GRID INTEGRATION ISSUES OF WIND FARMS

Lata Gidwani and Akanksha Pareek
Department of Electrical Engineering,
Rajasthan Technical University, Kota, Rajasthan, India

ABSTRACT

Due to growing power demand and environmental concerns, electrical power generation from renewable is receiving more attention. Wind energy generation systems are being connected in increasing numbers to power systems worldwide. With the development of wind energy and power electric control technology, more wind farms are integrated into power grids. While wind turbine systems improve the stability and power quality of systems, several new problems are introduced in power grid. Integrating renewable into grid to any considerable degree can expose the system to issues that need attention. Such issues can be (MPPT) Maximum Power Point Tracking, Power Quality Issues, Power System Stability .This paper provides an overview to the relevant latest research issues related to the integration of wind farms. This paper presents a critical survey on grid integration issues of wind farms. This paper shows an overview of relevantly latest achievements on this area and categorized them into different research directions.

KEYWORDS: *Maximum Power Point Tracking, Power Quality Issues, Neural Network, Power System Stability.*

I. INTRODUCTION

With the progress of society, the importance of energy, especially electric energy, has become more significant in 21st Century. However, the development of electric industry has been seriously restricted by the shortage of primary energy and the expansion of traditional power plants may also increases CO2 emission that consequently causes serious environment problems. Under this situation, the exploitation of wind energy which provides new solutions to the contradiction between economic development and environment pollution has been inevitable.

Before the late 1990s, most wind turbine manufacturers built fixed-speed wind turbines systems (FSWTSs) using a multistage gearbox and a standard squirrel-cage induction generator, directly connected to the grids [1]. However, the FSWTS is designed to maximum efficiency at the particular wind speed and induction generators consume reactive power when connected with grids [2]. Since the late 1990s, most wind turbine manufacturers have changed to variable speed wind turbines. [3] Because a power electronic converter is used to help generators connected with grids, much more flexible control could be implemented to achieve better performance such as tracking maximum power point and producing reactive power [2].

While more variable-speed generators are installed in wind farms, several new problems are introduced in power systems. How to evaluate the performance of power systems under high wind power penetration conditions has newly become a hot topic for researchers. This paper provides an overview to the relevant latest research issues related to the integration of wind farms with variable speed wind turbines (VSWTS) into power systems.

The common type of wind power generators in use are squirrel cage induction generator (SCIG), doubly fed induction generator (DFIG) and synchronous generator with full scale power electronic converter [4]. For more secure operation, the wind turbine generation should be more grid friendly [5]. This study deal with different aspects of grid integration of wind farms. This paper is organized as follows; Section 2 presents an overview of different research areas which have been examined in more detail in past. Results and discussions are elaborated in section 3. Conclusions are drawn in Section 4.

II. RESEARCH AREAS IN WIND POWER INTEGRATION

The study in this paper reveals that the topics, like stability analysis, maximum power point tracking, low voltage/fault ride through capability, DFIG operation under network unbalance, contribution of DFIG for frequency control and DFIG as reactive power ancillary service etc. have been extensively studied by researchers. The other areas which are also in focus are reliability assessment, grid synchronization, impact of wind power generation on power system operation and control, planning and operation of offshore wind farm, wind energy economics, hybrid wind power systems.

2.1 Power System Stability and Grid Integration

According to the classification of power system stability in reference [6], power system stability could be categorized into voltage stability, frequency stability and rotor angle stability [7-9]. VSWTSs have the ability to control reactive power and decouple active and reactive power control through electronic converters. Thus, the voltage stability of power systems is improved. Besides that wind energy could be restored as rotating kinetic energy in blade and hub, and then released by VSWTSs if necessary. So the frequency stability of grids could be enhanced temporarily. Although the system stability is improved, the complexity of the whole system is increased by affiliated control system of VSWTSs. How to evaluate the impact on system stability with VSWTSs has become one of the hotspots of current wind power research. Fig. 1 presents a block diagram for the main components of a general configuration of wind-farms.

