MITIGATION OF HARMONICS AND POWER QUALITY ENHANCEMENT FOR GRID CONNECTEDWIND TURBINEWITH SEIG USING SOFT COMPUTING TECHNIQUE

[1]Sahil Kumar,[2]Ashwani Kumar,
[1]Student Mtech,[2]Assistant Professor,
[1]Department of Electrical Engineering,
[1]Hindu College of Engineering, Sonipat, India.

Abstract: Wind energy is integrated with the grid to meet the energy demand. Non Linear loads and SEIG consume reactive power and produce harmonics in the system. Due to harmonics many problems occurs as the power factor reduces, the devices may not work properly. Voltage fluctuations can also take place in case of harmonics. So there is need to reduce the harmonics and to inject the reactive power into the system. So STATCOM is connected in the system. STATCOM is a family of FACTS devices. STATCOM generate reactive power and reduce the harmonics.

Modelling of STATCOM and Wind Generator is done on MATLAB platform. In Control scheme of STATCOM fuzzy controller is used. The harmonics are reduced and voltage regulation is improved in the MATLAB Simulink Model.

IndexTerms: **Wind Energy Conversion System, Fuzzy Controller, STATCOM.**

I. Introduction

The energy demand is rising day by day as the population is increasing at a very rapid rate. So to meet the energy need we have to generate more electricity. In conventional method to produce electricity the fossil fuels are used that pollute the environment and has a very negative impact. So to have a sustainable growth we need to generate more electricity by the use of renewable energy. The renewable energy that includes wind energy, solar energy, tidal energy etc. These types of energy is clean and produce no pollution and do not harm the environment. The power generated by the wind must be integrated to the grid. In the recent years there has been extensive growth in the use of wind energy. Various power quality issues are also associated with the integration of wind turbines. To solve the problem of poor power quality STATCOM is used. STATCOM injects the reactive power into the system and hence harmonics are reduced by the injection of reactive power. The flow of the reactive power is controlled by the control of the bus voltage, the magnitude of the bus voltage decides the direction of reactive power flow. The induction generator is used in the wind turbine. Induction generator has various advantages that includes cost effectiveness and robustness. But the reactive power is required by the induction machine. In this thesis STATCOM based control scheme is introduced that is based on the fuzzy system. In a conventional STATCOM PI controller is used in the voltage regulator. But in this thesis the fuzzy system is used. Generally fuzzy system is used where the mathematical model cannot be formed. If there is experience based system then we use the fuzzy system.

II. BASIC PRINCIPLE OF STATCOM

The current I is given by the formula

$$I = \frac{V - E}{X}$$

The reactive power is given by

$$Q = \frac{I - \frac{E}{V}}{X} - V^2$$

So the basic principle of operation of STATCOM is controlling the magnitude of E. If the value of E is greater than V this will result in a leading current that is the STATCOM is operating as over excited machine, STATCOM is seen as capacitor by the system. If the value of E is lesser than V this will result in a lagging current that is STATCOM is operating as under excited machine, the STATCOM is seen as inductor by the system.

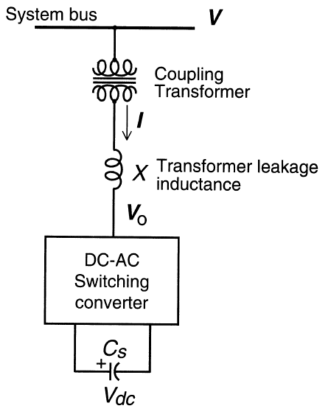

Figure 1.1 Reactive power generation by a voltage source switching converter

The basic principle of operation of voltage source switching converter is same as that of rotating synchronous compensator. If we change the amplitude of output voltage the reactive power will also be changed. If the value of output voltage is greater than the system bus voltage then the current will flow from the converter to the system bus, the converter generates the reactive power. Conversely if the value of output voltage is lower than the voltage of the system bus voltage then the current will flow from system bus to converter, the converter absorbs reactive power.

