentioned before, to eliminate second-order component fluctuations of grid active power,  $P_{c2}$  and  $P_{s2}$  were set to zero; therefore, the second-order component fluctuations of grid active power is removed (see Fig. 4(j)). But, the fluctuations of reactive power of grid are retained. Hence, the reactive power oscillates with 100 Hz as shown in Fig. 4(j). It is important to note that the average of reactive power in Fig. 4(j) is the same with the reactive power reference ( $Q_0^{ref}$ ) in Fig. 4(d).



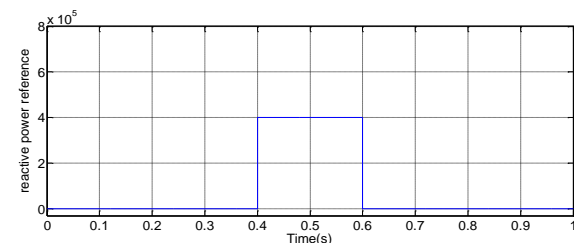
(a)



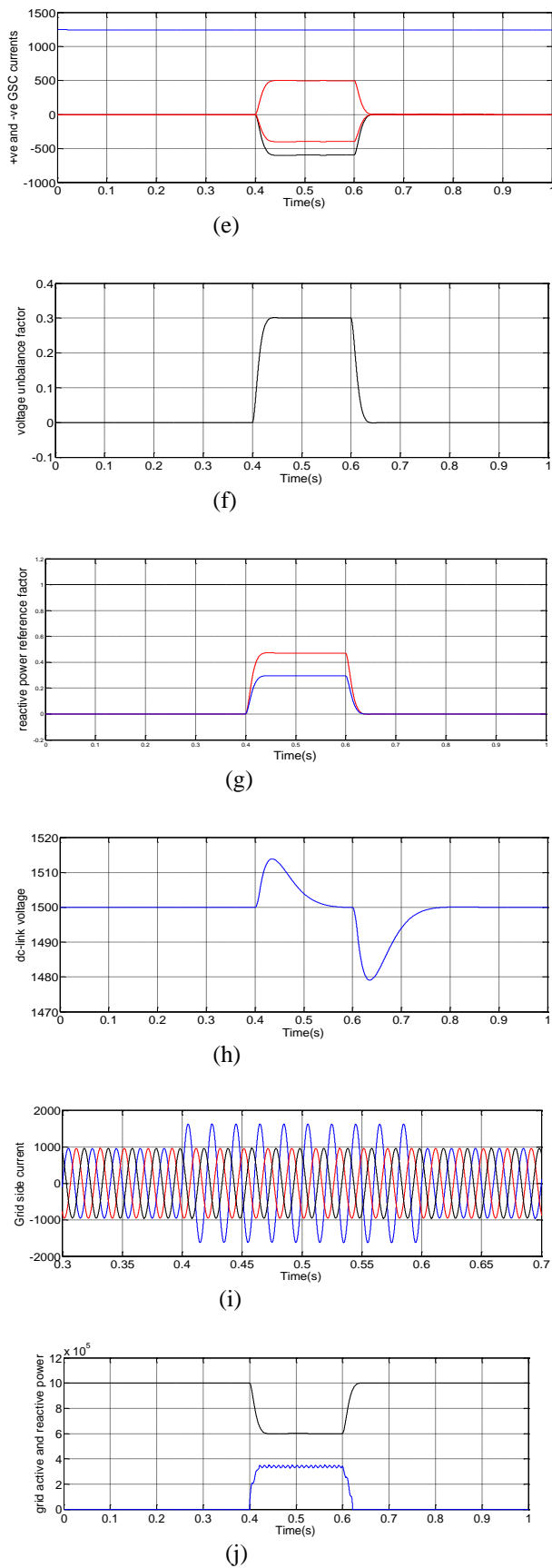
(b)



(c)



(d)



In order to reduce computational time, a proportional resonant controller is implemented in the system. Use of the proposed controller can remove the active grid oscillation and dc - link voltage ripples as shown in figure 5.

