Study on UPQC Integration Benefits in a Hybrid Solar Wind Energy System

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Abstract. The researchers are focusing on harnessing the electricity form the renewable energy resources by overcoming the challenges faced by them due its variable nature. This study discusses the developing significance of renewable energy sources (RES), in particular wind and solar electricity, in meeting future electricity demands. India's geographical length is highlighted as beneficial for integrating variable renewable energy outputs into its grid. The paper also addresses Power-quality (PQ) issues springing up from integrating renewable energy sources, proposing solutions including single and Unified active power filter (SUAPF) and distributed Static Compensators (DSTATCOM). The work examines power quality issues associated with grid-related solar PV systems and the combination of Unified Power Quality Conditioners (UPQCs) in hybrid solar-wind systems. The analysis of the UPQC integration with the solar wind energy based hybris system concludes the enhancement in the power quality issues such as total harmonic distortions along with balancing the reactive power in the line.

Keyword-: Renewable energy, grid integration, hybrid systems, wind energy, solar energy, Unified Power Quality Conditioners (UPQCs).

1 Introduction

Future energy requirements will shift to Renewable energy systems (RES), like wind and solar power. India is a continent-sized country, which helps to integrate renewable energy sources into all of India's systems and balance out their erratic output in a few states. During the past two to three decades, wind and solar energy have grown at a quicker rate, and are thought to be the main elements of renewable energy that are used to generate power. The

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amount of renewable energy produced by solar and wind power has significantly expanded in recent years, accounting for a sizeable share of the grid's overall generation [1]. These days, distribution networks are more vulnerable to PQ problems such as harmonics, sag/swell, and flicker power factor (PF), and interruptions because of the integration of variable loads from sources like wind, tidal, and solar energy, as well as linear, nonlinear, and imbalanced loads with power electronics. However, the drop in PF is caused by the rising use of massive non-liner industrial loads. As a result, maintaining PQ has emerged as the fundamental difficulty faced by power engineers [2]. For 3 and 4 wire distribution systems, different configurations of single and/or three phase SUAPF with different control strategies were recommended for balanced and unbalanced supply voltage situations to address PQ concerns. Furthermore, the latest advancements and uses of SUAPF were also covered [3].
Two renewable energy sources—wind and solar—are combined in a wind-solar hybrid system to produce electricity. The architecture of this system uses solar panels and small wind turbine generators to generate electricity. Understanding how solar and wind energy systems operate is essential to comprehending how solar wind hybrid systems operate. A solar power system is a system that generates power using solar radiation using solar panels. The graphic displays the block diagram of the solar wind hybrid system in Fig. 1, which generates power using wind turbines and solar panels.

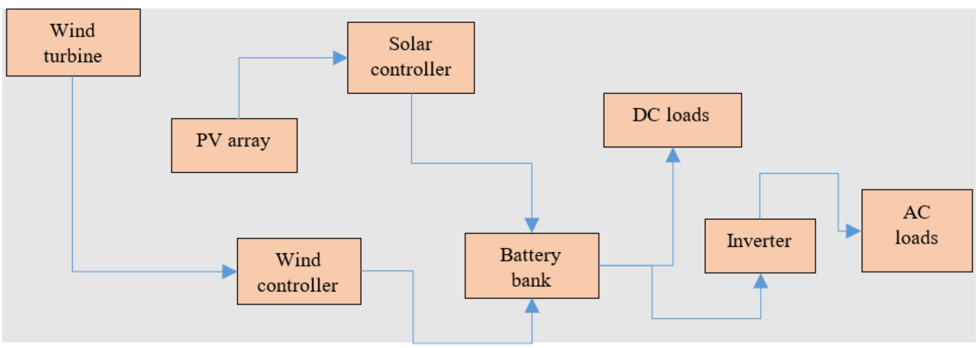

Fig. 1: Wind hybrid solar system

Wind energy, generated by wind turbines and generators, is an additional (RES) that might be employed to produce electricity. A fan with up to three blades that revolves in reaction to wind is known as a wind turbine; the rotation's axis must coincide with the direction of the wind. Because a gear box is used to move energy mechanically from one device for another, it is known as a high-precision mechanical system. Wind turbines come in many different varieties, but the two most popular types are horizontal and vertical axis turbines.

2 Wind Energy System

There is a lot of wind almost everywhere in the universe. The earth's revolution and uneven warming have resulted in its presence, which suggests that wind resources will generally have an opportunity to be accessible. The wind's energy will be tiny compared to Tom's reading speed through those streams of air are by Fig. 2. It has to do with dynamic energy; at the moment, we use wind farms to generate electricity [4]. Discusses advanced power electronics technologies for wind power, global market trends, turbine concepts, and future solutions, addressing challenges and future solutions in the growing renewable energy sector [5]. A well-established renewable energy resource with significant wind potential for power generation is wind energy. It has benefits including affordability, green power, and cleanliness. Upcoming technological developments must result in wind turbines that are more reliable, strong, and affordable. This study offers creative, useful solutions together with an analysis of the wind energy markets in Romania, Europe, and the rest of the world. A windmill could be a device that modifies wind energy under rotational energy. Tom eventually developed his examining technique for vanes called cruises or blades. In the beginning, grain was processed by windmills to create sustenance [6]. There is almost always a lot of wind in the universe. Due to uneven warming, it is present throughout nature. Throughout the course of history, the windmill may have undergone numerous mechanical adjustments. Pump water may have been the subject of an urgent request. Generally speaking, wind turbines are windmills that are used to generate electricity. [7] The study presents a novel control technique that outperforms DSTATCOM in terms of power quality improvement in wind energy conversion systems by utilizing an ANN-based Distribution Static Compensator. [8] The traditional methods of producing electricity by using non-renewable resources like coal, natural gas, oil, and so forth have a tremendous negative impact on the environment because they release a constant amount of carbon dioxide into the atmosphere, raising global temperatures.