III. CONTROL SCHEME OF STATCOM

There are two components of source currents

i. In phase component
ii. Quadrature component

The component which is responsible for active power is in phase component which is represented by (i^*_{sad}, i^*_{sbd}, i^*_{scq})
The component which is responsible for AC voltage control is quadrature component which is represented by (i^*_{saq}, i^*_{sbq}, i^*_{scq})
The amplitude of reference voltage is compared with the AC voltage. The error produced is then processed in PID controller. Then a current controller which is based on PWM is used to control STATCOM currents.

$$v_m = \sqrt{\frac{2}{3}(v_a^2+v_b^2+v_c^2}$$

The unit vector u_a, u_b, u_c are calculated as

$$u_a = \frac{v_a}{v_m}$$

$$u_b = \frac{v_b}{v_m}$$

$$u_c = \frac{v_c}{v_m}$$

The unit vector in quadrature with v_a, v_b, v_c may be derived by taking a quadrature transformation of in phase unit vector.

$$w_a = -\frac{u_b}{\sqrt{3}} + \frac{u_c}{\sqrt{3}}$$

$$w_b = \frac{\sqrt{3}}{2}u_a + \frac{u_b}{2\sqrt{3}} - \frac{u_c}{2\sqrt{3}}$$

$$w_c = -\frac{\sqrt{3}}{2}u_a + \frac{u_b}{2\sqrt{3}} - \frac{u_c}{2\sqrt{3}}$$

the voltage error V_{CR} at the n^{th} sampling instant $V_{er}(n) = V_{ref}(n)-V_m(n)$ The output of PID controller at the nth instant is expressed as $I^*_{smq}(n) = I^*_{smq}(n-1)+K_p(V_{cr}(n)-V_{cr}(n-1))+K_iV_{cr}(n)$ Where K_p and K_i are proportional and integral constant

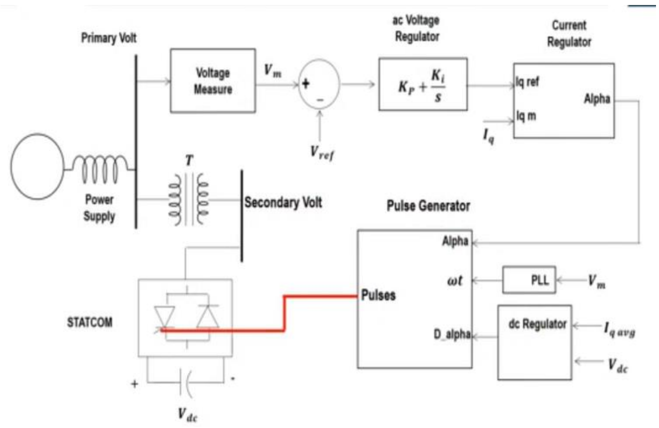

Figure 1.2 Control Scheme of STATCOM

From the power supply the voltage is measured and this voltage is compared with V_{ref} and an error signal is produced, this error signal is passed through ac voltage regulator where PI controller is used. After that the control signal is produced and it is passed through Current Regulator and this signal is compared with I_{ref} and after that alpha signal is produced and which is passed through Pulse Generator. And after that the pulses are given to the STATCOM.

IV. OPERATIONAL SCHEME IN GRID SYSTEM

This is the operational scheme in Grid System. Generator is connected to the non-linear load through grid. In the grid wind generator is integrated at the PCC. The STATCOM is connected to the grid which injects reactive power to the system.

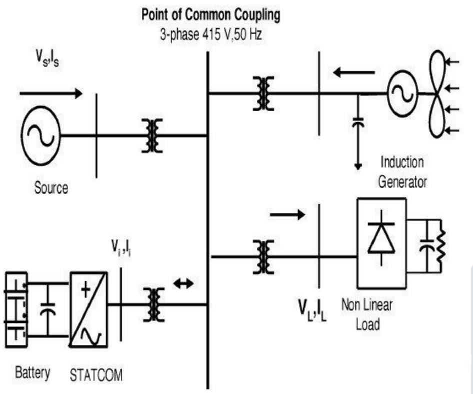

Figure 1.3 Operational Scheme in Grid System

V. MATLAB SIMULINK MODEL OF THE SYSTEM

The figure shows MATLAB Simulink model of the system. The STATCOM can supply as well as absorb the reactive power in accordance with the voltage of the grid. In the conventional control scheme of STATCOM PI controller is used in voltage regulator block. In this research work fuzzy control scheme is used to further enhance the power quality.

