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Control of Doubly Fed Induction Wind Generator under Unbalance Grid Voltage Condition

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ABSTRACT: In case of three phase unbalanced grid voltage conditions on wind generator, causes number of problems such as overcurrent, unbalanced voltage, reactive power pulsations and tension on mechanical components from torque pulsations. As doubly fed induction generator (DFIG) provides the control of rotor excitation for adjustable speed and reactive power control. This paper introduces a DFIG control technique that improves variable speed and reactive power control operation by balancing the rotor current to achieve simultaneous regulation of the positive / negative-sequence current of DFIG. The proposed control technique is also able to eliminate torque and reactive power pulsations of output. The MATLAB simulation results of DFIG demonstrate the correctness of the developed technique in which rotor side converter is controlled using SVPWM method.

KEYWORDS: Doubly-Fed Induction Generator, Unbalanced Grid Voltage, Control Technique, MATLAB, Rotor Current, Space Vector Plus Width Modulation.

I. INTRODUCTION

Wind power plant generator is most often installed in remote, rural areas. These remote areas usually have weak grids, often with over current and under or over-voltage conditions. Under such abnormal conditions, induction wind turbine produces unbalanced torque which contains periodic pulsations at twice the grid frequency. It results in acoustic noise at low level and at high level may destroy the rotor shaft, gearbox or turbine blades. Also an induction wind turbine connected to an unbalance voltage grid will draw unbalance currents. These unbalanced currents support to magnify the grid voltage unbalance as well as create over current problem. However a special type of induction generator called doubly fed induction generator (DFIG) is used extensively for variable speed and high power wind applications. DFIG is one of most favourable type of wind generator used practically because of the various advantages over other types of variable speed wind generators namely full rated convertor or synchronous generator. DFIG's quality to control rotor currents and frequency allow for reactive power control and variable speed operation, so it can work at very high efficiency over a wide range of wind speeds.

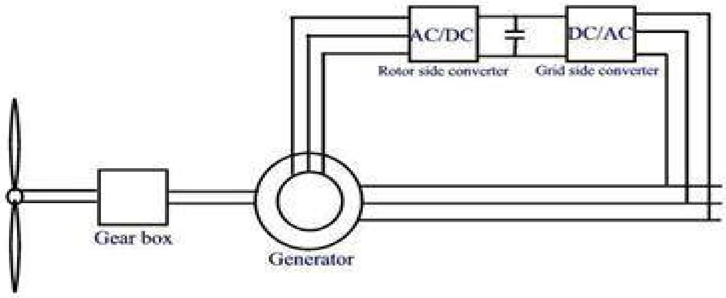

Figure 1- Doubly fed induction generator wind turbine

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The investigation objective is to develop DFIG control technique which increases rotor control capability for unbalanced stator voltage. This control method will allow DFIG to stay connected with the grid under conditions in which they usually disconnected for their own protection. In this proposed control technique only rotor side converter control was taken into account and grid side converter control is not permitted, but is a good topic for future investigation.

There are various methods to define a three-phase grid unbalances. In this paper, voltage unbalance factor (VUF) is explained as the ratio of negative sequence magnitude divided by the position sequence magnitude. The benefit of control technique is that it can account for magnitude as well as phase angle. In the same way unbalance factor can be defined for three phase current called as current unbalance factor (CUF). Using symmetrical components theory, stator voltage unbalances can be seen as adding negative sequence to the stator voltage. From the orientation of the negative sequence current, rotor is turning in opposite direction. Hence the negative sequence current in DFIG attains a very slip, which causes large amount of negative sequence current to flow. This result in unbalanced stator currents, and may also generate an over current condition. In addition to this the torque and reactive power will have a second harmonic pulsation.

By controlling the operation of rotor side converter using proposed control technique this paper demonstrates the enhance control and operation for the DFIG based wind generator system under generalized unbalanced grid voltage conditions with the help of MATLAB simulation. MATLAB simulation is very useful research method to model and simulate DFIG wind turbine under grid voltage unbalances. MATLAB simulation is also commonly used to simulate distorted waveform for power system event analysis. There are many power system simulation tools are available with their own advantages. In this paper MATLAB simulation with sim-power systems is chosen as the platform of simulation.