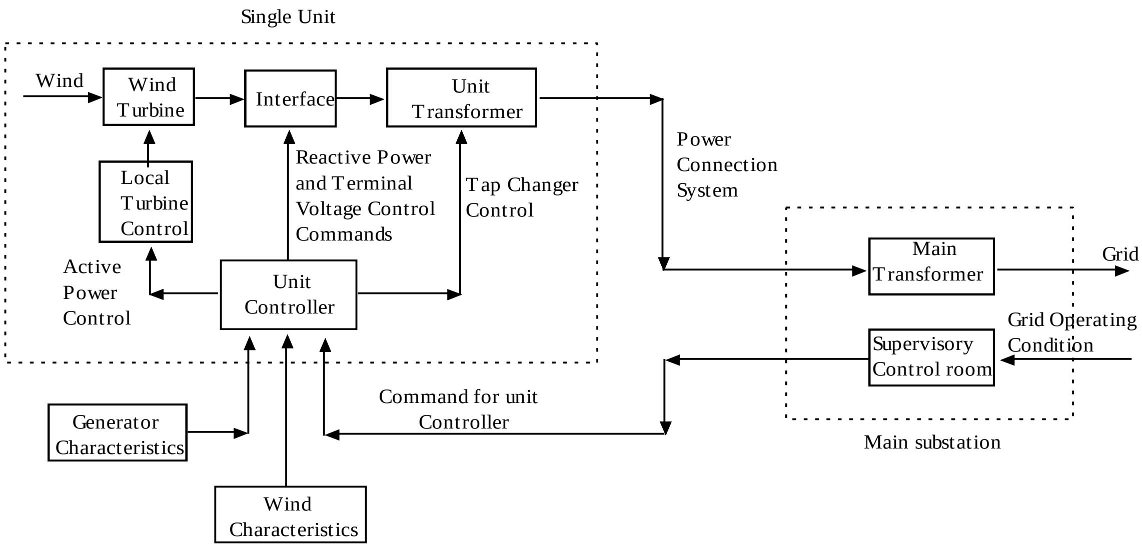

Figure 1. Main Components of a Wind-farm

With large penetration level, wind power will influence the stability and dispatch of power system due to its fluctuating nature. It is necessary to investigate the key issues caused by large scale wind power integration into power system. The requirements (Grid codes) for wind farm interconnection are given in [7]. A model of DFIG based system for transient stability studies is developed in [10]. The effect of adding a 100 MW DFIG based wind farm on a weak transmission system is studied in [11]. The rise in steady state power transfer capacity of a transmission line is 17% due to wind power as reported in [12]. The use of STATCOM for improving stability of SCIG and DFIG based wind systems is studied in [13]. A reduced order DFIG model for stability analysis is proposed in [14]. A detailed model to study power quality of a grid is proposed in [15]. A generic model of controller that uses particle swarm optimization is proposed in [16]. The use of TurbSim, FAST and Simulink for stability analysis is reported in [17]. In [18] the influence of various model parameters of DFIG based wind farm on transient responses is studied. A FACT based controller to suppress the effect of sub-synchronous resonance in series compensated power system containing induction generators is studied in [19]. A linearized model for DFIG based wind power plant connected to a series compensated transmission line is proposed in [20]. It is proposed in [21] that a wind farm can be modeled in a way similar to the conventional generator for steady state analysis. A control scheme for rotor side converter of DFIG to damp inter-area oscillations is proposed in [22]. A method wherein the adjustment of the magnitude of the rotor voltage vector and its phase angle employed for the control of terminal voltage and power is proposed in [23]. The contribution of WFs to short circuit current at HV substations, due to three phase faults is discussed in [24]. The effect of increased wind power penetration on inter–area oscillation damping is studied in [25]. An operational feature of ABB make STATCOM for DFIG based wind farm is studied in [26]. The effect of stator resistance on the magnitude and phase angle of the resultant optimal rotor excitation voltage is examined in [27]. A simplified model to evaluate the error in the estimated rotor position and to perform a local stability analysis of a system is discussed in [28]. An analysis of sub synchronous resonance in series compensated wind farm is reported in [29]. The WECS considered for analysis consist of a DFIG driven by a wind turbine, rotor side converter and grid side converter, as shown in Fig.2.

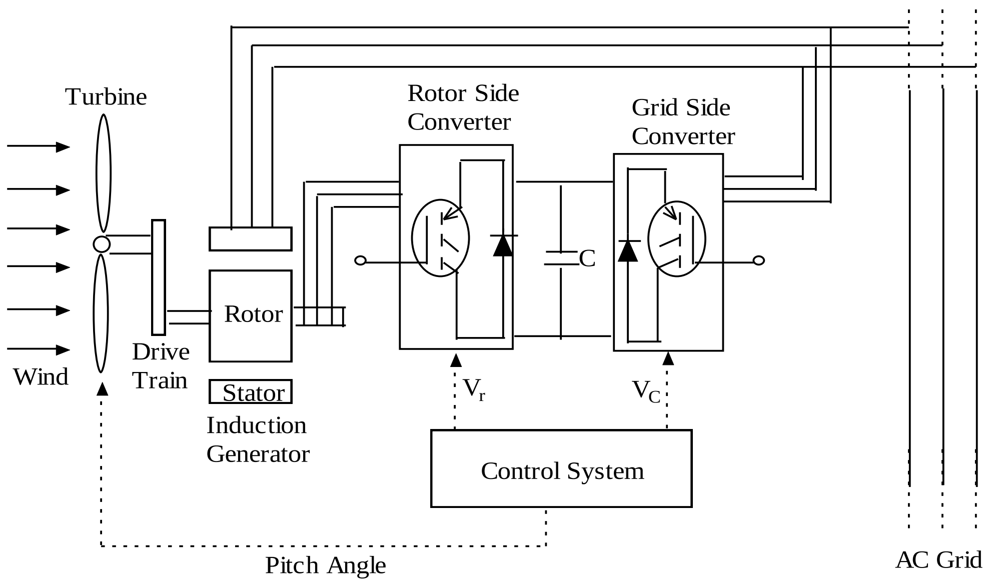

Figure 2. Wind Energy Conversion System with DFIG and Conventional Converters

2.2 Maximum Power Point Tracking (MPPT) Method

Broadly, the MPPT techniques may be categorized in five types. The above said five types have their own merits and demerits. A comprehensive survey further classified the MPPT algorithms into eight categories. These categories are based on the methodology employed in generating the reference signal and technique involved. In Fig 3, the classification of MPPT algorithm [30-32] is given.