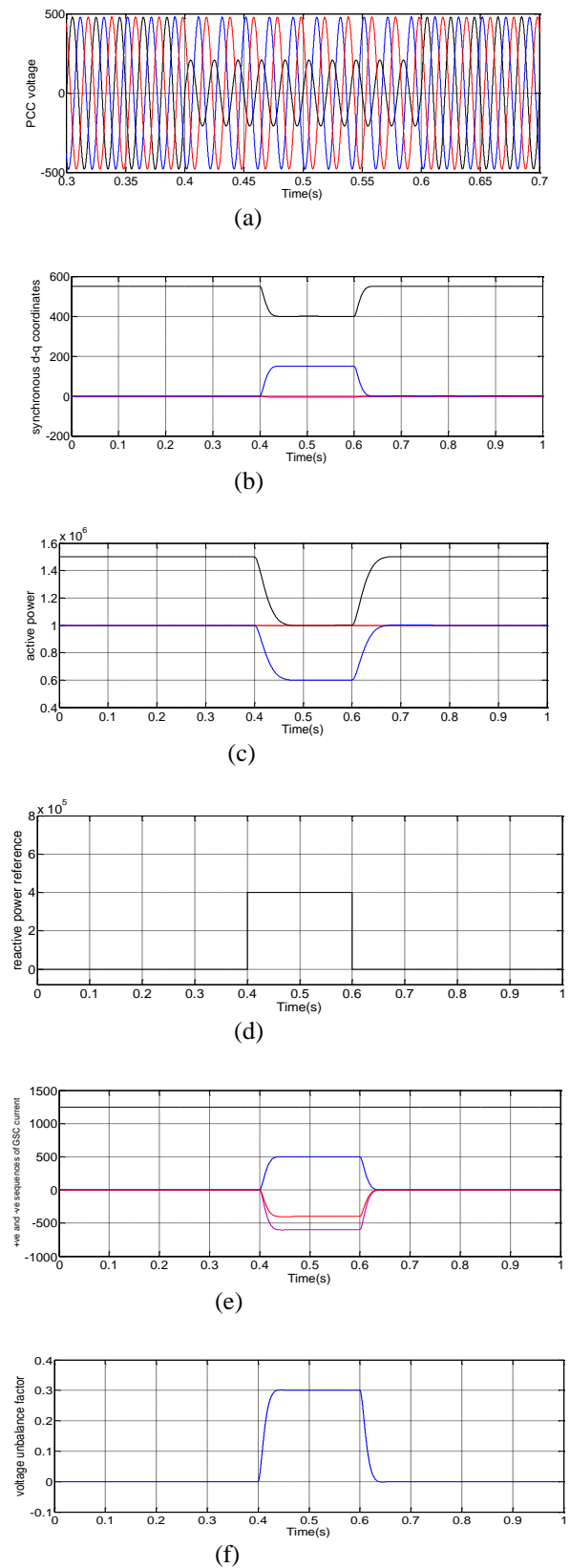


Fig: 4(a) PCC voltage, (b) PCC voltage in the synchronous d-q coordinates, (c) active power limitation ( $P_{lim}$ ), active power reference ( $P_o^{ref}$ ), applied active power reference ( $P_{grid}^{ref}$ ), and (d) reactive power reference. (e) the d-q components of positive- and negative-sequences of GSC current, (f) the voltage unbalance factor ( $m$ ), (g) reactive power reference factor ( $\kappa$ ), the reactive current to rated GSC current ratio ( $I_q/I_{max}$ ) and ( $\alpha$ ), and (h) dc-link voltage. (i) grid side current, (j) grid active power and grid reactive power in one-phase voltage sag.