II.CONTROL MODEL AND ASSUMPTIONS

To understand second harmonics in torque and reactive power of DFIG, it is helpful to use space vectors in the stationary, stator frame. In Space vector theory, the negative sequence stator voltage space vector rotates at synchronous with constant amplitude in negative direction. The same thing can also apply to the flux; the flux generated from the positive sequence voltage will rotate at synchronous speed in the positive direction and the flux produced from the negative sequence voltage will rotate synchronously in negative direction. Therefore these two flux vectors will add constructively and destructively two times per revolution, which increases the double synchronous frequency disturbances in the torque and reactive power.

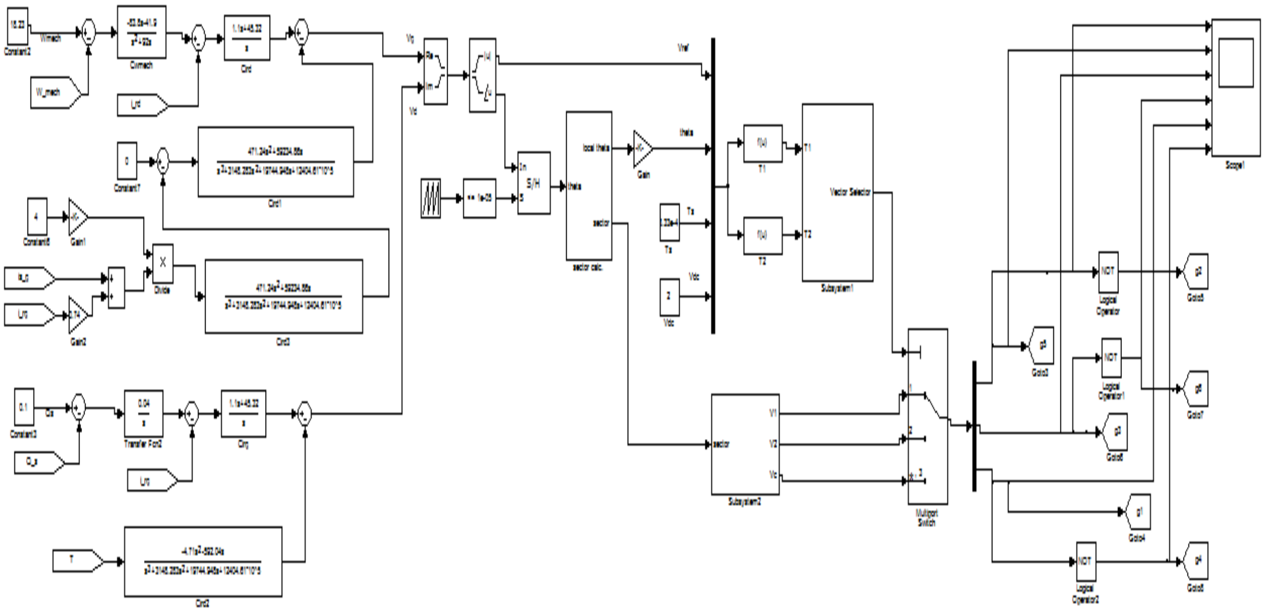

Figure 2- Simulation control model of DFIG wind turbine system

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For the proposed control technique, stator voltage dq vector control is used. This orientation can also called as grid flux oriented control. In this method the d-axis is aligned with stator voltage space vector. As the d-axis is collinear with the stator voltage and q-axis quadrature, therefore the d-axis is used to control torque and the q-axis is used to control reactive power. The control technique is fairly standard except for the addition of the Cd,comp and Cq,comp controllers, which supply the d and q-axis rotor voltage. These supplementary feedback controllers give the loops of very high gain at the known disturbance frequency of 100Hz, allowing the controllers to compensate for the torque and reactive power pulsations that develop when the stator voltage is unbalanced. Reducing the reactive power pulsation dramatically reinforce the unbalance of the stator current. From the symmetrical components point of view, compensating for torque and reactive power pulsations is similar to a controller injecting a negative sequence into the rotor circuit in such a way as to compensate for the negative sequence in the stator circuit. The net effect is to dramatically reduce the torque pulsations, vibrations in reactive power, and stator current distortions under unbalanced grid voltage conditions.

