International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-2, December 2012

Improvement of Power Quality of Grid Integrated Wind Distributed Generation by STATCOM

Surekha Manoj, Puttaswamy Palahalli Srinivasaiah

Abstract— ***Worldwide fast depletion of conventional energy resources necessitates the implementation of renewable energy sources for generation to satisfy the growing demand. Since last decade, technological innovations and a changing economic and regulatory environment have resulted considerable revival of interest in connecting wind generation to the grid. Utilities are seeking to understand possible impacts on system operations when a large amount of wind power is introduced into the electric power system. Producers of renewable energy must condition the power produced in order to interconnect with the power grid and not interface with the grid's overall performance. In these aspects Flexible AC Transmission Systems (FACTS) Technology plays a vital role in enhancing the power system performance and improving the power quality of the system. This paper concentrates on power quality issues when wind power integrates with grid and the solution with the usage of STATCOM. An attempt is made with IEEE 16 Bus, 3 feeder test system and modeled for simulation study using MATLAB/SIMULINK simulation. Scopes obtained from the simulation results are proven for the improvement of voltage profile which in turn improves the overall power quality issues.***

Index Terms— ***FACTS, Wind Energy, Power Quality, Grid Integration.***

I. INTRODUCTION

India's rapidly growing economy and population leads to relentlessly increasing electricity demand. As a result, the country's installed power generation capacity has increased from just 1.4 GW in 1947 to over 170 GW in 2010. According to the Ministry of New and Renewable Energy(MNRE), today the share of renewable based capacity is 10.9%(excluding large hydro) of the total installed capacity of 170 GW in the country. This includes 13,065.78 MW of wind, 2939 MW of small hydro power, 1,562 MW of co-generation, 997 MW of biomass, 73.46 MW of waste to power and 17.8 MW of solar PV for grid connected renewable at the end of 2010 [1].

Present scenario is not only to satisfy demand but also maintaining higher power quality along with the rising concern about problems related to our environment, such as global warming. These are new challenges to the power grid and it is expected to perform better and be "Greener". The drawbacks of centralized generation such as, long gestation period, high transmission and distribution losses, poor efficiency, high carbon footprint and peak demand management through load shedding caused the rapid development of Distributed Generation (DG) technology and is gradually reshaping the conventional power systems in number of countries [2].

DGs applications in the vicinity of the load had shown greater operational and power quality advantages, in addition to transmission losses reduction. DGs are very appropriate for particular site and specific applications as they require short period of construction and need low investment. It is defined on the basis of size of the plant, which may vary from few KW to MW (10–50 MW). DG options can be classified based on the fuel source as renewable or non-renewable [3]. DG has brought greater attention from the power community, when it is associated with renewable energy sources, as a sustainable alternative energy.

In addition to the environmental benefits, renewable energy conversion systems penetration increases the utility's reserve capacity by adding converted power into electricity. They can provide power to remote areas, relieving the generating and distribution utilities from expanding their resources. They can also be integrated with existing transmission or distribution networks [5]. Grid connected wind capacity is undergoing through fastest rate of growth compared to any form of renewable electricity generation, achieving global annual growth rates of 20–30 % [4]. Fig. 1 depicts the global wind power installed capacity.

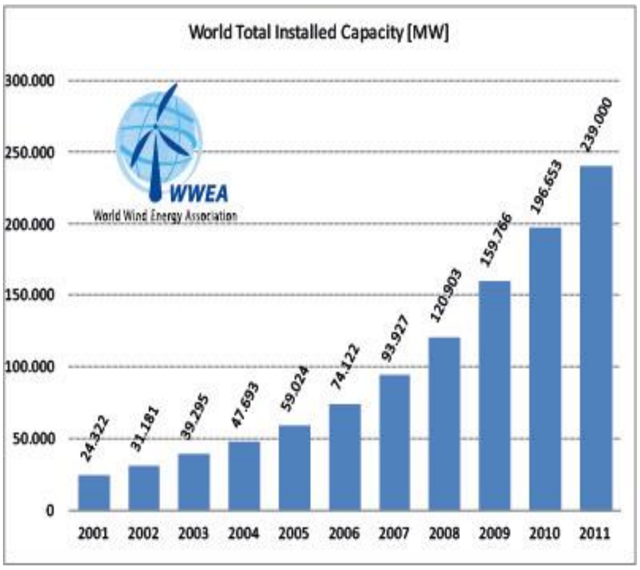

Fig.1 Global Wind Power installed Capacity

ghlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. Do not change the font sizes or line spacing to squeeze more text into a limited number of pages. Use italics for emphasis; do not underline.