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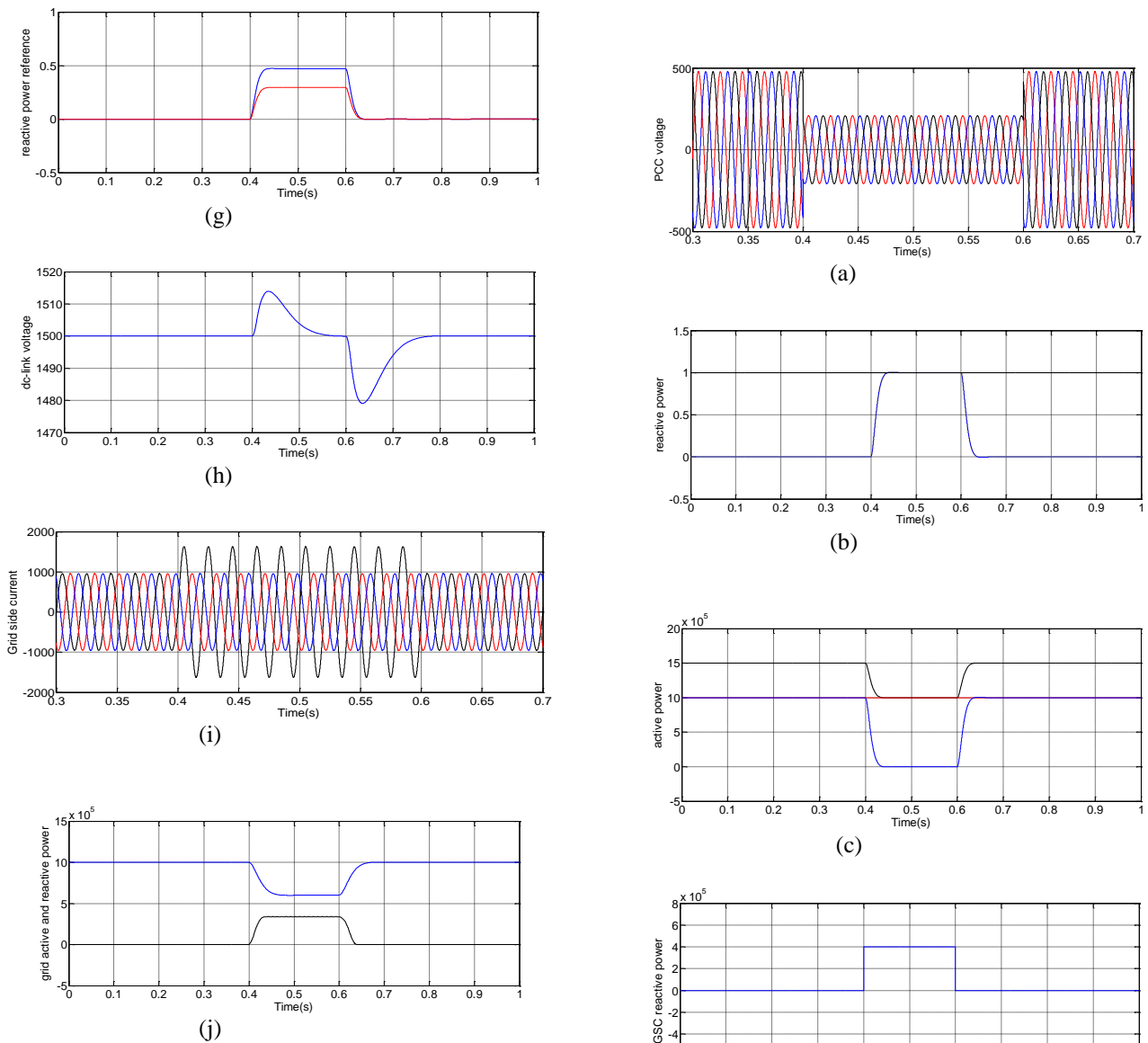
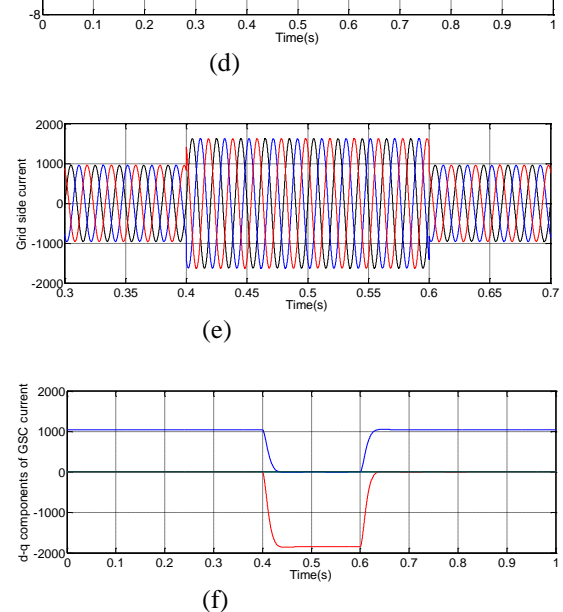