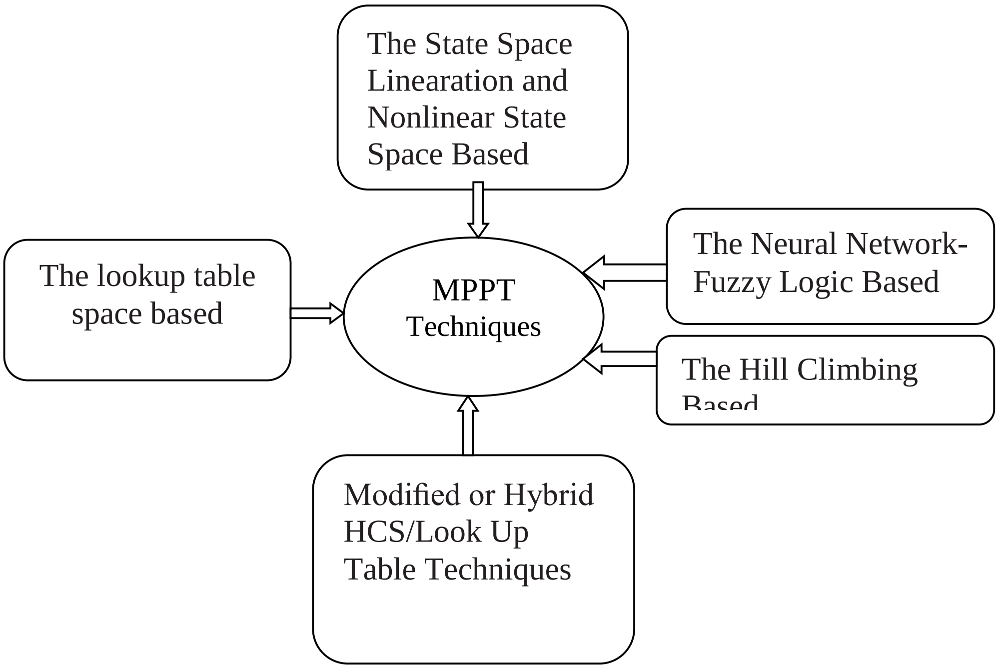

Figure 3. Five types of MPPT Techniques

2.2.1 The lookup table space based

It is the most extensively used technique. Traditionally, the most popular approach is the Power Signal Feedback (PSF) [33]-[34]. It uses either a 2-D lookup table with the maximum power in the ordinate or a mapping function employing the product of the cube of measured generator speed with the optimum proportionality constant. The second commercially employed lookup table MPPT is the Tip Speed Ratio (TSR) control. It needs an anemometer to measure the wind speed. To convert the wind velocity measurement into its corresponding reference for optimal generator speed, the pre-known value of the optimal TSR is also necessary [33]-[34].

2.2.2. The State Space Linearation and Nonlinear State Space Based

These techniques find its applications in the field of nonlinear control problem [35], shows the combination of feedback linearation with optimal control theory, whereas [36] employs feedback linearation theory with sliding mode control. TSR control technique is given in [37]-[38]. This technique along with input-output feedback linearization is used to reduce or eliminate the effects of nonlinearity. This deals with a disturbance observer. It gives the estimation of uncertainties through feedback linearization. Numerous papers used the sliding mode or passivity based Variable Structure Control (VSC) [39]-[43].

2.2.3. The Neural Network-Fuzzy Logic Based

With the advancement in microcontroller technology, Neural Networks (NN) [44]-[50] and Fuzzy Logic Control (FLC) have become popular in wind maximum power control. In [51]-[59] FLC it is used either independently or along with other methods for MPPT applications. Generally FLC has three stages [60].

2.2.4. The Hill Climbing Based

The hill climbing based is another type of MPPT technique. Hill Climb Search (HCS) [61]-[71] involves a perturbation in reference or control variable (generator speed or duty cycle) and observing the change in power. Fig.6 shows that incrementing (decrementing) the generator speed (or terminal voltage) increases (decreases) the power when operated with left of the MPP and decreases (increases) the power when on the right

2.2.5. The Modified or Hybrid HCS/Look up Table Techniques

Among the different techniques discussed in the previous section, the lookup table based MPPT and HCS are most feasible MPPT techniques. Therefore the majority of the research papers on MPPT are written on the modified or hybrid version of HCS and PSF. Here, those research papers are presented.

2.3 Power Quality Issues

Approximately 70 to 80% of all power quality related problems [72-74] can be attributed to Power frequency disturbances, electromagnetic interference, transients, harmonics and low power factor are the other categories of PQ problems that are related to the source of supply and types of load. Among these events harmonics are the most dominant one. The effects of harmonics on PQ are specially described according to the IEEE standards, harmonics in the power system should be limited by two different methods; one is the limit of harmonic current that a user can inject into the utility system at the point of common coupling (PCC) and the other is the limit of harmonic voltage that the utility can supply to any customer at the PCC. Again, DG interconnection standards are to be followed considering PQ, protection and stability issues.