Manuscript published on 30 December 2012.
***** Correspondence Author (s)
Surekha Manoj*, Electrical and Electronics Department, Vidya Vikas Institute of Engineering & Technology, VTU, Mysore, India.
Second Author name, Puttaswamy Palahalli Srinivasaih, Electrical and Electronics Department, PES College of Engineering, Mandya, India.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

II. GRID INTEGRATION WITH WIND ENERGY

A. Challenges:Integrating renewable technologies with the traditional power grid may face many challenges.

- When DG is fed into the power grid, it produces changes on the power flow pattern and may bring different challenges including voltage quality problems, limiting the maximum penetration capacity of DG units on the network and their location [2,6,7]. The installations must meet requirements of the grid connection codes such as fault ride through capability, reactive power range, voltage control and frequency range and control [8, 11].
- Majority of the wind power based DG technologies employ induction generators instead of synchronous generators, for the technical advantages of induction machines like, reduced size, increased robustness, lower cost, increased electromechanical damping and its capability to be synchronized directly to the grid [4]. The main disadvantage is that the grid has to supply not only the load and lines reactive power but also the generator. Its reactive power consumption depends on active power production. It is therefore very important to meet the variable VAR requirements within the wind farm locality and to relieve the hosting utility from supplying extra VAR's [5].
- Following the fault conditions the induction generator draws more reactive power from the grid and the voltage recovery may become impossible, and consequently the wind farm may experiences voltage collapse at its terminals [4, 9, 11].
- During a grid fault, the wind turbines are rapidly disconnected from the power network and reconnected when normal operation has been resumed. This is possible, as long as wind power penetration remains low. However, the penetration of wind power is increasing rapidly and also demand is starting to influence overall power system behavior [9, 12].
- Wind being a geographically and climatically uncontrollable resource and the nature of distributed wind induction generators, the stability and power quality issues of integrating large wind farm in grid may become pronounced [10].

B. Solution

To minimize reactive power exchange between wind power plant and distribution network, dynamic compensation of reactive power can be employed which would help in preventing the voltage collapse at the terminals of wind farms and lead to improving the stability of the wind farm. There are several ways offered to fulfill the requirements of reactive power compensation and to overcome the drawbacks mentioned above.

C. Cables

The cable itself represents a VAR source that should be used to supply reactive power into the grid. With slightly under-compensated cables it is possible to provide a considerable contribution to VAR generation [11]. However, to increase the transmission capacity and reduce the losses, long AC cables always need compensation by shunt reactors on both sides. Besides, the switching capability of circuit breakers is also limited.

D. Transformers equipped with on-load Tap Changers (TC)

By using tap changers the voltage on the wind farm side can be controlled in a definite range. It is also possible to reduce the reactive power demand by operating the system at higher voltage levels [13]. But TC cannot solve the power quality issues, such as power fluctuations, voltage fluctuations, and harmonics, satisfactorily because these devices are not fast enough [14].

E. Mechanical Switched Capacitor banks (MSC)

Switched shunt capacitor banks may also be an option to generate capacitive power, but it presupposes a proper medium or low voltage level where the capacitors can be connected. Although mechanically switched capacitors can play a significant part in an overall VAR compensation system, it doesn't have the response or the repeatability of operation that are generally needed for the dynamic compensation of power system. Precise and consistent control of the MSC closure is not possible.

Moreover, the frequent switching of MSC and TC causes resonance and transient overvoltage, which add additional stress on wind turbine gearbox and shaft, make themselves and turbines wear out quickly and hence, increase the maintenance and replacement cost.