Fig: 5(a) PCC voltage, (b) PCC voltage in the synchronous d-q coordinates, (c) active power limitation ( $P_{lim}$ ), active power reference ( $P_0^{ref}$ ), applied active power reference ( $P_{grid}^{ref}$ ), and (d) reactive power reference. (e) the d-q components of positive- and negative-sequences of GSC current, (f) the voltage unbalance factor ( $m$ ), (g) reactive power reference factor ( $\kappa$ ), the reactive current to rated GSC current ratio ( $I_q/I_{max}$ ) and (a), and (h) dc-link voltage. (i) Grid side current, (j) grid active power and grid reactive power in one-phase voltage sag.

## CASE B: SYMMETRICAL FAULT

On simulation of the symmetrical fault, as in Fig.6 (a), symmetrical voltage sag occurred 0.4 s which is more than 70%. As shown in Fig. 6(b), arising from the absence of a negative sequence component,  $\alpha$  is equivalent with  $I_{gf}^+ / I_{max}$ , and they are one. Also, reactive power reference factor  $\kappa$  is one. When this fault occurs,  $P_{lim}$  approaches zero. Therefore, as shown in Fig. 6(c),  $P_{grid}^{ref}$  will be zero. Hence, the capacity of GSC is released and maximum reactive current will be injected to the grid. Fig. 6(e) shows the grid side current of GSC. All of the phase currents were retained in the safe limit. Also, Fig. 6(f) shows GSC current in the d-q reference frame. It is shown that the all capacity of GSC is occupied by positive sequence of reactive current in fault condition. The prevention of dc-link overvoltage is the main advantage of the proposed method as shown in Fig. 6(g).