The inner loop rotor d-axis and rotor q-axis current controllers are designed using linearized state equations. Assume the mechanical dynamics are very much slower than the electrical dynamics. The rotor d and q axis current controllers are simple PI controllers each designed for second harmonic that is for 100Hz loop gain cross-over frequency and 90^{o} of phase margin. DFIG naturally, have a pair of poorly damped poles near the grid frequency. Fast inner current controller loops have a fast response time, but also tend to force the poorly damped system poles toward the right half plane. Slow loops are much stable, but the controllers must be fast enough to handle the rotor converter blanking time harmonics, which develops at the slip frequency sixth harmonic. A loop gain bandwidth of 100 Hz is found to be a good compromise. The defined control technique is tested on 15kW DFIG wind turbine.

Table 1- Parameters of DFIG simulation model

Generator nominal power	15kW
Line-line voltage	400V
Frequency	50Hz
Stator resistance	0.16Ω
Stator inductance	60mH
Rotor resistance	0.08Ω
Rotor inductance	40mH

The Cd,comp and Cq,comp controller shown in figure 2 come into operation only in the presence of a stator voltage unbalances. In case of grid voltage unbalance on DFIG a negative sequence component of voltage is added in stator voltage, which gives increase in stator voltage unbalances. To reduce torque and reactive power unbalances in this case the excitation is provided to the rotor with the help of rotor side converter, which supply a negative sequence component in such a manner to compensate for the negative sequence component in the stator circuit. The Cd,comp and Cq,comp controllers supplement the output of nominal operation controllers to remove the 100Hz disturbances from the torque and reactive power. Removing the second harmonics from rotor d and q axis current will not completely destroy the second harmonic from the torque and reactive power, although it can decrease its effect.

$$\text{Cd,comp} = \frac{471.24s(s+125.7)}{(s+3142)(s2+6.283s+3.948\times 105)}\text{..............1}$$

$$\text{Cq,comp} = \frac{-4.71s(s+125.7)}{(s+3142)(s2+6.283s+3.948\times 105)}\text{..............2}$$

These two equations of Cd,comp and Cq,comp controllers are created to have a large gain at the known unbalance frequency twice the synchronous frequency of 100 Hz but also to have a negligible effect at all other frequencies. This

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is done by using a second order resonant filter. The compensating controllers can be represented as having components like a bandpass filter followed by a lead-lag controller, the natural frequency of the filter is the second harmonic.

III. RESULT AND DISCUSSION

In the MATLAB simulation model of DFIG wind turbine proper concentration is made on voltage unbalances in single phase line occurred because of the grid unbalances and analysis is made to overcome this fault using defined control technique. Figure number 3 to 7 shows the operation of DFIG under grid voltage unbalances. Before time t=0.2, Cd,comp and Cq,comp controllers are in off condition. At t=0.2 generalised fault is occurred from grid because of that voltage unbalances takes place on DFIG, hence Cd,comp and Cq,comp controllers are activated. Simulation results shown below are obtained using MATLAB/SIMULINK. The controllers are working from time t=0.2 to t=0.5 in between this time duration DFIG is able to overcome torque and reactive power pulsations occurred due to unbalance grid voltage. Figure 3 shows variations in stator d-axis and q-axis current due to grid voltage unbalances.