F. Flexible AC Transmission Systems (FACTS)

It is a power electronics revolution, which not only offered the advantage of high speed and reliability of switching but enhanced the value of electric energy. FACTS technology opens up new opportunities for controlling power and enhancing the usable capacity of present as well as new and upgraded lines and overtook MSC and TC [14]. The ability of FACTS controllers to control the interrelated parameters that govern the operation of transmission systems including series impedance, shunt impedance, current, voltage, phase angle and the damping of oscillations opens a wide door for power system. When smooth reactive power control is needed, FACTS may be the right option.

Several studies have found that FACTS technology not only provides solutions for efficiently increasing transmission system capacity but also increases available transfer capability, relieve congestion, improve reliability and enhances operation and control [11]. Different FACTS can be used to generate/absorb the reactive power required. They are classified as, Shunt connected controllers, Series connected controllers, Combined shunt and series connected controllers. Static Synchronous Compensator (STATCOM) and Static VAR Compensator (SVC) are shunt controllers and widely used for voltage control, VAR compensation and for damping oscillation. Static Synchronous Series Compensator (SSSC) is a series controller and used for current control, damping oscillations fault current limiting. Unified Power Flow Controller (UPFC) is combination of shunt and series controllers, which is used for active and reactive power control, voltage control, VAR compensation etc [14]. The installation of the DFACTS in the distribution network allows better and higher penetration of DGs [2]. Simulation results show that the FACTS controllers prevents large deviations of bus voltage magnitude induced by reactive power drawn from grid during an external three-phase fault and under wind speed changes [4].

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Usage of fixed type VAR across each wind turbine generator would not be practical as the VAR level changes with the power delivered and hence suggested a FACT system to regulate [5]. The placement of both STATCOM and SSSC at suitable locations proved that dynamic voltage control of the wind farm to ride through the grid disturbances is achieved [9]. The effectiveness of STATCOM in facilitating the integration of a large windmill into a weak power system has been studied and a STATCOM is proposed for dynamic voltage control and steady state of the system [10].

The best improvement can also be achieved by connecting static shunt capacitors to the system during fault conditions [15]. SVC and TCSC applied to damp sub synchronous resonance caused by the induction generator connected to the grid through series compensated line [16]. The inclusion of SVC in fixed speed wind turbine improves voltage stability and prevents the disconnection [17]. Several researches show that SVC and STATCOM can improve power system performance when wind farm connects the grid [18]. But STATCOM implementation is better than SVC for overall improvements of power system.

The capabilities of FACTS made ENERCON power electronics technology to implement FACTS controller in the ENERCON wind energy converters itself [19]. ABB has experience of installing over 600 FACTS application in over 50 countries and seen an improvement in capability and flexibility of transmission corridors at least by 10% to 15% [6]. Many researchers have proposed about FACTS implementation in windmills integrated with grid in order to overcome the associated problems discussed above. .

III. CASE STUDY AND SIMULATION RESULTS

A modified IEEE 16 node and 3 feeder test system is selected for the case study as shown in fig.2. Here grid is supplying feeder 1, 2 and 3. One of the feeders is replaced by wind DG whose total generation is 9 MW to see the effect of renewable integration with the grid. This test system is modeled using MATLAB/SIMULINK as shown in fig 3.

