International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.5, Nov-Dec. 2012 pp-4030-4033 ISSN: 2249-6645

Enhancement of Power Quality by UPQC Device in SCIG Wind Fram to Weak Grid Connection

Laxman Rao[1], Hari Krishna[2]
1(P.G Student, MIST, Sathupally, Khammam Dist, and A.P)
2 (Assoc. Professor & HOD of EEE, MIST, Sathupally, Khammam Dist, and A.P)

ABSTRACT : *In the last years, the wind power generation incorporated into standard grids has been increased significantly. This situation forced the revision of grid connection code requirements, to guarantee the reliability in systems with high wind power penetration. These strategies were implemented using a Unified Power Quality Compensator (UPQC). A model of wind farm with induction generators connected to a weak grid system, including a detailed UPQC compensator was developed on simulation software. In case of wind farms based on SCIG directly connected to the grid, is necessary to employ the last alternative. Custom power devices technology (CUPS) result very use full for this kind of application. A customized internal control scheme of the UPQC device was developed to regulate the voltage in the WF terminals, and to mitigate voltage fluctuations at grid side. The internal control strategy is based on the management of active and reactive power in the series and shunt converters of the UPQC, and the exchange of power between converters through UPQC DC–Link. This approach increases the compensation capability of the UPQC with respect to other custom strategies that use reactive power only. Simulations results show the effectiveness of the proposed compensation strategy for the enhancement of Power Quality and Wind Farm stability.*

Keywords: *Unified Power Quality Compensator (UPQC), Squirrel Cage Induction Generators (SCIG), Power Quality, Wind Fram, Voltage Fluctuations.*

I. INTRODUCTION

The location of generation facilities for wind energy is determined by wind energy resource availability, often far from high voltage (HV) power transmission grids and major consumption centers [1]. In case of facilities with medium power ratings, the WF is connected through medium voltage (MV) distribution head-lines. A situation commonly found in such scheme is that the power generated is comparable to the transport power capacity of the power grid to which the WF is connected, also known as weak grid connection. The main feature of this type of Connections are the increased voltage regulation sensitivity to changes in load [2]. So, the system's ability to regulate voltage at the point of common coupling (PCC) to the electrical system is a key factor for the successful operation of the WF. Also, is well known that given the random nature of wind resources, the WF generates fluctuating electric power. These fluctuations have a negative impact on stability and power quality in electric power systems. [3] Moreover, in exploitation of wind resources, turbines employing squirrel cage induction generators (SCIG) have been used since the beginnings. The operation of SCIG demands re-active power, usually provided from the mains and/or by local generation in capacitor banks [4], [5]. In the event that changes occur in its mechanical speed, ie due to wind disturbances, so will the WF active (reactive) power injected(demanded) into the power grid, leading to variations of WF terminal voltage because of system impedance. These power disturbances propagate into the power system, and can produce a phenomenon known as "flicker", which consists of fluctuations in the illumination level caused by voltage variations. Also, the normal operation of WF is impaired due to such disturbances. In particular for the case of "weak grids", the impact is even greater. In order to reduce the voltage fluctuations that may cause "flicker", and improve WF terminal voltage regulation, several solutions have been posed. The most common one is to upgrade the power grid, increasing the short circuit power level at the point of common coupling PCC, thus reducing the impact of power fluctuations and voltage regulation problems [5]. In recent years, the technological development of high power electronics devices has led to implementation of electronic equipment suited for electric power systems, with fast response compared to the line frequency. These active compensators allow great flexibility in: a) controlling the power flow in transmission systems using Flexible AC Transmission System (FACTS) devices, and b) enhancing the power quality in distribution systems employing Custom Power System (CUPS) devices [6] [9]. The use of these active compensators to improve integration of wind energy in weak grids is the approach adopted in this work.

In this paper we propose and analyze a compensation strategy using an UPQC, for the case of SCIG–based WF, connected to a weak distribution power grid. This system is taken from a real case [7].