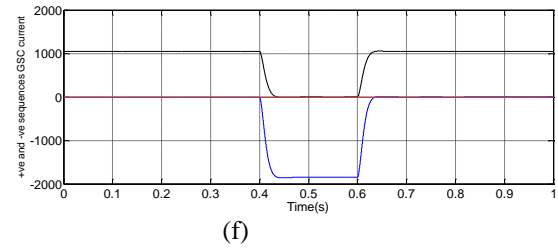
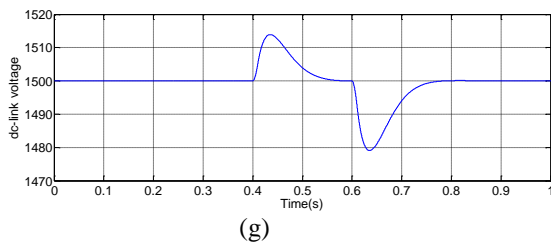
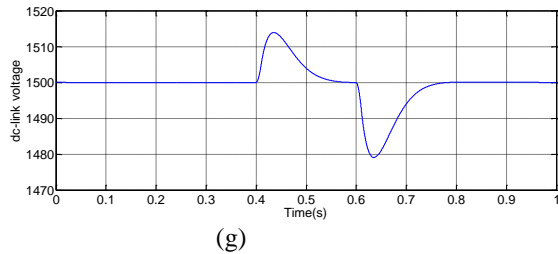
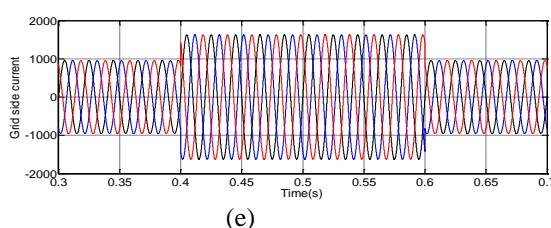
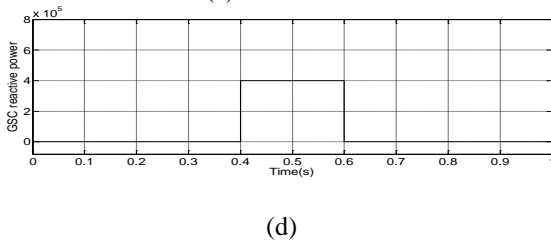
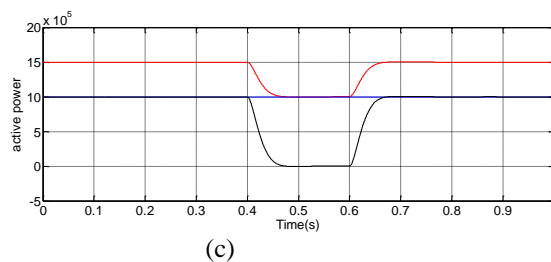
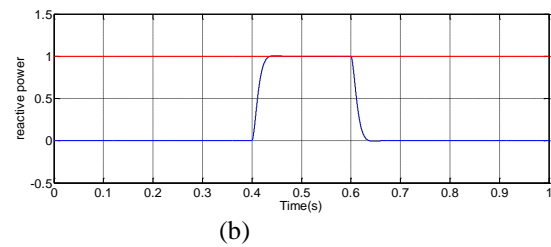
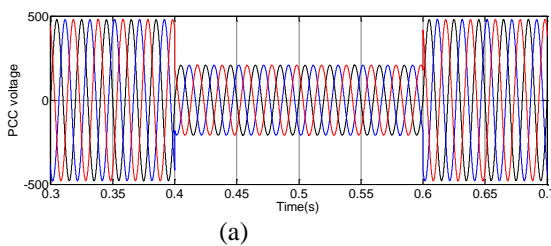


Fig:6(a) PCC voltage, (b) reactive power reference factor ( $\kappa$ ) the reactive current to rated GSC current ratio ( $I_q/I_{max}$ ) and ( $\alpha$ ), (c) active power limitation ( $P_{lim}$ ), active power reference ( $P_{0ref}$ ), applied active power reference ( $P_{grid}^{ref}$ ), and (d) GSC reactive power in symmetrical fault. (e) Grid side current, (f) the d-q components of positive- and negative-sequences of GSC current, and (g) dc-link voltage in symmetrical fault.



The results of the proportional resonant controller for this case is shown in figure 7 and this controller is used to reduce the computational time

Fig:7(a) PCC voltage, (b) reactive power reference factor ( $\kappa$ ) the reactive current to rated GSC current ratio ( $I_q/I_{max}$ ) and ( $\alpha$ ), (c) active power limitation ( $P_{lim}$ ), active power reference ( $P_{0}^{ref}$ ), applied active power reference ( $P_{grid}^{ref}$ ), and (d) GSC reactive power in symmetrical fault. (e) Grid side current, (f) the d-q components of positive- and negative-sequences of GSC current, and (g) dc-link voltage in symmetrical fault



#### IV. CONCLUSION

It is successfully demonstrated that the ripples on the grid side can be suppressed using the proportional resonant controller with the active power control and dc - link voltage. This follows a reduction in computational time by the suppression of over voltages by dc-link through enhanced BTB converters. The design of an active power limiter is to keep the grid side inverter peak current safe during various faults conditions. A novel control strategy is suggested to improve fault ride through capability of permanent magnet synchronous generator based wind turbine.

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