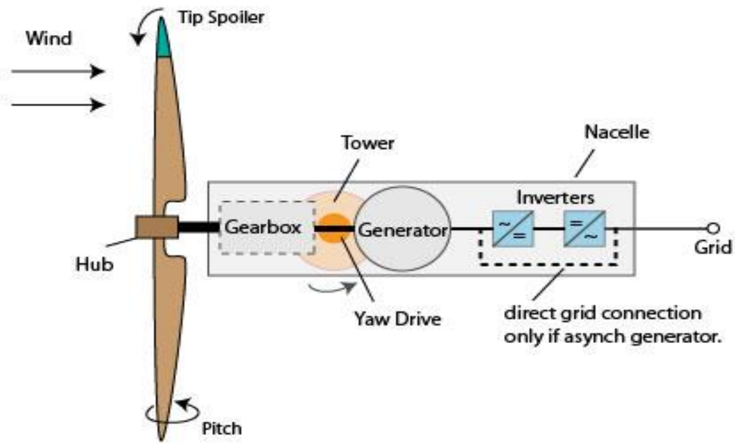

Fig. 2: Wind Energy System

This phenomenon is referred to as the "greenhouse effect." Thus, with those advances in science and technology, avenues for producing energy from renewable resources—such as wind—were established. In comparison to the cost of producing power from coal and oil, the cost of claiming wind energy that is connected to the grid these days may be as high. As a result, the growing popularity of green power suggests that demand for electricity produced from non-renewable energy sources may also rise appropriately.

Since wind originates from the sun's uneven heating of the surrounding atmosphere, imperfections in the earth's ground, and the earth's rotation, wind is theoretically considered a form of solar energy. Wind power is generated by using wind turbines, which use the kinetic energy of the earth's natural airflows to generate electricity. To place it quickly, wind turbines turn flowing air into energy, which powers a power driven generator to make modern. Electricity is produced by the generator as the wind propels the blades, which turn a shaft.

2.1 Types of Wind Energy

These are the three main categories of wind power.

- **Utility-Scale Wind:** Electric utilities or power providers supply the electricity from wind turbines with capacities ranging from 100 kW to multiple megawatts to the grid and thereafter deliver it to the final user.
- **Offshore Wind:** Windmills placed in broad stretches of water. These are often larger than onshore turbines, and as turbine efficiency increases with size, larger turbines may produce more electricity.
- **Distributed or "Small" Wind:** This term refers small wind turbines under 100 kW in size that are utilized to provide direct electricity to a non-grid dwelling, farm, or small company.

3 Integration Techniques

The renewable sources of energy such as wind and solar are combined to create the hybrid power system. Technology of a particular kind is employed to integrate wind and solar power. A Technology for Wind Turbines when compared to fixed speed turbines, variable velocity wind turbines use 5 percent more energy yearly. Active and reactive power problems can also be readily resolved, but if an extra power converter is needed for a good balance between quantity and quality, an improved MPPT control approach for a solar-wind hybrid power system will also be required [9] [10]. The strategy's goal is to maximize energy production while decreasing fluctuation rate. Renewable energy sources like hybrid energy can be hybridized to meet rising demand while lowering costs and improving dependability [11], but this approach needs arctihecture as shown Fig. 3.

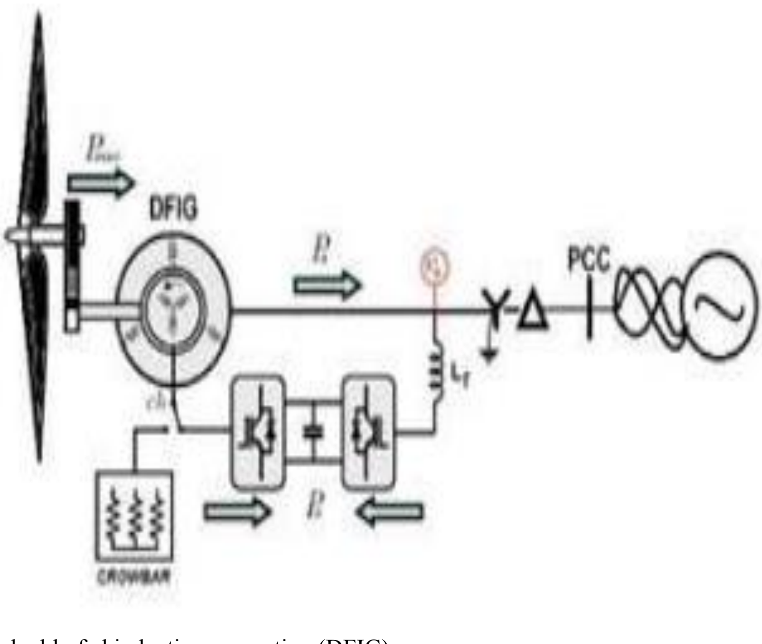

Fig. 3: The doubly fed induction generation (DFIG)

Variable velocity ideas in wind turbines have developed drastically, imparting advanced performance and grid integration. [12] The double feed induction generator (DFIG) permits for variable speed wind operation through constantly feeding the rotor winding, even if the stator winding is directly linked to the grid. This configuration allows particular vector manipulation of active and reactive powers, even as reducing the harmonic that was added to the grid. Another method entails the use of a complete power inverter, where the generator's output is rectified to an intermediate circuit earlier than being inverted back to AC. This technique gives better manage over the generator's velocity and energy output. Additionally, advancements in semiconductor generation have brought about the usage of electricity semiconductors with stepped forward electric properties and lower prices, improving the overall performance of variable pace wind turbines. Renewable electricity property like the idea of using the sun and wind for power needs in the future. India's continental length helps to balance the erratic output from renewable energy sources spread across a few states by allowing them to be integrated into all of India's systems [13].

