Asian Journal of Convergence in Technology **Volume IV Issue I**
ISSN NO: 2350-1146 I.F-5.11

Wind Farm System: Literature Survey

Nitesh Kumar
Assistant Professor
Electrical Engg.
BKC-MET-Institute of Engineering, Nashik

Dr. D. P. Kadam
Professor
Electrical Engg.
BKC-MET-Institute of Engineering, Nashik

K. S. Kulkarni
Assistant Professor
Electrical Engg.
BKC-MET-Institute of Engineering, Nashik

Sai Kiran Adapa
Assistant Professor
Electrical Engg.
BKC-MET-Institute of Engineering, Nashik

dpkadam@gmail.com, kirtigosavi16@gmail.com

***Abstract*—With increased wind power capacity, transmission system operators have become more concerned about the power quality; reliability and reactive power management of Grid connected wind farms and have issued grid codes. The major concerns and issues highlighted in grid code are active, reactive power control and power quality. In India the majority of wind farms are in rural area. Increasing size of wind farm connected to grid will lead to various challenges such as power quality, security and reactive power control during normal operation, and fault ride through capability during fault conditions. Considering the challenges to be faced related to interfacing of large wind farms using Induction and Synchronous generators, it is necessary to study the various power quality, stability and reactive power requirement of large-scale wind farm connected to grid and provide cost effective solution for management of power quality and reactive power. Overviews of literature survey on Power Quality and Reactive Power Management Of Grid Connected Wind Farm are discussed.**

***Index Terms*—Wind Farm, Wind Generator, Power Quality issues, Power Quality and Reactive Power Management.**

I. INTRODUCTION

Wind electricity installed capacity in India is around 8757.2 MW till March 31st 2008 and gross potential is 45,000 MW. Though India ranks 4th globally, the country managed to register a growth rate of just 25.2 % against the world average of 26.6%. This puts India far behind countries like the Germany, US, Spain, China. Wind generation installed capacity in Maharashtra state is 1,755.9 MW and a gross potential is 3,650 MW. It ranks 2nd after Tamil Nadu having capacity 3,873.4 MW in India. Today India is a major player in the global wind energy.

Considering the increasing share of wind generation interfaced to grid it is necessary to study the power quality and reactive power issues considering voltage quality and stability issues. In case of Induction type wind energy converter reactive power management in cost effective way is essential.

II. LITERATURE SURVEY

In reference [1], presents a method for the steady state analysis of self-excited induction generators using balanced terminal capacitors. The operating characteristics are governed by the magnetic saturation in the machine. Saturation has been incorporated by the use of experimental data, which indicate the variation in magnetizing reactance with air gap flux. Operational and steady state equivalent circuits of the induction machine are employed to predict the steady state performance under different load conditions. The analytical procedure and the related computer program are described in the paper. Simulated results are presented and compared with corresponding results obtained experimentally and a reasonable correlation has been observed.

In reference[2], discussed the capacitance requirements for isolated self-excited induction generators. It is concluded that the steady state as well as operational equivalent circuit methods give same value of the terminal capacitance required to maintain self-excitation under steady state operation. No load terminal capacitances requirements can be estimated by the analytical method proposed and give good agreement with the experimental measurements. Simplified no load model can be used to predict the performances of the self-excited induction generator with good accuracy. The influence of load impedances and its power factor on the terminal capacitance required to maintain self-excitation under steady state is also examined. Also it is concluded that the terminal capacitance required for a loaded machine is significantly higher than the corresponding no load values. It is affected by load impedance, its power factor and machine speed. The maximum power output from an isolated self-excited generator depends upon the terminal capacitances and the machine speed.

In reference [3], presents an accurate method of analysis to predict the steady state performance characteristics of a three-phase isolated induction generator self excited with a single capacitor and feeding a single-phase load. It has been concluded that analytical equations are proposed to find the limiting values of the terminal capacitor, C, and the machine speed, below which an unloaded machine does not maintain self-excitation. For a loaded machine, there are also limiting values which determine the ranges of C, V, and the load impedance over which self-excitation can be maintained. These extreme values can be computed by following the proposed method of analysis. C, V, and the load parameters affect the performance characteristics of a self-excited induction generator. Generally, the value of C has a stronger influence on the performance characteristics and should be selected such that the terminal voltage is near its rated value while keeping C close to its lower limiting value. Also in the mode of operation discussed in this paper, the voltages and currents are unbalanced with relatively high losses and rather low efficiency. Between the two configurations discussed, the delta-connected generator offers a higher current and lower terminal voltage and a wider (three times) range of excitation capacitance.

