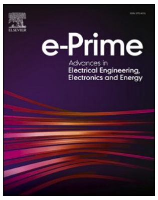
e-Prime - Advances in Electrical Engineering, Electronics and Energy 8 (2024) 100520

Contents lists available at ScienceDirect

e-Prime - Advances in Electrical Engineering, Electronics and Energy

journal homepage: www.elsevier.com/locate/prime



A critical analysis of different power quality improvement techniques in microgrid

Subhashree Choudhury [a,*], Gagan Kumar Sahoo [b]

[a] *Department of EEE, Siksha 'O' Anusandhan Deemed To Be University, Bhubaneswar, India*
[b] *Department of EE, Siksha 'O' Anusandhan Deemed To Be University, Bhubaneswar, India*

ARTICLE INFO

Keywords:
Active power filter (APF)
Distributed generation (DG)
FACTS
Optimization techniques (OTs)
Harmonics reduction
MicroGrid (MG)
Power quality (PQ)
Renewable energy

SUMMARY

Recently, the exponential decay of traditional petroleum and coal-based reserves with the ever-rising energy demand has led to the need for alternate energy sources. Distributed Generation (DG) based on renewable energy sources serves as a viable alternative solution for researchers to counter the issue of rising load. Hence the use of renewable energy sources is of utmost priority. Renewable non-traditional energy resources also have the advantage of being an unlimited energy source and climate-friendly in nature. In this context, distributed micro-generating units come into the picture, popularly known as MicroGrid (MG). The MGs are small-scale resources generating electrical energy and connected to the main utility through power electronic converters. The main drawbacks associated with MGs are their association with converters and switching devices, which leads to the injection of disturbances in the power system. Due to the tremendous use of MGs in modern power systems, the inherent intermittent nature of the renewable sources increased infiltration of nonlinear loads, and the distributed nature of micro-generating units, huge power quality (PQ) issues are observed hazardous to both generation and supply ends. PQ issues could be either the reactive power compensation or the generation of harmonics that hamper the normal functioning of the electrical energy system. To maintain healthy transmission and distribution of electrical power, these issues must be taken care of utmost priority. Because of customer satisfaction, utilities have adopted many profitable schemes and power quality improvement methods. In this regard, around 350 recent review articles have been comprehensively surveyed, and a detailed discussion about regulation of power quality issues using the filters, controllers, Flexible AC Transmission Systems (FACTS), optimization techniques (OTs), and machine learning tools with modern and advanced control techniques have been highlighted in this review article. A clear idea regarding power quality and its enhancement in MG has been presented. The technical and economic aspects have also been projected in brief. In addition, an in-depth study covering all challenges has been cited, and possible solutions in the future for hassle-free PQ improvement have been suggested in detail. It is believed that this review article would serve as an efficient background for researchers, academicians, electrical engineers, industrialists, and manufacturers working towards the hassle-free operation of MGs by efficient PQ issues mitigation.

Abbreviations: DG, distributed generation; MG, microgrid; PQ, power quality; FACTS, flexible ac transmission systems; OTs, optimization techniques; DERs, distributed energy resources; MLTs, machine learning tools; PPFs, passive power filters; PV, photovoltaics; APFs, active power filters; HPFs, hybrid power filters; PI, proportional integral; PR, proportional resonant; MIMO, multiple-input and multiple-output; FL, fuzzy logic; ANN, artificial neural network; SVC, static var compensator; TSC, thyristor switched capacitor; TCR, thyristor controlled reactor; TCSC, thyristor controlled series compensator; ATC, available transfer capability; DSTATCOM, distributed static synchronous compensator; DFACTS, distributed FACTS; DTCSC, distributed thyristor-controlled series compensator; DSSC, distributes static series compensator; DSFC, distributed switched filter compensator; ZVRT, zero-voltage-ride-through; PSO, particle swarm optimization; PP-FFO, predator-prey based firefly optimization; GOA, grasshopper optimization algorithm; DVR, dynamic voltage restorer; BA, bat algorithm; PSO-GWO, PSO-grey wolf optimiser; SSWO, salp swarm optimization; CDOA, collecting decision optimization algorithm; TEO, thermal exchange optimization; CSO, crow search optimization; BCO, bee colony optimization; WSAA, weighted superposition attraction algorithm; SOA, seeker optimization algorithm; SMO, spider monkey optimization; GA, genetic algorithm; DE, differential evolution; PCC, point of common coupling; EVs, electric vehicles; UPS, uninterruptible power supply; APC, active power conditioner; UPQC, unified power quality conditioners; CPDs, custom power devices; IDFA, improved discrete firefly algorithm; VSI, voltage source inverter; CSI, current source inverter; HRES, hybrid renewable energy system; ASO, atom search optimization; FFT, fast Fourier transform; FLC, fuzzy logic controller; PMU, phasor measurement unit; ADALINE, adaptive linear combiner; KF, Kalman filtering; HT, Hilbert transform.

[*] Corresponding author.
E-mail address: subhashreechoudhury@soa.ac.in (S. Choudhury).

https://doi.org/10.1016/j.prime.2024.100520
Received 15 November 2023; Received in revised form 8 February 2024; Accepted 18 March 2024

Introduction

Recently, most countries have started to adopt renewable energy-based DGs, leaving behind conventional energy sources due to their limitations such as environmental pollution, depletion of fossil fuels, very low energy efficiency, non-flexible and ageing. The concept of MG refers to an assemblage of several micro-generating units popularly known as DGs, which can operate alone and can be connected to the main utility through power electronic-based converters [1]. The various DG units are solar, hydro, biomass, wind, fuel cells, and microturbine [2]. The modes of operation are popularly referred to as islanded mode (supplying own loads only and detached from the utility) and grid-connected mode (connected to the main grid). The random distant location and a huge number of micro resources lead to the use of power converters which helps in promoting flexibility in control and better operation of the overall power system. However, this power electronic interface gives rise to an abundance of PQ hindrances such as the injection of harmonics and disturbances in the system [3–5]. These disturbances are dangerous and can cause mal-operation of load and source-side equipment and overheating, which must be taken care of. These disturbances are commonly termed PQ issues. Several PQ issues exist in an MG system, such as harmonic distortion, voltage imbalance, voltage sag, voltage swell, voltage interruption, transient phenomenon, frequency deviation, etc.[6]. These PQ issues should be taken care of for the efficient operation of the MG system and the effective utilization of the power at the load side. This study provides an elaborate discussion of the PQ issues and their mitigation methods associated with recent and future trends.

Authors have also reported the operation of an MG, where the optimized planning and working of the MG are discussed to increase the longevity, considering the climatic issues [7]. The MG control and construction, along with the dynamics, are also discussed [8]. A summary of the types, modes of operation, control, and coordination of a typical MG is presented. The PQ may be defined as the proficiency of the utility grid to deliver consumers consistent, ideal, and continuous power. The control of MG is of vital importance as it deals with the coordination among the DGs and affords power-sharing according to the load demand between the DGs. The authors have discussed the classification of MG control schemes into three levels: primary, secondary, and tertiary [9]. Primary and secondary levels deal with the operation of the MG itself, while the tertiary level concerns the coordinated operation of the MG. The use of multiple uses of Distributed Energy Resources (DERs) is suggested by researchers with storage devices and controllable loads [10]. Authors have proposed the modelling and investigation of the independent action of inverter-based MG, where each sub-section is designed in the state-space method, and all are united collectively through a common reference frame [11]. The researchers have proposed the smaller potential DERs that can encounter consumer needs and can be attached to the grid by unifying these resources into MG [12]. In this way, a bidirectional flow of power can be possible, allowing a lesser burden on the grid for power production. This active and reactive power-controlling approach of electronically integrated DG units has been suggested by authors, where a multiple-DG MG system environment is considered [13]. According to load data, the optimized distribution of energy is discussed, where individual DGs provide their energy receiving and collecting data [14]. The grid can be broadly divided into AC or DC grids, in both types of grids, the instruments and equipment are dissimilar, and both may operate independently or combinedly. In this context, the exploration of power-sharing concerns of a self-governing hybrid MG is studied, apart from a purely AC grid, the hybrid MG comprises DC and AC sub-grids unified through power electronic interfaces [15]. The governing of a complex MG is vital as it takes care of control, coordination, and distribution of power between micro resources in different ways, as suggested by various researchers [16–18].

The PQ associated with various disturbances must remain within specified limits. According to IEEE Std. 1250–2011, the PQ factors such as voltage deviation must be maintained within an acceptable range within 10% of the nominal limit in the MG system. The power factor must be equivalent to or more than 0.9 as given in IEC 60831-1/2 standard. The voltage/current harmonic is limited to within 5%, as denoted in IEEE Std. 519–2014. The frequency distortion must be within ± 0.1 Hz as notified in IEEE Std.1159–2009 [19]. These limitations request consistent and proficient control, which must be connected so that PQ should be preserved systematically and effectively during grid-connected and islanded levels of operation. PQ may be defined as the capacity of the grid to deliver a spotless and steady flow of electric power. The power components such as voltage and current must have a pure sinusoidal waveform, and the power must be constrained within acceptable voltage and frequency tolerances. The PQ issues as discussed above can be hazardous to the MG system, hence these must be controlled by specific and advanced techniques. Fig. 1 illustrates the review methodology undertaken in this present survey article.

The primary contributions of this review article include:

1) In this research work, various techniques that have been incorporated into the literature for PQ issues mitigation have been meticulously reviewed and explored in detail.
2) A deep insight into PQ and enhancement in MG has been presented.
3) Around 350 recent research papers have been comprehensively surveyed. In addition, a detailed discussion about the regulation of PQ issues using the Filters, Controllers, FACTS, OTs, Compensators, Conditioners, and Machine Learning Tools has been highlighted.
4) A comprehensive evaluation of technical and economic aspects has been presented.
5) An in-depth study covering all challenges has been cited, and possible solutions in the future for hassle-free PQ improvement have been suggested in detail.
6) This comprehensive survey paper is believed to serve as an efficient background for researchers, academicians, electrical engineers, industrialists, and manufacturers working in the field of PQ enhancement.

The entire article has been categorized into the following sections: In Section 2, details about PQ and its issues have been highlighted. A thorough study of the various PQ mitigation techniques has been presented in Section 3. The technical and economic aspects have been projected in Section 4. The challenges faced and the possible solutions for hassle-free PQ improvement in the future have been suggested in Section 5. Finally, in Section 6, the conclusions have been discussed.

Power quality and overview of issues

The utilization of nonlinear power electronics loads has posed threats among the industrial and commercial utilities, consumers, and manufacturers, thus making the quality of the electrical power produced a vital factor [20]. Nowadays, sustaining the electrical power quality under suitable indices is a chief concern [21]. Therefore, the power grid should ensure the customers with a consistent, safe, and uninterrupted power supply. Power quality is usually manifested as the ability to maintain a near sinusoidal voltage or current waveform with a particular rated magnitude and frequency [22]. Any deviation to the waveforms is termed a PQ issue, leading to the electrical power grid system [23]. PQ issues may pose several problems to the power grid network, such as more losses, interference with neighbouring communication lines, maloperation of equipment, etc. Therefore, optimizing several factors such as voltage, frequency, real and reactive power imbalance, and harmonics is the primary need for ensuring the reliable operation of the MG.

Various PQ disturbances associated with MG as reported in the literature are as follows: 1) voltage sag, 2) voltage swell, 3) voltage unbalance, 4) voltage spike, 5) voltage fluctuation, 6) voltage flicker, 7)

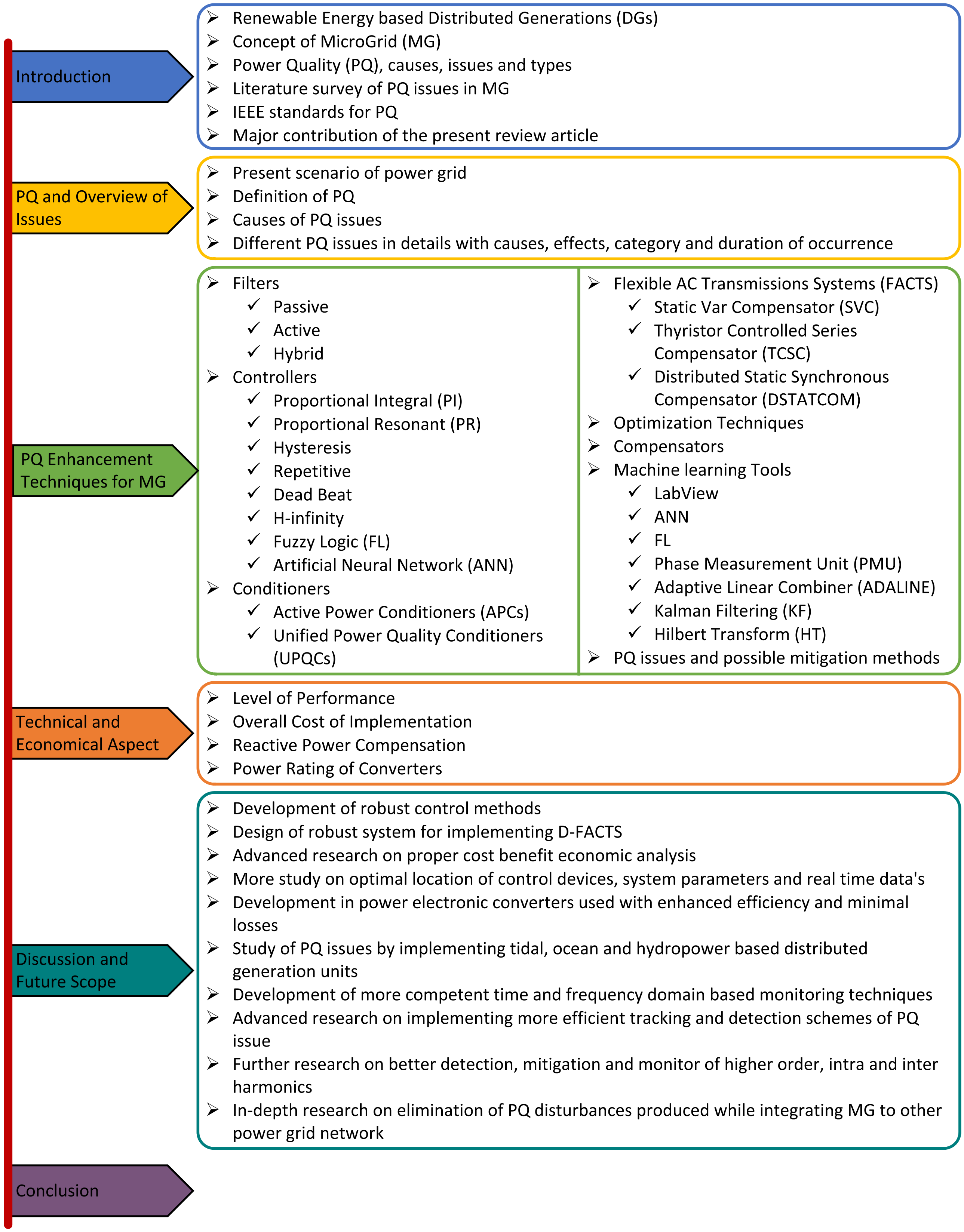


Fig. 1. Review methodology undertaken in this present survey article.

interruptions, 8) harmonics, 9) noise, 10) switching transients [23,24] The voltage sags and the transients are reported to have the maximum and minimum contribution towards the PQ disturbances. The comprehensive research on PQ consists of detecting, classifying, and mitigating methods of PQ. Many authors have reported the numerous methods facilitating the detection and classification of various PQ events in the literature [25–30].