4 Solar and Wind Energy System Power Quality Issues

Electricity is produced using a grid-connected solar (PV) power system, which is linked to the utility grid. It can be installed on everything from huge power plants to residential rooftops. It is made up of solar panels, inverters, and other equipment.
With an average capacity of 407 MW, grid-connected photovoltaic (PV) panels may supply extra power to the grid while meeting substantial consumer needs. To make money, the extra electricity can be sold to the grid. PV panels gather solar energy, which is converted from DC input power to AC voltage for the grid by a grid-connected inverter. To stop solar energy from coming through if the grid is down or strays too far, the inverter must keep an eye on the voltage, waveform, and frequency of the grid. Grid-connected PV power systems consist of solar panels, inverters, an energy conditioning unit, and equipment for connecting to the grid. This category includes anything from tiny rooftop solar energy systems for residences to enormous utility-scale solar energy plants.

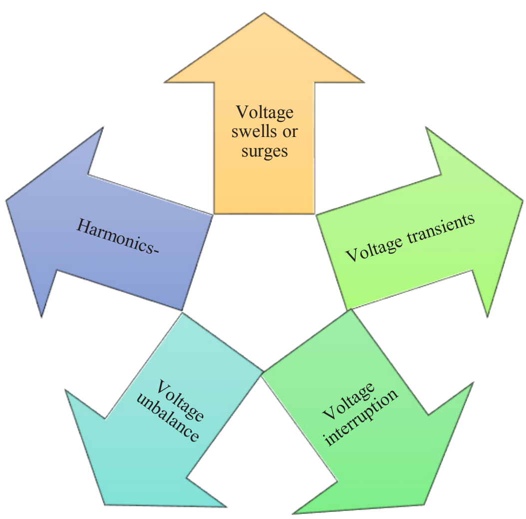

Fig. 4: Power quality issues

The price of low power quality is high in Fig. 4. Power outages can result in financial losses, but damaged assets may have additional costs, such as possible losses from manufacturing process downtime. The lifespan of equipment harmed by power quality incidents that result in elevated heat will be reduced automatically. Electrical distribution system issues may be subjected to power quality issues as presented in Table 1. The first step in resolving power quality problems is understanding and identifying the most typical power quality symptoms as well as how to diagnose and fix them [14].

Table 1: Power Quality Studies and Findings

Study	Parameter	Issues	Values	Findings
[15]	Multi-level Swell Voltage Control	Minimizing damage to on-grid system	1.3 to 1.8 pu	Compliance with IEEE and IEC standards
[16]	Power Quality Anomalies Detection	Preserve power line frequency	-	Enhances characterization of power anomalies; 83% accuracy in real-life signal examination
[17]	Surge Robustness of GaN FET-based Flyback	Surviving surge events	Peak voltage over 800V; efficiency over 90VAC - 264VAC line conditions	GaN FETs switch through surge events; operate without losing efficiency in the event of a brief line voltage swell.
[18]	Bidirectional Isolated DC-DC Converter	High voltage gain, wide input voltage	Maximum efficiency in step-up mode: 94.2% - 96.9%; step-down mode: 92.6% - 94.5%	Improved efficiency and energy recovery in bidirectional power conversion systems
[19]	Modular Surge Current Source Design	Surge current testing capability	Peak currents up to 100 kA (HCM); highly dynamic load current trajectories with peak currents up to 50 kA (DCM)	Adjustable current waveforms for power semiconductor tests
[20]	Lightning Stroke Effects on PV Power Plants	Mitigation techniques and effects	-	Efficiency of mitigation techniques in reducing peak voltage and maintaining PV farm components
[21]	Honeycomb Design Parameters in Aircraft	Transient response of sandwich structure	-	Optimal honeycomb parameters for minimum transient response in sandwich structure
[22]	2UPQC-2PV Configuration for Power Quality	Improving power quality performance	-	Improved power quality performance with 2UPQC-2PV configuration
[23]	Dynamic Voltage Restorer for Power Quality	Enhancing power quality	-	DVR effectively compensates for voltage disorders and minimizes THD

[24]	EVs-Involved Operation Framework for SDNs	Coordinated unbalance compensation	-	Improved operational conditions of SDNs through EVs-involved operation framework
[25]	(UPQC)	reducing issues with power quality	Series and shunt active power filters; THD of less than 5%	UPQC effectively mitigates power quality issues
[26]	Dynamic Voltage Restorer (Controllers	Tackling power quality issues	-	In terms of lowering overshoot, undershot, and spike voltage, ANFIS controller performs better than PI controller.

Voltage swells or surges-: Less often than dips, voltage swells can create short-term voltage surges, which can lead to issues. It's critical to keep an eye on parameters and interpret findings [27]. Equipment failure is one of the symptoms, however some might not show up right away. If defective power supplies are discovered, keep an eye on voltage trends and assess how frequently related pieces of equipment fail.