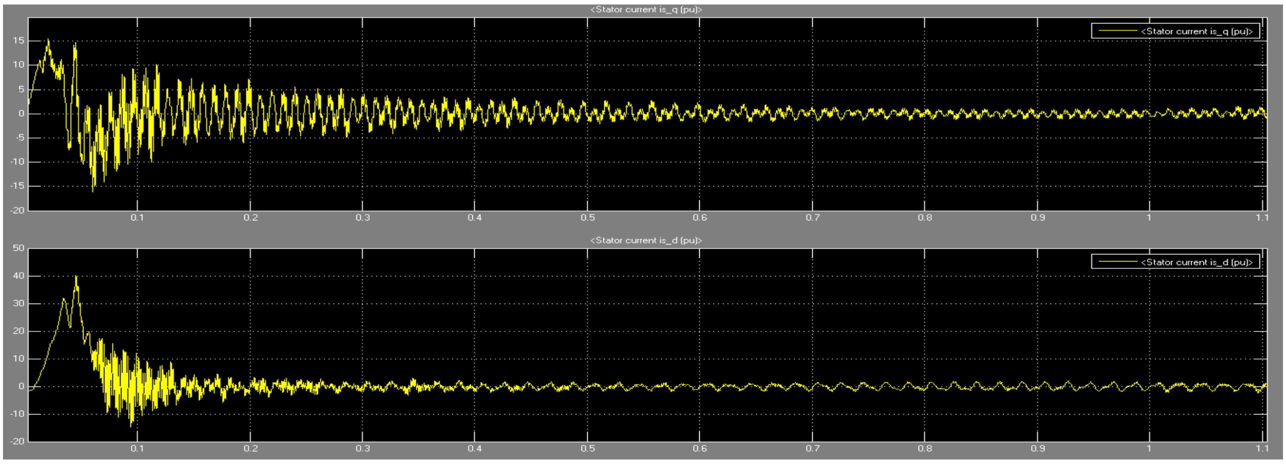

Figure 3- Stator d-axis and q-axis current

In figure 4 changes in rotor d-axis and q-axis voltage is observed according to which rotor excitation changes which results in reduction of torque and reactive power pulsations of DFIG under grid unbalances.

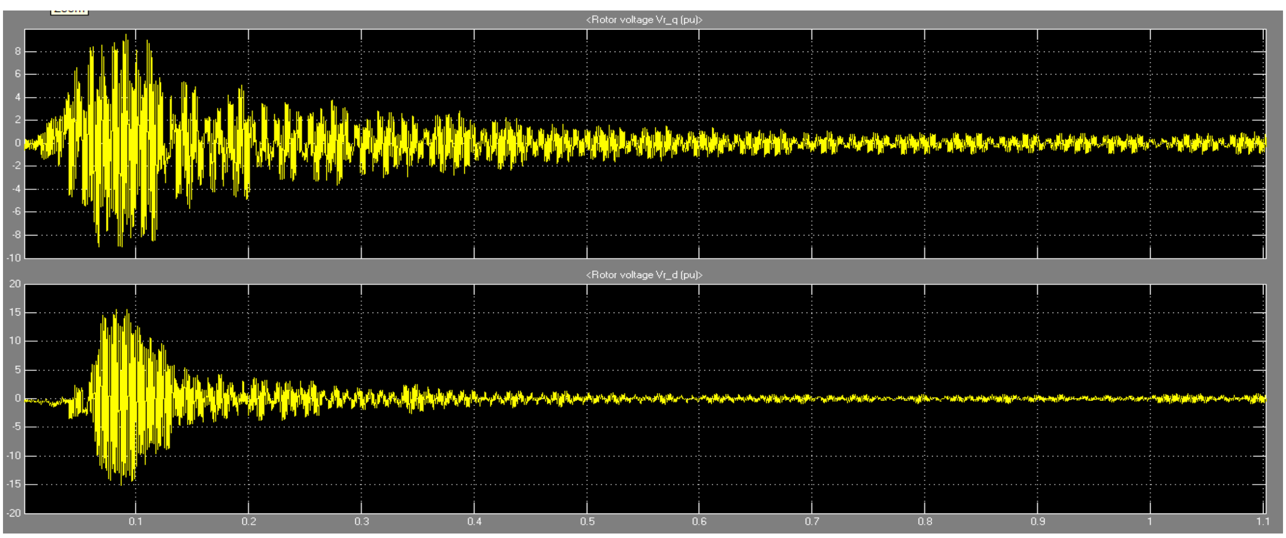

Figure 4- Rotor d-axis and q-axis voltage

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DFIG is able to feed power in the grid from both stator side and rotor side. With the help of figure 5 observations are made on transformation in stator and rotor active power and the addition of both that is total generated active power. By using this control technique unbalances in active power output and generator are removed.