Integration of DERs in the form of MG plays a vital role in enhancing the overall system reliability, efficiency, and security, and meeting the requirements of the end-users. MG can supply the critical loads by either operating in islanded or grid-connected mode during the power failure from the main grids [30,31]. The seamless operation of static transfer switch employed with robust controllers helps to perform the transition of one mode to another mode of operation [32]. PQ disturbances such as voltage swells and sags are predominant in a smaller and weaker MG [33,34]. In islanded operation, the PQ issues such as voltage distortion and unbalance are most likely to occur, whereas, in grid-tied mode, voltage sags have frequent occurrence [35]. Properly selecting inverter and associated control strategies play a significant role in mitigating power quality problems in MG [36,37]. Table 1 demonstrates the different PQ issues highlighting the cause, effects, category, and duration of occurrence.

Power quality enhancement techniques for microgrid

Power quality can be termed MG's capacity to deliver a spotless and steady flow of electric power. The power components such as voltage and current must have a pure sinusoidal waveform, and the power must

Table 1
PQ types, causes, effects, category, and duration.

PQ Issue Types	Causes	Effects	Category	Duration
Voltage Sag [38]	✓ Energizing of transformer ✓ Switching of heavy loads ✓ Faults on network ✓ Starting of large motors ✓ Faults on the consumer's installation side	✓ Tripping of sensitive equipment and protecting relays ✓ Efficiency loss and disconnection for rotating machines	✓ Short duration ✓ Instantaneous ✓ Momentary ✓ Temporary	✓ 0.5 to 30 cycles ✓ 30 cycles to 3 s ✓ 3 s to 1 min
Voltage Swell [39]	✓ Turning up of large loads ✓ Improperly regulated transformers during off-peak hours	✓ Loss of stored data ✓ Damage to delicate power electronics interface units ✓ Hardware failure	✓ Short duration ✓ Instantaneous ✓ Momentary ✓ Temporary	✓ 0.5 to 30 cycles ✓ 30 cycles to 3 s ✓ 3 s to 1 min
Voltage Unbalance [40]	✓ Load variation ✓ Due to voltage variation where magnitude and phase angle differences between the phases are unequal.	✓ Torque pulsation ✓ Enhanced vibration and mechanical stress ✓ More losses ✓ Overheating of motor	✓ Long duration	✓ Steady State
Voltage Spike [41]	✓ Lightning ✓ Due to static electricity ✓ Magnetic fields ✓ Internal changes in voltage use ✓ Turning off heavy loads	✓ Interference ✓ Maloperation of electronic units ✓ Damage to insulation materials ✓ Loss of data	✓ Short duration	✓ < 3 nano-sec
Voltage Fluctuation [42]	✓ Loose connections ✓ Continuous switching ON and OFF of oscillatory loads and elevators powered by electric motors ✓ Arc furnaces	✓ Produces deteriorated power quality and discomfort ✓ Disruption of production processes ✓ Affects the vision process and brain reaction	✓ Long/Short duration	✓ >1 min
Voltage Flicker [43]	✓ Fluctuation of the supply voltage ✓ Due to the use of large loads with rapid fluctuation in active and reactive power demand.	✓ Hampers the production by the environment ✓ Causes personnel fatigue among workers ✓ Reduces work concentration levels	✓ Long/Short duration	✓ 8 to 10 cycles per sec
Interruptions [44]	✓ Short interruptions are mainly due to the constant opening and closing of safety equipment to remove the faulty part and due to the failure of insulation ✓ Long interruptions are mainly due to storms, wind, objects, humans, fire, failure of safety equipment, and failure of materials	✓ Tripping of protecting relays and devices ✓ Information loss ✓ Misfunctioning of data processing units ✓ Breakdown of all power electronic components	✓ Short/ long duration ✓ Momentary ✓ Temporary	✓ 0.5cycles-3 s. ✓ 3sec-1 min.
Harmonics [45]	✓ Due to the presence of nonlinear loads ✓ Due to the operation of a highly efficient lighting system ✓ Due to power electronic interfaces ✓ Due to the employment of variable frequency drives	✓ Leads to resonance ✓ Excessive heating of power electronic equipment and cables ✓ Reduced efficiency ✓ Interference with the neighbouring communication line ✓ Tripping of thermal protectors	✓ Wave distortion	✓ Steady-state ✓ > 2.5 min
Noise [46]	✓ Electromagnetic interferences provoked by Hertzian waves such as microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. ✓ Incorrect grounding	✓ Loss of stored data ✓ May create data processing errors ✓ Creates issues on nonlinear loads	✓ Wave distortion	✓ Steady-state
Switching Transients [47]	✓ Any abrupt change in the circuit ✓ Switching of devices ✓ Static discharge ✓ Arcing furnace	✓ This leads to the degradation of insulation ✓ May cause flashover ✓ May lead to total equipment damage	✓ Short duration	✓ Micro-sec to several milli-sec

be constrained within acceptable voltage and frequency tolerances. The PQ issues as discussed above can be hazardous to the MG system, hence these must be controlled by specific, robust, and advanced techniques. In this regard, a thorough review of the literature has been carried out, and in-depth ideas about various PQ mitigation techniques have been highlighted, such as 1) Filters, 2) Controllers, 3) FACT Devices, 4) OTs, 5) Compensators, 6) Conditioners and 7) Machine Learning Tools (MLTs). Fig. 2 illustrates the overall techniques employed for PQ issues mitigation.

Filters

Filters play a vital role in regulating harmonics, compensating real power and neutral current, reducing voltage flickers and unbalance, balancing loads, and mitigating voltage distortions, sags, and swells [43,45,48–50]. The filters can be generally categorized into three types, namely passive, active and hybrid power filters.

Passive power filters (PPFs)

A passive filter is the simplest among all filters and can be defined as the grouping of passive elements such as capacitors and inductors adjusted for a particular frequency or a range of frequencies [49]. Fig. 3 depicts a schematic representation of PPF. Numerous topologies of PPFs are reported in the literature, such as series, shunt, low pass, high pass, bandpass, band rejection, LCL, and LLC [51,52]. The passive filters are utilized to overpower harmonic currents and minimize bias in voltage which occurs in delicate components of the power system network. Several literatures suggest using passive filters to mitigate PQ issues in renewable energy systems such as photovoltaics (PV) and wind, electric traction, and industrial power systems [53–57]. Authors have proposed an optimization problem formulation to allocate and size single-tuned passive filters in power distribution systems to minimize total harmonic distortion [58]. However, the PPFs suffer from serious shortcomings such as: 1) the filtering property is heavily affected due to resonance caused by source impedance, 2) the size is large, 3) limitation in the reactive power compensation, 4) bulkier in size, 5) improper tuning, 6) suffers from harmonic amplification issue, 7) dynamic compensation is not possible, 8) needs many filtering units and 9) not flexible. Owing to the above-cited issues, the PPFs find less utilization in the case of a complex MG associated with multiple distributed generators. Further, due to the intermittent nature of DERs and the nonlinear and variable nature of loads in modern power systems, the use of equipment that can actively participate in mitigating the harmonic components of current and at the same time could compensate the reactive VARs is highly necessary. Therefore, the researchers opt to implement the active power filters (APFs) in the power system network.

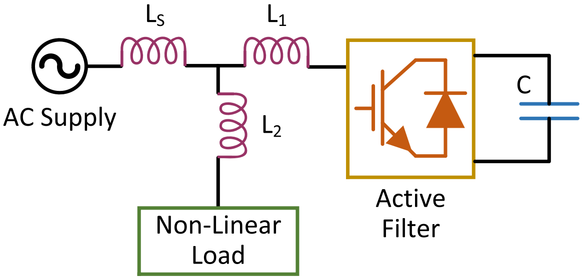


Fig. 3. Schematic structure of PPF.

Active power filters (APFs)

APFs consist of power electronics interfaces and passive storage units like inductors and capacitors, as shown in Fig. 4. APFs are the feasible alternative over conventional PPFs due to many merits such as 1) fastest dynamic response, 2) less volume and lighter in weight, 3) ability to compensate harmonics and reactive power requirement of nonlinear loads [59]. The APFs make a difference from passive filters because they inject real power at the source frequency and the opposite phase to mitigate the harmonic components [48]. The mitigation of harmonics with the help of an active power filter for a PV and fuel-cell-based MG system has been reported [60]. Furthermore, the authors have discussed implementing an active power filter for current harmonics mitigation in an industrial power system [61]. The APFs mostly find their application in medium power applications, thus facilitating active response to voltage notch, voltage distortion, and power factor enhancement [62–64]. Topologically, the active power filters are mainly of three types

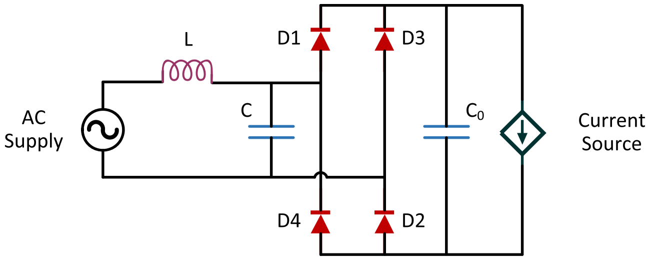


Fig. 4. Schematic structure of APF.

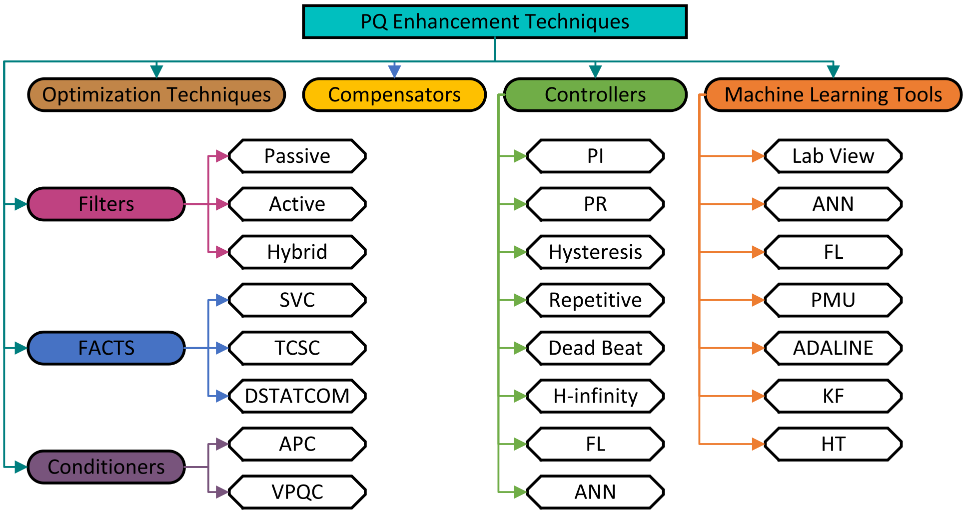


Fig. 2. Overall techniques for PQ issues mitigation.

such as series,[65] shunt,[66] and hybrid filter [67]. The hybrid filter is the amalgamation of both series and shunt active filters. Depending on the nature of the converter used, an APF can be either voltage source-based,[68] or current source-based [69]. Basing on several phases, APFs can be single-phase,[70] or three-phase types [71].

Hybrid power filters (HPFs)

The combination of PPFs and APFs results in the HPFs, as illustrated in Fig. 5. They are assumed to be the best among other filters as they combine the advantages of PPFs being cost-effective and the merits of APFs for providing efficient harmonic mitigation and regulation of voltage [72–75]. HPFs are reported to be available in different forms such as single-phase,[76] three-phase three-wire,[77] and three-phase four-wire [78]. Further, each type mentioned earlier can be classified into active,[79] or passive types [80]. Many researchers have reported the implementation of HPFs along with their control methods in various fields such as PV,[81–85] wind energy,[86,87] electric traction,[87–89] reducing inverter power rating,[90] and frequency regulation [91]. Further, a volume of work has been reported in the literature regarding harmonic regulation [92–96]. The authors have also discussed the analysis and control of new reduced switch count HPFs for ensuring high output voltage at minimum distortions [97].

Controllers

Controllers play a significant role in enhancing the system's stability and quality by regulating system voltage and frequency. The inverter of the MG can be controlled through various methods depending on the type of distributed generation resources used. A volume of research work employing controllers as control methods has been suggested in the literature to facilitate power quality issues mitigation. In this regard, a rigorous review of many recent articles has been carried out, and a summary regarding each type of controller used, its merits, demerits, and application has been presented in Table 2.

