# Power quality improvement of wind energy system using energy storage model and DSTATCOM

**Kishor V. Bhadane[1], Mohan Thakre[2], Rakesh Shriwastava[3], Deepak P. Kadam[4], Dnyaneshwar V. Bhadane[5], Mahesh Harne[6]**
[1,6]Electrical Engineering, Amrutvahini College of Engineering, Sangamner Maharashtra, India
[2]K. K. Wagh Institute of Engineering Education and Research, Nashik, Maharashtra, India
[3]Matoshri College of Engineering & Research Center, Eklahare, Nashik, Maharashtra, India
[4]MET Institute of Engineering, Nashik, Maharashtra, India
[5]Jamia Institute of Engineering and Management Studies, Akkalkuwa, Nandurbar, Maharashtra, India

**Article Info**

***Article history:***

Received Jul 26, 2022
Revised Aug 15, 2022
Accepted Aug 18, 2022

***Keywords:***

Custom power device
DSTATCOM
Energy storage device
supercapacitor
Power quality
Wind energy

**ABSTRACT**

Nowadays power crises in different countries are observed and the main cause of the power crisis is the huge gap between the supply and demand of electricity, renewable energy sources are identified as an alternative to overcome the power crisis gap. Renewable wind energy is the most promising energy source. Increasing the integration of wind energy into the grid causes the exploitation of power quality. Hence there is a need to deal with this issue. In this case, supercapacitors and custom power devices are introduced as smart energy storage devices in grid-connected wind energy systems for power quality enhancement features. The indirect current control scheme has interfered with custom power devices based on DSTATCOM. The optimal MATLAB-based smart energy storage model and hardware results are compared and validated. power quality improvement feature of grid-connected wind energy system using DSTATCOM is highlighted. The main aim of this study is to determine and interface the optimistic energy storage device into grid connected wind energy system. So that the stability of the wind energy system is to be maintained and also able to enhance the overall efficiency of the wind energy system.



***Corresponding Author:***

Kishor V. Bhadane
Electrical Engineering, Amrutvahini College of Engineering
Near Pune Nashik Highway, Ahmadnagar, Sangamner, Maharashtra 422608, India
Email: kishor4293@yahoo.co.in

## 1. INTRODUCTION

Due to the fast rise in Industrialization, the Information Technology sector, and development in the retail sector, electrical power requirements have increased significantly. There is a large gap between the supply side and load side demand. In this situation, alternate energy sources (renewable sources) can play an important role to overcome this electric power gap. Out of many alternate sources for the generation of electricity, wind energy is the most promising [1]. wind power as a generation source has specific characteristics, which include variability and geographical distribution. These raise challenges for the integration of large amounts of wind power into electricity grids. To integrate large amounts of wind power successfully, several issues are needed to be considered, including the design and operation of the power system, grid infrastructure issues, grid connection of wind power, power quality, and transient stability enhancement of wind generator systems [2]. Electrical power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. "Power quality" is a term used to describe the most important aspect of the electricity supply. Power quality has become a very important issue over the last decade. The addition of wind turbines can have a significant effect and increases the complexity of this problem. Depending on the grid configuration and the type of wind turbine used, different power quality problems may arise [3]. Integrating renewable into grids to any considerable degree can expose the system to issues that need attention lest the functionality of the grid is impaired. Such issues can be voltage fluctuation and frequency deviation of power supply [4].

There is a need for the assessment of electric power quality in grid-connected wind energy because electric power of poor quality has detrimental effects on the health of different electrical equipment and systems. Moreover, power system stability, continuity, and reliability fall with the degradation of the quality of electric power. Moreover, a present-day deregulated scenario of a power network demands high-quality electric power [5], [6]. There are various causes of poor power quality in grid-connected wind energy, as referred to in [5], [6]. The impact of poor power quality such as harmonics, voltage swell, dip, unbalance, fault condition, reactive power, and interruptions problems are affecting the wind power generation, additional losses, affecting the life of electrical equipment used in wind power system, direct impact on a grid system with chances of grid failure, violation of grid codes, affecting the wind power penetration, increasing of power demand by decreasing the power generation, increasing the load shedding problem in a rural area, affecting the continuity of power in the wind-based system, affecting the industrial development based on wind system, economic growth is affected, the additional cost is increased. Hence it is needed to consider the impact of wind energy in terms of increasing the cost of poor power quality:

- The ultimate objective of this study is to determine and interface the optimistic energy storage device into grid connected wind energy system. So that the stability of the wind energy system is to be maintained and also able to enhance the overall efficiency of the wind energy system.
- The statement of the problem is to study the integration of wind energy into the grid system, the power quality of the entire system is affected and hence there is a need to deal with the exploited power quality issues. The energy storage devices are playing a very important role in the power enhancement capacity of wind energy with power quality improvement features by using custom power devices.