Investigation of behavior of grid connected induction generators driven by typical prime movers are presented [4] with certain practical operational problems. Effects of variation in grid voltage and frequency input power and terminal voltage are studied. Analysis of self-excitation conditions on disconnection of supply has been carried out. The various practical aspects considered for study are a) The primary distribution network considered is having significant variations in voltage and frequency depending on loading and other conditions. b) Studies with both constant and input powers are carried out. c) Capacitors are connected to generator terminal for power factor improvement. d) The terminal capacitor may cause self-excitation and results high voltage under disconnection from the grid and over speeding of the turbine. E) Effects of system parameters.

Transient Behavior of a wind driven induction generator after its disconnection from power grid is investigated [5]. The variation of the terminal voltage, armature current, and the rotational speed of a wind driven induction generator after its disconnection from the power grid were presented. Suggestions for protection against self-excitation are made. However, in all cases, the generator was assumed to cover all active power that the local load has consumed.

Reference [6], presented a case study of fixed speed wind turbine Induction generator of Wind farm system consisting of 36 ∗ 600 KW fixed speed stall regulated wind turbines interfaced to 33 KV network. This paper has described a comprehensive study of the application of a STATCOM to a wind farm. Several strategies for steady-state voltage and reactive power flow control of a wind farm equipped with a STATCOM were investigated. The unity power flow strategy for controlling reactive power flows of a wind farm is likely to lead to close to minimal losses in real distribution networks. However, it may lead to an inefficient use of compensators in regulating the voltage in distribution systems in extreme circumstances when the system is heavily or/and lightly loaded. The unity power factor control may limit the active power output of embedded generators that can be accommodated, and therefore adversely influence the level of penetration of embedded generation particularly that connected to weak distribution systems. The use of a unity power factor control technique and a voltage control scheme for the STATCOM was also examined. An electromagnetic simulation (EMTDC) was used to model the network, the wind farm and the STATCOM. The STATCOM was able to supply the reactive power requirements of the wind farm under various operating conditions, to control the network voltage actively and hence increase the permitted wind farm capacity and to improve the steady-state stability limit of the network. Its application to prevent damaging over voltages, which may occur under islanding conditions, was demonstrated. The STATCOM was also used to mitigate voltage fluctuations at blade passing frequency successfully. The operation of the STATCOM with a unity power factor control scheme is used to minimize total network losses at the expense of reducing the penetration of embedded generation. The operation of the STATCOM with a voltage-control technique operating on a conventional slope characteristic would improve the steady-state voltage stability of the network and increase the capacity of embedded generation that could be connected. This control technique can also prevent large over voltages due to self-excitation at islanding if a controller with a fast enough speed of response is used. The proposed work is limited to improve only steady state voltage stability and to mitigate voltage fluctuations at blade passing frequency successfully and voltage ride through during disturbances is not studied. The use of STATCOM for reduction of flicker is also not considered.

To facilitate the investigation of the impact of a wind farm on the dynamics of the power system to which it is connected, an adequate model is required. In order to avoid the necessity of developing a detailed model of a wind farm with tens or hundreds of wind turbines and their interconnections, aggregated wind farm models are needed. The work reported in [7], focuses mainly on the development and specification of aggregated wind farm models. Proposed aggregated wind farm model consist of three models a) Wind speed model b) Model of individual wind turbine c) Specification of wind park layout. The various assumption made are the impedances of cables are neglected and only transformer impedance is considered. The wind speed can be split up in a fully deterministic and fully stochastic part. The fully stochastic part is different for each wind turbine and fully deterministic part is same for each wind turbine. The advantages and disadvantages of various wind turbines are presented.

