POWER ENHANCEMENT WITH GRID STABILIZATION OF RENEWABLE ENERGY-BASED GENERATION SYSTEM USING UPQC-FLC-EVA TECHNIQUE

[1]S Rajesh, [2]U Yojana, [3]B Sravanthi, [4]P Shobha
[1234]Assistant Professor,
Department of Electrical and Electronics Engineering,
Visvesvaraya College of Engineering, Hyderabad.

ABSTRACT
The proposed work focuses on the power enhancement of grid-connected solar photovoltaic and wind energy (PV-WE) system integrated with an energy storage system (ESS) and electric vehicles (EVs). The research works available in the literature emphasize only on PV, PV-ESS, WE, and WE-ESS. The enhancement techniques such as Unified Power Flow Controller (UPFC), Generalized UPFC (GUPFC), and Static Var Compensator (SVC) and Artificial Intelligence (AI)-based techniques including Fuzzy Logic Controller (FLC)-UPFC, and Unified Power Quality Conditioner (UPQC)-FLC have been perceived in the existing literature for power enhancement. Further, the EVs are emerging as an integral domain of the power grid but because of the uncertainties and limitations involved in renewable energy sources (RESs) and ESS, the EVs preference towards the RES is shifted away. Therefore, it is required to focus on improving the power quality of the PV-WE-ESS-EV system connected with the grid, which is yet to be explored and validated with the available technique for enhancing power quality. Furthermore, in the case of the bidirectional power flow from vehicle-to-grid (V2G) and grid-to-vehicle (G2V), optimal controlling is crucial for which an electric vehicle aggregator (EVA) is designed. The designed EVA is proposed for the PV-WE-ESS-EV system so as to obtain the benefits such as uninterruptible power supply, effective the load demand satisfaction, and efficient utilization of the electrical power. The power flow from source to load and from one source to another source is controlled with the support of FLC. The FLC decides the economic utilization of power during peak load and off-peak load. The reduced power quality at the load side is observed as a result of varying loads in the random fashion and this issue is sorted out by using UPQC in this proposed study. From the results, it can be observed that the maximum power is achieved in the case of PV and WE systems with the help of the FLC-based maximum power point tracking (MPPT) technique. Furthermore, the artificial neural network (ANN)-based technique is utilized for the development of the MPPT algorithm which in turn is employed for the validation of the proposed technique. The outputs of both the techniques are compared to select the best-performing technique. A key observation from the results and analysis indicates that the power output from FLC-based MPPT is better than that of ANN-based MPPT. Thus, the proper and economical utilization of power is achieved with the help of FLC and UPQC. It can be inferred that the EVs can play a vital role in imparting the flexibility in terms of power consumption and grid stabilization during peak load and off-peak load durations provided that the proper control techniques and grid integration are well-established.

INTRODUCTION

The conventional energy resources are being substituted by RESs, such as solar, wind, tidal and many others. Also. the utilization of RESs is increasing tremendously because these are clean, easy to access, and abundant in nature. Moreover, a favourable scenario such as the reduction in global warming and less emission of carbon dioxide has been observed when RESs are implemented. Therefore, RESs prevails as better alternatives to conventional resources. The increasing load demand can also be fulfilled by introducing RESs in existing power grid [1]. In spite of having numerous advantages, the solar and wind energy resources are highly sensitive to the weather and geographical location, which are the prime drawbacks of using RESs. These drawbacks affect the grid stability to the greater extent which can be potentially minimized by integrating the RESs with ESS. The various problems associated with RESs and the process to overcome those problems are detailed in the referred study [2]–[4]. The uncertainties involved in PV system cause Total Harmonic Distortion (THD) in the grid. As a result of which the load voltage and current are distorted. Therefore, the Flexible AC Transmission System (FACTS) devices have been utilized to overcome the THD and voltage stabilization issues. The FACTS devices, including UPFC, UPFCFLC, GUPFC, UPQC, and SVC are the commonly used devices to improve power quality. The implementation of FACTs devices fixes the voltage stability issue and simultaneously, improves the grid power quality [5]–[7]. The enhancement in grid stability and reduction in THD have been achieved by implementing the Static Compensator (STATCOM) accompanying with ESS [5]. Similarly, wind power generation system experiences unstable voltage and THD. Therefore, STATCOM has also been implemented with the grid-connected WE system [6]. The three FACTS devices, including Dynamic Voltage Restoration (DVR), Distribution STATCOM (DSTATCOM), and UPQC have been implemented for power quality improvement and voltage stabilization [7]. Moreover, the implementation of UPQC in the grid-connected PV system has been discussed for power quality enhancement [8]. The WE integrated grid system has been considered for power quality improvement using UPQC [9]. The power quality of the grid connected RESs can be improved using various MPPT algorithms based on FLC and ANN. Further, the uncertainties involved in RESs can be avoided using FLC-based MPPT algorithms. The FLC-based MPPT have been implemented for avoiding the weatherinduced uncertainties related to the solar PV output power [10], [11]. The authors concluded that the proposed method has overcome the conventional methods for power quality enhancement.