Voltage transients-: Short-term voltage spikes, also known as voltage transients, can result in a number of problems, such as damaged insulation, flashover, computer lockups, and broken electronic devices. Lightning strikes, mechanical switching, and unexpected equipment breakdowns are common reasons. To link distribution system events and operational issues, monitoring at load rates is essential [28-31].

Voltage interruptions-: Equipment stops working during two to five second voltage outages. More than five seconds pass between prolonged disruptions. Since unattended equipment cannot be identified, it is essential to monitor power outages and correlate them with equipment problems in order to identify unattended equipment.

Voltage unbalance-: In three-phase systems, voltage unbalance is a frequent problem that can seriously harm equipment. A power quality analyzer gives precise information, and it can happen anywhere in the distribution system. Every phase should have an equal amount of load, and an excessive load might result in problems like hotter motors or early failure [32]. Accurate readings require a three-phase power quality analyzer, and long-term monitoring is necessary to detect imbalance.

Harmonics-: Harmonics are voltages and currents that have an integer multiple of the fundamental frequency. They can lead to heat loss and overheating in motors as well as in neutral conductors and transformers. The harshness of each harmonic can be ascertained by engineers and electricians by comparing it to the fundamental frequency. The most severe symptoms, which include alarms, data loss, unexplained problems, and inappropriate device operation, are brought on by harmonic distortion.

5 Integration of UPQC in Hybrid Solar-Wind Systems

Power quality arises from large nonlinear loads, modern power electronics, and the presence of distributed generation. A slight PQ increase can improve equipment performance and lifespan. Issues with harmonic currents, voltage dips, and swells, and unbalanced load can be resolved using the flexible AC transmission system devices [33]. When combined with distribution static compensators and dynamic voltage restorers, harmonic current, voltage dips and swells, and unbalanced load is alleviated. Controller selection and design affect the capability of universal power quality conditioners to eliminate PQ difficulties.

Voltage swings and surges, UPQC uses a combination of serial and shunted-active energy filters (SAPFs or shunt active power filter [SHAPF]) to account for volt ampere reactive, harmonic, and other currents. Technology. Additionally, by utilizing the sliding mode controller case, the UPQC design can be connected to SHAPF and SAPF.

Today, the production of electricity from renewable energy sources has increased dramatically [34-37]. This is primarily because of the growing global efforts to lessen the harmful environmental effects of energy sources that are known to cause pollution, such as coal, oil, and gas, as well as the growing need for electrical energy. Consequently, the greenhouse effect and global warming have compelled a number of states to ratify an agreement in Paris during the 2015 Climate Change Conference to tighten international regulations aimed at limiting the rise in global temperatures to far below 2 degrees Celsius [38]. Study presents a distributed generation system that integrates wind turbine and photovoltaic systems, utilizing a unified power quality conditioner, enhancing power quality indicators, voltage drops, and harmonics [39-40]. To higher the standard of quality of power in distribution networks, this study presents a hybrid controller for Unified power quality conditioners (UPQC) with integration for fuel cells and solar systems. The controller eliminates grid voltage fluctuations, minimizes harmonics, maintains constant DC-Link voltage, compensates load current, and combines fuzzy and integral sliding mode controllers. Research demonstrates better results in a number of case studies [41].

$$M\frac{do\omega}{dt} = P_m - P_g - D\frac{d6}{dt} \qquad (1)$$

It is necessary to calculate Pg based on UPFC and network parameters. Pg is Eg times Ig, therefore current generator must be calculated. The equation uses M as momentum of rotor, Pm as input mechanical power, Pg output generator power and D is friction coefficient. The symbol ω is for rotor speed and δ is load angle [42].

$$\begin{bmatrix} E_g \\ I_g \end{bmatrix} = \begin{bmatrix} 1 & \frac{1}{Y_s} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \bar{T} & 0/1 \\ \bar{T}Yu & \dot{\bar{T}} \end{bmatrix} \begin{bmatrix} 1 & \frac{1}{Y_s} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix} \qquad (2)$$

Equation (2) can be written as (3).

$$\begin{bmatrix} E_g \\ I_g \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix} \qquad (3)$$

$$A = \frac{\bar{T}Y_s}{Y_s} + \frac{\bar{T}Y_u}{Y_s}$$

$$B = \frac{\left||\bar{T}|^2 Y_s\right|}{\dot{\bar{T}}Y_L Y_s} + \frac{\left||\bar{T}|^2 Y_u + Y_L\right|}{\dot{\bar{T}}Y_L Y_s} \qquad (4)$$

$$C = \bar{T}Y_u$$

$$D = \frac{\left||\bar{T}|^2 Y_u + Y_L\right|}{\dot{\bar{T}}Y_L} \qquad (5)$$

And generator current is:

$$I_g = V_s C - V_s\frac{DA}{B} + \frac{D}{B}E_g \qquad (6)$$

The above equations the internal voltage of generator is represented by E_g where ABCD is transmission matrix. The variable T is the complex ratio of transformer. UPQC admittance is represented by Y_u and Generator admittance is presented by Y_s. The equations make use of line admittance as Y_L

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6 UPQC controlled with traditional Programmable integral controls in the hybrid system.