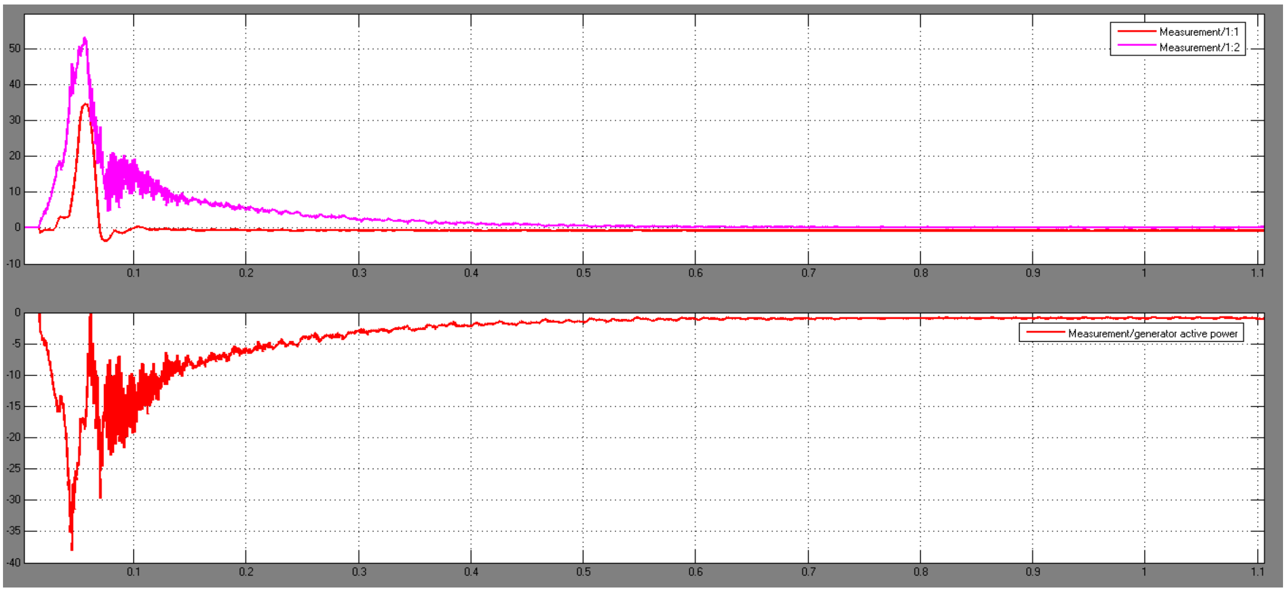

Figure 5- Stator-Rotor active power and Total active power

In the same way figure 6 shows stator and rotor reactive power as well as the total generated reactive power by DFIG under unbalance grid voltage condition.