The converters are used along with the RESs to convert the power and make it suitable for connecting to the grid. The configuration layout of hybrid microgrid, including PV and WE has been provided in the referred study [12] in which the RESs are connected with a bidirectional converter. Various factors including average wind speed, irradiation, and temperature are needed to be considered while modelling the PV and WE systems as RESs are sensitive to weather and location. The scenario of RESs for various countries such as India, China, Iceland, Sweden, and the USA differ widely [2], [3]. To add upon it in WE system, the output power capacity is different on onshore and offshore [13]. Therefore, depending upon the various factors affecting the PV and WE systems, flexible mathematical model and optimization techniques are required to model the seasonable WE and PV systems. The non-linear characteristics of PV are challenging to design. Therefore, various optimization techniques like particle swarm optimization are used to estimate the parameters associated with the PV system and to improve the power output of PV and WE systems [14]. These techniques would ultimately help in configuring the RESs modelling. The RESs configurations available in literature are illustrated in Table 1. Among the power electronic-based FACTS techniques, the UPQC has better performance when compared to other techniques, essentially STATCOM, DVR, and SVC. The UPQC fulfills most of the desired qualities, including voltage improvement, harmonic mitigation, current improvement, and overall power quality improvement of the system [8], [27]. Therefore, UPQC is utilized in this study to improve the power output quality of the PV-WE-ESS-EV system integrated with EVs and ESS. A dynamic battery controller is designed to effectively control the ESS system. On the other hand, EVA is implemented for controlling the EVs system, which manages the power transfer between the PVWE-ESS system and EVs. The UPQC connected with the PV-WE-ESS-EV system functions in two ways which are as follows [28]. • The series part of UPQC (active converter) helps to reduce the harmonic mitigation and voltage disturbances. • The shunt part of UPQC (active converter) helps to reduce the current distortion and improve the dc-link voltage regulation.

The implementation of UPQC for a solar PV system and its investigation under an unbalanced loading condition has also been carried out [29]. The authors concluded that the implemented UPQC was able to improve both the power quality and harmonic mitigation. The controlling of the PV-UPQC system has been done using a proportional-integral (PI) controller, FLC, or neural network (NN)-based algorithm. The PI controller has been used to control the working of PV-UPQC [30] and FLC technique has been used for improving the power quality in the PV-UPQC system integrated with a battery storage system (BSS) [27]. The authors have provided a comparative analysis between the PI and FLC techniques and concluded that the FLC technique gives better results for the PV-UPQC-BSS system relative to the other technique based on PI. The implementation of the NN approach in PV-UPQC for power quality improvement has been mentioned [31], [32]. This technique requires proper learning and validation before implementing it to the electrical system. It consumes more time to evaluate the output response of the system but it gives accurate and appropriate responses. EVs also support to improve the power quality when used in parallel with grid connected ESS integrated RESs. The role of EVs, charging schemes, and benefits are discussed in [33]–[35]. The EVs are mainly for transportation purpose and thus, the availability of EVs is uncertain. For this issue, the EVA is used to manage the availability and to allot the charging-discharging schedule of EVs connected to the grid [36], [37]. The EVA enables the grid system to control the charging and discharging operation and acts as a mediator controller between the grid and the vehicles. This helps the grid system to improve the quality of power, reduce the THD, load balancing, and to improve the voltage profile under different load unbalancing conditions. Several controlling techniques and optimization techniques of the EV system connected with the grid have been discussed [38], [39]. The block diagram of the proposed system is illustrated in Fig. 1. A three-phase, three-wire grid is integrated with the PV, WE, ESS, and EVs through a phase inverter. The line-to-line voltage of the system and frequency is 254.4 V and 50 Hz, respectively. The voltage disturbance is observed due to non-linear loading, voltage swell, and voltage sag. To overcome this issue, a UPQC is designed and connected to the grid for voltage regulation. Two WE systems having 30 kW power output each are connected which totals the generated power through WE is 60 kW. The ESS system contains a battery bank connected to the grid having 36 series connected 12V, 100 Ah batteries. The capacity of the ESS system is 40 kWh and is connected to the grid through a bidirectional converter. The capacity of the PV system is 100 kW. The PV and WE systems are connected to the grid through boost converters. In this work, EVs are also considered each having a capacity of 29 kW. The FLC and ANN-based MPPT algorithms are designed for both PV and WE systems. The problem statement, contributions and objectives of this research work are highlighted in the next section. The paper is organized as follows. The problem formulation along with contribution and objectives is discussed in Section II. Section III presents the methodologies involved in this research work that include the modelling of PV and WE systems and the connection with EVs and ESS systems, modelling of UPQC, and modelling of FLC and ANN-based MPPT algorithms. The control of charging-discharging of ESS and EVs is achieved using the FLC technique which controls the whole system. The control diagram and rules are explained in Section IV. Section V discusses the results obtained from FLC and ANN control of the PV-WE-ESSEV system and performance of the UPQC-FLC-EVA technique in power enhancement and THD reduction. Section VI provides a comparative analysis of both FLC and ANN based-techniques for power improvement and THD reduction. Finally the work is concluded along with the future scope of this work in Section VII.