In reference [8], presents the results of a case study concerning reliability evaluation of Ramgiri Wind Farm in Andhra Pradesh, India. It consists of several 250 KW wind electric generators connected to the grid. The failure and repair rates were presented. From each generating station the probability of the total generating capacity not exceeding a given power level were computed by using a computer software program. It has been concluded that the system availability for the given capacity is evaluated. This gives a measure of the reliability of the system.

Reference [9], describes how wind farms affect grid voltages and how faults in the connected transmission system impact on induction generators in a wind farm. In this paper the voltage variations associated with a 60 MW offshore wind farm being connected into an existing power network have been discussed. The paper concludes that an SVC at the grid connection point can mitigate voltage problems. In addition to this, the instability that can occur in a wind farm due to network faults and the recovery from such faults has been discussed. This paper also presents, the induction generator can recover successfully from the short-circuit fault only if it becomes magnetized sufficiently fast so that it can produce torque and reduce the generator rotor over speed. If the over speed becomes too large the generator will pass over the pullout frequency and then it will consume large amounts of reactive power. If the network is weak this situation will cause a voltage collapse to occur in the transmission system. This paper presents, the process can be dynamically supported by an SVC, a STATCOM, or a combination of both, installed close to the connection point of the wind farm to improve voltage stability and to improve recovery from network faults and mitigate voltage flicker. The various reactive power combinations and effects of size of SVC on cost are not considered.

In reference [10], various reactive power techniques are presented for improvement of the ride through capability of induction generators during disturbances on a 114 MW wind farm interconnected to 138 KV transmission systems. Voltage ride through capabilities during system disturbances with different reactive power compensation techniques are studied and compared. Effects of various types of reactive power compensation techniques on all voltages of wind farm terminals and nearby buses are studied. The various cases considered for simulation studies are 1) System without any reactive power compensator. 2) System with fixed capacitor banks and various generations as a percentage of total installed capacity.3) System with FC TCR for different wind generation as a proportional of total installed capacity. The proposed work is carried out considering the various assumptions. a) The compensation of SVC is assumed on power factor control mode. b) All induction generators are assumed to operate at 0.85 leading power factors for the entire operation range. According to authors operation of wind farm at 0.95 leading, unity power factor does not survive after disturbance and the situation is better during disturbance at 0.95 lagging power factor and the performance of SVC is better than fixed capacitor on both steady state as well as dynamic stability.

In reference [11], a work is carried out in relation to the harmonic behavior of wind electric converter in grid-connected mode varying wind speed condition at Maharashtra Energy Development Agency’s 1.84 MW demonstration wind power project at Gudhepanchgani in Maharashtra state (India) as a case study. The voltage and current waveforms are observed in this paper. Author has concluded that the power pollution is caused due to the variation of frequency, voltage, wave shape, asymmetry, transients, impulses, non-sinusoids etc. This pollution is unavoidable as the wind parameters are continuously changing.

In reference [12], presents the measurements taken at wind power project and 220/33 KV substations in Satara district of Maharashtra state in India for the comparison of voltage harmonics generated by grid connected wind turbines. The parameters like voltage distortion factor, harmonics, and crest factor are monitored. It is concluded that the short circuit level of the grid network is very high than the wind power penetration into the network; the impact of wind turbines on power quality is not significant.

Reference [13], presented STATCOM based on voltage source converter (VSC) PWM technique rated at 50 Hz, 50 MVA to stabilize grid connected squirrel cage wind generator system. Fuzzy logic controller (FLC) is used as the control methodology of STATCOM, rather than conventional PI controller. The voltage sag and swell improvement of wind power generation system (WPGS) is compared with both fuzzy and PI controller where the simulations have been done by PSCAD/EMTDC.It is concluded that STATCOM equipped with FLC gives better performance than STATCOM equipped with conventional PI controller. Voltage sag and swell improvement of wind power generation system (WPGS) is compared with both fuzzy logic controller (FLC) and PI controller. The proposed work is carried out for small power system. It is necessary to investigate the WPGS connected with D-STATCOM to large power system and use of more intelligent controller for STATCOM and its interface to large power systems addressing various issues such as security, stability, voltage profile improvement and power quality. Effect of network strength at point of interface on rating and cost of STATCOM is not addressed.