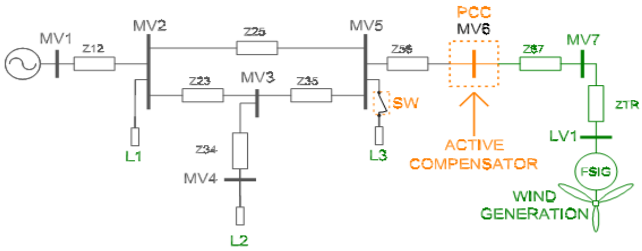

Fig. 1 Study Case Power System

The UPQC is controlled to regulate the WF terminal voltage, and to mitigate voltage fluctuations at the point of common coupling (PCC), caused by system load changes and pulsating WF generated power, respectively.

The voltage regulation at WF terminal is conducted using the UPQC series converter, by voltage injection "in phase" with PCC voltage. On the other hand, the shunt converter is used to filter the WF generated power to prevent voltage fluctuations, requiring active and reactive power handling capability. The sharing of active power between converters is managed through the common DC link. Simulations were carried out to demonstrate the effectiveness of the proposed compensation approach.

II. UNIFIED POWER QUALITY COMPENSATOR

A. *UPQC:*

The UPQC is utilized for simultaneous compensation of the load current and the voltage disturbance at the source side. Normally the UPQC has two voltage source inverters of three-phase four-wire or three-phase three-wire configuration. One inverter, called the series inverter is connected through transformers between the source and the common connection point. The other inverter, called the shunt inverter is connected in parallel through the transformers. The series inverter operates as a voltage source, while the shunt inverter operates as a current source. The UPQC has compensation capabilities for the harmonic current, the reactive power compensation, the voltage disturbances, and the power flow control. However, it has no compensation capability for voltage interruption because no energy is stored.

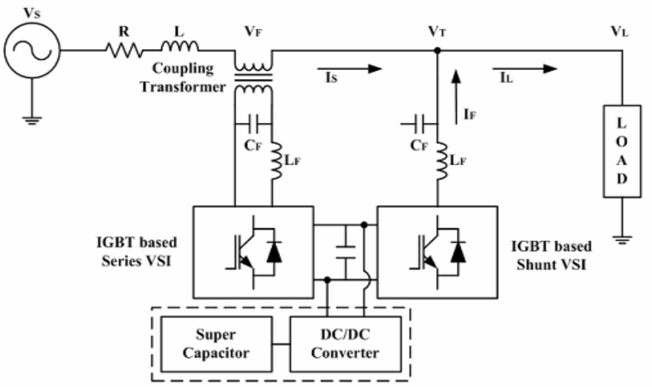

Fig. 2 UPQC system interconnected with energy storage

Fig. 3 Phasor diagram of UPQC

B. *UPQC control strategy:*

The UPQC serial converter is controlled to maintain the WF terminal voltage at nominal value (see U1 bus-bar in Fig.4), thus compensating the PCC voltage variations. In this way, the voltage disturbances coming from the grid cannot spread to the WF facilities. As a side effect, this control action may increase the low voltage ride–through (LVRT) capability in the occurrence of voltage sags in the WF terminals. Fig.5 shows a block diagram of the series converter controller. The injected voltage is obtained subtracting the PCC voltage from the reference voltage, and is phase aligned with the PCC voltage (see Fig.3).On the other hand, the shunt converter of UPQC is used to filter the active and reactive power pulsations generated by the WF. Thus, the power injected into the grid from the WF compensator set will be free from pulsations, which are the origin of voltage fluctuation that can propagate into the system. This task is achieved by appropriate electrical currents injection in PCC. Also, the regulation of the DC bus voltage has been assigned to this converter. Fig. 4 shows a block diagram of the shunt converter controller. This controller generates both voltages commands $Ed\_shu(t)^*$ and $Eq\_shu(t)^*$ based on power fluctuations ΔP and ΔQ, respectively. Such deviations are calculated subtracting the mean power from the instantaneous power measured in PCC. The mean values of active and reactive power are obtained by low–pass filtering, and the bandwidth of such filters are chosen so that the power fluctuation components selected for compensation, fall into the flicker band as stated in IEC61000-4-15 standard. In turn, $Ed\_shu(t)^*$ also contains the control action for the DC–bus voltage loop. This control loop will not interact with the fluctuating power compensation, because its components are lower in frequency than the flicker–band.