Literature survey

[1] R. M. Elavarasan, "The motivation for renewable energy and its comparison with other energy sources: A review," Eur. J. Sustain. Develop. Res., vol. 3, no. 1, p. em0076, Feb. 2019.

Energy is the backbone of the evolution of humanity, it has assisted mankind to endeavor through various ages of history. The quest to obtain energy with minimal expenditure and pollution is still being worked on and will continue on in the future. Even in this modern age, energy production in several developing countries often falls short of energy requirements which results in frequent power cuts. As the world economy continues to grow, energy consumption is expected to continue to grow. Fossil fuel is limited, so it is important to consider other sources of energy e.g. renewables especially solar to meet the energy demands in the future. The world has diverse solar energy sources which are not yet fully explored. This review sheds light on the solar renewable energy and other non-renewable sources of energy available in the world and a comparative analysis of both the energy resources across the world is also included as a separate section titled ‘Comparative analysis’. It also gives a brief overview of the various techniques employed by different countries to overcome the energy crisis through and also a framework for employing such techniques in countries which are lagging in energy production in order to fully avail the benefits of energy sources, which are abundant in the world.

R. M. Elavarasan, “Comprehensive review on India’s growth in renewable energy technologies in comparison with other prominent renewable energy based countries,” J. Sol. Energy Eng., vol. 142, no. 3, pp. 1–11, 2020.

Renewable energy will be the irrefutable future of mankind, where fulfilling fuel needs is concerned and its non-renewable predecessors were by definition, destined to short-lived in the grand scheme of things. Debating this issue is equivalent to flogging a dead horse, so now what is left is to optimize the utilization of these resources. This research work first reviews India’s technological advancements in the renewable energy field in recent decades. Simultaneously, it is going to be compared with the rate of other country’s work in the same field. The goal of this study is to identify the specific renewable methods of electricity generation where India is significantly trailing behind and that requires a redirection of the country’s efforts. A focus is given not only to the technological aspects of the various renewable energies but also to the obstacles faced while using them. And the policies to overcome those obstacles are also discussed. Other than China, India is the only other nation with a population exceeding 1.3 billion mark and the nation with the highest population density at a rather astonishing 382 humans/km^2. India also has a population growth rate of 1.10%, compared with China’s 0.39%. Its current energy consumption model may prove unsustainable and will soon need to convert to renewable energy sources for basic survival.

R. Madurai Elavarasan, S. Afridhis, R. R. Vijayaraghavan, U. Subramaniam, and M. Nurunnabi, “SWOT analysis: A framework for comprehensive evaluation of drivers and barriers for renewable energy development in significant countries,” Energy Rep., vol. 6, pp. 1838–1864, Nov. 2020.