## 2. WIND ENERGY AND POWER QUALITY PERSPECTIVE

Globally wind power generation has received more attention because of its merits. An induction generator is extremely popular for directly connected to the grid because of its low cost and robust energy conversion. During the start-up of induction generators, the requirement of reactive power is increased for its magnetization. Reactive power drained by the induction generators is tied to the active power generated by them, the variability of wind speed results in variations of the induction generator's real and reactive powers. It is this variation in active and reactive powers that interacts with the network, voltage, and frequency fluctuations:

- These fluctuations cause flickering and inaccuracy in the timing devices. If good penetration of wind power is to be achieved, some remedial measures must be taken for power quality improvement.
- Since both frequency and voltages are often affected in these systems, fast-acting control devices (i.e., the energy storage devices) are capable of exchanging active as well as reactive powers. Electrical energy in an alternating current (AC) system cannot be stored electrically. However, energy can be stored by converting the AC electricity and storing it electromagnetically, electrochemically, kinetically, or as potential energy. Each energy storage technology usually includes a power conversion unit to change the energy from one form to another. Integration of possible energy storage technology with custom power devices is among the possible power applications of energy storage.
- The possible benefits include transmission enhancement, power oscillation damping, dynamic voltage stability, tie line control, short-term spinning reserve, load levelling, under-frequency load shedding reduction, circuit-breaker reclosing, sub synchronous resonance damping, and power quality improvement [2]–[4].

## 3. PROBLEM FORMULATION

Mathematical model:

$$Pm = Cp\frac{1}{2}\rho A v^3 = CpPm - W \quad (1)$$

In this (1), Pm is the power extraction of the wind turbine, is the wind velocity in m/s, and A is the area of the wind turbine [7]–[10]. The (1) indicates that the wind velocity is forced to the wind turbine and conversion of wind energy into kinetic energy can be obtained. Later on, kinetic energy is converted into mechanical energy and mechanical energy is finally converted into electrical energy using the wind generator model. The overall efficiency of the wind energy system is about 15 to 16% due to its less power extraction, poor power quality, constraints, and limitations. Hence as compared to its capacity very less power is injected into the grid and hence there is a need to enhance the overall efficiency of the wind energy system and stability too.

Due to the integration of wind energy into the grid, the power quality of the entire system is affected and hence there is a need to deal with the exploited power quality issues. The energy storage devices are playing a very important role in the power enhancement capacity of wind energy with power quality improvement features. Modeling and operation of the grid-connected wind energy system are considered herewith. The power quality analysis of the wind energy system in the grid is proposed via MATLAB/Simulink. According to the simulation results of power quality issues, the design and development of the supercapacitor-based energy storage system are developed and interfaced with the wind energy system. Custom power devices based on DSTATCOM are interfaced in association with a supercapacitor for overall power quality improvement of the grid-connected wind energy system.

## 4. TYPES OF ENERGY STORAGE SYSTEMS AND WIND ENERGY SYSTEM

Energy storage systems are available in various natures like electric springs, batteries, ultracapacitors, superconductors, mechanical flywheels, magnetic energy storage systems, and combinational methods too [11]. Due to the interfacing of smart energy storage devices into the wind energy system, more flexibility is provided to the grid system. The injection of more wind power into the grid is also obtained. Energy storage system interfacing with wind energy increases the overall efficiency of the grid system by increasing the capacity factors of various resources available.

Out of many energy storage devices available, the supercapacitor and battery combination is selected herewith due to its huge merits [12], [13]. More power can be injected into the grid due to the interfacing of battery and supercapacitor as energy storages system. There are different types of wind generators used in the grid-connected mode of operation but the asynchronous generator is commonly preferred due to its huge merits. Commonly used wind generators are squirrel cage and wound rotor induction generators. They are also called doubly fed induction generator (DFIG). In this case, DFIG is used in the wind energy system in grid connected mode of operation. DFIG has more efficiency due to its flexible operation in various speed ranges by using back-to-back converter feeding to the rotor of DFIG with variable frequency currents as compared to traditional fixed speed operated wind energy system. DFIG is also enough able to control both the active and reactive power of wind energy systems using converters [14], [15].

## 5. SUPER CAPACITOR-BASED ENERGY STORAGE MODEL OF WIND FARM USING DSTATCOM

Due to interfacing of variable wind energy in the wind farm via point of common coupling (PCC) in to the grid the power quality (PQ) issues are arises and PQ issues are voltage sag and swell, reactive power, voltage flickers, power factor, harmonics, faults, etc. At PCC proposed DSTATCOM with indirect current control scheme is connected along with smart energy storage devices like supercapacitor and battery to compensate the PQ. Supercapacitor and battery are integrated as energy storage system to sustain the active power flow under variable wind constraints [16].