The impacts of poor quality are usually divided into three board categories: direct, indirect and social. A detail of these impacts has been described in [75-76]. A recent survey based on interviews and web based submission, conducted over a 2-years period in 8 European countries, and has been reported in [77]. Survey reported PQ costs due to the effect of voltage dips and swells, short & long interruption, harmonics, surges and transient, flicker, unbalance, earthling and electromagnetic compatibility (EMC) problems. It is found that the annual cost of wastage cause by poor PQ for EU-25 according to this analysis exceeds 150bn where industry accounts for over 90% of this wastage. Dips and short interruptions account for almost 60% of the overall cost to industry and 57%for the total sample the study also shows that the economic impact of inadequate PQ costs industry and services sector some 4% and 0.15% of their annual turnover. At the same time it is necessary to consider the impact of DG in terms of cost of power Quality in [78-83].

III. RESULTS AND DISCUSSION

This paper investigated the references on various grid integration issues applied to wind systems from 1981 to 2016. Eighty papers were collected from different proceedings, journals and international conferences. The quantitative and qualitative analysis among various research areas has been made. Fig. 4 shows number of papers reviewed in various years from 2000 to 2016. Fig. 5 shows the ratio of papers reviewed on each approach to the total number of papers. As shown in Fig. 5, MPPT technique offers the greatest share in the total number of papers written since 1981 till date on research areas in wind power integration. Hence, for solving the problem of controlling wind energy, MPPT technique is the most popular method.

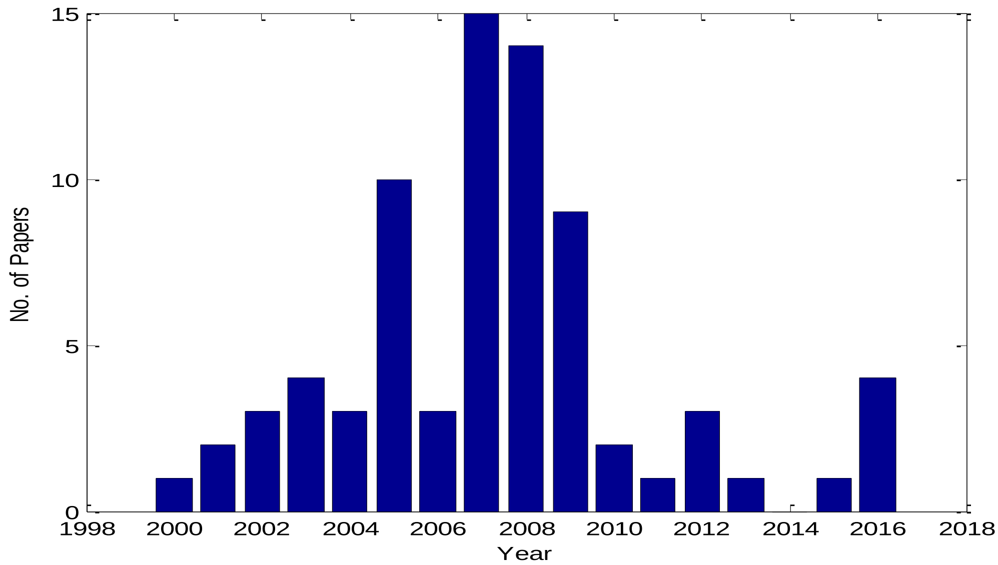

Figure 4. Number of papers reviewed

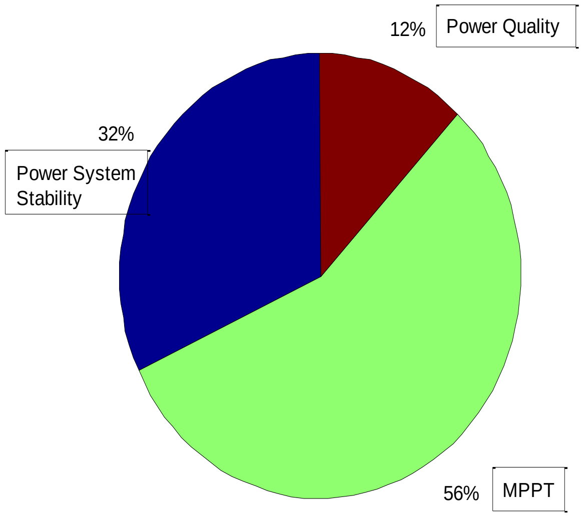

Figure 5. The ratio of papers reviewed on each approach to the total number of papers.

IV. CONCLUSION & FUTURE SCOPE

Wind energy has developed over past 25 years and it will probably continue to advance over the next 20 years. However there are still a number of issues associated with integration of wind farms into power systems. This paper has provided an overview of the relevantly latest achievements on this area and categorized them into different research directions. Among them, according to the statistics results of papers published in important international journals, the improvement on voltage and frequency stability, the influences on power quality, and the coordination with energy storage utilities are the hottest topics in this area. This paper has critically reviewed the different aspects of grid integration. Even though there are many ways to deal with grid integration, more research is needed to determine the most effective approach for specific situation. Due to state of art power electronics technology, wind power systems have the capability to support and contribute on grid stability. Authors of this paper will pay more concerns about these directions in future. The overall operation of grid integration issues of wind farm is again a big challenge and researchers have to show a rapid growth in this area.