FACTS devices

According to the IEEE, FACTS can be defined as: "Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability" [141]. FACTS have been successfully employed in various sectors such as MGs, renewable systems, electric vehicles, aircraft, etc. facilitating many advantages such as 1) enhancement in the useable capacity of transmission lines, 2) proper control of the power flow over selected transmission paths, 3) improvement of power quality, 4) strengthening of power system's control, 5) delivers rapidity and flexibility to the transmission network, 6) deliberates electronically controlled high voltage power flow by the use of high-speed power electronic interfaces and algorithms, 7) allows increased loading of the transmission lines thus making the operation nearer to the thermal limits and 8) efficient damping of harmful power system oscillations [142]. According to their connection, FACTS devices can be of several types: series, shunt, and combined series-shunt. A detailed discussion of some basic FACTS devices and their applications in power quality enhancement as a technique is highlighted in the following subsections after a meticulous literature survey.

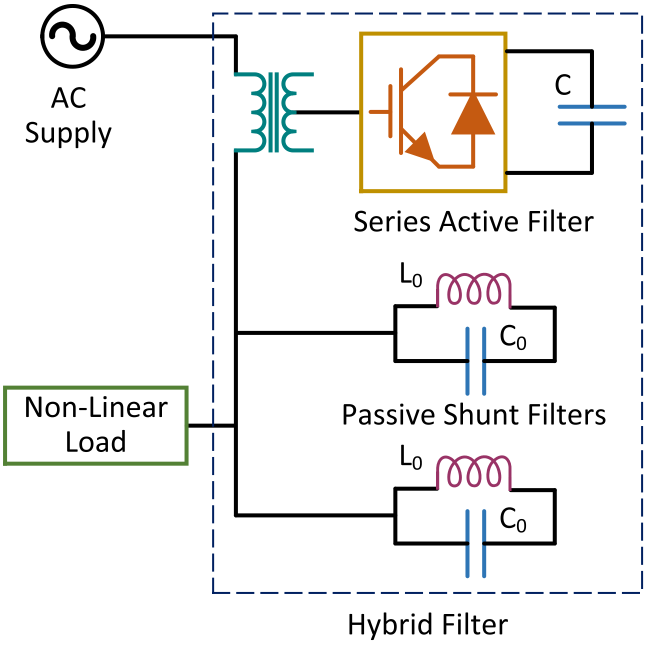


Fig. 5. Configuration of HPF.

Static var compensator (SVC)

SVC came into existence in the 1970s and is referred to as the first generation of FACTS controllers as it is controlled with the help of a thyristor [143]. It is a shunt-connected electrical controller which injects reactive power into the system and controls various parameters of the electrical grid network. Incorporation of SVC into MG serves many advantages such as 1) proper exchange of capacitive or inductive power for controlling various system parameters, 2) faster response, 3) highly capable and reliability as compared to other synchronous condensators, 4) better improvement in voltage quality, 5) efficient in mitigating voltage oscillations, 6) good regulation of voltage transmission, 7) supports and stabilizes the power grid effectively, 8) high accuracy, 9) ease of availability and 10) helps control of reactive power for enhancement in system's transient stability, reduction in system losses and effective damping of flickers and swings [142]. Fig. 6 illustrates the typical circuit diagram of SVC consisting of two blocks connected in parallel, namely Thyristor Switched Capacitor (TSC) and Thyristor Controlled Reactor (TCR) [144]. These blocks play the primary role in varying the circuit reactance based on the thyristor's partial conduction. Authors in literature have reported SVC to play an essential role in various fields with numerous applications, some of which are summarized in Table 3.

Thyristor controlled series compensator (TCSC)

Depending on the technological characteristics, TCSC has been classified as the first generation of FACTS devices. TCSC was first installed in 1992 and enhanced the transmission network capacity by 30% [165]. It is a series-connected device consisting of a thyristor-controlled reactor in a shunt with many parallel capacitor banks to generate smooth variable series capacitive reactance [166]. Fig. 7 shows a simple circuit of a TCSC. Combining an inductor in shunt with a series capacitor facilitates proper control of equivalent reactance of the transmission system and empowers a continuous and quick variation in the series compensation system. The primary functions of TCSC in an MG include 1) proper power flow control, 2) mitigation of sub-synchronous resonance, 3) prevent the flow of short circuit current, 4) improvement in the system's transient and dynamic stability, 5) damping out harmful oscillations, 6) enhancement in power transfer capability, 7) ability to operate near thermal and electric limits by increasing the loading on the power line and 8) can transmit more real power [167–169]. A rigorous review of the literature based on TCSC applications in different fields, as suggested by many researchers, has been carried out in this article, and some of them are presented in Table 4.

Distributed static synchronous compensator (DSTATCOM)

The DFACTS (Distributed FACTS) are the last-generation controllers mostly employed in the distribution system. Unlike conventional FACTS devices, DFACTS is a new concept introduced recently that possesses the

Table 2
Merits, demerits and applications of different control strategies for PQ enhancement.

Control Strategy	Merits	Demerits	Application
Proportional Integral (PI)	✓ Easy to implement ✓ System response is linear ✓ No steady-state error ✓ Regulation of fundamental components is possible	✓ Fails to respond to nonlinear and imbalanced systems ✓ Stability covers a very narrow range ✓ Poor dynamic and transient response	✓ Renewable energy resources integration [98] ✓ Dual instantaneous power theory [99] ✓ Dynamic Voltage Restorer [100] ✓ Industrial electrical drives [101] ✓ Doubly fed induction generator [102]
Proportional Resonant (PR)	✓ The ability to introduce an infinite gain at the fundamental frequency ✓ Can achieve zero steady-state error ✓ The decoupling method and complex transformation are not required. ✓ The capability of attaining higher gains ✓ Robust current controller	✓ Fails to operate at any other frequency apart from the tuning frequency ✓ Provides low gain and cannot regulate the reference signal is made to work at any other frequency rather than the resonant frequency	✓ A wind power converter [103] ✓ Smart household [104] ✓ PV [105] ✓ Micro hydropower generation [106] ✓ Multilevel inverter control [107] ✓ Multifunctional capacitive-coupling grid-connected inverter [108] ✓ Converters for renewable energy resources [109]
Hysteresis	✓ Simple in structure ✓ Overall system dynamics are satisfactory ✓ It does not depend on load parameters ✓ Robust working ✓ Faster response	✓ The fundamental period may change the switching frequency resulting in irregular inverter working ✓ Lower-order harmonics are not filtered out ✓ Operation at higher power is not possible due to switching losses.	✓ Capacitance reduction in a 1-φ Quasi Z-Source Inverter [110] ✓ Power Quality Enhancement [111] ✓ MG application [112] ✓ Grid-tied Solar systems [113]
Repetitive	✓ Capable of mitigating frequent disturbances ✓ Robust operation ✓ Ability to maintain zero steady-state error at any frequency.	✓ Fails to show efficient stability when the disturbances at the load end are not periodic ✓ Sluggish response due to uncertainty of load.	✓ In Synchronous Rotational Frame [114] ✓ 3-φ, 4-Wire SAPF [115] ✓ MG application [116]
Dead Beat	✓ The structure is very simple ✓ The dynamic response is the fastest ✓ Accuracy is more	✓ Requires a high rate of sampling for operation ✓ Depends on system parameters	✓ Smart-grids [117] ✓ Grid-connected inverters [118] ✓ Wind energy [119] ✓ Aircraft [120] ✓ Solar energy [121]
H-infinity	✓ Robust to any load variations ✓ Modular in structure ✓ Quick response ✓ Consumes less energy for operation ✓ The overall cost is less ✓ It can be applied to multiple-input and multiple-output (MIMO) systems ✓ Enhanced performance	✓ System modelling is complex ✓ Requires high-level knowledge of mathematics for modelling the control unit	✓ Aircraft systems [122] ✓ MGs [123] ✓ Electric Vehicle [124] ✓ Grid-connected converters [125] ✓ MG and energy storage units [126] ✓ Fuel cell [127] ✓ Photovoltaic generation systems [128] ✓ Wind energy [129]
Fuzzy Logic (FL)	✓ Simple in computation ✓ Can handle system non-linearity ✓ Convergence speed is good ✓ Can control single or multiple inputs and output system ✓ Illustration of the knowledge about the control action is easy	✓ Design is complicated ✓ Dependent on the performance of the expert's knowledge and experience ✓ Needs a proper choice of parameters, the definition of membership functions, and the fuzzy rules ✓ Operation is quite slow	✓ Hybrid FC-PV-Wind-Battery energy utilization scheme [130] ✓ Commercial airplane [131] ✓ PV and battery-based system [132] ✓ MG with battery-based energy storage system [133] ✓ Photovoltaic with partial shading effects [134] ✓ DSTATCOM based MG [135]
Artificial Neural Network (ANN)	✓ Holds high fault-tolerant abilities ✓ The ability to store a huge amount of information over a network ✓ Capability to operate with incomplete information ✓ Robust to faults	✓ Weights require proper training ✓ Manufacturing costs are higher ✓ Only numeric data can be fed as input ✓ Depends on the user's ability	✓ Electric vehicles [136] ✓ Wind energy-based DC MGs [137] ✓ Harmonic mitigation in the solar system [138] ✓ Multilevel inverter [139] ✓ Wavelet-based islanding detection in AC MGs [140]

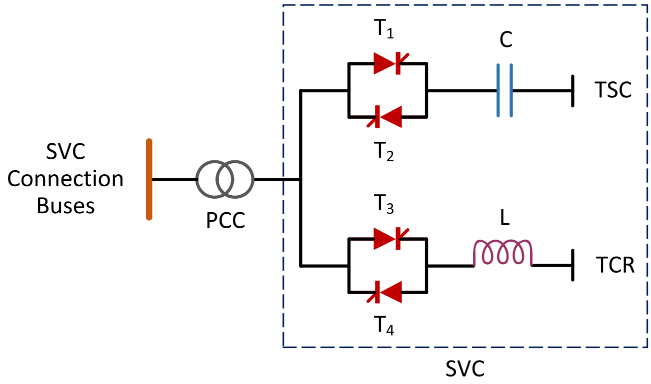


Fig. 6. Typical circuit diagram of SVC.

advantages of having a modular structure and loss cost for efficient power flow control [188]. Further, it also has the capability of effective dynamic control of the line impedance, enhancing system controllability and reliability, improving utilization of assets, and ensuring better power quality to end users with reduced environmental hazard and cost, which makes it a superior candidate for extensive deployment in the power system network [189]. There are many types of DFACTS reported in the literature, namely DSTATCOM,[190] Distributed Thyristor-Controlled Series Compensator (DTCSC),[191] Distributes Static Series Compensator (DSSC),[192] Distributed Switched Filter compensator (DSFC),[193] etc. Among all, the DSTATCOM-based DFACTS device has been reported to serve as a powerful FACTS controller having the capability to compensate currents regarding PQ events. It is usually a voltage source inverter comprising a current-controlled insulated-gate bipolar transistor

Table 3
Literature survey citing the SVC applications in numerous fields.

Application Field	Major Effect of SVC Implementation
Wind generator [145,146]	✓ Voltage profile enhancement ✓ Enhancement in voltage stability and low-voltage ride-through capability
Electric railways [147,148]	✓ Compensation of harmonic and negative sequence components in the power system ✓ Voltage stability improvement
Low voltage grids [149]	✓ Mitigation of voltage fluctuation and reactive power compensation
Arc Furnace [150–153]	✓ Voltage flicker mitigation
Solar PV system [154–156]	✓ Active and Reactive power management ✓ Stability Improvement
Fuel cell-wind-diesel hybrid power system [157–159]	✓ Enhanced dynamic response ✓ Reactive power control
Electric Vehicles [160,161]	✓ Power factor improvement of the distribution system ✓ Improvement of voltage profiles and reduction of losses of unbalanced multiphase smart grid
Two machine system [162]	✓ Transient stability improvement
Energy storage units in MGs [163]	✓ Mitigation of switching over-voltages in MGs
MG [164]	✓ Proper Voltage Sag Investigation

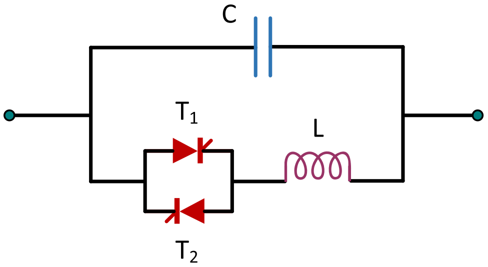


Fig. 7. Simple circuit of TCSC.

Table 4
Literature review citing the TCSC applications in different fields.

Application Field	Major Effect of TCSC Implementation
Interconnected multi-source power system [170–172]	✓ Effective oscillations damping ✓ Mitigation of inter-area oscillations ✓ Power system stability
Grid-connected Solar Farms [173–175]	✓ Improvement of Power Quality and Performance
Wind energy [176,177]	✓ Mitigating subsynchronous resonance ✓ Analysis and protection of transmission lines
Electrified railway [178,179]	✓ Low-Frequency Oscillation Suppression
Electric vehicle [180,181]	✓ Low-Frequency Oscillation Suppression ✓ Stability Improvement
MG [182,183]	✓ Intelligent voltage and reactive power management ✓ Enhancement of stability and Available Transfer Capability (ATC) of transmission lines.
Energy Storage [184,185]	✓ Transmission Expansion Planning
Directional relaying [186]	✓ Fault direction estimation technique
IEEE Fourteen Bus Power System Network [187]	✓ Power transmission congestion management

that is being fed from a DC voltage source. A schematic diagram of DSTATCOM is shown in Fig. 8. DSTATCOM has several advantages such as 1) helps in power factor correction, 2) compensation of harmonics, 3) facilitates load balancing, 4) ability to generate the rated current at virtually any network voltage, 5) better dynamic response and 6) uses moderately small capacitor on the DC bus [194]. Table 5 highlights some of the major implementations of DSTATCOM in numerous fields.

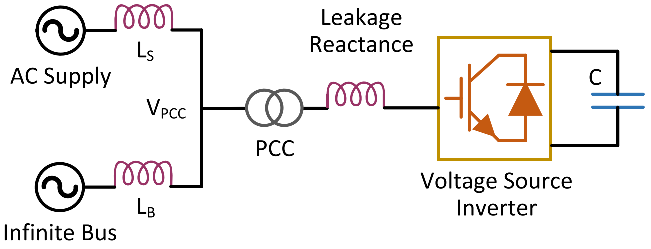


Fig. 8. Schematic diagram of DSTATCOM.

Table 5
Literature review citing the DSTATCOM implementations in different fields.