### 5.1. Topology of DSTATCOM: past and current journey of DSTATCOM

#### 5.1.1. Significance of DSTATCOM

In wind turbine the effective power management is obtained by using controller. Controller can start, stop the wind turbine operation and also support to coordinate the various wind turbines operation as per the requirement of environmental conditions. Hence controller is integral part of wind energy system.

The acceptance and implementation of grid codes during grid connected mode of wind energy system is found under the guidance of American wind energy Association in United States. In U.S., due to experience of black out in 2003 the introduction of first grid code was implemented at distribution level side. International Electrotechnical Commission (IEC) and Regulatory Authority of grid codes are introduce the rules and regulations about the interfacing of wind energy system in to grid using IEC -61400-21.

Basically, DSTATCOM is current controlled voltage source inverter used to injects the current in to the grid so that maintain the stabilized harmonics free source current and also maintain the phase shift as per source rated value. This additional injection of current needs to compensate the reactive power and harmonics of load and wind generator too. Hence the entire system power factor with specific power quality indices also improves. To obtain the same, sensing of grid voltages is going on and its synchronization with grid using current of inverter [16], [17].

### 5.2. Comparison of DSTATCOM: Significance of proposed DSTATCOM

In this case, various control strategies of DSTATCOM are considered such as bang-bang controller, PI, PID and indirect current control scheme. PI and PID controller are the basic wind turbine controllers. In this controller, generally initial tuning is received by using pole placement method and later on extensive method of aeroelastic simulation are utilized to get the good tuning for obtaining better regulations and lesser loading .in this case, rotor speed and generated power control can be obtained. It is applicable for small capacity wind turbines. It uses pitch angle controlling method for getting the rated output. As compared to other control schemes Its response time is more [7].

Basically Bang-Bang controller is nothing but hysteresis current control scheme. In Bang Bang controller, injection of currents in to the grid is obtained. By using this controller, the boundaries of hysteresis area are controlled accurately and provides the exact switching pulses for operation of DSTATCOM [16], [17]. This controller needs huge measurements of variables like source current, using the sensor measure inverter current, and DC output voltage.

Indirect current control scheme based DSTATCOM having response time is very less compared to other control schemes. This controller required less variables as compared to other control schemes. Hence the operation time required is less. Extraction of maximum power from wind turbine is possible by using improved coefficient of performance i.e. cp. Maximum power point tracking based optimizations of output power is obtained using this controller [8]–[10].

### 5.3. Super capacitor-based energy storage model of wind farm using indirect current control scheme based DSTATCOM

Energy storage by using a supercapacitor is considered. Due to this power enhancement of wind power is obtained. It also helps to increase the power quality [18], [19]. Figure 1 shows the detailed model of a supercapacitor interfaced with a DSTATCOM-based wind farm. Advanced capacitors: capacitors store electric energy by accumulating positive and negative charges (often on parallel plates) separated by an insulating dielectric [20]–[25].

The basic configuration of a DFIG wind turbine equipped with a super capacitor-based ESS is shown in Figure 1. By using the gearbox, the integration of small speed to large speed is established for DFIG. Basically, slip ring rotor-based induction machine is nothing but the DFIG. DFIG is integrated with grid system by using converters of stator and rotor side. In depth of DFIG, stator is feeding to grid directly while injection of rotor power to the grid is obtained by using rotor side converter/inverter as well as grid side converter/inverter in back to mode of connection via DC link. Wind generators are operating at the speed ranges of ±27–31% of the synchronous speed and capable of controlling the real and reactive power individually. In this model, the smart energy storage system is utilized with ultracapacitors, battery and smart converter of DC -DC is linked with converters of DFIG. The controlling of generated real power of wind generator is obtained by using smart energy storage system of supercapacitor and battery. The entire smart energy storage system is monitored and controlling is given as below in Figure 1.

Universal bridge controller: This block implements a bridge of selected power electronics devices. Series RC snubber circuits are connected in parallel with each switch device. Discrete synchronized 6 pulse generator: use this block to fire the 6 Thyristors of a 6-pulse converter. The output is a vector of 6 pulses (0-1) individually synchronized on the 6 commutation voltages. Pulses are generated alpha degrees after the increasing zero-crossings of the commutation voltages. Input 1 is the alpha firing signal (degrees). Inputs 2, 3, and 4 are the synchronization voltages AB BC CA which should be in phase with the 3 phase-phase voltages at the converter terminals. Input 5: Frequency of the synchronization voltages (use a constant or the Freq PLL output). Input 6 allows blocking of the pulses when the applied signal is non-zero. When the 'Double pulsing' option is checked, two pulses are sent to each Thyristor: a 1st pulse when the alpha angle is reached, then the 2nd pulse 60 degrees later, when the next Thyristor is fired.