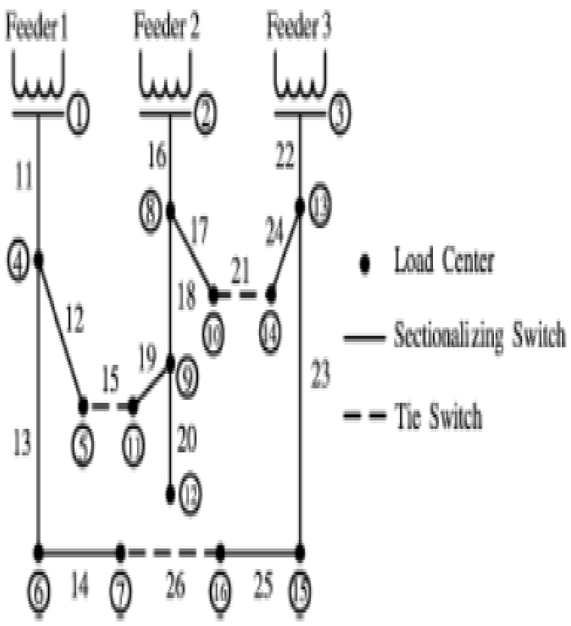

Fig. 2 IEEE 16 node three feeder distribution system

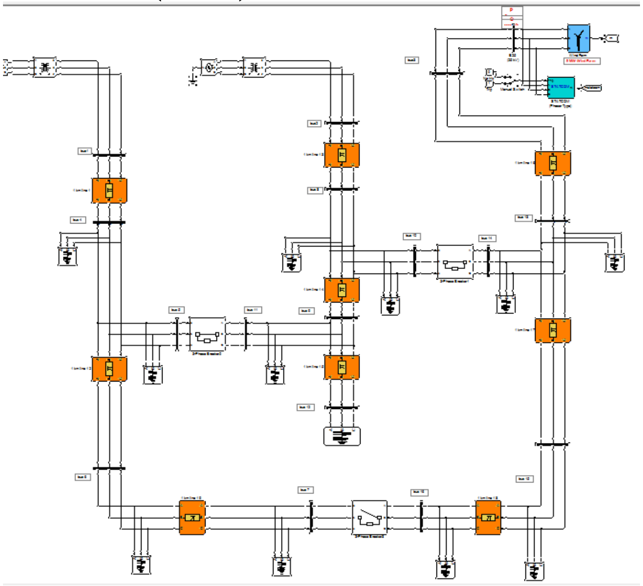

Fig. 3 Simulink model of Wind Farm integrated with grid and analyzed the system with wind integration at feeder 3 point from simulation studies.

For this position simulation is carried out with STATCOM and without STATCOM. This is carried out by changing the position of switches in the simulation model. The obtained results from the scopes are shown in fig 4 and fig 5.

It is very well seen from the scope that a considerable improvement in voltage profile and considerable improvement in power output when STATCOM is connected at the point of common coupling than when there was no STATCOM connected at the point of common coupling.

Further a double line to ground fault is created at one of the wind turbine generator as disturbance in the system to observe how the total system behaves with STATCOM and without STATCOM. The results obtained are shown in fig. 6 and fig. 7.