Application Field	Major Effect of DSTATCOM Implementation
Grid-connected PV system [195–197]	✓ Power quality improvements employing active current control
Hybrid renewable energy system [198]	✓ Enhancement of low-voltage ride-through capability
Multi-grounded distribution network [199]	✓ Voltage compensation
Wind energy [200–202]	✓ Distribution Network Compensation ✓ Thermal and reliability assessment in MGs ✓ Adaptive reactive power control in weak AC grid
Energy storage unit [203,204]	✓ Power quality improvement in the distribution network ✓ Mitigate Grid Disturbances with Solar Energy Penetration
Hybrid wind and energy storage systems [205]	✓ Intelligent voltage and reactive power management ✓ Enhancement of stability and ATC of transmission lines.
MGs [135,206–210]	✓ Economic load sharing ✓ Enhancement in power quality ✓ Harmonic mitigation ✓ Low-voltage ride-through characteristics and capability to support the utility grid during external faults ✓ Enhancement in voltage regulation
Diesel generator [211,212]	✓ Compensation of the neutral current, harmonic current, reactive power, and unbalanced load
Multilevel inverter [213–215]	✓ Effective Load Compensation ✓ Zero-voltage-ride-through (ZVRT) capability

Optimization techniques (OTs)

OTs play a significant role in overall PQ enhancement in an MG. Various authors have implemented and reported the advantages of incorporating numerous OTs as controllers by considering the filters, controllers, and power-sharing methods as the optimization constraints [216]. The major advantage of OTs is that they can be employed in any either linear or nonlinear system in an autonomous or grid-tied mode of operation. A thorough review of the articles presented by researchers on OTs as a supreme controller for PQ mitigation in MG and other applications has been carried out in this section and is summarized in Table 6.

Compensators

Compensators find their primary application mostly in renewable-based DERs and MGs to ensure low current harmonic distortion and generation of enhanced power quality. Many research papers highlight the impact of compensators in attenuating current harmonics in an MG [252,253]. Some of the major contributions of the compensators for PQ enhancement in MG and other power system networks are listed in Table 7.

Conditioners

A conditioner is also termed a power line conditioner, which is usually a device that aims to enhance the PQ delivered to electrical load

Table 6
Literature review citing the OTs applications in different fields.

OTs	Application Field	Major Effect of OTs Implementation
Particle Swarm Optimization (PSO) [217–224]	✓ Autonomous MG ✓ Grid-connected fuel cell ✓ Grid-tied PV ✓ AC MG ✓ PV-based DC MG ✓ Grid-tied MG system	✓ Power quality enhancement ✓ Intelligent frequency control ✓ Proper regulation of voltage and frequency ✓ Optimal Energy Scheduling ✓ Overcomes partial shading impact ✓ Economic Optimization of Electricity Generation and Sales
Predator-Prey based Firefly Optimization (PP-FFO) [225]	✓ Power system network	✓ Optimal design of shunt active power filter for power quality enhancement
Grasshopper Optimization Algorithm (GOA) [226]	✓ Dynamic voltage restorer (DVR)	✓ Robust control of DVR and power quality enhancement
Hybrid algorithm: a combination of PSO and Bat Algorithm (BA) [227]	✓ Distributed solar PV-based MG	✓ Robust capacity configuration optimization
Hybrid PSO-Grey Wolf Optimiser (PSO-GWO) [228]	✓ Solar/wind/bio-generator/diesel/battery-based MGs	✓ Optimal planning of MG
Salp Swarm Optimization (SSWO) [228,229]	✓ Grid-tied AC MG ✓ Three-Phase Soft Starter-Based Induction Motor	✓ Dynamic response enhancement ✓ Mitigate Transients
Novel Collecting Decision Optimization Algorithm (CDOA) [230]	✓ Hybrid Power Source-Based solid oxide fuel cell and Supercapacitor for Grid Integration	✓ Enhanced Dynamic Performance
Thermal Exchange Optimization Technique (TEO) [231]	✓ Hybrid Energy Storage Systems	✓ Supervisory State of Charge and State of Power Management Control
Crow Search Optimization Technique (CSO) [43]	✓ Grid-Tied Solid Oxide Fuel Cell	✓ Improvement of Performance and Quality of Power in Grid
Novel Bee Colony Optimization (BCO) [232]	✓ Static Synchronous Compensator (STATCOM)	✓ Voltage Flicker Compensation
Novel Weighted Superposition Attraction Algorithm (WSAA) [233]	✓ Islanded System with Battery and SuperCapacitor-based Hybrid Energy Storage System	✓ for the State of Charge and Power Management
Modified PSO [234]	✓ Solar	✓ Harmonic Cancelation
Hybrid Fuzzy Logic and Seeker Optimization Algorithm (SOA), [36]	✓ Among micro-sources and supercapacitors in an islanded MG ✓ Between hybrid PV and SOFC in an islanded MG	✓ Optimal energy management ✓ Economic load sharing
SOA based on PI [235]	✓ Grid-connected diesel generator	✓ Power quality enhancement
Spider Monkey Optimization Technique (SMO) [236]	✓ Unified Design of power system stabilizer and TCSC	✓ Efficient damping of Inter-Area Oscillations
Genetic Algorithm (GA) [237]	✓ MG	✓ Optimized power generation
Differential Evolution (DE) [238, 239]	✓ Grid-connected MG	✓ Dynamic cost analysis ✓ Operating cost reduction under real-time pricing
Ordered Flower Pollination Algorithm [240]	✓ Solar PV system	✓ Improved MPPT Tracking Time by 85% ✓ Reduction in tracking time ✓ Increase in the efficiency
Optimized Ten Check Algorithm (OTCA) [241]	✓ 4S2P PV system configuration	✓ Enhanced MPPT speed and efficiency ✓ Better settling time
HOMER Software [242]	✓ Microgrid system that supplies uninterrupted power supply to Mirpur University of Engineering and Technology (MUST), Azad Jammu and Kashmir AJK, Pakistan	✓ A solar photovoltaic system, a diesel generator, a battery bank, and a power converter make up the proposed system for the university campus; together, they provide a reliable means of meeting energy needs for the next 25 years at a reasonable cost. With 99% of its energy coming from renewable sources, the system encourages the development of clean, green energy and helps to significantly lower greenhouse gas emissions.
MPPT Techniques [243]	✓ Solar PV System	✓ It is clear from examining a number of traditional and soft-computing methods for Maximum Power Point Tracking (MPPT) that no single method is appropriate for every meteorological scenario. ✓ In partial shading settings, effectiveness frequently results in algorithmic complexity and large computations, while simplicity sacrifices efficiency in such conditions. ✓ The best MPPT algorithms should be straightforward, simple to implement, able to discriminate between local and global MPP, track MPP quickly and correctly in both uniform and partial shading situations, and free of oscillations in the steady state with zero electric parameters.
Modified Flower Pollination Algorithm (MFPA) [244]	✓ Solar PV System	✓ A few structural changes have been suggested for the FPA in order to enhance its search capabilities and obtain faster, more precise, and more effective MPPT results for solar PV systems.
Strategic Perturb and Observe Algorithm [245]	✓ Photovoltaic system	✓ Structural modifications in P&O method has been carried out to obtain efficient results under partial shading conditions such as tracking speed, tracking time, efficiency, and ability to track the Global MPP (GMPP).
Adaptive Flower Pollination Algorithm (AFPA) [246]	✓ Standalone solar photovoltaic system	✓ To improve tracking speed and efficiency, a well-known, nature-inspired Flower Pollination Algorithm (FPA) was carefully examined, changed, and integrated with a random walk filter. ✓ The suggested technique has shown excellent performance, especially in monitoring global Maximum Power Points (GMPPs) under different Partial Shading Conditions (PSCs).
Optimized Flower Pollination Algorithm [247]	✓ Solar System	✓ The proposed method shows outstanding performance in zero shading condition, weak PSC, strong PSC, and changing weather conditions.

(*continued on next page*)

Table 6 (*continued*)

OTs	Application Field	Major Effect of OTs Implementation
Ten Check (TC) algorithm [248]	✓ PV array	✓ Analysis showed that, in comparison to the P&O and FPA algorithms, the developed method attained the GMPP precisely and effectively.
Decrease and Fix method with Pertub and Observe [249]	✓ Standalone solar photovoltaic system	✓ In this research, a novel technique called "Decrease and Fix" is effectively provided as an enhancement to the PAO algorithm to address these tracking speed and oscillation problems. ✓ The decrease and fix approach is the first effective use of the PAO algorithm for achieving stability and expediting the photovoltaic system tracking process.
IRG based MOR techniques [250]	✓ Discrete time systems	✓ The suggested methods outperform traditional stability-preserving techniques in ensuring model stability even after reduction. ✓ The suggested methods produce stable ROMs and improve inaccuracy in comparison to other stability-preserving frequency-limited MOR methods already in use.
Optimized hill climbing algorithm (OHC) [251]	✓ Off shore PV system	✓ The suggested optimised HC (OHC) algorithm maintains the strength of the traditional HC algorithm while achieving zero steady-state oscillations. ✓ Both algorithms were implemented on an off-grid photovoltaic system in both constant and fluctuating weather scenarios, and the outcomes show that the suggested OHC method outperforms the traditional HC approach.

equipment. There are two basic types of Conditioners, namely, 1) Active Power Conditioner (APC) and 2) Unified Power Quality Conditioner (UPQC), which is discussed in depth in this section.

Active power conditioners (APCs)

APC is regarded as one of the efficient Custom Power Devices (CPDs) capable of mitigating PQ issues such as harmonic distortion and voltage sag, facilitating power factor correction, and enhancing system efficiency [263]. It is generally connected in parallel and is assumed to be a multi-function compensating device based on the available controller design. The primary part of APC consists of a voltage source converter that converts the DC-link voltage into three-phase AC voltages with controllable amplitude, frequency, and phase [264]. Numerous applications of APCs have been reported in the literature for PQ disturbances mitigation and overall enhancement of system stability, some of which are summarized in Table 8.

Unified power quality conditioners (UPQCs)

UPQC is regarded as a Universal APF which combines the shunt APF with the series APF sharing the same DC-link to mitigate supply voltage power quality disturbances (such as sags, swells, unbalance, flicker, harmonics) and load current power quality issues (such as, harmonics, unbalance, reactive current and neutral current) [272]. The main objective of UPQC is to maintain the supply voltage sinusoidal at a nominal value along with the source currents to become sinusoidal in phase with the source voltages [273]. A UPQC comprises two voltage source converters sharing a common DC-link either in a single-phase, three-phase three-wire, or three-phase four-wire configurations. Among the two converters, one acts as a current source inverter (CSI) being placed in parallel at the PCC with the help of a transformer as shown in Fig. 9(a), and the other acts as a Voltage Source Inverter (VSI), being connected in series between the source and the load with the help of a transformer as depicted in Fig. 9(b). The series converter carries out the following functions: 1) compensation of disturbances at the supply voltage such as sags, swells, harmonics, flickers, imbalances, etc., 2) facilitates harmonic isolation, and 3) damps out harmonic oscillations. The DC-link voltage regulation and compensation of load current waveform distortions are brought about by the shunt converter [274,275]. A thorough survey of the articles reported in the literature regarding UPQC application for PQ enhancement in MG and other sectors has been carried out in this research paper and presented in Table 9.

Machine learning tools (MLTs)

Appropriate monitoring of power system dynamics is essential for maintaining constant PQ, and this is brought about by incorporating MLTs into the power system network. Authors have studied the fluctuations in the power system by adopting the frequency spectrum analysis method based on the acquisition of time-domain signals by using the LabVIEW-based monitoring and analyzing tool [296,297]. Numerous harmonic analysis techniques have been reported in the literature for PQ enhancement, such as Artificial Neural Network (ANN),[298–302] Fast Fourier Transform (FFT),[303–307] and Fuzzy logic Controller (FLC) [36,135,308–311]. Detection and monitoring of PQ issues at a specific power line location is possible by the Phasor Measurement Unit (PMU) device, which determines the phasor quantity. The phasor helps in finding the appropriate magnitude and phase angle of the supply voltage and current. Further, this information can also determine the frequency and analyze system conditions [312]. Researchers have also discussed and implemented some applications of PMU for PQ improvement [312–326].

Authors have adopted an Adaptive Linear Combiner (ADALINE) to detect PQ issues such as voltage sag, swell, transients, interruptions, etc. The main merits of this method are: 1) does not require setting up a threshold value for detecting PQ issues and 2) provides true and higher tracking ability [327–331]. Kalman Filtering (KF) method is also adopted for detecting various PQ disturbances. It has proved to be a more efficient technique as the PQ issues can be identified in the wavelet domain [332]. The application of the KF technique for PQ improvement has been thoroughly investigated in the literature [333–341]. Another algorithm suggested by researchers for signal processing in both the time and frequency domains is the Hilbert Transform (HT) algorithm [342–345]. This technique operates in a specific frequency range and uses an analog all-pass filter to effectively monitor mostly the voltage flicker type of PQ issues [346–351]. Fig. 10 shows the various MLTs for PQ events. Table 10 describes the major PQ issues and some of its possible PQ mitigation methods.

The overview and literature review of Deep Learning and Machine Learning's application to power system control Issues has been critically discussed by many authors [352,353]. To preserve reliability, machine learning techniques are used to extract patterns and arrange data to analyse, process, predict, and classify massive amounts of data relevant to the assessment of intricate power system dynamic security challenges. An overview of the various uses of AI-based methods in microgrids, including energy management, cyber security, protection, load and generation forecasts, and power electronics control, has been presented by the researchers [353]. Authors have reported the application of machine learning and intelligent controllers for prediction, control, energy management, and vehicle-to-everything (V2X) in hydrogen fuel cell vehicles [354]. A comprehensive review of the role of artificial

Table 7
Literature review citing the compensators applications in MG and other power system network.