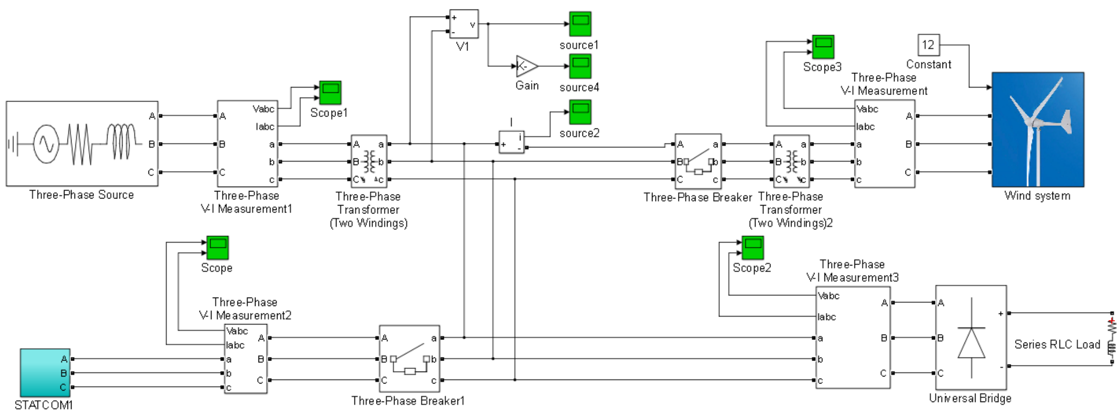

Figure 1.4 MATLAB Simulink Model of the system

Fuzzy Rule base

This is the fuzzy rule base that is used in this thesis

e \ Δe	NB	NS	Z	PS	PB
NB	NB	NB	NS	NS	Z
NS	NB	NS	NS	Z	PS
Z	NS	NS	Z	PS	PS
PS	NS	Z	PS	PS	PB
PB	Z	PS	PS	PB	PB

VI. Simulation Results without STATCOM

Voltage and current waveform at PCC

As the non-linear load and induction generator is connected so it will absorb reactive power. The nonlinear load injects harmonics in the system. From the waveform we can see the distorted waveform, this is basically due to the harmonics injected in the system. From the waveform the voltage output is coming as 0.78 pu which results in poor voltage regulation.
The voltage regulation is calculated as 21.31%.

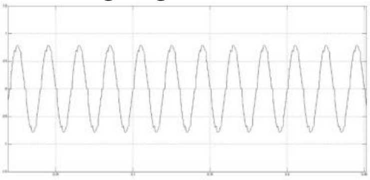

Figure 1.7 Voltage waveform at PCC

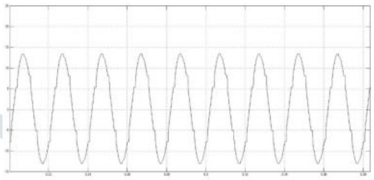

Figure 1.8 Current Waveform at PCC

FFT analysis of waveform at PCC

FFT analysis of voltage and current waveform is done in FFT window. The total harmonic distortion in voltage waveform is calculated as 6.18%. The THD in current waveform is calculated as 6.14%

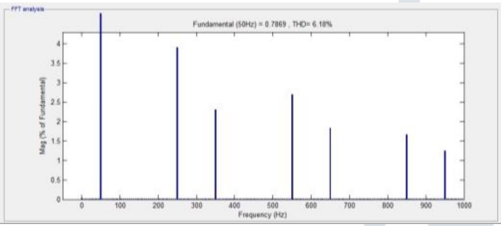

Figure 1.9 FFT analysis of voltage waveform at PCC

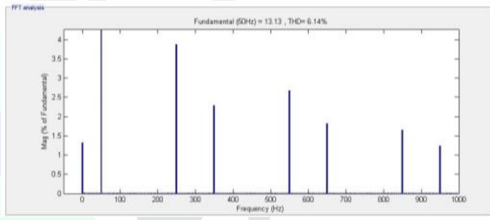

Figure 1.10 FFT analysis of current waveform at PCC

VII. Simulation Results with conventional controller in STATCOM

Voltage Waveform at PCC

The STATCOM is connected at the PCC. The STATCOM injects the reactive power into the system and improves the voltage profile of the system. The following waveform shows the impact of STATCOM when it is connected. It reduces the harmonics in the system and makes the waveform smooth. The voltage regulation is also improved. The voltage regulation is calculated as -2.3%. Thus power quality of the system is improved.