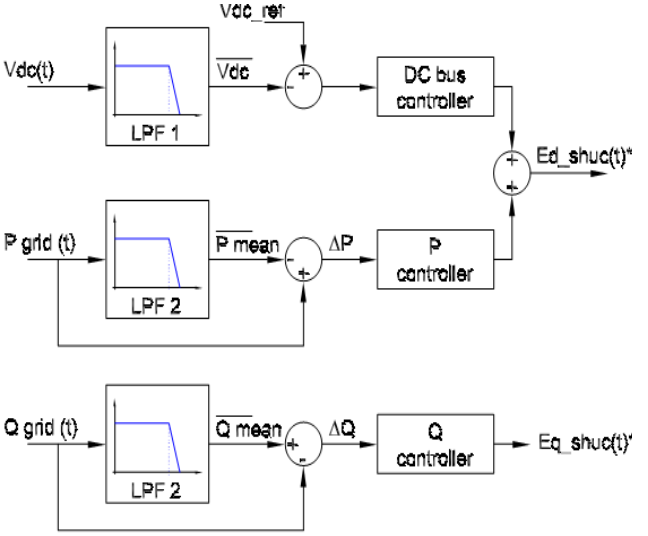

Fig. 4 Shunt compensator controller

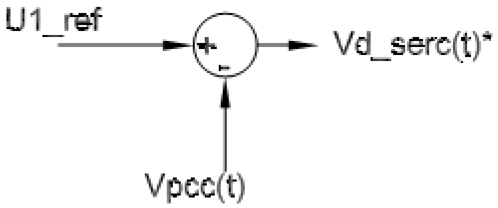

Fig. 5 Series Compensator Controller

In summary, in the proposed strategy the UPQC can be seen as a "power buffer", leveling the power injected into the power system grid. The Fig.6 illustrates a conceptual diagram of this mode of operation. It must be remarked that the absence of an external DC source in the UPQC bus, forces to maintain zero–average power in the storage element installed in that bus. This is accomplished by a proper design of DC voltage controller .Also, it is necessary to note that the proposed strategy can-not be implemented using other CUPS devices like D–Statcom or

DVR. The power buffer concept may be implemented using a D-Statcom, but not using a DVR. On the other and, voltage regulation during relatively large disturbances, cannot be easily coped using reactive power only from D-Statcom; in this case, a DVR device is more suitable.

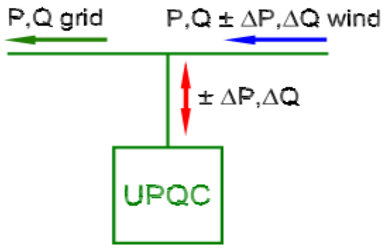

Fig. 6 Power Buffer Control

III. S IMULATION RESULTS AND DISCUSSION

The model of the power system scheme illustrated in Fig. 1, including the controllers with the control strategy detailed in section III, was implemented using Matlab/Simulink software. Numerical simulations were performed to determine and then compensate voltage fluctuation due to wind power variation, and voltage regulation problems due to a sudden load connection. The simulation was conducted with the following chronology:

- at t = 0.0″ the simulation starts with the series converter and the DC–bus voltage controllers in operation.
- at t = 0.5″ the tower shadow effect starts;
- at t = 3.0″ Q and P control loops(see Fig.4) are enabled;
- at t = 6.0″ L3 load is connected.
- at t = 6.0″ L3 load is disconnected