The simulation for the system in this work is proposed using solar energy and UPQC converters that are powered by PI controllers. For the further analysis the system is then further integrated with the grid. Additional analysis has been done on the voltage current, active power, and reactive power waveforms [43]. The Proportional-Integral controller performs a feedback control system that adjusts the system output by comparing the desired set point with the actual output. In the case of the UPQC, the PI controller would adjust the control signals being sent to the converters, based on the parameters measured from the system to ensure it performs optimally. The solar energy is converted into electrical energy and conditioned by the UPQC, the output is then synchronized and integrated within the grid [46-48]. This implies that the power produced by the solar panels and the UPQC conditioning is fed into the existing electrical infrastructure.

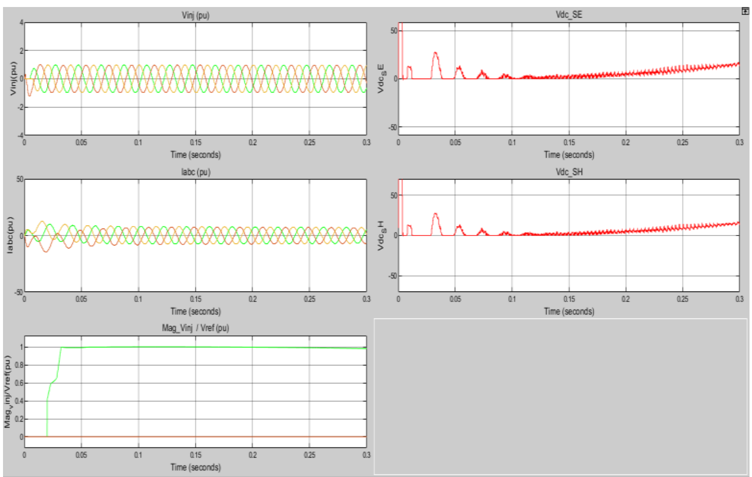

Fig. 5: Series converter voltage outputs from the system with UPQC having PI controller

The various waveforms making use of PI controller for voltage and current enhancement is shown in Fig. 5. The first waveform is of three phase AC injected voltage which is 1 p.u. The current at the series converter is also represented by in per unit system. The PI based control system uses reference voltage which is represented by the fig. 5. The DC link voltage in the UPQC is also presented by the figure as Shunt voltage and series converter voltage. Theses are found to be stabilized after use of UPQC in the hybrid solar wind energy system [44].

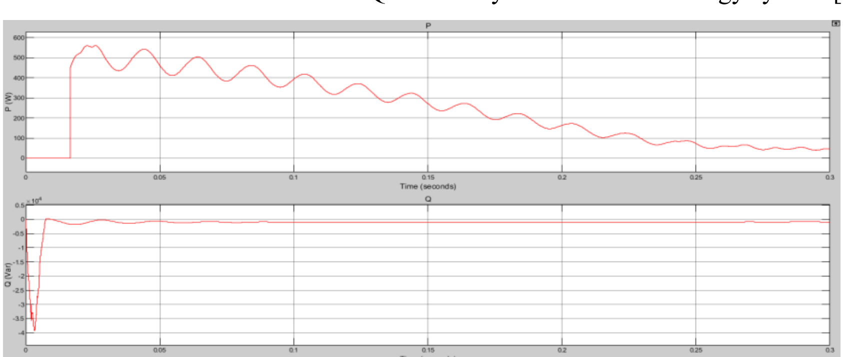

Fig. 6: Active and reactive power at the line in system having UPQC with PI control

By utilizing PI control in both the SAPF and ShAPF, the UPQC ensures precise regulation of active and reactive power at the line. This helps in improving the power quality parameters such as voltage regulation, power factor correction, and harmonic mitigation, ultimately leading to a more stable and efficient power system operation [50]. The output achieved after the integration of UPQC in the system is represented by the Fig. 6. The results depicts that the reactive power in the system is balanced by the use of this device and the active power is significantly enhanced and stabilized.

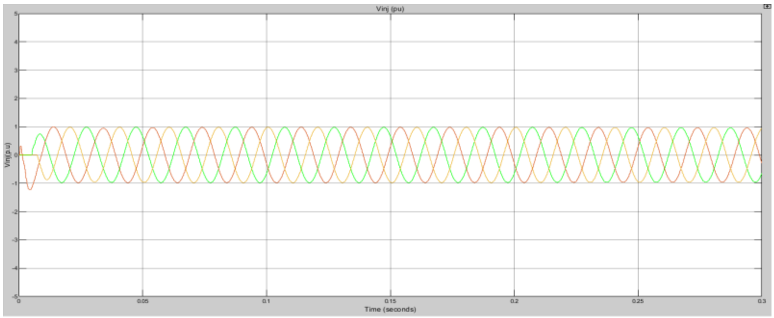

Fig. 7: Voltage injected in p.u at the line from the UPQC with PI control

The UPQC system series converter, with a Proportional-integral (PI) controller, regulates voltage outputs to address power high-quality problems which is represented by the Fig.7. It manages both active and reactive electricity components, maintaining grid integrity and enhancing electricity quality. The PI controller ensures system reliability and efficiency, demonstrating its significance in modern power distribution infrastructure [45].

Table 2: Completive analysis of hybrid solar-wind systems

Study	Parameter	Values	Result
[46]	THD in voltage	2.44% to 2.32%	Reduction of THD
[47]	Grid Voltage THD	Below 5%	Compliance with grid voltage THD standards
[48]	Solar Irradiance	5.68 KW/m2 /day	Availability of solar irradiance
[49]	Wind Speed	12.9 mph	Wind speed data
[51]	Average Temperature	28°C	Average temperature range
[52]	Mean Square Error (MSE)	Reduction	Reduction of MSE
[53]	THD in current	2.45%, and 2.36%	Reduction of THD

The Table 2 various studies related to power quality, renewable energy sources, and environmental conditions. It includes parameters such as Total Harmonic Distortion (THD), Grid Voltage THD, Solar Irradiance, Wind Speed, Average Temperature [52-53]. The values reported include THD reductions, compliance with grid standards, and environmental data. The work contribute to understanding and improving power quality, utilizing renewable energy, and assessing environmental impacts.