Application Field	Major Objective of Compensator Implementation
Grid-Tied Photovoltaic Inverters [252]	✓ Determination of the capability curves of a multifunctional inverter during harmonic current compensation ✓ Identification of main system parameters that affect the inverter's capability to provide harmonic current compensation
Distributed generation based islanded MGs [253]	✓ Active resonance damping and harmonics compensation
MG [254]	✓ Improvements in Bidirectional Power-Flow Balancing and Electric Power Quality
Low voltage secondary distribution system [255]	✓ Design of a micro compensator to be installed and maintained by an electric utility for improved power quality
MGs [256]	✓ Formation of a consensus-based distributed control scheme, augmented by the conservative power theory for compensating imbalance and harmonics at the Point of Common Coupling (PCC)
5-node power system network [257]	✓ Proposing a novel expert system that automatically suggests the most appropriate and cost-effective solution for compensating reactive, harmonic, and unbalanced current through a careful analysis of several power quality indices and some grid characteristics.
Utility grid with solar energy penetration [258]	✓ Harmonic mitigation and power quality improvement
Wind energy [259]	✓ Optimization of the extracted wind power
Low inertia power systems and battery energy storage [260]	✓ Mitigation of frequency stability issues
Electric Vehicles (EVs) [261]	✓ Finding a solution based on the reactive power ✓ generation capability of PV systems to address the problem of increased voltage drop that will arise due to high EV penetration.
Multilevel inverter in Uninterruptible Power Supply (UPS) systems [262]	✓ Using the inverter cells as the VAR-compensator

Table 8
Literature review citing the APCs applications in MG and other power system network.

Application Field	Major Objective of APC Implementation
Radial distribution systems [263]	✓ Design of an enhanced technique for optimal location and size of the APCs for power quality enhancement distribution systems
Radial distribution systems [264]	✓ Design of a method for optimally placing APC for voltage profile improvement and minimization of total harmonic distortion and total investment cost using an improved discrete firefly algorithm (IDFA)
Industry [265]	✓ Mitigation of PQ problems
MG [266]	✓ Propose a three-phase back-to-back APC with dc-link voltage control strategies for the regulation of frequency and voltage to achieve high stability
Electrified railway systems [267]	✓ Use of APC to compensate power quality problems in single-phase 25 kV, 50 Hz railway traction substation
Wind energy systems [268]	✓ Mitigation of PQ issues
MGs [269]	✓ Harmonic power market framework for compensation management of DER
Power system network with 15 bus and six nonlinear loads [270]	✓ Optimal siting and sizing of multiple APCs for minimizing network harmonic distortions considering Harmonic Couplings
Solar Inverters [271]	✓ Harmonic Compensation for Nonlinear Loads

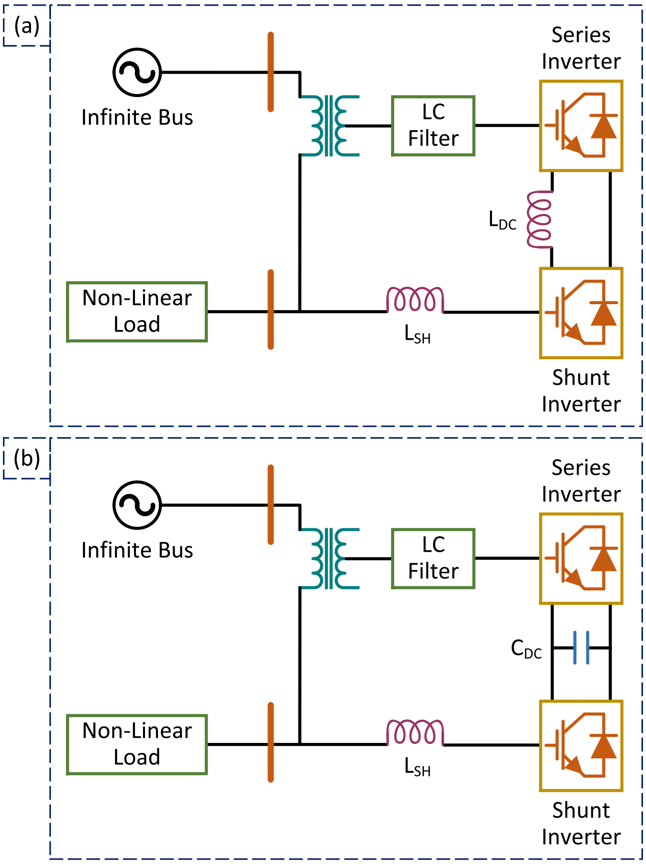


Fig. 9. (a) CSI based UPQC (b) VSI based UPQC.

intelligence methods and their sub-procedures in addressing problems in transient stability has been analysed and the rationality, applications, challenges and future opportunities have been projected [355]. The concept of deep learning, IoT and blockchain has been also implemented in the solar PV system to forecast maximum voltage to provide reference value to its MPPT technique [356,357]. Frequent blackouts and restricted access to energy in many poor countries have been studied by the application of artificial intelligence and machine learning applications in the energy sector [358]. Machine learning scopes on microgrid predictive maintenance with potential frameworks, challenges, and prospects have been comprehensively outlined and future research prospects in the industry have been discussed. A thorough analysis of the applications of artificial intelligence optimisation techniques in a hybrid microgrid during fault outbreaks has been elaborated by authors [359]. Researchers have given the concepts of synthesising control references for an active power filter (APF) that is installed in a smart grid with distortion loads to enhance power quality and adhere to standardised indices [360].

Power quality issues and mitigation methods in various sources of microgrid

It is essential to address power quality concerns and incorporate efficient mitigation techniques with diverse microgrid sources. The dependability, longevity, and efficiency of electrical systems are all strongly impacted by power quality, which also affects the functionality of vital equipment and the grid's general stability. Solar PV, wind, fuel cells, diesel gensets, and combined heat and power (CHP) are a few of the energy sources that are frequently used in microgrids [361]. Differential problems including voltage swings, harmonics, and transient events may compromise the quality of energy supplied to end consumers in solar PV, wind, fuel cells, diesel gensets, and combined heat and

Table 9
Literature review citing the UPQCs applications in MG and other power system network.

Application Field	Major Objective of UPQCs Implementation
Solar-fed grid network [276,277]	✓ For supplying a part or full reactive power required by the load and compensating the sag, swell, supply voltage unbalance and distortions. ✓ Shunt part for extracting power from PV array and series part for compensation of the grid side power quality problems such as grid voltage sags/swells
Three-Phase Solar PV and Battery Energy Storage System [278,279]	✓ To mitigate the power quality problems that existed in the grid and the harmonics penetrated by the nonlinear loads ✓ Designing a multi-objective planning approach for the optimal allocation of PV-BESS integrated open UPQC
MG system with Solar energy [280]	✓ To eliminate the sags and harmonics in the micro-grid system caused by the power electronic devices employed by the renewable sources
Energy storage system [281,282]	✓ Voltage sag mitigation ✓ Enhancement of the electric power quality by compensating the source voltage sag
Hybrid Renewable Energy System (HRES) consisting of PV/ Wind/ Battery [283,284]	✓ Atom Search Optimization (ASO) was employed with UPQC to solve the PQ issues
Wind Energy System [285–287]	✓ Power quality enhancement viz. Voltage sag, Voltage swell on the source voltage, and current harmonics mitigation on the source current.
Hybrid fuel cell and wind energy [288, 289]	✓ Enhancement of power quality
Electric Vehicle [290,291]	✓ Improvement of the PQ problems caused by electric vehicle charging equipment
Multilevel Inverter [292–295]	✓ Power flow control and power quality analysis in the power distribution system ✓ For increasing the number of sub-modules at a medium voltage level ✓ Power quality conditioning

power (CHP) modules. To minimise equipment downtime, ensure a steady and reliable power supply, and guard against potential damage, these problems must be mitigated. It is essential to optimise power quality in microgrids through the use of sophisticated techniques such as harmonic filters, smart inverters, and predictive analytics [362]. This will help to create resilient and sustainable energy systems that can meet the needs of contemporary applications. Table 11 describes the major PQ issues and their causes that occur in common energy sources such as Solar PV, Wind, Fuel Cell, Diesel Gensets and Combined Heat and Power (CHP) of microgrids as well as its probable PQ mitigation techniques.

Technical and economic aspect

As discussed in this article, the numerous methods for mitigating PQ issues have their own merits and demerits that need to be dealt with very seriously. Recently, filters have been made more technical developed with reduced cost, size, and losses for delivering efficient supply to critical loads [50]. However, they suffer from some shortcomings, such as the resonance effect, and do not provide load compensation. On the other hand, controllers play a significant role in maintaining the system's overall dynamic stability. Nevertheless, the use of controllers is, in fact, costly and makes the system more complex. The FACTS devices deliver superior reactive power and load compensation and have the highest power rating of converters, but the overall cost of implementation is extremely high [142]. OTs have proved to be a viable option for determining PQ issues; however, the cost of implementation is high [216]. Compensators ensure low current harmonic distortion and generation of enhanced power quality, but their overall cost is very high [252]. The enhancement in the PQ delivered to electrical load equipment is brought about by Conditioners. Still, the major disadvantage lies in its high cost of operation and lower power rating of power converters [263,272]. MLTs play a primary role in monitoring the event of the presence of PQ issues; however they suffer from many demerits such as 1) the need for massive data for operating, 2) requires high time and more resources, 3) choosing a particular feature is a key challenge that needs development of necessary tools in areas such as statistical analysis, machine learning, or data mining and 4) highly prone to errors [301]. So, the study of all PQ mitigation techniques regarding technical and economic aspects is essential. In this context, Table 12 highlights the Technical and Economic Aspects of various PQ improvement techniques.

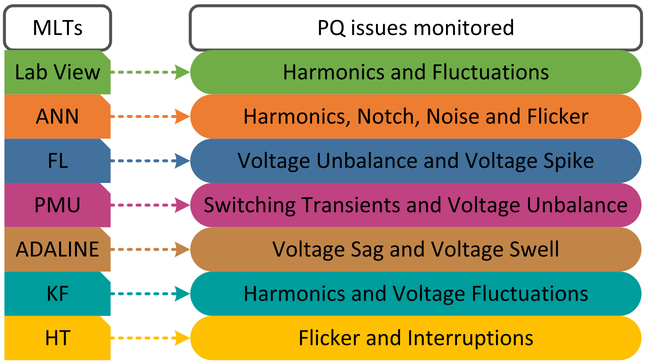


Fig. 10. Machine learning tools for monitoring PQ events.

Discussion and future scope

Although there have been numerous methods reported for the Mitigation of PQ disturbances the scope for future research work to be conducted on more efficient mitigation of PQ issues are many. It is

Table 10
PQ issues and its possible PQ mitigation methods.

PQ Issue Types	Some Possible PQ Mitigation Methods
Voltage Sag [38]	✓ UPS ✓ DVR ✓ Filters ✓ UPQC
Voltage Swell [39]	✓ Power Conditioners ✓ UPS ✓ Filters ✓ UPQC
Voltage Unbalance [40]	✓ Protective Schemes ✓ UPQC
Voltage Spike [41]	✓ Transient Voltage Surge Suppressors ✓ Series (blocking) connected Low Pass Filters. ✓ Parallel (shunting) connected Voltage Clampers and Voltage Clippers. ✓ Parallel (shunting) connected Crowbar devices
Voltage Fluctuation [42]	✓ SVC ✓ UPQC
Voltage Flicker [43]	✓ Voltage Imbalance Relay ✓ Filters ✓ SVC ✓ DSTATCOM ✓ UPQC
Interruptions [44]	✓ UPS
Harmonics [45]	✓ Active Filters ✓ DSTATCOM ✓ Compensators ✓ UPQC
Noise [46]	✓ Filters ✓ By-pass capacitors
Switching Transients [47]	✓ SVC ✓ DSTATCOM

Table 11
Major PQ issues and causes in solar PV with its possible PQ mitigation methods.

Type of Energy Source	PQ Issue Types	Causes	Probable PQ Mitigation Techniques
Solar PV [363–373]	Voltage Fluctuations	Variations in the amount of clouds and shade cause the sun's power output to fluctuate quickly.	✓ Smart Inverters with Advanced control algorithms ✓ Voltage Regulators
	Harmonics	Harmonics are introduced by inverters because of their switching mechanism.	✓ Harmonic Filter ✓ Advanced Inverter Control
	Voltage Sag	Abrupt decreases in power output are caused by variations in sun irradiation.	✓ Predictive Analytics: Machine learning tools ✓ Predictive Analytics through Machine Learning Tools
Wind [374–381]	Voltage Fluctuations	Variations in wind power output are caused by variations in wind speed.	✓ Pitch Control Systems ✓ FACTS Devices for voltage control
	Voltage Flicker	Rapid changes in wind speed result in voltage flicker.	✓ DVR for rapid voltage compensation ✓ Energy Storage Systems for storing excess power during high wind speeds.
	Grid-Resonance Issues	Resonance develops from grid interaction with wind turbines.	✓ Voltage Imbalance Relay ✓ Filters ✓ SVC ✓ DSTATCOM ✓ UPQC
Fuel Cell [382–387]	Voltage Fluctuations	Quick variations in load or variations in the availability of hydrogen.	✓ Advanced Power Electronics based on Artificial intelligence/ Machine Learning/Deep Learning Algorithms ✓ Hybrid Energy Systems for continuous supply
	Harmonic Distortion	Harmonic distortion in fuel cells is caused by power electronic converters.	✓ Harmonic filters ✓ Grid-Forming Inverters
	Transients	Transients are produced when fuel cell systems start and stop.	✓ Voltage Conditioners for smoothing transients. ✓ Advanced controllers with Artificial intelligence/ Machine Learning/Deep Learning Algorithms
Diesel Gensets [388–394]	Voltage and Frequency Fluctuations	Variability in load variations and combustion of fuel.	✓ Voltage Regulators ✓ Governor Controllers for stable frequency
	Harmonics and Voltage Distortion	Nonlinear loads when running a diesel generator set.	✓ Harmonic Filters to reduce harmonic distortion ✓ Active Power Filters to compensate for reactive power
	Start-up Transients	Rapid acceleration during start-up.	✓ Soft Starters for lowering mechanical and electrical stress. ✓ Voltage Conditioner to reduce transients while start-up
Combined Heat and Power (CHP) Modules [395–402]	Voltage Fluctuations	Variations in power demands and loads	✓ Controller Tuning with robust control algorithms ✓ Voltage Regulators for stabilizing voltage levels
	Harmonics and Inter-harmonics	Complicated power generation and nonlinear loads	✓ Harmonic Filters for mitigation of harmonic distortions ✓ Advanced Inverter Control through novel techniques based on Artificial intelligence/ Machine Learning/Deep Learning Algorithms
	Thermal Stress	Frequent shutdowns and starts.	✓ Load Shedding Systems ✓ Utilising machine learning and predictive analytics, thermal stress may be anticipated and managed.

nearly hard to point out which technique is superior as each has its pros and cons. All the PQ issues cannot be dealt with a single control method because the implementation of a particular technique depends upon many factors such as area of application, type of PQ issue, environmental effect, number of power switches used, power rating, the efficiency of reactive power and load compensation, etc. Some of the major suggestions to be implemented in the future for hassle-free operation and implementation of various PQ mitigation methods are enumerated below.