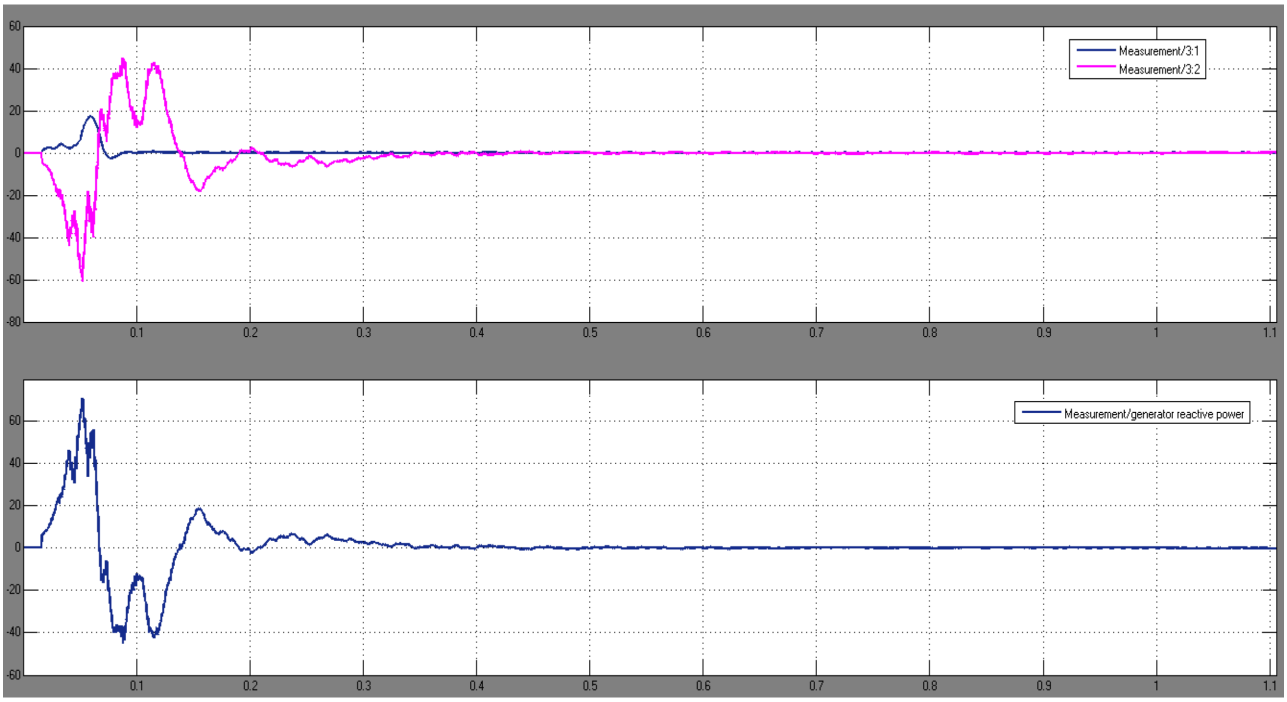

Figure 6- Stator-Rotor reactive power and Total reactive power

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Finally figure 7 demonstrates the total generated active and reactive power by DFIG wind turbine. As torque pulsations are eliminated therefore active power is smoothed and reactive power variations are also removed. It also shows the usefulness of compensation controllers Cd,comp and Cq,comp over the stator voltage unbalances. Generator total active and reactive power wave form is plotted with respect to time.