5 Conclusion

The paper highlights the increasing significance of energy from renewable sources, including solar and wind power, in meeting future energy needs. It underscores the ability to balance the variable output of renewable power resources through grid integration. The paper proposes various methodologies to address the power quality issues related to renewable energy-based power integration, which include SUAPF, DSTATCOM, and UPQCs. The paper is focused on exploring the evolution of wind energy structures and integration techniques for solar and wind energy, emphasizing the significance of advanced control strategies for hybrid structures. The analysis concludes that the UPQc when integrated with the solar wind energy systems are highly crucial to achieve a balance in the power at the line as well as reduction in the total harmonic distortion (THD) in the voltage and current waveforms.

References

1. V. Kumar, A. S. Pandey and S. K. Sinha, "Grid integration and power quality issues of wind and solar energy system: A review," 2016 International Conference on Emerging Trends in Electrical Electronics & Sustainable Energy Systems (ICETEESES), Sultanpur, India, (2016): 71-80, doi: 10.1109/ICETEESES.2016.7581355.
2. Srilakshmi, Koganti, Sravanthy Gadameedhi, D. Teja Santhosh, N. Yashaswini, J. Ganesh Prasad Reddy, N. M. G. Kumar, and D. Anil Naik. "Design and Performance Analysis of Fuzzy Based Hybrid Controller for Grid Connected Solar-Battery Unified Power Quality Conditioner." International Journal of Renewable Energy Research (IJRER) 13, 1 (2023): 1-13.
3. Jha, N., Prashar, D., Rashid, M., Khanam, Z., Nagpal, A., AlGhamdi, A. S., & Alshamrani, S. S. (2022). Energy-efficient hybrid power system model based on solar and wind energy for integrated grids. Mathematical Problems in Engineering, (2022).
4. F. Blaabjerg and K. Ma, "Wind Energy Systems," in Proceedings of the IEEE, 105(11), (2017): 2116-2131, doi: 10.1109/JPROC.2017.2695485.
5. Chiulan, E. A., & Anton, A.. "The (r) evolution of wind energy systems in Romania: state-of-the-art, new trends and challenges". In IOP Conference Series: Earth and Environmental Science, 664(1), (2021) 012016). IOP Publishing.
6. Gupta, Swapnil. "Comparative Analysis on Power Quality Assessment of Wind Energy And Solar Energy With Innovative Device." (2022).
7. Irfan MM, Malaji S, Patsa C, Rangarajan SS, Hussain SMS. "Control of DSTATCOM Using ANN-BP Algorithm for the Grid Connected Wind Energy System". Energies. 15(19), 2022:6988. https://doi.org/10.3390/en15196988
8. Tiwari, Tapan, and Mr Durgesh Vishwakarma. "Emerging Power Quality Challenges Due To Integration of Solar and Wind Energy Sources: A Review." (2020).
9. Firoz Sarkar, R. Ramaya, "Power Quality problem Mitigation in a Hybrid Power System with STATCOM and Active Filter" International Journal of Science, Engineering and Technology Research (IJSETR), 4(5), (May 2015)
10. Toual, B., L. Mokrani, A. Kouzou, and M. Machmoum. "Control and management of a solar-wind hybrid system for power quality improvement." J. Eng. Sci. Technol ,13(6), (2018): 1420-1439
11. Khan, F. A., Pal, N., & Saeed, S. H. Stand-alone hybrid system of solar photovoltaics/wind energy resources: an eco-friendly sustainable approach. In Renewable Energy Systems, (2021): 687-705. Academic Press. https://doi.org/10.1016/B978-0-12-820004-9.00030-9