REFERENCES

[1]. J. G. Slootweg and E.de Vries, "Inside wind turbines—fixed vs. variable speed," Renew. Energy World, vol. 6, no. 1, pp. 30–40, Jan.–Feb. 2003.

[2]. T. Ackerman, Wind Power in Power System. Chichester, U.K.: Wiley, 2005.

[3]. H. Polinder, S. W. H. de Haan, J. G. Slootweg, and M. R. Dubois, "Basic operation principles and electrical conversion systems of wind turbines," EPE J., vol. 15, no. 4, pp. 43–50, Dec. 2005.

[4]. H. Li, and Z. Chen, "Overview of different wind generator systems and their comparisons", *IET Renew. Power Gener.*, vol. 2, no. 2, pp. 123–138, 2008.

[5]. Y. Xue and N. Tai, "Review of contribution to frequency control through variable speed wind turbine", *Renewable Energy*, 2012.

[6]. P. Kundur, J. Paserba, V. Ajjarapu, G. Andersson, A. Bose, C. Canizares, N. Hatziargyriou, D. Hill, A. Stankovic, C. Taylor, T. Van Cutsem, and V. Vittal, "Definition andclassification of power system stability,". IEEE Tran. Power Systems, vol. 19, pp. 1387-1401, Aug. 2004.

[7]. M. Tsili, and S. Papathanassiou, "A review of grid code technical requirements for wind farms" *IET Renew. Power Gener*., vol. 3, no. 3, pp. 308–332, 2009.

[8]. Renedo, J.; Garcia-Cerrada, A.; Rouco, L., "Active Power Control Strategies for Transient Stability Enhancement of AC/DC Grids With VSC-HVDC Multi-Terminal Systems", , IEEE Transactions on Power Systems, Issue 99, 2016,pp. 1-10.

[9]. Nga Nguyen; Mitra, J., "An Analysis of the Effects and Dependency of Wind Power Penetration on System Frequency Regulation", IEEE Transactions on Sustainable Energy, Vol. 7, Issue 1, 2016, pp. 354-363.

[10]. L. Pablo and J. Usaola," Doubly fed induction generator model for transient stability analysis", *IEEE Trans on Energy Conversion*, vol. 20, no. 2, pp. 388–397, June 2005.

[11]. E. Muljadi, C. Butterfield, B. Parsons, and A. Ellis, "Effect of variable speed wind turbine generator on stability of a weak grid", IEEE Trans on Energy Conversion, vol. 22, no. 1, pp. 29–36, March 2007.

[12]. N. Ullah and T. Thiringer, "Variable speed wind turbines for power system stability enhancement", IEEE Trans. on Energy Conversion, vol. 22, no.1, pp. 52–60, Mar 2007.

[13]. Z. Chen, Y. Hu and F. Blaabjerg, "Stability improvement of induction generator–base wind turbine systems", IET Renew. Power Gener., vol. 1 no.1, pp. 81–93, 2007.

[14]. I Erlich, J. Kretschmann, J. Fortmann, S. Mueller, and H. Wrede, "Modeling of wind turbines based on doubly–fed induction generators for power system stability studies", *IEEE Trans on Power Syst*, vol. 22, no. 3, pp 909–919, August 2007.

[15]. I. Estanqueiro, "A dynamic wind generation model for power systems studies", *IEEE Trans on Power Syst,* vol. 22, no. 3, pp. 920–928, 2007.

[16]. F. Wu, X. Zhang, K. Godfrey, and P. Ju, "Small signal stability analysis and optimal control of a wind turbine with doubly fed induction generator", *IET Gener. Trans. Distrib*., vol.1, no.5, pp.751–760, 2007.

[17]. R. Fadaeinedjad, and G. Moschopoulos, "Simulation of a wind turbine with doubly fed induction generator by FAST and Simulink", *IEEE Trans on Energy Conv.*, vol. 23, no. 2, pp 690–700, June 2008.

[18]. M. Kayikçi, and J. Milanovic, "Assessing transient response of DFIG based wind plants - The influence of model simplifications and parameters", *IEEE Trans on Power Syst*, vol. 23, no. 2, pp. 545–554, May 2008.

[19]. R. Varma, S. Auddy, and Y. Semsedini, "Mitigation of subsynchronous resonance in a series–compensated wind farm using FACTS controllers", *IEEE Trans on Power Delivery*, vol. 23, no. 3, pp 1645–1654, July 2008.

[20]. A Ostadi, A. Yazdani and R. K. Varma, "Wind power generator interfaced with a series compensated line", *IEEE Trans on Power Delivery*, vol. 24, no. 3, pp. 1504 –1514, July 2009.

[21]. D. Gautam, V. Vittal and T. Harbour, "Impact of increased penetration of DFIG–based wind turbine generators on transient and small signal stability of power systems", *IEEE Trans. on Power Syst*, vol. 24, no. 3, pp. 1426– 1434, August 2009.