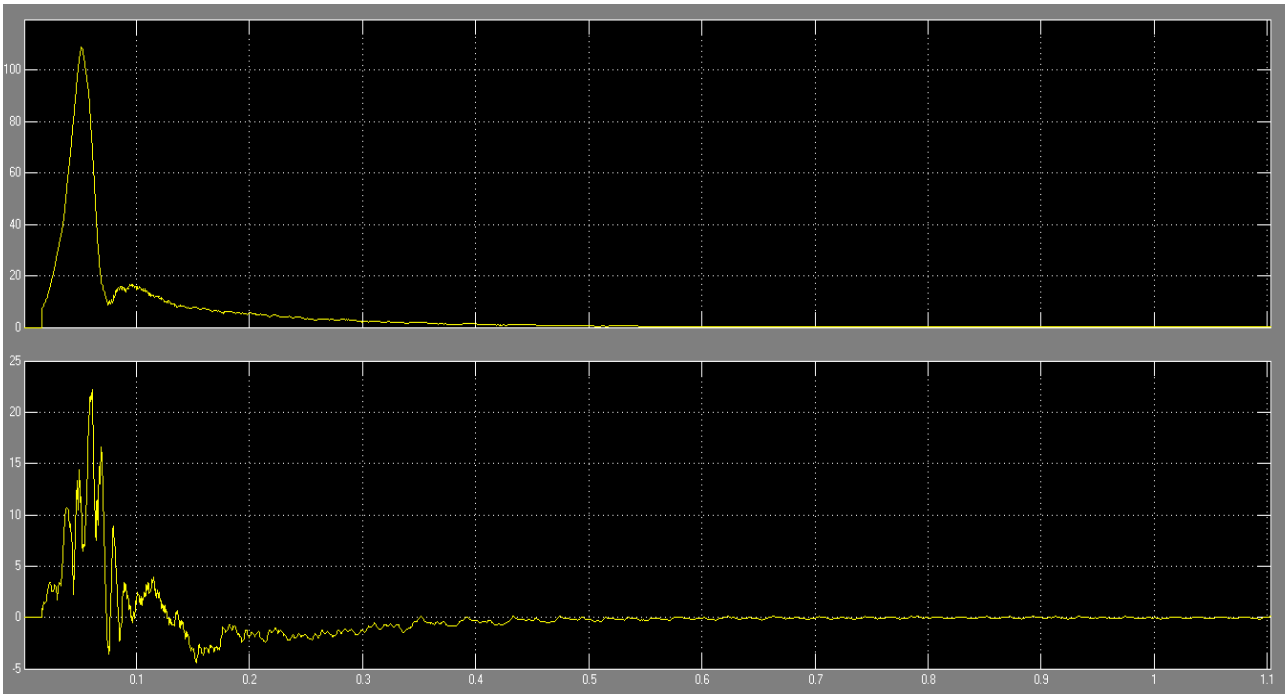

Figure 7- Generator total active & total reactive power

IV.CONCLUSION

In this paper a control methodology for the smooth operation of DFIG wind turbine with unbalanced grid voltage is presented. Simulation testing has shown that the control is simple to implement and very effective for compensating the torque pulsations, reactive power pulsations, and unbalanced stator current that naturally develops when stator voltage is unbalanced. From simulation results it can conclude that compensating control technique greatly reduces the second harmonics and also improve the quality of power fed into the grid.

REFERENCES

[1] R.Allan,N. Jenkins, F.Castro, Z. Saad-Saoud, J. Roman, M. A. Rodrigues, P. Gardner, M. Birks, J. Coneybeare, and A. Ferguson, “Large wind turbines and weak rural electricity systems,” presented at the 1994 BWEA Conf., Stirling, Scotland.

[2] R. Pena, J. Clare, G. Asher, “Doubly fed induction generator using back-to-back PWM convertors and its application to variable speed wind energy generation,” Electrical Power Appl., IEE Proc., vol. 143, no.3, pp. 231-241, May 1996.

[3] E. Muljadi, D. Yildirim, T. Batan and C. P. Butterfield, “Understanding the unbalanced voltage problem in wind turbine generation,” in Proc. IEEE 34th IAS Annu. Meeting, 1999, pp. 1359-1365.

[4] S. Muller, M. Deicke, and R. De Doncker, “Doubly fed induction generator systems for wind turbines,” IEEE Industrial Appl. Mag., vol. 8, no. 3, pp. 26–33, May/Jun. 2002.

[5] N. Mohan, T. M. Undeland, and W. Robbins, Power Electronics: Convertors, Applications and Design. New York: Wiley, 2003, pp. 626-637, 208-210.

[6] S. Bolik, “Modelling and analysis of variable speed wind turbines with induction generator during grid faults,” Ph.D. dissertation, Aalborg Univ., Aalborg, Denmark, 2004.

[7] A. Petersson, “Analysis, modeling and control of doubly fed induction generators for wind turbines,” Ph.D. dissertation, Chalmers Univ. of Technol., Gothenburg, Sweden, 2005.

[8] A. Petersson, L. Harnefors, and T. Thiringer, “Evaluation of current control method for wind turbines using doubly fed induction machines,” IEEE Tran. Power Electronic, vol. 20, no. 1, pp. 227-235, Jan. 2005.

[9] T. Brekken and Ned Mohan, "Control of a doubly fed induction wind generator under unbalanced grid voltage conditions," IEEE Trans. Energy Conv., vol. 22, no. 1, pp. 129-135, Mar. 2007.

[10] J. Hu, Y. He, L. Xu and B. W. Williams, "Improved control of DFIG systems during network unbalance using PI-R current regulators," IEEE Trans. Ind. Electro., vol. 56, no. 2, pp. 439-451, Feb. 2009.

[11] M. Tazil, V. Kumar, R. C. Bansal, S. Kong, Z. Y. Dong, W. Freitas and H. D. Mathur, " Three phase doubly fed induction generators: An overview," IET Electric Power Appl., vol. 4, no. 2, pp. 75-89, 2010.

[12] D. Rai, S. O. Faried, G. Ramakrishna, and A. Edris, "Damping of inter-area oscillations using phase imbalanced series compensation scheme," IEEE Trans. Power Syst., vol. 26, no. 3, pp. 1753–1761, Aug. 2011.

BIOGRAPHY

Ms.Jagruti Solanke received the B. E. degree in Electrical Engineering from Govt. Engineering College, Aurangabad in 2013. Her research interest is in Doubly-fed induction generator wind turbine.

Prof. A. V. Naik received the M.E. in Control System from Veermata Jijabai Technological Institute, Mumbai. Currently she is working as Associate Professor in Jawaharlal Nehru Engineering College, Aurangabad. Her research interest is in Power-Electronics Controller used in Doubly-fed induction wind turbine generator.