12. Ansari, Majhar Ali, and R. K. D. F. Student. "A Review On-Grid Integration and Power Quality Issues of Wind and Solar Energy System." (2023)
13. Mahela, Om Prakash, Abdul Gafoor Shaik, and Neeraj Gupta. "A critical review of detection and classification of power quality events." Renewable and Sustainable Energy Reviews, 41 (2015): 495-505.
14. Sai Sarita, Narala Chitti, Sanna Suresh Reddy, and Peddakotla Sujatha. "Hybrid controller-based solar-fuel cell-integrated UPQC for enrichment of power quality." Paladyn, Journal of Behavioral Robotics 14(1) (2023): 20220110.
15. Wongcharoen, Saktanong, and Sansak Deeon. "Multi-level swell voltage control for minimizing the damage to an on-grid system." Indonesian Journal of Electrical Engineering and Informatics (IJEEI) 8(2), (2020): 306-319.
16. Agüera-Pérez, Agustín, José Carlos Palomares-Salas, Juan Jose Gonzalez De la Rosa, José María Sierra-Fernández, Daniel Ayora-Sedeño, and Antonio Moreno-Muñoz. "Characterization of electrical sags and swells using higher-order statistical estimators." Measurement 44, 8 (2011): 1453-1460.
17. Varadarajan, Kamal, Sudhakar Singamaneni, and Santhosh Kappala. "Surge-robust flyback power supplies with GaN." In 2020 IEEE Applied Power Electronics Conference and Exposition (APEC), (2020):2584-2587. IEEE,
18. Y. -E. Wu and Y. -T. Ke, "A Novel Bidirectional Isolated DC-DC Converter With High Voltage Gain and Wide Input Voltage," in IEEE Transactions on Power Electronics, 36(7), (2021):7973-7985, doi: 10.1109/TPEL.2020.3045986.
19. Wettengel, Stefan, Andreas Hoffmann, Jonas Kienast, Lars Lindenmüller, and Steffen Bernet. "Topology, Design and Characteristics of a Modular, Dynamic 100 kA Surge Current Source with Adjustable Current Shape." IEEE Open Journal of Industry Applications (2024).
20. Olga, Ekaterina Myasnikova, and Oleg Loktionov. "Analysis of the climatic factors influence on the overhead transmission lines reliability." Rigas Tehniskas Universitates Zinatniskie Raksti 24, 3 (2020): 201-214.
21. Said, Abdelrahman, M. A. Abd-Allah, and Moustafa Mohsen. "Alleviation of the transients induced in large photovoltaic power plants by direct lightning stroke." Ain Shams Engineering Journal 14(3), (2023): 101880. https://doi.org/10.1016/j.asej.2022.101880
22. Sadiq, Sadiq Emad, Muhsin J. Jweeg, and Sadeq H. Bakhy. "The effects of honeycomb parameters on transient response of an aircraft sandwich panel structure." In IOP Conference Series: Materials Science and Engineering, 928(2), (2020): 022126. IOP Publishing,
23. Amirullah, Amirullah, and Adiananda Adiananda. "Dual Fuzzy-Sugeno Method to Enhance Power Quality Performance Using a Single-Phase Dual UPQC-Dual PV Without DC-Link Capacitor." Protection and Control of Modern Power Systems 9(1), (2024): 133-153.
24. Mamidi K.K., Valiveti S.N., Vutukuri G.C., Dhuda A.K., Alabdeli H., Chandrashekar R., Lakhanpal S., Praveen, "An IoT-based animal detection system using an interdisciplinary approach," E3S Web of Conferences, vol. 507, 2024, doi: 10.1051/e3sconf/202450701041.
25. Lalitha G., Gupta M., Arul S.J., Praveen, Parashar A.K., Hussien R.A., "Blockchain-Enabled Simulation and Optimization for Supply Chain Transparency," E3S Web of Conferences, vol. 472, 2024, doi: 10.1051/e3sconf/202447202007.
26. Dasari K., Chandrashekar R., Nijhawan G., Kalra R., Pahwa S., Abdul-Zahra D.S., "Dynamic Mechanical Characterization of Additively Manufactured Components," E3S Web of Conferences, vol. 505, 2024, doi: 10.1051/e3sconf/202450501007.

27. Jeevitha R., Selvan C., Nishitha T., Vijay Kumar Reddy P., Karthik Surya J., "ARTSY: Digital Assistance and Routing Detection Using ML," Proceedings - 2023 3rd International Conference on Smart Data Intelligence, ICSMDI 2023, , pp. 363-366, 2023, doi: 10.1109/ICSMDI57622.2023.00070.
28. Jency J., Anitha M.X., Josh F.T., Vinoth K.K., Vinodha K., "Implementation of Savonius Blad Wind Tree Structure by Super Lift Luo Converter for Smart Grid Applications and Benefits to Smart City," Smart Grids for Smart Cities: Volume 1, vol. 1, pp. 159-174, 2023, doi: 10.1002/9781119872108.ch8.
29. Ramaprabha J., Prema P., Gunasekar S., "HealthApex: Complete Healthcare Assistance With Consent Based Analytics," 2023 International Conference on System, Computation, Automation and Networking, ICSCAN 2023, , 2023, doi: 10.1109/ICSCAN58655.2023.10395884.
30. Gopal M.K., Amirthavalli M., Meenakshi Sundaram B., "Improved Sparse PLSR and Run-To-Run Algorithms for Traffic Matrix Prediction in Software-Defined Networks," Lecture Notes in Electrical Engineering, vol. 841, pp. 225-240, 2022, doi: 10.1007/978-981-16-8774-7_19.
31. Satish Kumar D., Samuel P., Giriprasad C., Vinoth Kumar K., Patil V., Gouda V., Shiradoni B., Khan P.M.D.M., Selve V., "Implementation of Smart Vehicle Accident Detection using Raspberry PI in Smart Cities," 4th International Conference on Inventive Research in Computing Applications, ICIRCA 2022 - Proceedings, , pp. 1611-1614, 2022, doi: 10.1109/ICIRCA54612.2022.9985762.
32. Kunjumon A., Thamban M., Roy A., "Automatic vehicle accident detection and alert system," AIP Conference Proceedings, vol. 3072, no. 1, 2024, doi: 10.1063/5.0198723.
33. Florance Viji G., "Dynamic Routing Mechanism to Reduce Energy Consumption in a Software-Defined Network," Internet of Behavior (IoB), , pp. 85-100, 2023, doi: 10.1201/9781003305170-6.
34. Shalini S.N., Sandhya C.H.V.L., Kumar D.K., Punniyamoorthy R., Sheshu A., Gurusamy M., "Ecological design and innovation," Asian Textile Journal, vol. 33, no. 2024-02-01 00:00:00, pp. 44-46, 2024.
35. Kavitha S.N., Asha V., "Predicting risk factors associated with preterm delivery using a machine learning model," Multimedia Tools and Applications, , 2024, doi: 10.1007/s11042-024-18332-7.
36. Rebinth A., Kumar S.M., "Channel separation with CNN model for glaucoma color spectral detection," AIP Conference Proceedings, vol. 2519, 2022, doi: 10.1063/5.0109768.
37. Yadav S., Singh N., Devi K.V.R., Nijhawan G., Zabibah R.S., Aravinda K., "Synchronizing Innovation and Accountability in the Ethical Consequences of Artificial Intelligence," 2023 10th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering, UPCON 2023, , pp. 397-402, 2023, doi: 10.1109/UPCON59197.2023.10434644.
38. Gupta M., Nigam S., Evangelin Y., Sumyukthaa P., Rakshitha L., "A Systematic Technique Used for Portable Telemedicine System," 2023 International Conference on Computer Communication and Informatics, ICCCI 2023, , 2023, doi: 10.1109/ICCCI56745.2023.10128419.
39. Saritha K., Abhiram C., Reddy P.A., Sathwik S.S., Shaik N.R., Alzubaidi L.H., Raj V.H., Dutt A., Yadav D.K., "IoT enabled hospital asset tracking using advanced interdisciplinary approaches," E3S Web of Conferences, vol. 507, 2024, doi: 10.1051/e3sconf/202450701007.
40. Asha V., Sreeja S.P., Saju B., Nisarga C.S., Purushotham N., Prasad A., "Performance Analysis of Olympic Games using Data Analytics," Proceedings of the 2023 2nd