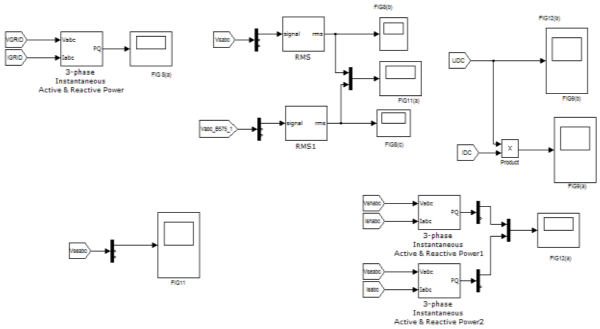

Fig. 7 Simulink diagram for UPQC Sub system

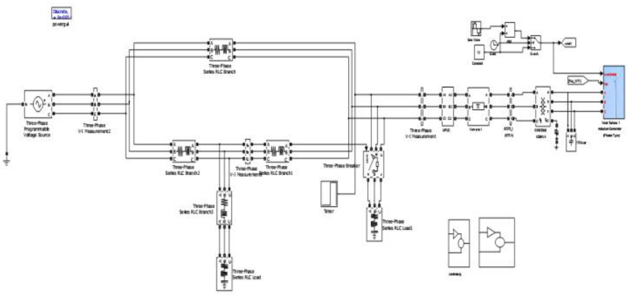

Fig. 8 Main Simulink diagram for UPFC

At t = 0.5″ begins the cyclical power pulsation produced by the tower shadow effect. As was mentioned, the tower shadow produces variation in torque, and hence in the active and reactive WF generated power. For nominal wind speed condition, the power fluctuation frequency is f = 3.4 Hz, and the amplitude of the resulting voltage variation at PCC, expressed as a percentage is 1.50%. This voltage fluctuation is seen in middle curve of Fig. 9 & Fig.10 for 0.5 < t < 3.

The fluctuation value is higher than the maximum allowed by the IEC61000-4-15 standard. This means that even in normal operation, the WF impacts negatively on the System Power Quality. At t = 3.0″the active and reactive power pulsations are attenuated because the P and Q controllers come into action. The amplitude of the PCC voltage fluctuation is reduced from its original value of 1.6% (without compensation) to this new value 0.18%. The pulsation of active power and voltage at the UPQC DC–side, are shown in Fig.9

As can be observed in the upper curve, the series converter requires negligible power to operate, while the shunt converter demands a high instantaneous power level from the capacitor when compensating active power fluctuation. Compensation of reactive powers has no influence on the DC side power.

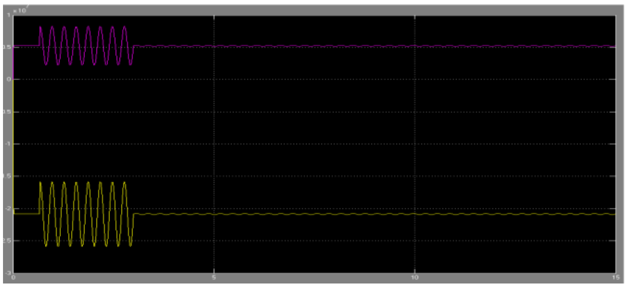

Fig. 9 active and reactive power demand at power grid side

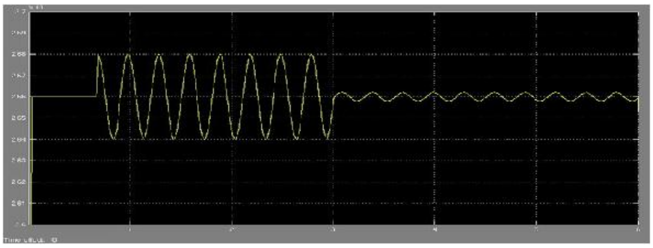

Fig. 10 PCC voltage

The DC-bus has voltage level limitations in accordance with the VSI's operational characteristics. As the fluctuating active power is handled by the capacitor, its value needs to be selected so that the "ripple" in the DC voltage is kept within a narrow range.