Figure 2 indicates the entire energy storage model with DSTATCOM in grid connected wind farm. MATLAB/Simulink based wind farm is considered herewith having four feeders. Each feeder having approximately 18 wind turbines likewise total 52 wind turbine are connected together in grid connected mode of operation. Induction generator of 1.25 MW each capacity is used, it generates wind power at 690 V. further step transformer is converting 690 V to 33 KV and 33 KV to 132/220 KV of grid system via power transformer of 50 MVA. Further smart energy storage system and custom power device i.e. DSTATCOM are playing role of real and reactive power exchanges of wind generators during its wind power injection to the grid system. Hence stability, voltage profile control and effective power quality enhancement is also obtained in this mode of operation which is shown in Figure 2.

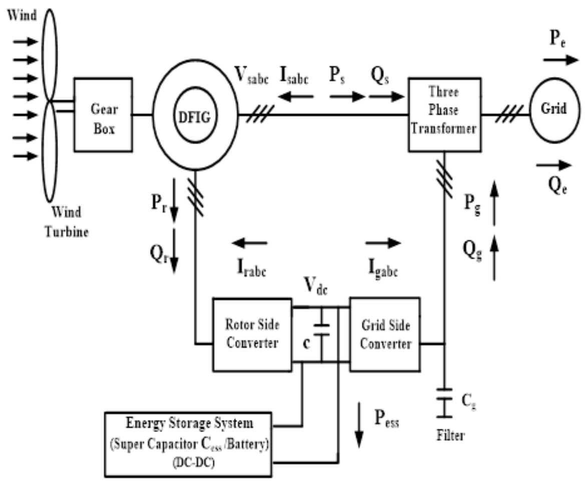


Figure 1. Energy storage model of DFIG with DSTATCOM in wind farm

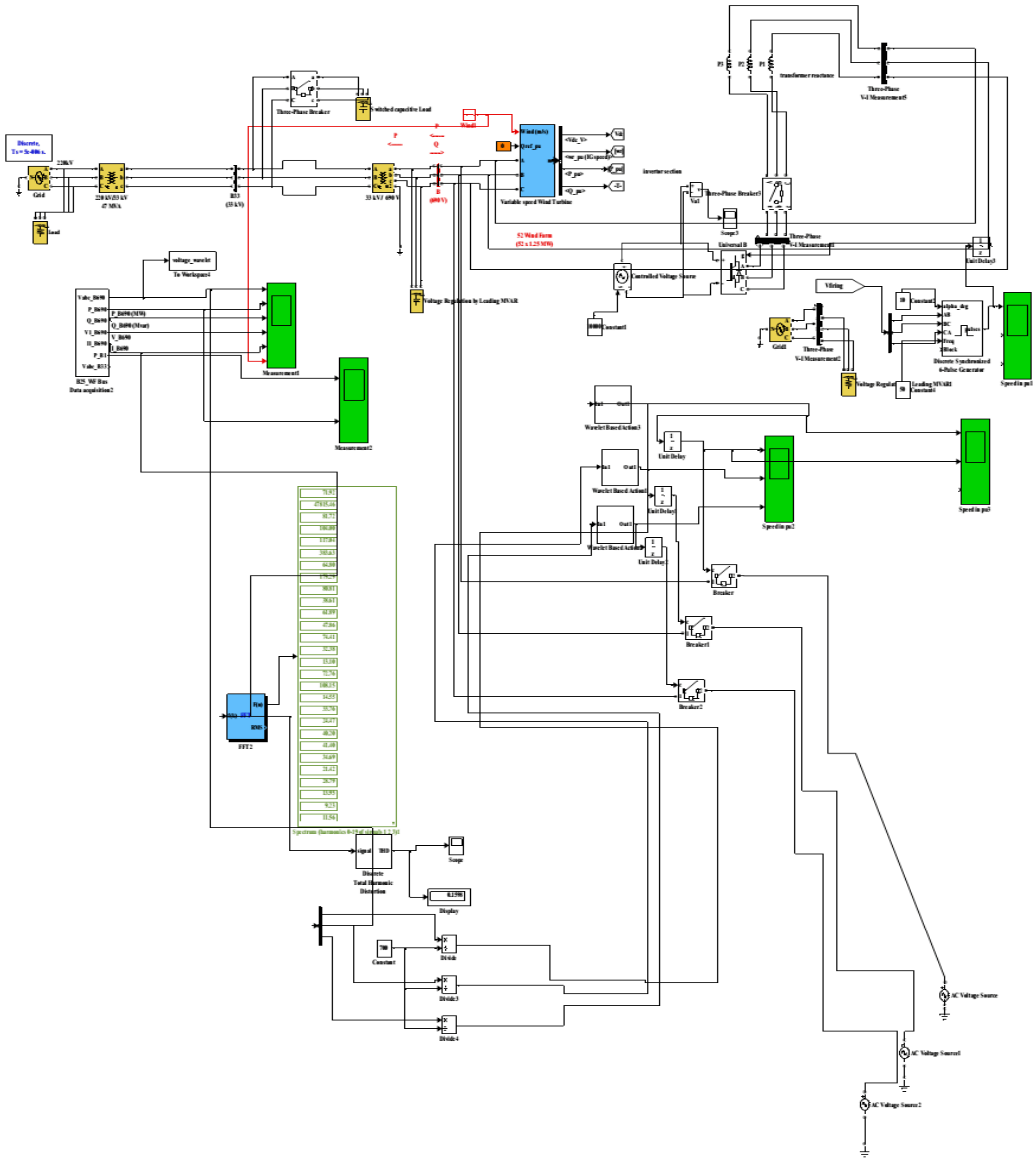

Figure 2. Energy storage model with DSTATCOM in wind farm

### 5.4. Simulation model of wind farm by using supercapacitor

The Novel technical results by using proposed indirect current control Scheme of DSTATCOM is mentioned in detailed as follows. Simulation models of the wind farm by using Supercapacitor: DFIG are considered for further simulation. It is a variable speed in nature and has a rotor and grid side converter for effective integration to the grid. But variable wind speed is affecting the power generation in fluctuating nature and which affects the power quality. So, for effective smoothening and balancing the wind power, the supercapacitor is interfaced with the wind farm which performs the effective exchange of active and reactive power by using power electronics control. Wind power is penetrated to the grid and also linked up with a universal bridge converter through inductances and breakers.