[22]. Z. Miao, L. Fan, D. Osborn and S. Yuvarajan, "Control of DFIG–based wind generation to improve interarea oscillation damping", *IEEE Trans on Energy Conversion*, vol. 24, no. 2, pp. 415–422, June 2009.

[23]. Y. Mishra, S. Mishra, M. Tripathy, N. Senroy and Z. Dong, "Improving stability of a DFIG based wind power system with tuned damping controller", *IEEE Trans on Energy Conversion*, vol. 24, no. 3, pp. 650–660, Sept 2009,

[24]. F. D. Kanellos and J. Kabouris, "Wind farms modeling for short–circuit level calculations in large power systems", *IEEE Trans. on Power Delivery*, vol. 24, no. 3, , pp. 1687–1695, July 2009.

[25]. G. Tsourakis, B. M. Nomikos, and C. D. Vournas, "Contribution of doubly fed wind generators to oscillation damping", *IEEE Trans on Energy Conversion*, vol. 24, no. 3, pp – 783 –791, September 2009.

[26]. B. Ronner, P. Maibach and T. Thurnher, "Operational experiences of STATCOMs for wind parks", *IET Renew. Power Gener.*, vol. 3, no. 3, pp. 349–357, 2009.

[27]. C. Liu and Y. Hsu, "Effect of rotor excitation voltage on steady–state stability and maximum output power of a doubly–fed induction generator" *IEEE Trans on Industrial Electronics 2010*.

[28]. M. Carmeli, F. Castelli, and R. Perini, "Effects of mismatched parameters in MRAS sensorless doubly fed induction machine drives", *IEEE Trans on Power Electronics*, vol. 24, no. 11, pp. 2842–2851, 2011.

[29]. L. Fan, R. Kavasseri, Z. Lee and C. Zhu,, "Modeling of DFIG– based wind farms for ssr analysis", *IEEE Trans on Power Delivery*, vol. 25, no. 4, pp. 2073–2082, October 2010.

[30]. Errami, Y.; Benchagra, M.; Hilal, M.; Maaroufi, M.; Ouassaid, M., "Control strategy for PMSG wind farm based on MPPT and direct power control", 2012 International Conference on Multimedia Computing and Systems (ICMCS), 2012, pp. 1125 – 113.

[31]. Errami, Y.; Maaroufi, M.; Cherkaoui, M.; Ouassaid, M., "Maximum power point tracking strategy and direct torque control of permanent magnet synchronous generator wind farm", 2012 International Conference on Complex Systems (ICCS), 2012, pp.1-6.

[32]. Zhigang Li; Wenchuan Wu; Boming Zhang; Bin Wang, "Adjustable Robust Real-Time Power Dispatch With Large-Scale Wind Power Integration", IEEE Transactions on Sustainable Energy, Vol. 6, Issue 2, 2015, pp. 357-368.

[33]. K. Buehring and L. L. Freris, "Control policies for wind energy conversion systems," IEE Proceedings, Part C - Generation, Transmission and Distribution, vol. 128, pp. 253-261, Sept. 1981.