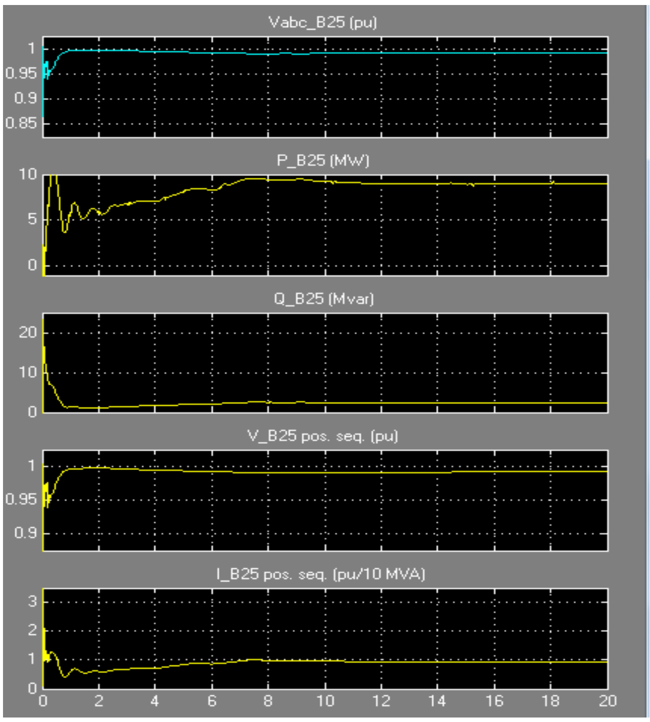

Fig. 4 Steady state analysis with STATCOM

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

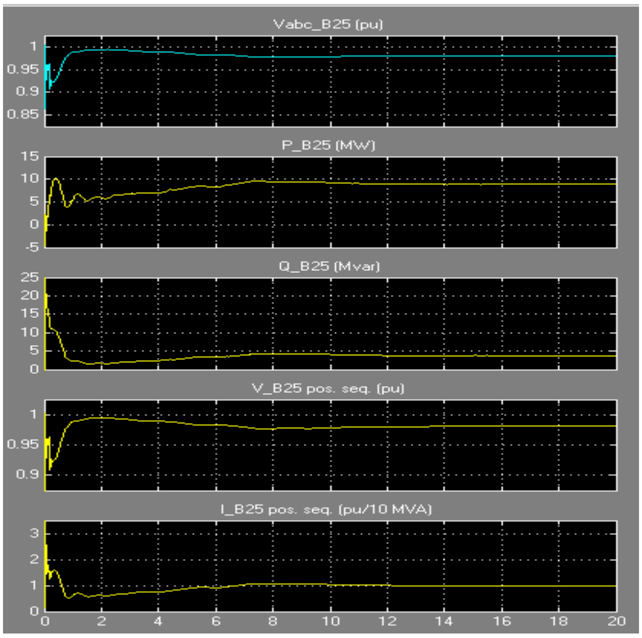

Fig. 5 Steady state analysis without STATCOM

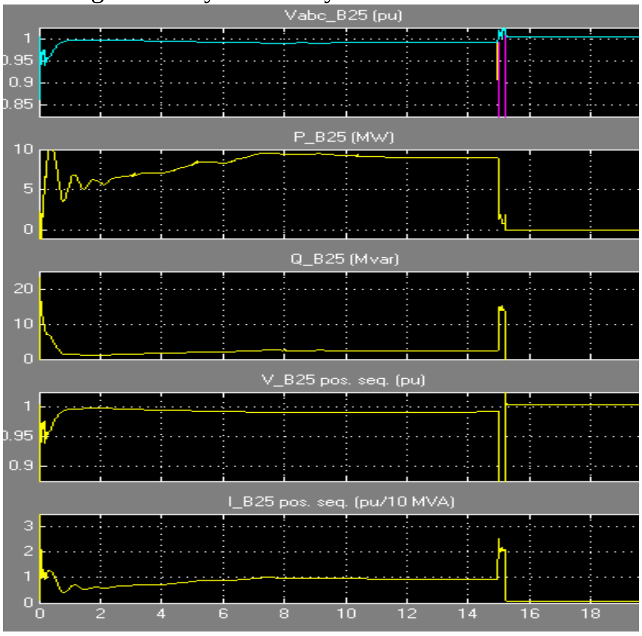

Fig. 6 Transient state analysis with STATCOM

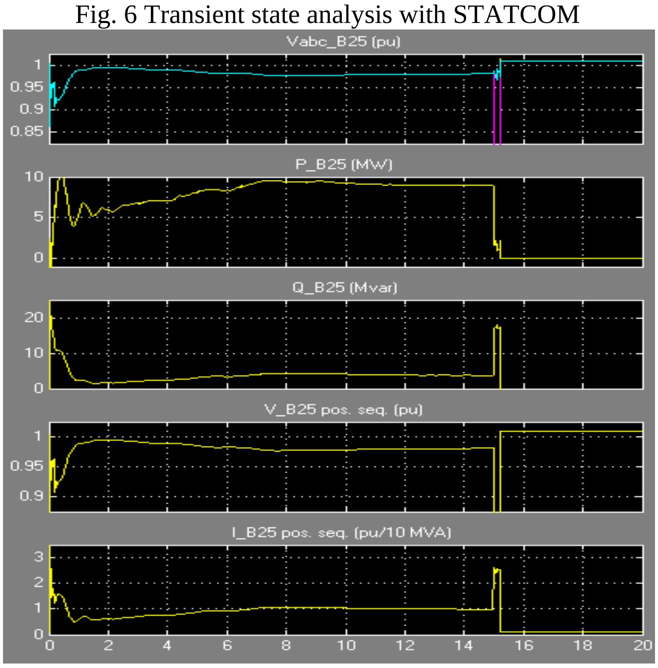

Fig. 7 Transient state analysis without STATCOM

All the performance parameters like voltage, real power and reactive power shows considerable improvement with STATCOM when compared with no STATCOM at the point of common coupling.

The response of real power P, reactive power Q, and voltage behavior in scope is observed for 20 seconds and fault is created at 15 seconds of the study considered.

From the scope it is very clear that after the fault active power goes to zero indicating that Wind Energy DG has been isolated from the system and voltage improvement with STATCOM is observed.