Reference [14], presented a stability of wind farms rated at 60 MW based on fixed speed induction generators (FSIG) and investigates the use of SVC and STATCOM for wind farm. Wind farm models based on FSIG and equipped with either SVC or STATCOM are developed in

PSCAD/EMTDC. Stability of FSIG based wind turbine is highlighted using torque slip and reactive power slip characteristics. A detailed investigation is conducted on impact of SVC/ STATCOM on system recovering after a network fault. Influence of SVC/STATCOM ratings and network strength on system stability is considered. The performance of SVC and STATCOM is compared during disturbances on connected network. It was found that SVC and STATCOM considerably improves the stability during and after disturbances especially when network is weak. According to author compared to SVC, STATCOM give a much better reactive support to the network. The study is carried out for 60 MW wind farm. It is necessary to investigate the application of STATCOM for large size remote wind farms where load centers are far away from the point of connection.

Reference [15], presented a case study of 12-bus multimachine benchmark power system including a large wind farm rated at 360MW. Using suitable software packages to investigate the effects of the STATCOM and SSSC devices on the 12-bus power system including a large wind farm by conducting simulation studies. STATCOM has been used to provide smooth and rapid steady state and transient voltage control at points in the network. Static synchronous series compensator (SSSC) has an excellent performance in damping low frequency power oscillations in a power network. It is concluded that FACTS devices provide an effective means of dynamic voltage control of wind farm, dynamic power control of the transmission lines, improving power oscillations damping and transient stability. It is necessary to extend the work for the large wind farms having DFIG, SFIG and variable speed Induction generators. The sizing of FACTS devices is not considered.

Reference [16], presented solution for integration of large offshore DFIG based wind farms with common collection bus controlled by a STATCOM into the main onshore grid using line commutated HVDC connection. The rated voltage of the offshore AC bus is 132 KV, rated HVDC power is 1000 MW (500KV/2KA) and STATCOM energy storage is 9 MJ. A design procedure is described and controlled system is validated using PSCAD/EMTDC simulations confirming high performance of the proposed control strategy in both normal operation condition and faults. Engineering issues related to STATCOM capacitor sizing and reduction of STATCOM rating are considered and effectiveness is confirmed. According to authors reduction of STATCOM rating can be achieved by increasing the HVDC rectifier current loop band with or by utilization of reactive power capabilities of grid side converter controlling DFIG's. According to authors the proposed control system can be satisfactory solution for integrating large offshore DFIG based wind farms into existing AC networks. The proposed work focuses mainly on DFIG based offshore wind farms integration into existing AC network by using line communicated HVDC connections. It is necessary to study the power quality aspects and implementation of STATCOM for improvement of power quality.

Reference [17], presented a discrete-time sliding mode control of a VSC based STATCOM for wind farm connection to the grid. A sliding-mode controller has been used for currents while pole placement with a slower dynamic response has been used for DC bus voltage control. It is concluded that a discrete-time sliding mode control of a VSC based STATCOM show a small variation of DC bus voltage and a one-sample time step response for reactive power changes in case no voltage saturation occurs. The work is restricted to grid using ideal voltage source with its line resistances and inductances with VSC control. The various objectives are DC bus voltage regulation to its reference value and reactive power tracking at connection point. The considered network is small and effect of SCL at point of connection is not considered.

III NEED OF MORE RESEARCH

As compared to develop countries Indian Grid system is very weak also having poor infrastructure. The percentage of wind-based generation will increase at faster rate, which will results into the impact on the power quality and reactive power management of large wind farm comprising of Synchronous and Induction generator.

IV CONCLUSION

The paper provides an overview of literature survey on Power Quality Management of Grid connected Wind Farm and provides a Cost effective techniques having fast response, which will optimize reactive power, improve reliability, power quality, dynamic and transient stability and security of grid of existing wind farm system including ride through capability during normal as well as faulted conditions.

REFERENCES

[1] A. K. Tandon, S. S. Murthy, G. J. Berg, "Steady State Analysis of Capacitor Self- Excited Induction Generators" IEEE Transactions on Power Apparatus and Systems, Vol. PAS-103, No 3, PP.612-618, March 1984.