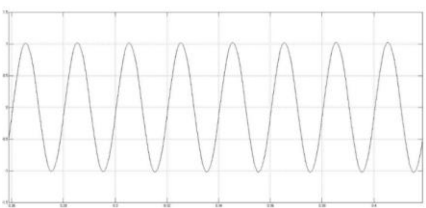

Figure 1.11 Voltage Waveform at PCC

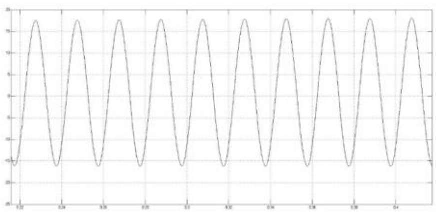

Figure 1.12 Current Waveform at PCC

STATCOM injecting current

The following waveform shows how STATCOM is injecting current into the system.

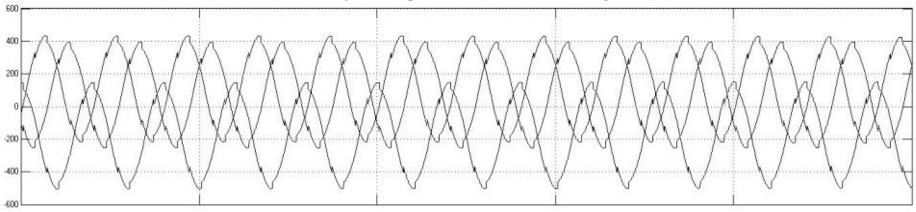

Figure 1.13 STATCOM injecting current

FFT analysis of the Voltage and Current Waveform at PCC

FFT analysis of the voltage waveform is done at PCC. The THD in voltage waveform is obtained as .81%. The THD in current waveform is obtained as .83%. So the harmonics are reduced by the application of the STATCOM.

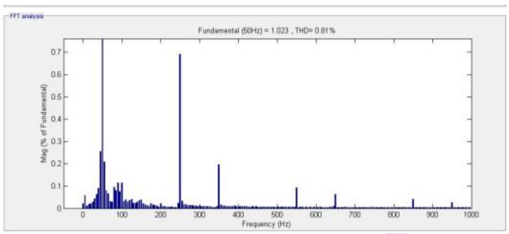

Figure 1.14 FFT analysis of the Voltage Waveform

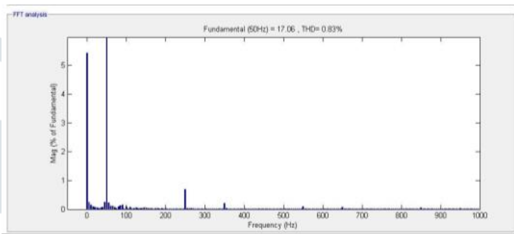

Figure1.15 FFT analysis of the Current Waveform

VIII. RESULTS WITH FUZZY CONTROLLER WITH TRIANGULAR MF

Voltage Waveform at PCC

Now fuzzy control scheme is applied in STATCOM and different Membership functions are used. The following waveform shows the voltage waveform at PCC when triangular MF is used.

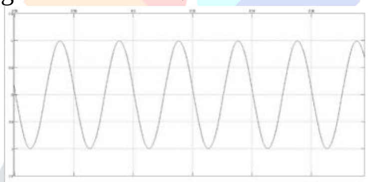

Figure 1.16 Voltage Waveform at PCC

8.6.2 FFT analysis of voltage and current waveform at PCC

FFT analysis of the voltage and current waveform is done. The THD in voltage waveform comes out to be .63% which is reduced when compared with the conventional scheme. The THD in current waveform is obtained as .64%.The voltage regulation is calculated as .57% which is further improved.