The pitch of the blade is varied in the given range in order to maintain the power constant for the varying wind with its cut-in and cut-out speed ranges to handle different loads, here the maximum pitch angle is given as 45 degrees and maximum rate of change of pitch is given as 2deg/sec. Maximum power of 1pu can be generated at a wind speed of 9 m/s and it can be observed from Fig.8

IV. CONCLUSION

The attempt made to verify the performance of power system with STATCOM and without STATCOM found satisfactory as it is very clearly seen from the scopes the improvement in the performance curves at the point of common coupling. Very interesting is that voltage is stabilized even during fault condition.

FACTS controller implementation plays a vital role in the improvement of overall performance of the power system. As the wind integration draws reactive power from mains, causes the system voltage deterioration, specially at the point of coupling. A suitable controller helps the system to uplift to maintain grid codes. In this case study STATCOM is used to maintain voltage within limits or as required by the system. With this test study further work is planned to apply the same on real system case study. This work made the confident report to apply on real system.

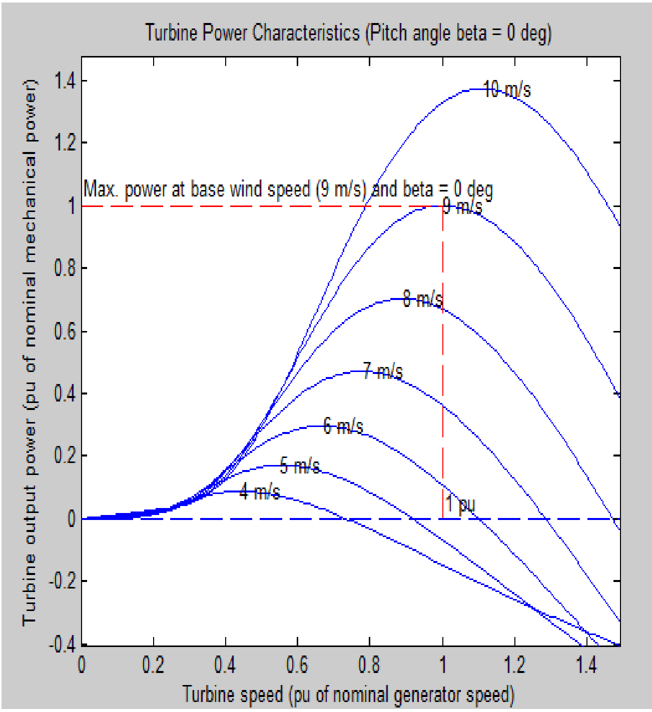

Fig. 8 Turbine Power Characteristics

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

REFERENCES

[1] Indian Wind Energy Outlook 2011 - Global Wind Energy Council, 2011.

[2] Ren H, Yu X, Watts D. Application of DFACTS for the improvement of penetration capacity of distributed generation. DFACTS 2009; 2009 (web.ing.puc.cl/~power/paperspdf/**Dfacts**2009.pdf).

[3] Banerjee R. Comparison of options for distributed generation in India. Energy Policy 2006; 34-1, p. 101-111.

[4] Panda S, Padhy NP. Power electronics based FACTS controller for stability improvement of a wind energy embedded distribution system. International Journal of Electronics, Circuits and Systems 2007; 1-1, p. 30-37.

[5] Zobaa AF, Nigim KA, Bansal RC. Technology of VAr compensation for induction generator applications in wind energy conversion systems. Journal of Electrical Systems 2006; 2-3, p.172-184.

[6] Jones P. Harder and Smarter. IET Power Engineer 2007; p. 34-37 (www.theiet.org/power).

[7] Douglas J, Orme M. Time to Connect. IET Power Engineer 2006; p. 31-33 (www.theiet.org/power).

[8] Cartwright P, Anaya-Lara O, Wu X, Xu L, Jenkins N. Grid compliant offshore wind power connections provided by FACTS and HVDC solutions. Proceedings EWEA conference 2004, p. 1-8.

[9] Qiao W, Harley RG, Venayagamoorthy GK. Effects of FACTS Devices on a power system which includes a large wind farm. Proceedings of Power Systems Conference and Exposition 2006, p. 2070-2076.