A universal bridge converter is feeding the power to a controlled voltage source and is linked with a super capacitor for energy storage. There is an inverter section for reverse application i.e., from the supercapacitor, DC power is inverted to ac and further integrated into a grid for effective exchanging of electric power. Smoothening and balancing of wind power are obtained which provides good power quality. Hence additional power has penetrated the grid. even at low wind speed, power is stored and further reused as an inverter for integration to the grid which is shown in Figures 3 and 4 respectively.

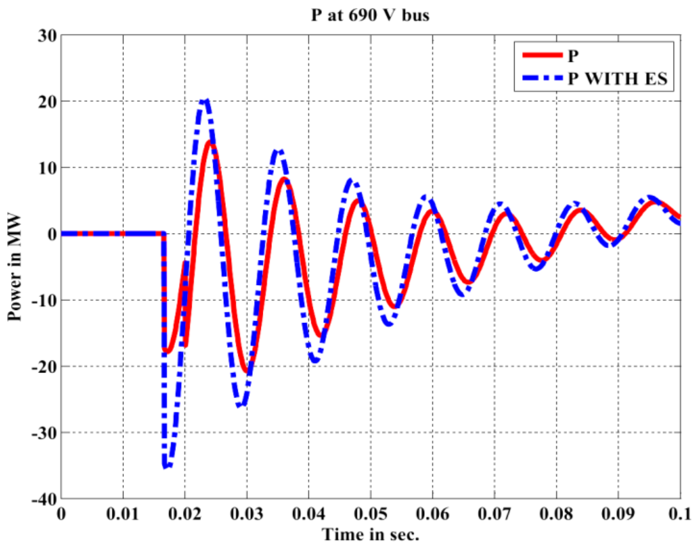


Figure 3. Active power in energy storage model with DSTATCOM in wind farm

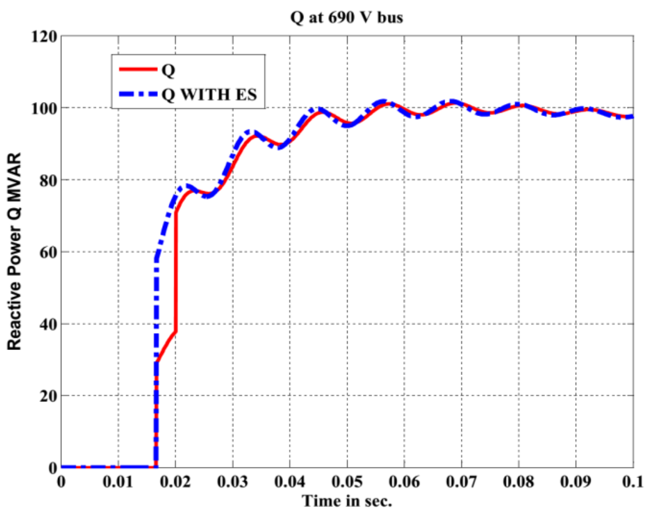


Figure 4. Reactive power in energy storage model with DSTATCOM in wind farm

It shows that initial power quality (PQ) and power fluctuations due to variable wind are smoothed by using an energy storage system and 20 MW of active power is reached. Active power penetration is enhanced from 15 to 20 MW due to the supercapacitor and hence the active power enhancement is increased by 15% because of PQ enhancement due to super capacitor-based energy storage system. An additional 15% of wind power has penetrated the grid. Similarly, due to the effect of the energy storage system the reactive power enhancement in the wind farm is obtained which is shown in Figure 4.