1. Development of more robust control methods which can mitigate any type of PQ disturbances irrespective of any factors.
2. Design of robust systems that can implement D-FACTS devices more efficiently into new and existing power markets.
3. More research is to be carried out on the proper cost-benefit economic analysis of all techniques adopted.
4. The optimal location of the control devices, system parameters, and real-time data need to be studied for the accurate functioning of the devices.
5. Further development in the power electronic converters used in the control structures needs to be carried out to enhance efficiency and minimise losses.
6. Future research areas can study the PQ issues incorporating tidal, ocean, and hydropower systems as generation units.
7. More competent time domain and wavelet domain analysis methods can experiment to enhance their monitoring capabilities further.
8. Tracking and detection schemes of PQ issues must be developed in the future to enhance efficacy.
9. Detection, mitigation, and monitoring of higher-order, inter, and intra-harmonics are also important considerations that can be addressed in future research.
10. In-depth research on eliminating PQ issues while integrating MG to other power systems needs to be carried out.

Conclusion

MG system paves its way to maintain the present-day electrical grid network's reliability, stability, and flexibility by integrating renewable-based DERs, energy storage devices, and loads. Nevertheless, the quality of power generated is adversely affected due to the intermittent generation of renewable sources, a great demand for nonlinear load, and harmonic injection due to power electronic interfaces. So, presently maintaining controlled regulation of PQ and delivering compensation at all levels of power is a vital issue to be considered. In this regard, a meticulous survey of numerous PQ mitigation techniques such as Filters, Controllers, FACTS, OTs, Compensators, Conditioners, and Machine Learning Tools for enhancing the quality of electrical power delivered to the distribution systems has been carried out and highlighted in detail in this article. Further, deep insight into PQ and enhancement in MG have been enumerated.

Furthermore, a detailed discussion and comparative study among all PQ improvement techniques from technical and economic aspects have been projected comprehensively. Further, a detailed study covering almost all challenges has been cited, and possible solutions in the future

Table 12
Technical and economic aspects of various PQ improvement techniques.

PQ Improvement Techniques	Level of performance	Overall Cost of Implementation	Reactive Power Compensation	Power Rating of Converters
Filters	Medium to low	✓ High (Active) ✓ Low (Passive) ✓ Medium (Hybrid)	✓ Medium (Active) ✓ Low (Passive) ✓ Medium (Hybrid)	✓ High (Active) ✓ Low (Hybrid)
Controllers	High to medium	High	Medium	Medium
FACT Devices	High to medium	High	High	High
OTs	Medium to low	Medium	Medium	Medium
Compensators	High to medium	Medium to High	High	High
Conditioners	High to medium	High	High	Low
MLTs	Medium to low	Medium	Low	Low

for hassle-free PQ improvement have been suggested in detail. Therefore, this research article is also believed to serve as an excellent platform for providing considerable ideas to beginners, academicians, researchers, industrialists, manufacturers, and engineers working in this area.

CRediT authorship contribution statement

Subhashree Choudhury: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. **Gagan Kumar Sahoo:** Conceptualization, Data curation, Formal analysis, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

[1] S. Choudhury, A comprehensive review on issues, investigations, control and protection trends, technical challenges and future directions for Microgrid technology, Int. Trans. Electr. Energy Syst. 30 (9) (2020) e12446.

[2] I.E. Series, Microgrids and active distribution networks, Inst. Eng. Technol. (2009).

[3] M.J. Afroni, D. Sutanto, D. Stirling, Analysis of nonstationary power-quality waveforms using iterative Hilbert Huang transform and SAX algorithm, IEEE Trans. Power Deliv. 28 (4) (2013) 2134–2144.

[4] M. Valtierra-Rodriguez, Jesus de, R. Romero-Troncoso, R.A. Osornio-Rios, A. Garcia-Perez, Detection and classification of single and combined power quality disturbances using neural networks, IEEE Trans. Ind. Electron. 61 (5) (2013) 2473–2482.

[5] B. Biswal, M. Biswal, S. Mishra, R. Jalaja, Automatic classification of power quality events using balanced neural tree, IEEE Trans. Ind. Electron. 61 (1) (2013) 521–530.

[6] B. Singh, A. Chandra, K. Al-Haddad, Power Quality: Problems and Mitigation Techniques, John Wiley & Sons, 2014.

[7] O. Hafez, K. Bhattacharya, Optimal planning and design of a renewable energy based supply system for microgrids, Renew. Energy 45 (2012) 7–15.

[8] H. Bevrani, B. François, T. Ise, Microgrid Dynamics and Control, John Wiley & Sons, 2017.

[9] D.E. Olivares, A. Mehrizi-Sani, A.H. Etemadi, C.A. Cañizares, R. Iravani, M. Kazerani, A.H. Hajimiragha, O. Gomis-Bellmunt, M. Saeedifard, R. Palma-Behnke, Jiménez-Estévez GA, Trends in microgrid control, IEEE Trans. Smart. Grid. 5 (4) (2014) 1905–1919.

[10] H. Jiayi, J. Chuanwen, X. Rong, A review on distributed energy resources and MicroGrid, Renewable Sustainable Energy Rev. 12 (9) (2008) 2472–2483.

[11] N. Pogaku, M. Prodanovic, T.C. Green, Modeling, analysis and testing of autonomous operation of an inverter-based microgrid, IEEE Trans. Power Electron. 22 (2) (2007) 613–625.

[12] R. Lasseter, A. Akhil, C. Marnay, J. Stephens, J. Dagle, R. Guttromsom, A. S. Meliopoulous, R. Yinger, J. Eto, Integration of Distributed Energy resources. The CERTS Microgrid Concept, Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States), 2002.

[13] F. Katiraei, M.R. Iravani, Power management strategies for a microgrid with multiple distributed generation units, IEEE Trans. Power Syst. 21 (4) (2006) 1821–1831.

[14] M.T. Ozog, Inventor; Integral Analytics Inc, assignee. Optimization of microgrid energy use and distribution. United States patent US 8,364,609. 2013.

[15] P.C. Loh, D. Li, Y.K. Chai, F. Blaabjerg, Autonomous operation of hybrid microgrid with AC and DC subgrids, IEEE Trans. Power. Electron. 28 (5) (2012) 2214–2223.

[16] P.O. Kriett, M. Salani, Optimal control of a residential microgrid, Energy 42 (1) (2012) 321–330.

[17] R. Zamora, A.K. Srivastava, Controls for microgrids with storage: review, challenges, and research needs, Renewable Sustainable Energy Rev. 14 (7) (2010) 2009–2018.

[18] A. Hirsch, Y. Parag, J. Guerrero, Microgrids: a review of technologies, key drivers, and outstanding issues, Renewable Sustainable Energy Rev. 90 (2018) 402–411.

[19] S. Khalid, B. Dwivedi, Power quality issues, problems, standards & their effects in industry with corrective means, Int. J. Adv. Eng. Technol. 1 (2) (2011) 1.

[20] F.Y. Mahfoud, B.D. Guzun, G.C. Lazaroiu, H.H. Alhelou, Power quality of electrical power systems. Handbook of Research on Smart Power System Operation and Control, IGI Global, 2019, pp. 265–288.

[21] M. Esmaeili, H. Shayeghi, K. Valipour, A. Safari, F. Sedaghati, Power quality improvement of multimicrogrid using improved custom power device called as distributed power condition controller, Int. Trans. Electr. Energy Syst. 30 (3) (2020) e12259.

[22] C. Natesan, S.K. Ajithan, P. Palani, P. Kandhasamy, Survey on microgrid: power quality improvement techniques, Int. Sch. Res. Notices. 2014 (2014).

[23] B.B. Sharma, K.P. Singh, A. Patel, A. Banshwar, N.K. Sharma, M. Pathak, Classification of power quality events-an inclusive review, J. Phys.: Conf. Ser. (2021) 012020. Apr 1 (Vol. 1854, No. 1IOP Publishing.

[24] N. Singh, M.A. Ansari, M. Tripathy, V.P. Singh, Feature extraction and classification techniques for power quality disturbances in distributed generation: a review, IETE J. Res. (2021) 1–6.

[25] P. Khetarpal, M.M. Tripathi, A critical and comprehensive review on power quality disturbance detection and classification, Sustainable Comput.: Informat. Syst. (2020) 100417.

[26] O.P. Mahela, A.G. Shaik, N. Gupta, A critical review of detection and classification of power quality events, Renewable Sustainable Energy Rev. 41 (2015) 495–505.

[27] U. Subudhi, S. Dash, Detection and classification of power quality disturbances using GWO ELM, J. Ind. Inf. Integr. 22 (2021) 100204.

[28] N. Kishor, R. Singh, S.R. Mohanty, O. Yadav, Evolving disturbances detection and classification in real-time for grid-connected system, IEEE Trans. Ind. Electron. 68 (9) (2020) 8265–8273.

[29] M. Shafiullah, M.A. Khan, S.D. Ahmed, PQ disturbance detection and classification combining advanced signal processing and machine learning tools, in: Power Quality in Modern Power Systems, Academic Press, 2021, pp. 311–335.

[30] G.S. Chawda, A.G. Shaik, M. Shaik, S. Padmanaban, J.B. Holm-Nielsen, O. P. Mahela, P. Kaliannan, Comprehensive review on detection and classification of power quality disturbances in utility grid with renewable energy penetration, IEEE Access. 8 (2020) 146807–146830.

[31] S.P. Chowdhury, S. Chowdhury, P.A. Crossley, Islanding protection of active distribution networks with renewable distributed generators: a comprehensive survey, Electr. Power Syst. Res. 79 (6) (2009) 984–992.

[32] G. Shahgholian, A brief review on microgrids: operation, applications, modeling, and control, Int. Trans. Electr. Energy Syst. (2021) e12885.

[33] Y.W. Li, J. He, Distribution system harmonic compensation methods: an overview of DG-interfacing inverters, IEEE Ind. Electron. Mag. 8 (4) (2014) 18–31.

[34] S.Y. Mousavi, A. Jalilian, M. Savaghebi, J.M. Guerrero, Coordinated control of multifunctional inverters for voltage support and harmonic compensation in a grid-connected microgrid, Electr. Power Syst. Res. 155 (2018) 254–264.

[35] Z.A. Arfeen, A.B. Khairuddin, R.M. Larik, M.S. Saeed, Control of distributed generation systems for microgrid applications: a technological review, Int. Trans. Electr. Energy Syst. 29 (9) (2019) e12072.

[36] S. Choudhury, T.P. Dash, P. Bhowmik, P.K. Rout, A novel control approach based on hybrid fuzzy logic and seeker optimization for optimal energy management between micro-sources and supercapacitor in an islanded microgrid, J. King Saud Univ.-Eng. Sci. 32 (1) (2020) 27–41.

[37] O. Bassey, C. Chen, K.L. Butler-Purry, Linear power flow formulations and optimal operation of three-phase autonomous droop-controlled microgrids, Electr. Power Syst. Res. 196 (2021) 107231.

[38] A.S. Poste, B.T. Deshmukh, B.E. Kushare, Detection, classification & characterisation of voltage sag, in: In2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), IEEE, 2016, pp. 232–237.

[39] S.D. Dhakulkar, V.A. Manwar, S.G. Banole, B.S. Rakhonde, Inspection of voltage sags and voltage swells incident in power quality problems-a review, Int. Res. J. Eng. Technol. 4 (1) (2017) 1734–1736.

[40] G. Gupta, W. Fritz, Voltage unbalance for power systems and mitigation techniques a survey, in: 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), IEEE, 2016, pp. 1–4.

[41] N.D. Mehta, A.P. Patel, A.M. Haque, A review on power quality improvement via custom power devices, Int. J. Adv. Eng., Manage. Sci. 2 (9) (2016) 239649.

[42] P. Chaudhary, M. Rizwan, Voltage regulation mitigation techniques in distribution system with high PV penetration: a review, Renewable Sustainable Energy Rev. 82 (2018) 3279–3287.

[43] S. Choudhury, Voltage flicker compensation of STATCOM through novel bee colony optimization, in: 2020 International Conference on Smart Electronics and Communication (ICOSEC), IEEE, 2020, pp. 1018–1024.

[44] R. Kumar, B. Singh, D.T. Shahani, A. Chandra, K. Al-Haddad, Recognition of power-quality disturbances using S-transform-based ANN classifier and rule-based decision tree, IEEe Trans. Ind. Appl. 51 (2) (2014) 1249–1258.

[45] M. Faifer, C. Laurano, R. Ottoboni, S. Toscani, M. Zanoni, Harmonic distortion compensation in voltage transformers for improved power quality measurements, IEEe Trans. Instrum. Meas. 68 (10) (2019) 3823–3830.

[46] S.M. Bhuiyan, J. Khan, G. Murphy, WPD for detecting disturbances in presence of noise in smart grid for PQ monitoring, IEEE Trans. Ind. Appl.. 54 (1) (2017) 702–711.

[47] M.S. Javadi, A.E. Nezhad, P. Siano, M. Shafie-khah, J.P. Catalão, Shunt capacitor placement in radial distribution networks considering switching transients decision making approach, Int. J. Electr. Power Energy Syst. 92 (2017) 167–180.

[48] J. Gong, D. Li, T. Wang, W. Pan, X. Ding, A comprehensive review of improving power quality using active power filters, Electr. Power Syst. Res. 199 (2021) 107389.

[49] A. Baitha, N. Gupta, A comparative analysis of passive filters for power quality improvement, in: 2015 International Conference on Technological Advancements in Power and Energy (TAP Energy), IEEE, 2015, pp. 327–332.