[10] Han C, Huang AQ, Litzenberger W, Anderson L, Edris A-A. STATCOM impact study on the integration of a large wind farm into a weak loop power system. Proceedings of Power Systems Conference and Exposition 2006, p. 1266-1272.

[11] Wilch M, Pappala VS, Singh SN, Erlich I. Reactive power generation by DFIG based wind farms with AC Grid connection. Proceedings of Power Tech conference 2007, p. 626-632.

[12] Wessels C., and Fuchs F.W., (2009), “High Voltage Ride Through with FACTS for DFIG based Wind Turbines”- EPE 2009

[13] Andrew Keane, Luis F. Ochoa, Eknath vital, Chris J. Dent, Gareth P. Harrison- “Enhanced Utilization of Voltage Control Resources with Distributed Generation”-IEEE Transaction on power systems- paper accepted for inclusion in future issue of the journal-2010

[14] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission System. IEEE Press.2000.

[15] S. K. Salman, Senior Member, IEEE, and A. L. J. Teo, Associate Member, IEE-“ Dynamic Behaviour of Integrated Multiple Wind Farms during Fault Conditions on the Hosted Distribution Network” Power Tech, 2005 IEEE Russia, Page(s): 1 - 4

[16] Rajiv K. Varma, Member, IEEE, Soubhik Auddy, Student Member, IEEE, and Ysni Semsedini-“ Mitigation of Subsynchronous Resonance in a Series-Compensated Wind Farm Using FACTS Controllers”- IEEE TRANSACTIONS ON POWER DELIVERY,VOL. 23,NO. 3,JULY 2008 164

[17] V. Salehi, S. Afsharnia, S. Kahrobaee “Improvement of Voltage Stability in Wind Farm Connection to distribution Network Using FACTS Devices”- IEEE Industrial Electronics, IECON 2006 - 32nd Annual Conference Publication Year: 2006 , Page(s): 4242 - 4247 , **I**EEE CONFERENCES.

[18] Stephan Wachtel, Stefan Hartge- “Technical and economical benefits of wind energy converters with FACTS capabilities for power systems and the grid integration of wind power”’-EWEC2007, Milan, May 2007 ENERCON.

[19] G. O. Young, “Synthetic structure of industrial plastics (Book style with paper title and editor),” in Plastics, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.

[20] W.-K. Chen, Linear Networks and Systems (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.

[21] H. Poor, An Introduction to Signal Detection and Estimation. New York: Springer-Verlag, 1985, ch. 4.

[22] B. Smith, “An approach to graphs of linear forms (Unpublished work style),” unpublished.

[23] E. H. Miller, “A note on reflector arrays (Periodical style—Accepted for publication),” IEEE Trans. Antennas Propagat., to be published.

[24] J. Wang, “Fundamentals of erbium-doped fiber amplifiers arrays (Periodical style—Submitted for publication),” IEEE J. Quantum Electron., submitted for publication.

Surekha Manoj secured her Bachelor Degree in Electrical & Electronics Engineering at Bapuji Institute of Engineering & Technology under Mysore University during 1990. She Completed her Master’s Degree in Power Systems at National Institute of Engineering under Mysore University during 1994. Currently she is pursuing Ph.D. at PESCE, Mandya, Research centre, under Mysore University in the field of FACTS & hybrid DGs. Her research area includes, Distribution Generation, Hybrid energy, and FACTS Controllers. She has attended and presented 4 international conferences and 3 National conferences. She has published her research work in 4 international journals. She is an IEEE member and also mentor for students IEEE chapter. Also she is a member for IETE and also Institute of Engineers. Presently she is Head of the Department at Vidya Vikas Institute of Engineering and Technology, VTU, Mysore, India.

Puttaswamy Palahalli Srinivasaiah Born on 13/07/1959 qualified his Engineering degree from Mysore University in electrical power engg. during 1983. He completed his M.E in power apparatus and electric drives in 1989 and his Doctoral degree in power apparatus and electric drives in the year 2000 from IIT Roorkee. Presently working as Professor in the Department of E&E, PESCE, Mandya, India. His research area of interest is Power electronics, Electric Drives, and FACTS. He has published several papers in national and International Journals and attended conferences too. He is member of Institute of Engineer.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)