## 6. NOVEL RESULTS AND ITS VALIDATION:

The output power of wind turbine is enhanced by using smart energy storage devices like supercapacitor and battery with DSTATCOM. By using efficient blade pitching method with indirect current control scheme maximum extraction of wind power is obtained. Indirect current control scheme is best suitable for grid connected wind energy system due to its merits. As its time response is quick and less variables are required for analysis purpose, more power injection in to the grid is obtained as compared to other control schemes like PI, and PID. The simulation results obtained from MATLAB is compared and validated with power quality Analyzer based hardware results. As compared to results of PI, PID controller of wind energy system, the results of indirect current control scheme of DSTATCOM are better and an additional 15% of wind power has penetrated in to the grid.

## 7. CONCLUSION

The system development is case study in which the power quality analysis of wind farms is described by using a computational method i.e., MATLAB/Simulink. The simulation model is described for power quality issues such as active power, reactive power, fault ride through capability, and energy storage in detail. The enhancement of power quality issues by using DSTATCOM and energy storage of supercapacitor for wind energy are described in detail for various power quality issues in the case study. With and without custom power device-based PQ analysis is described. It has been observed that initial power quality and power fluctuations due to variable wind are smoothed by using an energy storage system and 20 MW of active power is reached. Active power penetration is enhanced from 15 to 20 MW due to the supercapacitor and hence the active power enhancement is increased by 15% because of PQ enhancement due to super capacitor-based energy storage system.

## REFERENCES

[1] J. F. Manwell, J. G. McGowan, and A. L. Rogers, *Wind Energy Explained: Theory, Design and Application*. Chichester: John Wiley & Sons Ltd., 2009.

[2] M. H. Ali, *Wind Energy Systems*. London: CRC Press, Taylor & Francis Group, 2012.

[3] T. Burton, N. Jenkins, D. Sharpe, and E. Bossanyi, *Wind Energy Handbook*. Chichester: John Wiley and sons Ltd, 2001.

[4] Z. Chen and E. Spooner, “Grid power quality with variable speed wind turbines,” *IEEE Transactions on Energy Conversion*, vol. 16, no. 2, pp. 148–154, Jun. 2001, doi: 10.1109/60.921466.

[5] S. Chattopadhyay, M. Mitra, and S. Sengupta, *Electric Power Quality*. Dordrecht: Springer Netherlands, 2011. doi: 10.1007/978-94-007-0635-4.

[6] A. Ghosh and G. Ledwich, *Power Quality Enhancement Using Custom Power Devices*. Boston, MA: Springer US, 2002. doi: 10.1007/978-1-4615-1153-3.

[7] O. Apata and D. T. O. Oyedokun, “An overview of control techniques for wind turbine systems,” *Scientific African*, vol. 10, p. e00566, Nov. 2020, doi: 10.1016/j.sciaf.2020.e00566.

[8] M. Shafiullah, S. D. Ahmed, and F. A. Al-Sulaiman, “Grid Integration Challenges and Solution Strategies for Solar PV Systems: A Review,” *IEEE Access*, vol. 10, pp. 52233–52257, 2022, doi: 10.1109/ACCESS.2022.3174555.

[9] R. Aazami, O. Heydari, J. Tavoosi, M. Shirkhani, A. Mohammadzadeh, and A. Mosavi, “Optimal Control of an Energy-Storage System in a Microgrid for Reducing Wind-Power Fluctuations,” *Sustainability*, vol. 14, no. 10, p. 6183, May 2022, doi: 10.3390/su14106183.

[10] C. R. Reddy, B. S. Goud, F. Aymen, G. S. Rao, and E. C. Bortoni, “Power Quality Improvement in HRES Grid Connected System with FOPID Based Atom Search Optimization Technique,” *Energies*, vol. 14, no. 18, p. 5812, Sep. 2021, doi: 10.3390/en14185812.

[11] A. Ghaffari, A. Askarzadeh, and R. Fadaeinedjad, “Optimal allocation of energy storage systems, wind turbines and photovoltaic systems in distribution network considering flicker mitigation,” *Applied Energy*, vol. 319, p. 119253, Aug. 2022, doi: 10.1016/j.apenergy.2022.119253.