[34]. Eftichios Koutroulis and Kostas Kalaitzakis, “Design of a maximum power tracking system for windenergy-conversion applications,” IEEE Transactions on Industrial Electronics, vol. 53, no. 2, April 2006.
[35]. K. Uhlen, B. A. Foss, and O. B. Gjosaeter, “Robust control and analysis of a wind-diesel hybrid power plant,” IEEE Transactions on Energy Conversion, vol. 9, no. 4, Dec. 1994.
[36]. José Matas, Miguel Castilla, Josep M. Guerrero, Luis García deVicuña, and Jaume Miret, “Feedback linearization of direct-drive synchronous wind turbines via a sliding mode approach,” IEEE Transactions on Power Electronics, vol. 23, no. 3, May 2008.
[37]. Wei Qiao, Liyan Qu, and Ronald G. Harley, “Control of IPM synchronous generator for maximum wind power generation considering magnetic csaturation,” IEEE Transactions on Industry Applications, Vol. 45, Issue 3, May/June 2009.
[38]. Hernán De Battista, Ricardo J. Mantz, and Carlos F. Christiansen “Dynamical sliding mode power control of wind driven induction generators,” IEEE Transactions on Energy Conversion, vol. 15, no. 4, Dec. 2000.
[39]. Fernando Valenciaga, Pablo F. Puleston, and Pedro E. Battaiotto “Power control of a solar/wind generation system without wind measurement: A passivity/ sliding mode approach,” IEEE Transactions on Energy Conversion, vol. 18, no. 4, Dec. 2003.
[40]. Fernando Valenciaga and Paul F. Puleston, “Variable structure control of a wind energy conversion system based on a brushless doubly fed reluctance generator,” IEEE Transactions on Energy Conversion, vol. 22, no. 2, June 2007.
[41]. Brice Beltran, Tarek Ahmed-Ali, and Mohamed El Hachemi Benbouzid, “Sliding mode power control of variable-speed wind energy conversion systems,” IEEE Transactions on Energy Conversion, vol. 23, no. 2, June 2008.
[42]. Iulian Munteanu, Seddik Bacha, Antoneta Iuliana Bratcu, Jo¨el Guiraud, and Daniel Roye, “Energy reliability optimization of wind energy conversion systems by sliding mode control,” IEEE Transactions on Energy Conversion, vol. 23, no. 3, Sept. 2008.
[43]. H. Li , K. L. Shi and P. G. McLaren “Neural-network based sensorless maximum wind energy capture with compensated power coefficient,” IEEE Trans. Ind. Appl., vol. 41, pp. 1548, Nov./Dec. 2005.
[44]. Ro, K. Choi, H. h., “Application of neural network controller for maximum power extraction of a grid connected wind turbine system”, Journal of Electrical Engineering, Vol. 88, 2005, pp 45-53
[45]. P. Flores, A. Tapia and G. Tapia, Application of a control algorithm for wind speed prediction and active power generation, Renew Energy 305 (2005), pp. 23–536.
[46]. Zhang Xinyan, Wang Weiqing, Cheng Jing, “Analysis on control of variable speed wind turbine using neural network controller”, Journal of Chongqing University, Chongqing of China, 28(11), 2005, pp 65-68.
[47]. M.N. Eskander, “Neural network controller for a permanent magnet generator applied in a wind-energy conversion system”, Renew Energ. 26 (2002) (3), pp. 463–477
[48]. 8. S. Kelouwani and K. Agbossou, “Nonlinear model identification of wind turbine with a neural network”, IEEE Transaction Energy Conversion, vol. 19, 2004, pp. 607-612.
[49]. Wei Qiao, Wei Zhou, J.M Aller, R.G. Harley, “Wind Speed Estimation Based Sensorless Output Maximization Control for a Wind Turbine Driving a DFIG,” IEEE Trans. on Power Electronics, vol. 23, no. 3, pp. 1156 – 1169, May 2008.
[50]. M. G. Simões, B. K. Bose, and R. J. Spiegel, “Fuzzy logic based intelligent control of a variable speed cage machine wind generation system,” IEEE Trans. Power Electron., vol. 12, pp. 87-95, Jan. 1997.
[51]. Z. Mohamed, M. N. Eskander, and F. A. Ghali, “Fuzzy logic control based maximum power tracking of a wind energy system,” Renew. Energy, vol. 23, no. 2, pp. 235-245, Jun. 2001.
[52]. Abo-Khalil, AG, Lee D-C, Seok J-K. Variable speed wind power generation system based on fuzzy logic control for maximum output power tracking” IEEE 35th annual power electronics specialists conference – PESC 04, Aachen, Germany, vol. 3.pp. 2039–44.
[53]. Z. Chen , S. Gomez and M. Mc Cornick “A fuzzy logic controlled power electronic system for variable speed wind energy conversion systems,” Proc. IEE PEVD Conf., 2000, p. 114.
[54]. V. Galdi, A. Piccolo, P. Siano: “Designing an adaptive fuzzy controller for maximum wind energy extraction”, IEEE Transactions on Energy Conversion, Vol. 23, June 2008
[55]. R. Hilloowala and A. M. Sharaf, “A rule-based fuzzy logic controller for a PWM inverter in a standalone wind energy conversion scheme,” IEEE Trans. Ind. Applicat., vol. IA-32, pp. 57-65, Jan. 1996.
[56]. Xin-yan Zhang Jing Cheng Wei-qing Wang, “The intelligent control method study of variable speed wind turbine generator”, IEEE International conference on Sustainable Energy Technologies, Nov. 2008, pp 173-177
[57]. V. Calderaro, V. Galdi, A. Piccolo, P. Siano: “A fuzzy controller for maximum energy extraction from variable speed wind power generation systems”, Electrical Power Systems Research, Elsevier Editorial, vol. 78, issue 6, pp 1109-1118, 2008.