Energy has been the cornerstone for all the technological advancements that are happening in the world. The need for energy at present is great than ever before and it is foreseen to rise in the future, as a result, it triggered us to look into zero-emission alternatives i.e. renewables to meet our energy demand. Energy demand surge is not the only cause, rising fossil fuel prices and global warming are among the major factor for such a verdict. Governments of nearly all the nation are taking the necessary measures that will result in a greater good. Carbon neutralization is a feat that every nation must attain to ensure sustainable global development, renewables prove to be the best tool to achieve it. The scope of the study is to analyse both the drivers and de-motivators for renewable energy development for the study nations including India, China, Iceland, Sweden, and the US are taken into account, each country has its unique strongholds in renewable energy genesis. This work will give a descriptive overview of the country’s renewable assets and its green future by means of a SWOT analysis where each country will be assessed based on the four parameters namely Strength, Weakness, Opportunities and Threats for renewable resources. This study has been carried out to access each country potential for renewable energy generation. The motive for selecting these countries is that, these countries show promising outcomes to the leap towards green energy generation and utilization. Their positive results are due to various factors that will be analysed in this work. Additionally an arithmetic based approach was formulated to identify which of the countries will be able to attain Sustainable Development Goal 7 (SDG 7).

R. Madurai Elavarasan, L. Selvamanohar, K. Raju, R. R. Vijayaraghavan, R. Subburaj, M. Nurunnabi, I. A. Khan, S. Afridhis, A. Hariharan, R. Pugazhendhi, U. Subramaniam, and N. Das, "A holistic review of the present and future drivers of the renewable energy mix in Maharashtra, state of India," Sustainability, vol. 12, no. 16, p. 6596, Aug. 2020.

A strong energy mix of Renewable Energy Sources (RESs) is needed for sustainable development in the electricity sector. India stands as one of the fastest developing countries in terms of RES production. In this framework, the main objective of this review is to critically scrutinize the Maharashtra state energy landscape to discover the gaps, barriers, and challenges therein and to provide recommendations and suggestions for attaining the RES target by 2022. This work begins with a discussion about the RES trends in various developing countries. Subsequently, it scrutinizes the installed capacity of India, reporting that Maharashtra state holds a considerable stake in the Indian energy mix. A further examination of the state energy mix is carried out by comparing the current and future targets of the state action plan. It is found that the installed capacity of RESs accounts for about 22% of the state energy mix. Moreover, the current installed capacity trend is markedly different from the goals set out in the action plan of the state. Notably, the installed capacity of solar energy is four times less than the target for 2020. Importantly, meeting the targeted RES capacity for 2022 presents a great challenge to the state. Considering this, an analysis of the state's strengths, barriers, and challenges is presented. Moreover, strong suggestions and recommendations are provided to clear the track to reach the desired destination. This can be useful for the government agencies, research community, private investors, policymakers, and stakeholders involved in building a sustainable energy system for the future.

Various renewable energy sources such as solar, wind, biomass, hydro, and waves are utilized around the world in developing the renewable energy sector [1]. Due to fluctuations in oil prices, many countries are pressured to shift toward environmentally friendly renewable technology with fixed prices [2]. Overall, 19% of the total energy demand was met by the renewable energy sector in 2015 [3,4]. As of November 2019, 195 members of the United Nations Framework of Climate Change (UNFCCC) signed an agreement to implement renewables [5]. To reduce the effect of carbon dioxide (CO_2) emissions on climatic conditions, the UNFCC suggested installing renewables and reducing per capita consumption [6]. It is recognized that the transition to renewable energy leads to resilience, transforms essential processes, and represents a strong approach to consumption and production [7]. Although Renewable Energy Sources (RESs) have relatively high installation costs, their running costs are low [8]. Since 1990, the Organization for Economic Co-operation and Development has increased their production of renewable energy by 2.3%, while other countries have increased their production by 4.5% [9]. Renewable energy production was seen to increase in many countries with a decrease in renewable energy production costs [10]. Moreover, in comparison to conventional energy production, renewable energy production was seen to reduce greenhouse gas emissions due to its efficient utilization of resources [11,12].