International Conference on Electronics and Renewable Systems, ICEARS 2023, , pp. 1436-1443, 2023, doi: 10.1109/ICEARS56392.2023.10084943.
41. Muthusamy M., Periyasamy K., "Artificial intelligence for renewable energy systems and applications: A comprehensive review," Philosophy of Artificial Intelligence and Its Place in Society, , pp. 160-186, 2023, doi: 10.4018/978-1-6684-9591-9.ch009.
42. Sreeja S.P., Asha V., Saju B., Chandrakantbhai P.P., Prabhasan P., Prasad A., "Cotton Plant Disease Prediction using Deep Learning," Proceedings of the 2022 3rd International Conference on Communication, Computing and Industry 4.0, C2I4 2022, , 2022, doi: 10.1109/C2I456876.2022.10051527.
43. Kumar A., Chakravarty S., Sharma M.K., Nanthaamornphong A., "A mathematical analysis of teleoperator optimization using multiple sensors," Journal of Interdisciplinary Mathematics, vol. 27, no. 2, pp. 201-209, 2024, doi: 10.47974/JIM-1810.
44. Reddy, Sanepalle Gopal, S. Ganapathy, and M. Manikandan. "Three phase four switch inverter based DVR for power quality improvement with optimized CSA approach." IEEE Access, 10 (2022): 72263-72278.
45. S. V. Saleh and M. A. Latify, "Coordinated Unbalance Compensation and Harmonic Mitigation in the Secondary Distribution Network Through EVs Participation," in IEEE Transactions on Smart Grid, (2020) doi: 10.1109/TSG.2024.3370861.
46. Alhatim, Ahmed Yahyia Qasim, Fadhil R. Tahir, and Ahmed Nasser B. Alsammak. "Optimization of power quality using the unified power quality conditioner (UPQC) with unbalanced loads." Al-Rafidain Engineering Journal (AREJ) 27(2), (2022): 101-109.
47. Salman, Saddam Subhi, Abdulrahim Thiab Humod, and Fadhil A. Hasan. "Dynamic voltage restorer based on particle swarm optimization algorithm and adaptive neuro-fuzzy inference system." Bulletin of Electrical Engineering and Informatics 11(6), (2022): 3217-3227.
48. Srilakshmi, Koganti, Nakka Srinivas, Praveen Kumar Balachandran, Jonnala Ganesh Prasad Reddy, Sravanthy Gaddameedhi, Nagaraju Valluri, and Shitharth Selvarajan. "Design of soccer league optimization based hybrid controller for solar-battery integrated UPQC." IEEE Access, 10 (2022): 107116-107136.
49. Patel, Gunvant A., and Murali Krishna Talari. "Performance Analysis and Power Quality Enhancement in Grid-Connected Solar PV-Wind Hybrid System." Webology (ISSN: 1735-188X) 18, 5 (2021).
50. Vadakkepurakkel, Anila Kumaran, and Anila Kumaran Vadakkepurakkel. "Design of a hybrid power generation system using solar-wind energy." PhD diss., Deakin University, (2019).
51. Ramadevi, Alapati, Koganti Srilakshmi, Praveen Kumar Balachandran, Ilhami Colak, C. Dhanamjayulu, and Baseem Khan. "Research Article Optimal Design and Performance Investigation of Artificial Neural Network Controller for Solar-and Battery-Connected Unified Power Quality Conditioner." (2023).
52. Lei, Tongfei, Saleem Riaz, Noor Zanib, Munira Batool, Feng Pan, and Shaoguo Zhang. "Performance analysis of grid-connected distributed generation system integrating a hybrid wind-PV farm using UPQC." Complexity 2022 (2022).
53. Gaddameedhi, Sravanthy, Koganti Srilakshmi, K. Krishna Jyothi, G. Kalyani, Y. Aryan, K. Sumanth, and Aravindhababu Palanivelu. "Hybrid controller based solar-fuel cell integrated UPQC for power quality enhancement." International Journal of Renewable Energy Research (IJRER) 11(4), (2021): 1673-1683.