[58]. Lei Zhang, Haidong Li, Chunliang E, Jianlin Li, Honghua Xu, "Pitch control of large scale wind turbine based on fuzzy-PD method", DRPT2008 6-9 April 2008 Nanjing China
[59]. T. Esram and P. L. Chapman "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Trans. Energy Convers., vol. 22, pp. 439, Jun. 2007.
[60]. Hui Li, K. L. Shi, and P. G. McLaren, "Neural network-based sensorless maximum wind energy capture with compensated power coefficient," IEEE Transactions on Industry Applications, vol. 41, no. 6, Nov./Dec. 2005.
[61]. D. Das , R. Esmaili , L. Xu and D. Nichols "An optimal design of a grid connected hybrid wind/ photovoltaic/fuel cell system for distributed energy production," Proc. IEEE IECON, 2005, p. 2499.
[62]. R. Esmaili, L. Xu, D. K. Nichols, A new control method of permanent magnet generator for maximum power tracking in wind turbine application, IEEE PES 2005, vol.3, pp. 2090- 2095, June 2005.
[63]. Raza, K.S.M. Goto, H. Hai-Jiao Guo Ichinokura, O., "A novel speed-sensorless adaptive hill climbing algorithm for fast and ef cient maximum power point tracking of wind energy conversion systems ", IEEE International conference on Sustainable Energy Technologies, No. 2008, pp 628-633
[64]. Schiemenz and M. Stiebler, "Control of a permanent magnet synchronous generator used in a variable speed wind energy system," in Proc. IEEE IEMDC, 2001, pp. 872–877.
[65]. R. Datta and V.T. Ranganathan, "A method of tracking the peak power points for a variable speed wind energy conversion system", IEEE Trans Energy Conver. 18 (2003), pp. 163–168
[66]. M. Molina, D. Pontoriero y Mercado P. E. An ef cient maximum power- point-tracking controller forgrid connected photo-voltaic energy conversion system. Brazilian Journal of Power Electronics, Vol.12, 2, pp.147-154. 2007
[67]. Tafticht, T. Agbossou, K. Cheriti, A., "DC bus control of variable speed wind turbine using a buck-boost converter", IEEE Power Engineering Society General Meeting, 2006.
[68]. Y-M Chen, Y-C Liu, S-C Hung, C-S Cheng, "MultiInput Inverter for Grid Connected Hybrid PV/Wind Power System", IEEE transactions on power electronics, vol. 22,no. 3, May 2007.
[69]. H.E.Mena.Lopez,"Maximum Power Tracking Control Scheme for Wind Generator Systems" Master's Thesis, Texas A&M university, Dec. 2007
[70]. Srighakollapu, N. Sensarma, P.S. , "Sensor-less maximum power point tracking control in wind energy generation using permanent magnet synchronous generator ", 34th Annual IEEE Industrial Electronics Conference, Nov. 2008
[71]. Jia Yaoqin, Yang Zhongqing, Cao Binggang, "A new maximum power point tracking control scheme for wind generation," in Proc. Power Con 2002.
[72]. Sheng-yen Lu; Li Wang; Shun-chin Ke; Che-hao Chang; Zhi-hao Yang, "Evaluation of Measured Power Quality Results of a Wind Farm Connected to Taiwan Power System", IEEE Transactions on Industry Applications, Volume: 52, Issue: 1, 2016, pp. 42-49.
[73]. Garcia-Sanchez, T.; Gomez-Lazaro, E.; Muljadi, E.; Kessler, M.; Molina-Garcia, A., "Statistical and Clustering Analysis for Disturbances: a Case Study of Voltage Dips in Wind Farms", IEEE Transactions on Power Delivery, Issue 99, 2016, pp. 1-6.
[74]. Yuan-Kang Wu; Chang, G.W.; Li Wang, "Power quality measurements and analysis for Zhong-Tun Wind Farm in Penghu", 2013 CACS International on Automatic Control Conference (CACS),2013, pp. 433-438.
[75]. J. G. Slootweg, Member IEEE ,S.W.H. de Haan, " General Model for representing Variable speed Wind Turbines in Power System Dynamics Simulation" , 08858950, 2003 IEEE.
[76]. Simple indicators for an effective Power Quality monitoring and analysis V. Ignatova; D. Villard; J. M. Hypolite Environment and Electrical Engineering (EEEIC), 2015 IEEE 15th International Conference on Year: 2015
[77]. Pedro Rodriguez , A. drianv Timbus , Member IEEE , "Flexible Active Power Control of Distributed Power Generation systems during Grid faults", IEEE Trans. On Industrial Electronics, Vol.54 , No.5 , Pp.2583-2592, oct, 2007.
[78]. J. Tamura , Member IEEE , "Wind Generator output Power Smoothing & terminal Voltage Regulation by Using STATCOM/ESS ",978-1-4244-2190, Pp.1232-1237, Power Tech 2007.
[79]. A Arulampalam M. Barnes , N. Jenkins and J. B. Ekanayake , "Power Quality and Stability Improvement of a Wind farm using STATCOM supplied with hybrid battery energy storage" IEE Proceeding of Genc. Transm, Distrib., Vol.153, No.6 , pp.701-710 , Nov.2006.
[80]. E.Diaz-Dorade ,C.Carrillo , J.Cidras an E.Albo , "Estimation of Energy losses in a Wind Park " , 9 International Conference , Electrical Power Quality & Utilisation , Barcelone , 9-11, Oct.2007.
[81]. T. Funabashi , Senior Member IEEE, K. Koyanagi , R.Yokoyama , Member IEEE, "Digital Simulation Examples of Custom Power Controllers ", 7803-7322, pp.499-501, 2002 IEEE.

[82]. Improvement of power quality and dynamic voltage of wind farms using an inductive filtering method Z. Xu; Y. Peng; Y. Li; M. Wen; L. Luo; Y. Cai; Y. Cao Environment and Electrical Engineering (EEEIC), 2015 IEEE 15th International Conference on Year: 2015

[83]. Combined Effect of CVR and DG Penetration in the Voltage Profile of Low-Voltage Secondary Distribution Networks A. Bokhari; A. Raza; M. Diaz-Aguiló; F. de León; D. Czarkowski; R. E. Uosef; D. Wang IEEE Transactions on Power Delivery Year: 2016

AUTHORS

Lata Gidwani is working as Associate Professor, in the Department of Electrical Engineering, Rajasthan Technical University, Kota.

Akanksha Pareek is studying as M.Tech Student in the Department of Electrical Engineering, Rajasthan Technical University, Kota.