[12] K. V. Bhadane, D. P. Patil, and S. S. Kadlag, “Grid Integration of Wind Energy Generation System and Grid Code Requirements,” in *Deregulated Electricity Market*, New York: Apple Academic Press, 2022, pp. 89–110. doi: 10.1201/9781003277231-6.

[13] K. V. Bhadane, D. P. Patil, A. S. Dube, and S. S. Kadlag, “Distributed Generation-Based Power Quality Analysis,” in *Deregulated Electricity Market*, New York: Apple Academic Press, 2022, pp. 249–278. doi: 10.1201/9781003277231-14.

[14] K. V. Bhadane, “Power Quality Enhancment of Grid Connected Wind Energy by using Custom Power Devices,” RTM Nagpur, 2017.

[15] M. Thakre, A. Ahmad, and K. Bhadane, “Measurement Class Phasor Measurement Unit Compliance for Electrical Grid Monitoring,” *MAPAN*, vol. 37, no. 1, pp. 125–135, Mar. 2022, doi: 10.1007/s12647-021-00440-6.

[16] S. K. George and F. M. Chacko, "Comparison of different control strategies of STATCOM for power quality improvement of grid connected wind energy system," in *2013 International Mutli-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s)*, Mar. 2013, pp. 650–655. doi: 10.1109/iMac4s.2013.6526394.
[17] S. W. Mohod and M. V. Aware, "A STATCOM-Control Scheme for Grid Connected Wind Energy System for Power Quality Improvement," *IEEE Systems Journal*, vol. 4, no. 3, pp. 346–352, Sep. 2010, doi: 10.1109/JSYST.2010.2052943.
[18] R. G. Shriwastava, M. P. Thakare, K. V. Bhadane, M. S. Harne, and N. B. Wagh, "Performance enhancement of DCMLI fed DTC-PMSM drive in electric vehicle," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 4, pp. 1867–1881, Aug. 2022, doi: 10.11591/eei.v11i4.3714.
[19] M. S. Ballal, K. V. Bhadane, R. M. Moharil, and H. M. Suryawanshi, "A Control and Protection Model for the Distributed Generation and Energy Storage Systems in Microgrids," *Journal of Power Electronics*, vol. 16, no. 2, pp. 748–759, Mar. 2016, doi: 10.6113/JPE.2016.16.2.748.
[20] S. Jain *et al.*, "Blockchain and Autonomous Vehicles: Recent Advances and Future Directions," *IEEE Access*, vol. 9, pp. 130264–130328, 2021, doi: 10.1109/ACCESS.2021.3113649.
[21] K. Bhadane *et al.*, "A Comprising Study on Modernization of Electric Vehicle Subsystems, Challenges, Opportunities and strategies for its Further Development," in *2021 4th Biennial International Conference on Nascent Technologies in Engineering (ICNTE)*, Jan. 2021, pp. 1–9. doi: 10.1109/ICNTE51185.2021.9487757.
[22] K. V. Bhadane, M. S. Ballal, R. M. Moharil, H. R. Kulkarni, and H. Prasad, "Enhancement of fault ride-through capability of grid-connected wind farm," *International Journal of Power Electronics*, vol. 13, no. 3, p. 267, 2021, doi: 10.1504/IJPELEC.2021.114467.
[23] H. Prasad, K. V. Bhadane, and P. Kumar, "Real-time Performance Evaluation of Single Phase 7 Level Z-Source Boost Inverter," in *2021 7th International Conference on Electrical Energy Systems (ICEES)*, Feb. 2021, pp. 28–31. doi: 10.1109/ICEES51510.2021.9383751.
[24] G. Bathla *et al.*, "Autonomous Vehicles and Intelligent Automation: Applications, Challenges, and Opportunities," *Mobile Information Systems*, vol. 2022, pp. 1–36, Jun. 2022, doi: 10.1155/2022/7632892.
[25] R. Zhu, A. Zhao, G. Wang, X. Xia, and Y. Yang, "An Energy Storage Performance Improvement Model for Grid-Connected Wind-Solar Hybrid Energy Storage System," *Computational Intelligence and Neuroscience*, vol. 2020, pp. 1–10, Aug. 2020, doi: 10.1155/2020/8887227.