Cicea and Marinescu [13] explained the advantages of renewable energy over conventional energy by considering various factors. Other works have analyzed the importance of renewable energy in improving the environment and obtaining energy sustainability [14,15]. In addition, studies have revealed that the Nordic countries—namely, Finland, Sweden, Norway, Denmark, and Iceland—are enhancing their utilization of renewable energy resources [16,17]. The European Commission supports and promotes the utilization of renewable energy sources [18]. With the year 2050 as a target, many countries are aiming for net-zero emissions of greenhouse gases [19]. Over the years, the energy sector has shown interest in the use of renewable energy resources by minimizing the use of fossil fuels to meet energy demand. Recently, various Association of Southeast Asian Nations (ASEAN) countries have made efforts to use renewable energy to overcome the drawbacks of fossil fuels [20,21]. In fact, the governments of many nations have decided to reduce the use of carbon and increase the use of renewables to ensure sustainable global development [22]. The United Nations (UN) released 17 Sustainable Development Goals (SDGs) in 2015 [23]. The UN, national governments, civil society, research community, policymakers, private sector, and stakeholders are working together toward the growth of sustainable energy systems [24]. Much ongoing research pertains to the fulfilment of SDG 7 [25]. Various countries adhere to the SDGs by forming cooperative structures that enable them to attain their individual targets for renewable energy production [26].

G. M. Shafiullah, M. T. Arif, and A. M. T. Oo, "Mitigation strategies to minimize potential technical challenges of renewable energy integration," Sustain. Energy Technol. Assessments, vol. 25, pp. 24–42, Feb. 2018.

A recent issue of increasing public focus is the need for robust, sustainable and climate friendly power systems that are intelligent, reliable and green. The intermittent nature of renewable energy generation and the associated power electronic inverters creates a number of potential challenges in integrating large-scale renewable energy (RE) into the grid that affects power quality of the distribution network. Therefore, this study initially, investigates the potential technical impacts in particular voltage regulation, active and reactive power variations, transformer loading and current and voltage harmonics causes with RE integration. Then, to reduce the level of impacts observed, STATCOM and energy storage system (both optimised) were integrated into the network that ensures a smooth power supply to the customers. As a case study, the Berserker Street Feeder, Frenchville Substation under Rockhampton distribution network, Central Queensland, Australia has been considered. Similar analyses also carried out with the IEEE 13 bus network to investigate the potential technical challenges of RE integration and identify suitable mitigation measures. Results shows that integration of both optimised STATCOM and energy storage enhances the overall power quality of the power network as it improves voltage regulation, power distribution, and transformer utilisation and reduce total harmonic distortion of the power network.

In general, power flows from the upstream network (the transmission network) to the downstream network (the distribution or low voltage network). Integration of renewable energy (RE) causes reverse power flows, i.e., feeding back into the grid as they are generally connected near the load centre, if the power generation from these systems is greater than the load in the local network. Therefore, RE integration introduces bi-directional power flows across distribution transformer (DT) and hence distribution network (DN) experiences with several potential problems that includes voltage variation, over loading of DT, poor power factor and harmonics injection in the DN which detracts the overall power quality (PQ) of the network [1], [2].

The intermittent nature of power output from renewable energy sources, in particular wind and solar, introduces potential technical challenges that affect quality of power observed including voltage fluctuation, frequency fluctuation, power system transients and harmonics, system blackouts, reactive power, low power factor, switching of electrical equipments, synchronisation problem, storage system, load management and forecasting and scheduling. Large scale RE integration in the DN causes voltage rise within the network and this voltage rise is significant in case of single phase PV system connections. The receiving end (customer premises) voltage may drop if RE is unable to support customer load demand, especially during peak demand periods [1], [2], [3], [4]. Moreover, the intermittent nature of RE causes uneven generation and hence might exceed the capacity of the connected transformer. Integration of RE also causes phase unbalanced conditions in the network due to uneven connection of RE source into different phases. The operation of the distribution network involves reactive power due to customer loads, line impedances and RE sources, in particular induction generators used in wind turbines which are unreliable for the smooth operation of the network [5], [6]. Inverters connected with RE sources, non-linear customer loads and power electronics devices introduce harmonics in the distribution network that causes overheating of transformers, tripping of circuit breakers, and reduces the life of connected equipment [6].