[2] N. H. Malik and A. A. Mazi, "Capacitance Requirements for Isolated Self Excited Induction Generators" IEEE Transactions on Energy Conversion, Vol. EC-2 No.1, PP. 62-69, March 1987.

[3] A. H. Al-Bahrani, N. H. Malik, "Steady State Analysis and Performance Characteristics of a Three- Phase Induction Generator Self Excited With a Single Capacitor", IEEE Transactions on Energy Conversion, Vol. 5, No. 4, PP.725-732, December 1990.

[4] S. S. Murthy, C. S. Jha and P. S. Nagendra Rao, "Analysis of Grid Connected Induction Generators Driven by hydro/wind Turbines under Realistic System Constraints" IEEE

Transactions on Energy Conversion, Vol. 5, No. 1, PP. 1-7, March 1990.

[5] C. S. Demoulias and P. S. Dokopoulos, "Transient Behavior and Self-Excitation of Wind-driven Induction generator after its Disconnection from the Power Grid" IEEE Transactions on Energy Conversion, Vol. 5, No. 2, PP. 272-278, June 1990.

[6] Z. Saad-Saoud, M. L. Lisboa, J. B. Ekanayake, N. Jenkins and G. Strbac, "Application of STATCOM to Wind Farms", IEEE Proceedings Generation Transmission Distribution, Vol. 145, No. 5 PP. 511-516, September 1998.

[7] J. G. Slootweg and W. L. Kling, "Modeling of Large Wind Farms in Power System Simulations", Paper published in IEEE Conference, PP. 503-508, and 2002.

[8] J. Bhagwan Reddy, D. N. Reddy, "Reliability Evaluation of a Grid Connected Wind Farm-A case Study of Ramgiri Wind farm in Andhra Pradesh, India", Paper published in IEEE Conference, PP. 659-662, 2004.

[9] R. Grunbaum, P. Halvarsson, D. Larsson, P. R. Jones, "Conditioning of Power Grids serving Offshore Wind Farms based on Asynchronous Generators", ABB Power Technologies, Swedan, PP. 34-39, 2004.

[10] Chai Chompoo-Inwai Chitra Yingvivatanapong K. Methaprayoon Wei-Jen Lee, "Reactive Compensation Techniques to Improve the Ride-Through of Induction Generators during Disturbance", IEEE Conference IAS 2004, PP. 2044-2050, 2004.

[11] W. Z. Gandhare and G. R. Bhagwatikar, "Power Pollution due to Grid Connected Wind Electric Converter", IEEE International Conference on Control Applications, Alaska, USA, 25-27 September 2000, PP. 892-895.

[12] G. R. Bhagwatikar and W. Z. Gandhare, "Impact of Voltage and Short Circuit Level on Harmonics Generated by Wind Turbines", International Conference - ELECTRIC POWER 2005, ASME, Chicago, USA, April 2005, PP. 1-6.

[13] S. M. Muyeen, Mohammad Abdul Mannan, Mohd. Hasan Ali, Rion Takahashi, Toshiaki Murata, Junji Tamura, "Stabilizaton of Grid Connected Wind Generator by STATCOM", Paper published in IEEE PEDS 2005 Conference, PP. 1584-1588, 2005.

[14] Lie Xu, Yao and Christian Sasse, "Comparison of Using SVC and STATCOM for Wind Farm Integration", IEEE Proceedings of the International conference on Power System Technology, PP. 1-7, 2006

[15] Wei Qiao, Ronald G. Harley, Ganesh K. "Effects of FACTS Devices on a Power System Which Includes a Large Wind Farm", Paper accepted for IEEE PSCE 2006 Conference, PP. 2070-2076, 2006.

[16] S. Bozhko, R. Li, R. Blasco-Gimenez, G. M. Asher, J. C. Clare, L. Yao, and C. Sasse, "STATCOM-Controlled HVDC Power Transmission for Large Offshore wind Farms: Engineering Issues" Paper accepted for IEEE Conference, PP. 4219-4224, 2006.