## BIOGRAPHIES OF AUTHORS

**Kishor V. Bhadane** currently working as Associate Professor in Electrical Engineering at Amrutvahini College of Engineering at Sangamner and earlier he was worked as a Professor and Head in the Electrical Engineering department at Sandip Foundations, Sandip Institute of Engineering & Management, Nashik. In addition to this, he is handling the responsibility of Dean Academics at the Institute level. He has total 18 years of experience in Teaching. He has completed a Ph.D. from RTM Nagpur University in Electrical Engineering under the guidance of Dr.M.S. Ballal, Prof. in Electrical Dept., V.N.I.T., Nagpur He has total 30 publications to his credit in reputed International Journals and conferences along with one Indian Patent on his research. He has a membership in different National & International professional bodies like IAENG and IEEE. He has delivered expert talks and sessions in various Institutes under STTP, FDP, and conferences, and also served as session chair and designated reviewers in reputed international journals and conferences. Dr. Kishor V. Bhadane has contributed to the Institute, not only in terms of teaching, but he is successfully handling the responsibility of Dean, Academics, and Projects. Under this portfolio, he has successfully collaborated with more than 20 Industries in the area of Industry problems research with the help of GIZ Germany and NIMA Nashik. He can be contacted at email: kishor4293@yahoo.co.in.

**Mohan P. Thakre** received the B.Tech. and M.Tech degrees in electrical power engineering from Dr. Babasaheb Ambedkar Technological University (Dr. BATU), Maharashtra, India, in 2009 and 2011 respectively, and the Ph.D. degree in electrical engineering from Visvesvaraya National Institute of Technology, (VNIT), Nagpur, Maharashtra, India in 2017. Currently, he is an Assistant Professor at the Department of Electrical Engineering, K. K. Wagh Institute of Engineering Education & Research, Nashik, India. His research interests include Flexible AC Transmission Systems (FACTS) and Power System Protection. He can be contacted at email: mohanthakre@gmail.com.

**Rakesh Shriwastava** obtained Ph.D. Degree in Electrical Engineering specializing in power electronics and drives from RTM Nagpur University, (India) in 2017. He occupied various positions to serve the engineering institutes for about 24 years. He is currently working as Professor in the Electrical Engineering Department of Matoshri College of Engineering & Research Center, Nashik. His research interests include the analysis and control of electrical drives, particularly in hybrid and electric vehicle applications. He has several publications in national and international journals. He attended International and National conferences and also worked as a jury member. He is a member of professional bodies such as ISTE and IAENG. He can be contacted at email: rakeshshriwastava9372@gmail.com.

**Deepak P. Kadam** received a B.E from Government College of Engineering, Amarawati, and M.E degrees in electrical power system from Walchand College of Engineering, Sangli, Maharashtra, India, in 1997 and 2005 respectively, and a Ph.D. degree in electrical engineering from Savitribai Phule Pune University, Pune Maharashtra, India in 2015. Currently, he is an Associate Professor at the Department of Electrical Engineering, Bhujbal Knowledge City, MET Institute of engineering, Nashik, India. His research interests include Renewable energy technology, Power Quality, and Power systems. His total teaching experience is around 23 years. He can be contacted at email: dpkadam@gmail.com.

**Dnyaneshwar V. Bhadane** obtained BE and ME Degree in Mech. Engineering specializing in General Engineering from N.M.U. Jalgaon, (India). He occupied various positions serving the engineering institutes for about 15 years. He is currently working as an Assistant Professor in the Mechanical Engineering Department of Jamia Institute of Engineering and Mang. Studies, Akkalkuwa, Nandurbar. His research interests include the analysis and control of electromechanical drives, and thermal engineering, particularly in hybrid and electric vehicle applications. He has several publications in national and international journals. He attended International and National conferences and also worked as a jury member. He can be contacted at email: dnyaneshwar.bhadane4293@gmail.com.

**Mahesh Harne** is working as an Assistant professor in mechanical engineering in the Department of Mechanical Engineering the College examination officer at Amrutvahini College of Engineering, Sangamner, Maharashtra (India). He worked as a faculty advisor at SAE India, RD coordinator of the college, and coordinator of the Institute Innovation Council. In his tenure as Faculty Advisor SAE, the Students team received the first position in the TIFAN Competition held by John Deer SAE India at Mahatma Phule Krishi Vidyapeeth Rahuri, successively four times overall Winner of the competition also team was the winner of the Solar Vehicle Championship held at Chitkara University, Chandigarh (India) further IIC got two stars certificate from AICTE New Delhi. He is a recognized postgraduate teacher of SPPU guided 03 post-graduate students, published 15 research papers in International National journals received a Project Grant of 2.4 lakh from BCUD, SPPU. He received his B.E. from North Maharashtra University, M.E. from Savitribai Phule Pune University (University of Pune), and Ph.D. in Mechanical Engineering from Rashtrasant Tukadoji Maharaj Nagpur University (Maharashtra). His research field of interest is All Tarren vehicles (ATV), Solar Powered Vehicles, Ergonomics product design, and development. He has a membership in SAE India, IE India, ISTE India, and QCFI. He can be contacted at email: mahesh.harne@avcoe.org.