Significant research and development works are undertaken by various agencies throughout the world to investigate and mitigate the observed potential technical challenges to ensure reliable and uninterrupted power supply to the consumers. Albarracin and Amaris [6] investigated a voltage fluctuation model used for the evaluation of flicker assessment under sunny and cloudy conditions with photovoltaic energy sources. Results showed that irregular solar irradiation caused by cloud movement produced voltage and power fluctuations. The Gardner MA PV project [8] explores four areas: the effect on the system in steady state and during slow and cloud transients; responses of concentrated PV under fast transients; harmonic effects on the PV system; and the overall performance of distribution system, in which the total impact of high penetration of PV was evaluated. Results showed that 37% penetration of PV at Gardner was achieved without any significant problems. Asano et. al. [9], analysed the impact of high penetration of PV on grid frequency regulation which responds to short-term irradiance transients due to clouds. It was shown that break-even cost of PV is unacceptably high unless PV penetration reaches 10% or higher. Therefore, PV integration needs to be increased and impacts to be identified and mitigated. A comprehensive study was carried out by Fekete et al. [10] that analysed the harmonic impacts in both winter and summer seasons with 10 kW PV penetration on the distribution network. Recent studies by Ergon Energy, and Chant et al. [11] have explored the issues involved with small-scale PV penetration in urban networks. It was found that increased penetration exhibited increased voltage rise on LV networks, increased harmonic distortion and, as a result, load rejection occurs. The impacts of wind power on the power system, in particular voltage stability, power system stability and PQ characteristics were investigated by Pedro Rosas [12] using dynamic simulation. Results shows that wind turbine technologies with power converters can actively control the reactive power consumption which increased the voltage stability of the power system.

] L. Ashok Kumar and V. Indragandhi, "Power quality improvement of gridconnected wind energy system using facts devices," Int. J. Ambient Energy, vol. 41, no. 6, pp. 631–640, May 2020.

This work presents a novel controller for an integrated STATCOM-BESS for grid connected wind energy system. The simulation of the proposed system is done in Simulink without the hysteresis current controlled PWM technique and with the controller, which is in the IEC 61400-21 standard. It is observed that the STATCOM with BESS, operated with the specified controller, provides reactive power support, good harmonic mitigation as well as maintaining the source current the voltage without any phase angle difference. The experimental setup composed of Matlab-dSPACE DS1104 interface for generating the gate pulse, isolation and gate driver circuit, and the three-phase inverter is created and the system is tested for various combinations of R load and R-L load, and the measurements are recorded using FLUKE 434 energy analyzer.

S. A. Mohamed, "Enhancement of power quality for load compensation using three different FACTS devices based on optimized technique," Int. Trans. Electr. Energy Syst., vol. 30, no. 3, p. e12196, Mar. 2020.

This paper presents a study of the interaction between loads, utility grids, and different devices of power quality enhancement. The essential motive of this study is mainly focused on the use of power electronic devices that are applicable to distribution systems, very responsive to disturbances in order to provide power quality improvement and solutions, and also to develop a model of these three FACTS devices (DVR, DSTATCOM, and UPQC) for enhancement of power quality in electrical grids. The DVR is a power quality that is applied as an efficient solution for the safeguard of sensitive loads with voltage troubles in distribution systems like voltage dips and rises related to faults. DVR efficiency depends upon the control method performance involved in switching the inverters. However, the transient response of the DSTATCOM compensating is very significant for nonlinearly varying and unbalanced loads. The UPQC is applied as an active power conditioning unit to alleviate both voltage and current harmonics at a distribution of the power system grid. The response of UPQC at most depends on how readily and carefully compensation signs are obtained by using control units. The various kinds of controllers are suggested for three devices applied here like PI and fuzzy logic controllers. The above modeling has been carried out on a distribution system for the power quality enhancement. A new design for the enhancement of PQ-based FACTS for the test results given from different control methods such as PI and FLC is given in this paper.

S. Paramanik, K. Sarker, D. Chatterjee, and S. K. Goswami, "Smart grid power quality improvement using modified UPQC," in Proc. Devices for Integr. Circuit (DevIC), Mar. 2019, pp. 356–360.

The Smart Grid (SG) system typically deals with different issues involving security and Power Quality (PQ) improvement. With frequent usage of power electronic devices and nonlinear load, harmonics are inserted into the system. The well-known Flexible AC Transmission System (FACTS) devices like Unified Power Quality Conditioners (UPQC) are usually employed to resolve the issues related to voltage sag, swell, flicker, PQ, and neutral current reduction of distribution systems. An UPQC itself inserts harmonics into the system that affects the system stability for sensitive loads. This paper describes biogeography based optimization (BBO) with harmonics elimination techniques for modified UPQC connected with SG. Lower order harmonics are eliminated by proper selection of switching angles and at the same time the higher order harmonics are suppressed by injecting same order harmonics with equal magnitude but opposite in phase from the other converter. The excitation of Modified UPQC converters are obtained from PV (Photo-Voltaic) panel. The firing angles of series-shunt converter are obtained in real-time from the already stored angles in the microcontroller memory