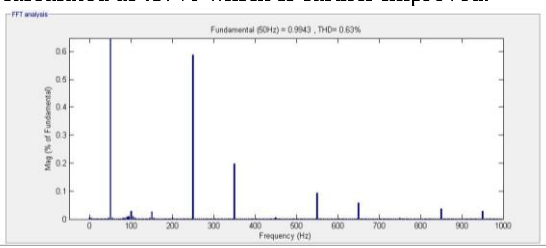

Figure 8. 1 FFT analysis of voltage waveform

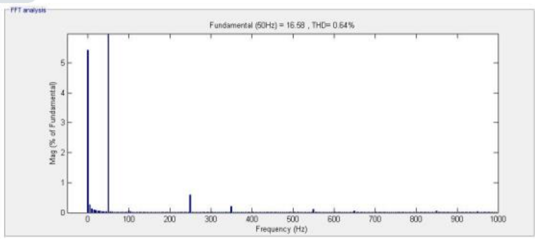

Figure FFT analysis of current waveform

IX. COMPARISON

	%THD in voltage waveform	%THD in current waveform	V_{pcc} (pu)	%Voltage Regulation
Without STATCOM	6.18%	6.14%	.7869	21.31%.
PI controller	.81%	.83%	1.023	-2.3%
Triangular MF	.63%	.64%	.9943	.57%

X. CONCLUSION

Without the use of STATCOM the total harmonic distortion is calculated as 6.18%. With the use of STATCOM with conventional control scheme the total harmonic distortion is calculated as .81%. From this we can say that the harmonics are reduced by the use of STATCOM. We get the smooth waveform which is nearly same as sinusoidal. With the use of fuzzy controller in STATCOM control scheme the total harmonic distortion is calculated as .63%. From this analysis we can say that the performance is further improved by the use of fuzzy control scheme in STATCOM. The power quality of the system is improved.

REFERENCES

[1] R. Dugan, Electrical Power Quality, The McGraw-Hill Companies, 2004.

[2] S. Bhadra and S. B. D Kastha, Wind Electrical system, Oxford University press, 2005.

[3] N. Hingorani and L. Gyugi, Understanding FACTS: Concepts And Technology Of Flexible Ac Transmission Systems, Wiley India Pvt Ltd, 2005.

[4] G. Dubey, Fundamentals of Electrical Drives, Narosa, 2005.

[5] J. M. Carrasco, J. T. Bialasiewicz, R. C. P. Guisado and J. I. León, "Power-Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey," *IEEE Transactions On Industrial Electronics,* vol. 53, no. 4, pp. 1002-1016, 2006.

[6] S.G.Thakare, H.S.Dalvi and K.D.Joshi, "Statcom Based Fuzzy Controller For Grid Connected Wind Generator," *Second International Conference on Emerging Trends in Engineering and Technology,* pp. 35-39, 2009.

[7] B. Ronner, P. Maibach and T. Thurnherr, "Operational experiences of STATCOMs," *IET Renew. Power Gener,* vol. 3, pp. 349-357, 2009.

[8] J. A. Barrado, R. Griñó and H. Valderrama-Blavi, "Power-Quality Improvement of a Stand-Alone Induction Generator Using a STATCOM With Battery Energy Storage System," *IEEE Transactions On Power Delivery,* vol. 25, pp. 2734-2741, 2010.

[9] A. Kasem, E. El-Saadany and H. El-Tamaly, "Power ramp rate control and flicker mitigation," *IET Renew. Power Gener,* vol. 4, no. 3, p. 261–271, 2010.

[10] S. W. Mohod and M. V. Aware, "A STATCOM-Control Scheme for Grid Connected," *IEEE Systems Journal,* pp. 346-352, 2010.

[11] S. W. Mohod and M. V. Aware, "Power Quality Issues and its Improvement in Wind Energy Generation Interface to Grid System," *MIT International Journal of Electrical and Instrumentation Engineering,* vol. 1, no. 2, pp. 116-122, 2011.

[12] M. Mansour, m. N. Mansouri and M. F. Mimouni, "Comparative Study afFixed Speed and Variable Speed Wind Generator with Pitch Angle Control," *International Conference on Communications, Computing and Control Applications (CCCA),* pp. 1-7, 2011.

[13] P. Thakur and M. D. Sharma, "Simulation on Micro Wind Power Generator with Battery Energy Storage for Critical Load," *International Journal of Engineering Research and,* vol. 3, no. 4, pp. 1613-1619, 2013.

[14] Y. Ansari, P. M.Gaidhane and Mr.K.Sawalakhe, "Stabilization of Voltage in Power System by Using STATCOM," *International Journal on Recent and Innovation Trends in Computing and Communication,* vol. 3, no. 2, pp. 96-100, 2015.