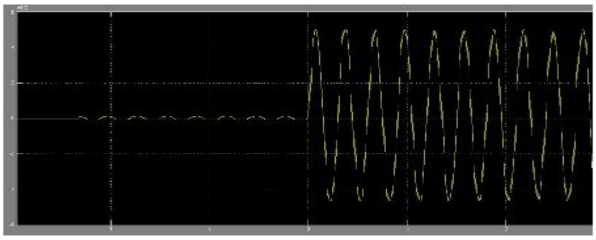

Fig. 11 Power of the capacitor in the DC–Bus

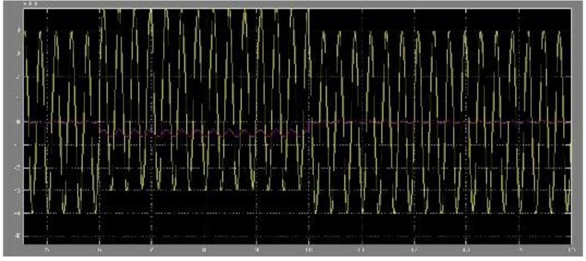

Fig. 12 Shunt and Series Active Power

In the upper curve of Fig.11 and Fig. 12 is seen shunt and series converter active power behavior. The mean power injected (absorbed) by series converter is absorbed (injected) by shunt converter, because of DC voltage regulation loop action (Fig.9). So, the step in series converter active power is the same but opposite sign, that shunt converter power. Fig.12 also shows DC–bus voltage, and is clearly seen the VDC control action

IV. CONCLUSION

In this paper, a new compensation strategy implemented using an UPQC type compensator was presented, to connect SCIG based wind farms to weak distribution power grid. The proposed compensation scheme enhances the system power quality, exploiting fully DC–bus energy storage and active power sharing between UPQC converters, features not present in DVR and D–Statcom compensators. The simulation results show a good performance in the rejection of power fluctuation due to “tower shadow effect” and the regulation of voltage due to a sudden load connection. So, the effectiveness of the proposed compensation approach is demonstrated in the study case. In future work, performance comparison between different compensator types will be made.

REFERENCES

[1] M.P. P´alsson, K. Uhlen, J.O.G. Tande. “Large-scale Wind Power Integration and Voltage Stability Limits in Regional Networks”; IEEE 2002. p.p. 762–769

[2] P. Ledesma, J. Usaola, J.L. Rodriguez “Transient stability of a fixed speed wind farm” Renewable Energy 28, 2003 pp.1341–1355

[3] P. Rosas “Dynamic influences of wind power on the power system”. Technical report RISØR-1408. Ørsted Institute. March 2003.

[4] R.C. Dugan, M.F. McGranahan, S. Santoso, H.W. Beaty “Electrical Power Systems Quality” 2nd Edition McGraw–Hill, 2002. ISBN 0-07- 138622-X

[5] P. Kundur “Power System Stability and Control” McGraw-Hill, 1994. ISBN 0-07-035958-X

[6] N. G. Hingorani y L. Gyugyi. “Understanding FACTS”. IEEE Press; 2000.

[7] Z. Saad-Saoud, M.L. Lisboa, J.B. Ekanayake, N. Jenkins and G. Strbac “Application of STATCOM’s to wind farms” IEE Proc. Gen. Trans. Distrib. vol. 145, No. 5; Sept. 1998

[8] T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi “Wind Energy Handbook” John Wiley & Sons, 2001. ISBN 0-471-48997-2.

[9] A. Ghosh, G. Ledwich “Power Quality Enhancement Using Custom Power Devices” Kluwer Academic Publisher, 2002. ISBN 1-4020-7180- 9

[10] C. Schauder, H. Mehta “Vector analysis and control of advanced static VAR compensators” IEE PROCEEDINGS-C, Vol.140, No.4, July 1993.

[11] E.M. Sasso, G.G. Sotelo, A.A. Ferreira, E.H. Watanabe, M. Aredes, P.G. Barbosa, “Investigac¸ ˜ao dos Modelos de Circuitos de Sincronismo Trif´asicos Baseadosna Teoria das Potˆencias Real e Imagin´aria Instantaneas (p–PLL e q–PLL)”, In: Proc. (CDROM) of the CBA 2002 – XIV Congresso Brasileiro de Automtica, pp. 480-485, Natal RN, Brasil, 1-4, Sep. 2002

[12] International Electrotechnical Commission ”INTERNATIONAL STANDAR IEC 61000-4-15: Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques Section 15: Flickermeter Functional and design specifications.” Edition 1.1 2003

[13] H. Akagi, E. H. Watanabe, M. Aredes “Instantaneous power theory an applications to power conditioning”, John Wiley & Sons, 2007. ISBN 978-0-470-10761-4.