CONCLUSION AND SCOPES FOR FUTURE WORK

The authors have proposed a technique for the power enhancement of the PV-WE-ESS-EV system using FLC and UPQC controllers. The FLC-based MPPT algorithms are designed for PV and WE to extract maximum power. The UPQC provides the voltage regulation support for different loading conditions. An EVA algorithm has been developed to provide load balancing and support to the weather-dependent PV and WE systems by connecting the required number of EVs. The proposed PV-WE-ESS-EV system ensures the grid system reliability and enhances the power quality of the system because of EVs addition to the grid. It is also observed that the distortions in voltage and current waveforms are avoided using the UPQC-FLC-EVA technique. The THD of load and source-side voltages and currents are obtained and are lesser than 5% using the proposed technique, which fulfils the threshold limit of THD as per the IEEE-519 (1992) standard. Conclusively, the performance of the UPQC-FLC-EVA technique has overcome the ANN-based controlling technique. The work performed in this research can be extended for the following future works. • Optimized operation of EVA in terms of cost. • ANFIS-based control of the PV-WE-ESS-EV system. • Other machine learning-based algorithms to control and manage the power flow.

REFERENCES

[1] R. M. Elavarasan, ''The motivation for renewable energy and its comparison with other energy sources: A review,'' Eur. J. Sustain. Develop. Res., vol. 3, no. 1, p. em0076, Feb. 2019.

[2] R. M. Elavarasan, "Comprehensive review on India's growth in renewable energy technologies in comparison with other prominent renewable energy based countries," J. Sol. Energy Eng., vol. 142, no. 3, pp. 1–11, 2020.
[3] R. Madurai Elavarasan, S. Afridhis, R. R. Vijayaraghavan, U. Subramaniam, and M. Nurunnabi, "SWOT analysis: A framework for comprehensive evaluation of drivers and barriers for renewable energy development in significant countries," Energy Rep., vol. 6, pp. 1838–1864, Nov. 2020.
[4] R. Madurai Elavarasan, L. Selvamanohar, K. Raju, R. R. Vijayaraghavan, R. Subburaj, M. Nurunnabi, I. A. Khan, S. Afridhis, A. Hariharan, R. Pugazhendhi, U. Subramaniam, and N. Das, "A holistic review of the present and future drivers of the renewable energy mix in Maharashtra, state of India," Sustainability, vol. 12, no. 16, p. 6596, Aug. 2020.
[5] G. M. Shafiullah, M. T. Arif, and A. M. T. Oo, "Mitigation strategies to minimize potential technical challenges of renewable energy integration," Sustain. Energy Technol. Assessments, vol. 25, pp. 24–42, Feb. 2018.
[6] L. Ashok Kumar and V. Indragandhi, "Power quality improvement of gridconnected wind energy system using facts devices," Int. J. Ambient Energy, vol. 41, no. 6, pp. 631–640, May 2020.
[7] S. A. Mohamed, "Enhancement of power quality for load compensation using three different FACTS devices based on optimized technique," Int. Trans. Electr. Energy Syst., vol. 30, no. 3, p. e12196, Mar. 2020.
[8] S. Paramanik, K. Sarker, D. Chatterjee, and S. K. Goswami, "Smart grid power quality improvement using modified UPQC," in Proc. Devices for Integr. Circuit (DevIC), Mar. 2019, pp. 356–360.
[9] S. Shetty, H. Suresh, M. Sharanappa, and C. V. Ramesh, "Performance of wind energy conversion system during fault condition and power quality improvement of grid-connected WECS by FACTS (UPFC)," in Emerging Research in Computing, Information, Communication and Applications. Springer, 2019, pp. 211–225.
[10] T.-U. Hassan, R. Abbassi, H. Jerbi, K. Mehmood, M. F. Tahir, K. M. Cheema, R. M. Elavarasan, F. Ali, and I. A. Khan, "A novel algorithm for MPPT of an isolated PV system using push pull converter with fuzzy logic controller," Energies, vol. 13, no. 15, p. 4007, Aug. 2020.
[11] M. Rajvikram, P. Renuga, and M. Swathisriranjani, "Fuzzy based MPPT controller's role in extraction of maximum power in wind energy conversion system," in Proc. Int. Conf. Control, Instrum., Commun. Comput. Technol. (ICCICCT), Dec. 2016, pp. 713–719.
[12] R. M. Elavarasan, A. Ghosh, T. K. Mallick, A. Krishnamurthy, and M. Saravanan, "Investigations on performance enhancement measures of the bidirectional converter in PV–wind interconnected microgrid system," Energies, vol. 12, no. 14, p. 2672, 2019.
[13] R. Krishnamoorthy, K. Udhayakumar, R. Kannadasan, R. M. Elavarasan, and L. Mihet-Popa, "An assessment of onshore and offshore wind energy potential in India using moth flame optimization," Energies, vol. 13, no. 12, p. 3063, 2020.
[14] A. T. Kiani, M. F. Nadeem, A. Ahmed, I. Khan, R. M. Elavarasan, and N. Das, "Optimal PV parameter estimation via double exponential function-based dynamic inertia weight particle swarm optimization," Energies, vol. 13, no. 15, p. 4037, Aug. 2020.
[15] Y. Mahmoud, W. Xiao, and H. H. Zeineldin, "A simple approach to modeling and simulation of photovoltaic modules," IEEE Trans. Sustain. Energy, vol. 3, no. 1, pp. 185–186, Jan. 2012.
[16] M. E. Glavin, P. K. W. Chan, S. Armstrong, and W. G. Hurley, "A standalone photovoltaic supercapacitor battery hybrid energy storage system," in Proc. 13th Int. Power Electron. Motion Control Conf., Sep. 2008, pp. 1688–1695.
[17] A. M. Knight and G. E. Peters, "Simple wind energy controller for an expanded operating range," IEEE Trans. Energy Convers., vol. 20, no. 2, pp. 459–466, Jun. 2005.