[15] N. B. Kadandani and Y. A. Maiwada, "Simulation of Static Synchronous Compensator (STATCOM) for Voltage Profile Improvement," *Innovative Systems Design and Engineering,* vol. 6, no. 7, pp. 1-7, 2015.

[16] R. N. Divakar, P.Kishore, C. Kumar, V. Kishore and V. Kumar, "Power Quality Improvement of Non-Linear Load by Using Instantaneous P-Q Theory," *International Journal of Electrical and Electronics Research,* vol. 3, no. 1, pp. 346-353, 2015.

[17] R. Daravath and E.Deepika, "Power Quality Improvement In Grid Connected Wind Energy System," *International Research Publication House,* vol. 8, no. 1, pp. 47-55, 2015.

[18] D. H. Naidu and D. H. Naidu, "Implementation of STATCOM- Control Scheme for Power Quality Improvement using PI and Fuzzy logic controller," *International Journal of Multidisciplinary Research Hub,* vol. 2, no. 8, pp. 28-45, 2015.

[19] K.Venkateswarlu, P.Lavanya and M.Rosaiah3, "Fuzzy logic based power quality improvement of grid connected," *International Journal of Recent Scientific Research,* vol. 6, no. 8, pp. 5638-5644, 2015.

[20] R.Bhavani, D. Prabha and C.Kanmani, "Fuzzy Controlled UPQC for Power Quality Enhancement in a DFIG based Grid Connected Wind Power System," *International Conference on Circuit, Power and Computing Technologies,* 2015.

[21] M. K. Jain and R. Dhaiya, "Enhancement of Power Quality in Wind Connected Energy System using Power Filter Compensation Scheme," *Journal of Energy Research and Environmental Technology,* vol. 2, no. 3, pp. 251-255, 2015.

[22] R. S. Kumbhare and D. H. K. Naidu, "Design Of Statcom Control Scheme To Mitigate The Power Quality Problems," *International Journal Of Advanced Computing And Electronics Technology,* vol. 2, no. 5, pp. 13-24, 2015.

[23] A. Awasthi, S. Gupta and M. Panda, "Design of a Fuzzy Logic Controller Based STATCOM for IEEE9 Bus System," *European Journal of Advances in Engineering and Technology,* vol. 2, no. 4, pp. 62-67, 2015.

[24] G.Vikas And Dr.K.Suneeta, "Comparison of Different Control Strategies of STATCOM for Power Quality Improvement of Grid Connected Wind Energy System," *International Journal of Scientific Engineering and Technology Research,* vol. 4, no. 7, pp. 1341-1345, 2015.

[25] R. S. Kumbhare and S. V. Raut, "A STATCOM- Control Scheme For Power Quality," *International Journal of Electrical, Electronics and Data Communication,* pp. 2320-2084, 2015.

[26] D.Simhadri and K. Jyothi, "A Hybrid Fuzzy based DSTATCOM for Power Quality Improvement of Grid Connected Wind Energy System," *International Journal & Magazine of Engineering,Technology, Management and Research,* vol. 02, no. 12, pp. 201-206, 2015.

[27] K. R. R. L. Reddy and N.Sreekanth, "A Bess Statcom Control Scheme For Power Quality Improvement In Wind Energy System," *Journal Research in Electrical and Electronics Communication,* 2015.

[28] Satish Reddy N, Manjunath. S, "Voltage Regulation Of Statcom By Adjusting Pi Coefficients With Fuzzy Logic Controller," *International Journal of Electrical & Electronics Engineering,* vol. 3, no. 4, pp. 48-54, 2016.

[29] F. A. B. A. Yusup, S. A. Rufus, P. K. Karunakaran, N. B. Junaidi and N. ‘. B. Hashim, "Power Quality Improvement on Wind Energy System by Using STATCOM," *Applied Mechanics and Materials,* pp. 33-40, 2016.

[30] T. F. Kashyap, "Power Quality Improvement of Grid Connected Wind Energy System: A Review," *International Journal Of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering,* vol. 4, no. 3, pp. 186-188, 2016.

[31] T. Agarwal and S. Verma, "Issues and Challenges of Wind Energy," *International Conference on Electrical, Electronics, and Optimization Techniques,* pp. 66-72, 2016.

[32] L. Gidwani and A. Pareek, "Grid Integration Issues Of Wind Farms," *International Journal of Advances in Engineering & Technology,* vol. 9, no. 2, pp. 167-176, 2016.

[33] V. Kumar1, A. Pandey and S. Sinha, "Grid Integration and Power Quality Issues of Wind and Solar Energy System: A Review," *International Conference on Emerging Trends in Electrical, Electronics and Sustainable Energy Systems,* pp. 71-80, 2016.

[34] D. A. Krishna and M. R. Sindhu, "Application of Static Synchronous Compensator (STATCOM) to enhance Voltage Profile in IEEE Standard 5 Bus Transmission System," *Indian Journal of Science and Technology,* vol. 9, no. 30, pp. 1-7, 2016.

[35] Devashish, A. Thakur, S. Panigrahi and R. R. Behera, "A Review on Wind Energy Conversion System and Enabling Technology," *International Conference on Electrical Power and Energy Systems,* pp. 527-532, 2016.

[36] F. S. S and J. R. I, "A review on pi control of statcom for voltage regulation," *Journal of Chemical and Pharmaceutical Sciences,* vol. 9, no. 1, pp. 334-340, 2016.

[37] F. Blaabjerg and K. Ma, "Wind Energy Systems," *IEEE,* vol. 105, no. 11, pp. 2116-2131, 2017.

[38] S. F. Stephen and I. J. Raglend, "Voltage Regulation Using Pi Control Of Statcom With Firefly Algorithm," *International Journal of Mechanical Engineering and Technology,* vol. 8, no. 8, pp. 766-776, 2017.

[39] M. V. Wankhede, "Static Synchronous Compensator (STATCOM) for the improvement of the Electrical System performance," *International Research Journal of Engineering and Technology,* vol. 3, no. 3, pp. 401-406, 2017.

[40] J. R. Babu and J. Ramesh, "STATCOM using A Control Scheme for Power Quality Improvement," *Imperial Journal of Interdisciplinary Research,* vol. 3, no. 10, pp. 168-174, 2017.

[41] S. S. Sasthri and M. Manohara, "Power quality improvement in grid connected wind energy conversion systems by using custom power device," *International Research Journal of Engineering and Technology,* vol. 4, no. 6, pp. 3254-3259, 2017.

[42] M. S. G. Bankar, M. A. P. Bhurbhure, M. A. R. Bhedarkar and B. S. Rakhonde, "Impact of Non Linear Load on Power Quality," *International Journal on Recent and Innovation Trends in Computing and Communication,* vol. 5, no. 1, p. 223 – 226, 2017.

[43] P. Tare and P. Pandey, "Enhancement of power quality of Grid connected wind energy system using STATCOM," *International Research Journal of Engineering and Technology,* vol. 4, no. 4, pp. 2654-2659, 2017.

[44] B. Babu and D. S, "Comparative study of different types of generators used in wind turbine and reactive power compensation," *IOSR Journal of Electrical and Electronics Engineering,* pp. 95-99, 2017.

[45] A. Tekale, D. Nawani, N. Belkar and V. Devkar4, "A Review Paper On Power Quality Issues And Mitigation Strategies," *Iaetsd Journal For Advanced Research In Applied Sciences,* vol. 4, no. 4, pp. 51-57, 2017.

[46] N. Patel, K. Gandhi, D. Mahida and P. Chudasama, "A Review On Power Quality Issues and Standards," *International Research Journal of Engineering and Technology,* vol. 4, no. 2, pp. 247-250, 2017.

[47] P. Sawai, S. Telang, V. Malyawar and V. B. Hardas, "Control Scheme for Wind Energy System with Fuzzy Controlled Statcom," *International Journal of Engineering Research in Electrical and Electronic Engineering,* vol. 4, no. 3, pp. 149-152, 2018.

[48] "Wikipedia," Wikimedia Foundation, [Online]. Available: https://www.wikipedia.org/.

[49] "Ministry of New and Renewable Energy," Govt. of India, [Online]. Available: https://mnre.gov.in/.

[50] "Matrix Laboratory," [Online]. Available: https://in.mathworks.com/.

[51] D. Driankov and M. R. Hans Hellendoorn, An Introduction to Fuzzy Control, Springer.

[52] [Online]. Available: https://www.danubewings.com.

.