[18] T. Aboul-Seoud and J. Jatskevich, "Improving power quality in remote wind energy systems using battery storage," in Proc. Can. Conf. Electr. Comput. Eng., May 2008, pp. 001743–001746.
[19] P. Nema, R. K. Nema, and S. Rangnekar, "A current and future state of art development of hybrid energy system using wind and PV-solar: A review," Renew. Sustain. Energy Rev., vol. 13, no. 8, pp. 2096–2103, Oct. 2009.
[20] H. Yang, L. Lu, and W. Zhou, "A novel optimization sizing model for hybrid solar-wind power generation system," Sol. Energy, vol. 81, no. 1, pp. 76–84, Jan. 2007.
[21] F. Giraud and Z. M. Salameh, "Analysis of the effects of a passing cloud on a grid-interactive photovoltaic system with battery storage using neural networks," IEEE Trans. Energy Convers., vol. 14, no. 4, pp. 1572–1577, Dec. 1999.
[22] A. Nottrott, J. Kleissl, and B. Washom, "Energy dispatch schedule optimization and cost benefit analysis for grid-connected, photovoltaicbattery storage systems," Renew. Energy, vol. 55, pp. 230–240, Jul. 2013.
[23] Z. Shu and P. Jirutitijaroen, "Optimal operation strategy of energy storage system for grid-connected wind power plants," IEEE Trans. Sustain. Energy, vol. 5, no. 1, pp. 190–199, Jan. 2014.
[24] S.-K. Kim, J.-H. Jeon, C.-H. Cho, J.-B. Ahn, and S.-H. Kwon, "Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer," IEEE Trans. Ind. Electron., vol. 55, no. 4, pp. 1677–1688, Apr. 2008.
[25] R. A. Badwawi, M. Abusara, and T. Mallick, "A review of hybrid solar PV and wind energy system," Smart Sci., vol. 3, no. 3, pp. 127–138, Jan. 2015.
[26] K. Mahmud, M. J. Hossain, and G. E. Town, "Peak-load reduction by coordinated response of photovoltaics, battery storage, and electric vehicles," IEEE Access, vol. 6, pp. 29353–29365, 2018.
[27] A. Amirullah, U. B. Surabaya, A. Adiananda, O. Penangsang, A. Soeprijanto, U. B. Surabaya, I. T. S. Nopember, and I. T. S. Nopember, "Load active power transfer enhancement using UPQC-PV-BES system with fuzzy logic controller," Int. J. Intell. Eng. Syst., vol. 13, no. 2, pp. 329–349, Apr. 2020.
[28] V. Khadkikar, "Enhancing electric power quality using UPQC: A comprehensive overview," IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2284–2297, May 2012.