[50] S.J. Gift, B. Maundy, Electronic Circuit Design and Application, Springer, 2020.

[51] M.W. Hussain, M.A. Qureshi, Analysis and design of passive filters for power quality improvement in 3ϕ grid-tied PV systems, in: 2021 4th International Conference on Energy Conservation and Efficiency (ICECE), IEEE, 2021, pp. 1–6.

[52] A.K. Mishra, P.K. Ray, R.K. Mallick, A. Mohanty, S.R. Das, Adaptive fuzzy controlled hybrid shunt active power filter for power quality enhancement, Neural Comput. Appl. 33 (2021) 1435–1452.

[53] R.P. Vishvakarma, S. Gupt, Power quality improvement with shunt and hybrid APF using PI and hysteresis current controllers: performance comparison, Intl J Eng Sci Adv Res. 1 (1) (2015) 113–120.

[54] W.U. Tareen, S. Mekhilef, M. Seyedmahmoudian, B. Horan, Active power filter (APF) for mitigation of power quality issues in grid integration of wind and photovoltaic energy conversion system, Renewable Sustainable Energy Rev. 70 (2017) 635–655.

[55] M. Jayaraman, V.T. Sreedevi, R. Balakrishnan, Analysis and design of passive filters for power quality improvement in standalone PV systems, in: 2013 Nirma University International Conference on Engineering (NUiCONE), IEEE, 2013, pp. 1–6.

[56] Z.A. Memon, M.A. Uquaili, M.A. Unar, Harmonics mitigation of industrial power system using passive filters. arXiv preprint arXiv:1605.06684. 2016.

[57] L. Zhao, M. Wu, Q. Liu, P. Peng, J. Li, Hybrid power quality compensation system for electric railway supplied by the hypotenuse of a Scott transformer, IEEE Access. 8 (2020) 227024–227035.

[58] I.D. Melo, J.L. Pereira, A.M. Variz, P.F. Ribeiro, Allocation and sizing of single tuned passive filters in three-phase distribution systems for power quality improvement, Electr. Power Syst. Res. 180 (2020) 106128.

[59] L. Morán, J. Dixon, M. Torres, 41-Active Power Filters, Editor (s): Muhammad H. Rashid. Power Electronics Handbook (Fourth Edition), Butterworth-Heinemann, 2018, pp. 1341–1379.

[60] S. Samal, P.K. Barik, P.K. Hota, Harmonics mitigation of a solar PV-fuel cell based microgrid system using a shunt active power filter, ECTI Trans. Electr. Eng., Electron., Commun. 19 (2) (2021) 127–135.

[61] M. Karthikeyan, K. Sharmilee, P.M. Balasubramaniam, N.B. Prakash, M.R. Babu, V. Subramaniyaswamy, S. Sudhakar, Design and implementation of ANN-based SAPF approach for current harmonics mitigation in industrial power systems, Microprocess. Microsyst. 77 (2020) 103194.

[62] M. Büyük, A. Tan, M. İnci, M. Tümay, A notch filter based active damping of llcl filter in shunt active power filter, in: In2017 International Symposium on Power Electronics (Ee), IEEE, 2017, pp. 1–6.

[63] S. Biricik, S. Redif, Ö.C. Özerdem, S.K. Khadem, M. Basu, Real-time control of shunt active power filter under distorted grid voltage and unbalanced load condition using self-tuning filter, IET Power Electron. 7 (7) (2014) 1895–1905.

[64] R. Noroozian, G.B. Gharehpetian, An investigation on combined operation of active power filter with photovoltaic arrays, Int. J. Electr. Power Energy Syst. 46 (2013) 392–399.

[65] Mahmoud MO, W. Mamdouh, H. Khalil, Power system distortion mitigation by using series active power filter, Int. J. Ind. Sustainable Dev. 1 (2) (2020) 36–48.

[66] V. Gali, N. Gupta, R.A. Gupta, Mitigation of power quality problems using shunt active power filters: a comprehensive review, in: 2017 12th IEEE Conference on Industrial Electronics and Applications (ICIEA), IEEE, 2017, pp. 1100–1105.

[67] C.M. Thuyen, A new design algorithm for hybrid active power filter, Int. J. Electr. Comput. Eng. 9 (6) (2019) (2088-8708).

[68] M. Büyük, A. Tan, M. Tümay, K.Ç. Bayındır, Topologies, generalized designs, passive and active damping methods of switching ripple filters for voltage source inverter: a comprehensive review, Renewable Sustainable Energy Rev. 62 (2016) 46–69.

[69] B. Exposto, V. Monteiro, J.G. Pinto, D. Pedrosa, A.A. Meléndez, J.L. Afonso, Three-phase current-source shunt active power filter with solar photovoltaic grid interface, in: In2015 IEEE International Conference on Industrial Technology (ICIT), IEEE, 2015, pp. 1211–1215.

[70] A. Sahli, F. Krim, A. Laib, B. Talbi, Model predictive control for single phase active power filter using modified packed U-cell (MPUC5) converter, Electr. Power Syst. Res. 180 (2020) 106139.

[71] M. Popescu, A. Bitoleanu, C.V. Suru, M. Linca, G.E. Subtirelu, Adaptive control of DC voltage in three-phase three-wire shunt active power filters systems, Energies 13 (12) (2020) 3147.

[72] M. Kumar, Z.A. Memon, M.A. Uqaili, Design and implementation of hybrid active power filter (HAPF) for UPS system, Int. J. Integr. Eng. 12 (6) (2020) 229–238.

[73] S. Rahmani, A. Hamadi, K. Al-Haddad, A comprehensive analysis of hybrid active power filter for power quality enhancement, in: IECON 2012-38th Annual Conference on IEEE Industrial Electronics Society, IEEE, 2012, pp. 6258–6267.

[74] J.C. Wu, H.L. Jou, K.D. Wu, H.H. Hsiao, Three-phase four-wire hybrid power filter using a smaller power converter, Electr. Power Syst. Res. 87 (2012) 13–21.

[75] C. Gong, W.K. Sou, C.S. Lam, Second-order sliding-mode current controller for LC-coupling hybrid active power filter, IEEE Trans. Ind. Electron. 68 (3) (2020) 1883–1894.

[76] K. Rameshkumar, V. Indragandhi, K. Palanisamy, T. Arunkumari, Model predictive current control of single phase shunt active power filter, Energy Procedia 117 (2017) 658–665.

[77] L. Wang, C.S. Lam, M.C. Wong, Unbalanced control strategy for a thyristor-controlled LC-coupling hybrid active power filter in three-phase three-wire systems, IEEE Trans. Power. Electron. 32 (2) (2016) 1056–1069.

[78] D.I. Brandao, T. Caldognetto, F.P. Marafao, M.G. Simões, J.A. Pomilio, P. Tenti, Centralized control of distributed single-phase inverters arbitrarily connected to three-phase four-wire microgrids, IEEe Trans. Smart. Grid. 8 (1) (2016) 437–446.

[79] P.P. Biswas, P.N. Suganthan, G.A. Amaratunga, Minimizing harmonic distortion in power system with optimal design of hybrid active power filter using differential evolution, Appl. Soft. Comput. 61 (2017) 486–496.

[80] D. Li, K. Yang, Z.Q. Zhu, Y. Qin, A novel series power quality controller with reduced passive power filter, IEEE Trans. Ind. Electron. 64 (1) (2016) 773–784.

[81] T. Demirdelen, R.I. Kayaalp, M. Tumay, Simulation modelling and analysis of modular cascaded multilevel converter based shunt hybrid active power filter for large scale photovoltaic system interconnection, Simul. Model. Pract. Theory. 71 (2017) 27–44.

[82] M. Vijayakumar, S. Vijayan, Photovoltaic based three-phase four-wire series hybrid active power filter for power quality improvement.

[83] I. Aboudrar, S El Hani, Hybrid algorithm and active filtering dedicated to the optimization and the improvement of photovoltaic system connected to grid energy quality, Int. J. Renewable Energy Res. (IJRER) 7 (2) (2017) 894–900.

[84] M. Pichan, H. Rastegar, A new hybrid controller for standalone photovoltaic power system with unbalanced loads, Int. J. Photoenergy 2020 (2020).

[85] A.A. Smadi, H. Lei, B.K. Johnson, Distribution system harmonic mitigation using a pv system with hybrid active filter features, in: 2019 North American Power Symposium (NAPS), IEEE, 2019, pp. 1–6.

[86] O.F. Kececioglu, H. Acikgoz, C. Yildiz, A. Gani, M. Sekkeli, Power quality improvement using hybrid passive filter configuration for wind energy systems, J. Electr. Eng. Technol. 12 (1) (2017) 207–216.

[87] K.N. Hasan, K. Rauma, A. Luna, J.I. Candela, P. Rodríguez, Harmonic compensation analysis in offshore wind power plants using hybrid filters, IEEE Trans. Ind. Appl. 50 (3) (2013) 2050–2060.

[88] B. Chen, C. Zhang, W. Zeng, G. Xue, C. Tian, J. Yuan, Electrical magnetic hybrid power quality compensation system for V/V traction power supply system, IET Power Electron. 9 (1) (2016) 62–70.

[89] S. Hu, Z. Zhang, Y. Chen, G. Zhou, Y. Li, L. Luo, Y. Cao, B. Xie, X. Chen, B. Wu, C. Rehtanz, A new integrated hybrid power quality control system for electrical railway, IEEE Trans. Ind. Electron. 62 (10) (2015) 6222–6232.

[90] B. Kędra, Reducing inverter power rating in active power filters using proposed hybrid power filter topology, in: 2015 IEEE 15th International Conference on Environment and Electrical Engineering (EEEIC), IEEE, 2015, pp. 443–448.

[91] D. Buła, M. Pasko, Model of hybrid active power filter in the frequency domain. Lecture Notes in Electrical Engineering, Springer International Publishing, 2014, pp. 15–26.

[92] S. Parthasarathy, S.C. Kanakavel, S.A. Karthickkumar, A harmonic distortion analysis of power distribution systems with hybrid power filter, in: 2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT), IEEE, 2016.

[93] C. Boonseng, R. Boonseng, K. Kularbphettong, The 3rd harmonic current and power quality improvements of data centers using hybrid power filters, in: 2019 22nd International Conference on Electrical Machines and Systems (ICEMS), IEEE, 2019.

[94] A.K. Mishra, S.R. Das, P.K. Ray, R.K. Mallick, A. Mohanty, D.K. Mishra, PSO-GWO optimized fractional order PID based hybrid shunt active power filter for power quality improvements, IEEE Access. 8 (2020) 74497–74512.

[95] L. Jianben, D. Shaojun, C. Qiaofu, T. Kun, Modelling and industrial application of series hybrid active power filter, IET Power Electron. 6 (8) (2013) 1707–1714.

[96] P.N. Babu, B. Kar, B. Halder, Comparative analysis of a Hybrid active power filter for power quality improvement using different compensation techniques, in:

2016 International Conference on Recent Advances and Innovations in Engineering (ICRAIE), IEEE, 2016.
[97] Z. Luo, M. Su, Y. Sun, W. Zhang, Z. Lin, Analysis and control of a reduced switch hybrid active power filter, IET Power Electron. 9 (7) (2016) 1416–1425.
[98] W.J. Praiselin, J.B. Edward, Voltage profile improvement of solar PV grid connected inverter with micro grid operation using PI controller, Energy Procedia 117 (2017) 104–111.
[99] G.S. Narayana, C.N. Kumar, C. Rambabu, A comparative analysis of PI controller and fuzzy logic controller for hybrid active power filter using dual instantaneous power theory, Int. J. Eng. Res. Dev. 4 (6) (2012) 29–39.
[100] M.I. Mosaad, M.O.A. El-Raouf, M.A. Al-Ahmar, F.M. Bendary, Optimal PI controller of DVR to enhance the performance of hybrid power system feeding a remote area in Egypt, Sustain. Cities Soc. 47 (2019) 101469.
[101] P. Lino, G. Maione, S. Stasi, F. Padula, A Visioli, Synthesis of fractional-order PI controllers and fractional-order filters for industrial electrical drives, IEEE/CAA J. Autom. Sin. 4 (1) (2017) 58–69.
[102] A.L.L.F. Murari, J.A.T. Altuna, R.V. Jacomini, C.M.R. Osorio, J.S.S. Chaves, A.J. S. Filho, A proposal of project of PI controller gains used on the control of doubly-fed induction generators, IEEE Lat. Am. Trans. 15 (2) (2017) 173–180.
[103] A. Uphues, K. Notzold, R. Wegener, S. Soter, PR-controller in a 2MW grid side windpower converter, in: 2012 IEEE International Conference on Industrial Technology, IEEE, 2012.
[104] A. Javadi, A. Hamadi, A. Ndtoungou, K. Al-Haddad, Power quality enhancement of smart households using a multilevel-THSeAF with a PR controller, IEEE Trans. Smart. Grid. 8 (1) (2017) 465–474.
[105] S.K. Dash, Pravat Kumar Ray, Power quality improvement utilizing PV fed unified power quality conditioner based on UV-PI and PR-R controller, CPSS Trans. Power Electron. Appl. 3 (3) (2018) 243–253.
[106] C.B. Tischer, J.R. Tibola, L.G. Scherer, R.F. Camargo, Proportional-resonant control applied on voltage regulation of standalone SEIG for micro-hydro power generation, IET Renew. Power Gen. 11 (5) (2017) 593–602.
[107] A.S. Pabbewar, M. Kowsalya, Three level neutral point clamped inverter using space vector modulation with proportional resonant controller, Energy Procedia 103 (2016) 286–291.
[108] T. Ye, N. Dai, C.-S. Lam, M.-C. Wong, J.M. Guerrero, Analysis, design, and implementation of a quasi-proportional-resonant controller for a multifunctional capacitive-coupling grid-connected inverter, IEEE Trans. Ind. Appl. 52 (5) (2016) 4269–4280.
[109] T.D. Raj, K. Chandrasekaran, Dynamic performance improvement of Buck-Cuk converter in renewable energy resources using EHO optimised PR controller, IET Power Electron. 13 (14) (2020) 3009–3017.
[110] S.A. Singh, N.A. Azeez, S.S. Williamson, Capacitance reduction in a single phase Quasi Z-Source Inverter using a hysteresis current controlled active power filter, in: 2016 IEEE 25th International Symposium on Industrial Electronics (ISIE), IEEE, 2016.
[111] A.E.M. Bouzid, P. Sicard, A. Cheriti, H. Chaoui, P.M. Koumba, Adaptive hysteresis current control of active power filters for power quality improvement, in: In: 2017 IEEE Electrical Power and Energy Conference (EPEC), IEEE, 2017.
[112] V. Prasad, J.P. R, S V, Hysteresis current controller for a micro-grid application, in: 2016 International Conference on Energy Efficient Technologies for Sustainability (ICEETS), IEEE, 2016.
[113] S.R. Mohamed, P.A. Jeyanthy, D. Devaraj, Hysteresis-based voltage and current control techniques for grid connected solar photovoltaic systems: comparative study, Int J Electr. Comput. Eng. 8 (5) (2018) 2671.
[114] H. Geng, T. Zou, A. Chandra, Fast repetitive control Scheme for shunt active power filter in Synchronous Rotational Frame, in: 2017 IEEE Industry Applications Society Annual Meeting, IEEE, 2017.
[115] G. Pandove, M. Singh, Robust repetitive control design for a three-phase four wire shunt active power filter, IEEE Trans. Ind. Inform. 15 (5) (2019) 2810–2818.
[116] C. Xie, X. Zhao, M. Savaghebi, L. Meng, J.M. Guerrero, J.C. Vasquez, Multirate fractional-order repetitive control of shunt active power filter suitable for microgrid applications, IEEE J. Emerg. Sel. Top. Power. Electron. 5 (2) (2017) 809–819.
[117] F.F. Costa, A.J.S. Filho, C.E. Capovilla, I.R.S. Casella, Morphological filter applied in a wireless deadbeat control scheme within the context of smart grids, Electr. Power Syst. Res. 107 (2014) 175–182.
[118] S.S. Seyedalipour, A novel deadbeat control for three-phase grid-connected VSI with an output LCL filter in natural frame, in: 2019 International Power System Conference (PSC), IEEE, 2019.
[119] F. Wang, D. Ke, X. Yu, D. Huang, Enhanced predictive model based deadbeat control for PMSM drives using exponential extended state observer, IEEE Trans. Ind. Electron. (2021) 1. Published online.
[120] S. Li, C. Gu, P. Zhao, S. Cheng, A novel hybrid propulsion system configuration and power distribution strategy for light electric aircraft, Energy Convers. Manage 238 (2021) 114171.
[121] M.G. Afjeh, M. Babaei, M.A. Bidgoli, A. Ahmarinejad, Deadbeat control of a modified single-phase five-level photovoltaic inverter with reduced number of switches. Wen H, ed, Int. J. Photoenergy 2020 (2020) 1–16.
[122] P. Zhang, W. Wang, M. Gao, Y. Wang, Square-root cubature Kalman filter based on H∞ filter for attitude measurement of high-spinning aircraft. Palmerini G, ed, Int. J. Aerosp. Eng. 2021 (2021) 1–11.
[123] H.R. Baghaee, M. Mirsalim, G.B. Gharehpetian, H.A. Talebi, A generalized descriptor-system robust H∞ control of autonomous microgrids to improve small and large signal stability considering communication delays and load nonlinearities, Int. J. Electr. Power Energy Syst. 92 (2017) 63–82.
[124] C. Yang, X. Jiao, L. Li, Y. Zhang, Z. Chen, A robust H∞ control-based hierarchical mode transition control system for plug-in hybrid electric vehicle, Mech. Syst. Signal. Process. 99 (2018) 326–344.
[125] L. Huang, H. Xin, F. Dorfler, H∞-control of grid-connected converters: design, objectives and decentralized stability certificates, IEEE Trans. Smart. Grid. 11 (5) (2020) 3805–3816.
[126] Q.L. Lam, A.I. Bratcu, D. Riu, C. Boudinet, A. Labonne, M. Thomas, Primary frequency H∞ control in stand-alone microgrids with storage units: a robustness analysis confirmed by real-time experiments, Int. J. Electr. Power Energy Syst. 115 (2020) 105507.
[127] M.Y. Hammoudi, R. Saadi, A.J.M. Cardoso, M.E.H. Benbouzid, M. Sahraoui, Practical implementation of H-infinity control for fuel cell-interleaved boost converter, Int. J. Model. Simul. 40 (1) (2018) 44–61.
[128] N. Yildiran, E. Tacer, A new approach to h-infinity control for grid-connected inverters in photovoltaic generation systems, Electr. Power Components Syst. 47 (14–15) (2019) 1413–1422.
[129] Y.-M. Kim, Robust data driven H-infinity control for wind turbine, J. Franklin. Inst. 353 (13) (2016) 3104–3117.
[130] A.A.A. Elgammal, M.F El-naggar, MOPSO-based optimal control of shunt active power filter using a variable structure fuzzy logic sliding mode controller for hybrid (FC-PV-Wind-Battery) energy utilisation scheme, IET Renew. Power Gen. 11 (8) (2017) 1148–1156.
[131] H. Radmanesh, G.B. Gharehpetian, Harmonic distortion reduction of commercial airplane electrical power system using fuzzy logic based current control of active power filter, Int. Trans. Electr. Energy Syst. 31 (4) (2021) e12811.
[132] A. Amirullah, Adiananda Adiananda, O. Penangsang, A. Soeprijanto, Load active power transfer enhancement using UPQC-PV-BES system with fuzzy logic controller, Int. J. Intell. Eng. Syst. 13 (2) (2020) 329–349.
[133] M.A. Rajabinezhad, A.G. Baayeh, J.M. Guerrero, Fuzzy-based power management and power quality improvement in microgrid using battery energy storage system, in: 2020 10th Smart Grid Conference (SGC), IEEE, 2020.
[134] S. Choudhury, P.K. Rout, Modelling and simulation of fuzzy-based MPPT control of grid connected PV system under variable load and irradiance, Int. J. Intell. Syst. Technol. Appl. 18 (6) (2019) 531–559.
[135] S. Choudhury, P. Bhowmik, P.K. Rout, Economic load sharing in a D-STATCOM integrated islanded microgrid based on fuzzy logic and seeker optimization approach, Sustain. Cities Soc. 37 (2018) 57–69.
[136] A.A. Hussein, Adaptive artificial neural network-based models for instantaneous power estimation enhancement in electric vehicles' Li-Ion batteries, IEEE Trans. Ind. Appl. 55 (1) (2019) 840–849.
[137] A.A. Tanvir, A. Merabet, Artificial neural network and kalman filter for estimation and control in standalone induction generator wind energy DC microgrid, Energies 13 (7) (2020) 1743.
[138] R. Rajkumar, U.S Ragupathy, An ANN-based harmonic mitigation and power injection technique for solar-fed distributed generation system, Soft. Comput. 24 (20) (2020) 15763–15772.
[139] S. Ray, N. Gupta, R.A. Gupta, Modified three-layered artificial neural network-based improved control of multilevel inverters for active filtering. Advances in Intelligent Systems and Computing, Springer, Singapore, 2018, pp. 547–558.
[140] S.C. Paiva, R.L. de Araujo Ribeiro, D.K. Alves, F.B. Costa, T. de Oliveira Alves Rocha, A wavelet-based hybrid islanding detection system applied for distributed generators interconnected to AC microgrids, Int. J. Electr. Power Energy Syst. 121 (2020) 106032.
[141] N.G. Hingorani, FACTS technology - state of the art, current challenges and the future prospects, in: 2007 IEEE Power Engineering Society General Meeting, IEEE, 2007.
[142] I.N. Muisyo, K.K. Kaberere, Utilization of FACTS devices in power systems: a review, in: Proceedings of Sustainable Research and Innovation Conference, 2018, pp. 1–7.
[143] M. Lima, S.L. Nilsson, Technical description of static var compensators (SVC). In: CIGRE Green Books, Springer International Publishing, 2020, pp. 155–206.
[144] S. Choudhury, N. Khandelwal, T.P. Dash, A unified scheme of PSS and SVC for voltage profile improvement in electrical grid network, in: 2021 1st Odisha International Conference on Electrical Power Engineering, Communication and Computing Technology{ODICON), IEEE, 2021.
[145] N.A. Lahaçani, D. Aouzellag, B. Mendil, Contribution to the improvement of voltage profile in electrical network with wind generator using SVC device, Renew. Energy 35 (1) (2010) 243–248.
[146] H. Rezaie, M.H. Kazemi-Rahbar, Enhancing voltage stability and LVRT capability of a wind-integrated power system using a fuzzy-based SVC, Eng. Sci. Technol. Int. J. 22 (3) (2019) 827–839.
[147] H. Wang, Y. Liu, K. Yan, Y. Fu, C Zhang, Analysis of static VAr compensators installed in different positions in electric railways, IET Electr. Syst. Transp. 5 (3) (2015) 129–134.
[148] T. Charoenchan, K. Bhumkittipich, A study of voltage stability improvement for EEC high-speed electrified railway system using SVC, in: 2021 18th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), IEEE, 2021.
[149] J. Balcells, P. Bogonez-Franco. Voltage control in a LV microgrid by means of an SVC. In: IECON 2013, IEEE, 2013.
[150] M. Červnan, Z. Müller, J. Tlustý, V. Valouch, An improved SVC control for electric arc furnace voltage flicker mitigation, Int. J. Electr. Power Energy Syst. 129 (2021) 106831.
[151] S. Morello, T.J. Dionise, T.L. Mank, Installation, startup and performance of a static var compensator for an electric arc furnace upgrade, in: 2015 IEEE Industry Applications Society Annual Meeting, IEEE, 2015.

[152] H. Samet, A. Mojallal, T. Ghanbari, M.R. Farhadi, Enhancement of SVC performance in electric arc furnace for flicker suppression using a Gray-ANN based prediction method, Int. Trans. Electr. Energy Syst. 29 (4) (2018) e2811.

[153] A.A. Nikolaev, V.V. Anokhin, I.A. Lozhkin, Estimation of accuracy of chosen SVC power for steel-making arc furnace, in: 2016 2nd International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM), IEEE, 2016.

[154] S. Rahman, M. Meraj, A. Iqbal, L. Ben-Brahim, R. Alammari, Thyristor based SVC and multilevel qZSI for active and reactive power management in solar PV system, in: 2017 11th IEEE International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG), IEEE, 2017.

[155] S.R. Paital, P.K. Ray, A. Mohanty, S. Dash, Stability improvement in solar PV integrated power system using quasi-differential search optimized SVC controller, Optik 170 (2018) 420–430.

[156] P.K. Ray, S.R. Paital, A. Mohanty, T.K. Panigrahi, Improvement of stability in solar energy based power system using hybrid PSO-GS based optimal SVC damping controller, Energy Procedia 109 (2017) 130–137.

[157] D.C. Das, H. Sriramoju, S. Ranjan, N. Sinha, Voltage control of fuel cell-wind-diesel hybrid power system using FA based SVC and AVR controller, in: 2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), IEEE, 2017.

[158] Y. Mi, C. Ma, S. Wang, C. Bi, Y. Zhu, H. Zhang, Reactive power control of an isolated wind-diesel hybrid power system based on SVC by using sliding mode control, in: 2016 35th Chinese Control Conference (CCC), IEEE, 2016.

[159] A. Banerjee, P.K. Guchhait, V. Mukherjee, S.P. Ghoshal, Seeker optimized SVC-PID controller for reactive power control of an isolated hybrid power system, Energy Syst. 10 (4) (2018) 985–1015.

[160] S.G. Farkoush, C.H. Kim, H.C. Jung, S. Lee, N. Theera-Umpon, S.B. Rhee, Power factor improvement of distribution system with EV chargers based on SMC method for SVC, J. Electr. Eng. Technol. 12 (4) (2017) 1340–1347.

[161] P. Juanuwattanakul, M.A. Masoum, S. Hajforoosh, Application of SVC and single-phase shunt capacitor to improve voltage profiles and reduce losses of unbalanced multiphase smart grid with PEV charging stations, in: 2012 22nd Australasian Universities Power Engineering Conference (AUPEC), IEEE, 2012, pp. 1–6.

[162] S. Choudhury, T. Dash, Modified brain storming optimization technique for transient stability improvement of SVC controller for a two machine system, World J. Eng. (2021).

[163] E.A. Awad, E.A. Badran, F.H. Youssef, Mitigation of switching overvoltages in microgrids based on SVC and supercapacitor, IET Gener. Transm. Distrib. 12 (2) (2017) 355–362.

[164] N. Fardad, S. Soleymani, F. Faghihi, Voltage sag investigation of microgrid in the presence of SMES and SVC, Signal Process. Renewable Energy 3 (1) (2019) 23–34.

[165] N. Agrawal, Extensive and classified literature review on facts device: TCSC.

[166] S. Choudhury, P. Rout, A. Satpathy, S. Bhakat, D. Pradhan, T.P. Dash, Spider monkey optimization technique for damping inter area oscillations through unified design of PSS and TCSC, in: In2018 International Conference on Smart Systems and Inventive Technology (ICSSIT, IEEE, 2018, pp. 16–21.

[167] P. Kathal, A. Bhandakkar, Power flow control in power system using FACT device thyristor controlled series capacitor (TCSC): a review, Int. J. Innovat. Res. Dev. 2 (4) (2013) 127–145.

[168] S.K. Rautray, S. Choudhury, S. Mishra, P.K. Rout, A particle swarm optimization based approach for power system transient stability enhancement with TCSC, Procedia Technol. 6 (2012) 31–38.

[169] C.A. Ordóñez, A. Gómez-Expósito, J.M. Maza-Ortega, Series compensation of transmission systems: a literature survey, Energies 14 (6) (2021) 1717.

[170] K. Zare, M.T. Hagh, J. Morsali, Effective oscillation damping of an interconnected multi-source power system with automatic generation control and TCSC, Int. J. Electr. Power Energy Syst. 65 (2015) 220–230.

[171] H. Hasanvand, M.R. Arvan, B. Mozafari, T. Amraee, Coordinated design of PSS and TCSC to mitigate interarea oscillations, Int. J. Electr. Power Energy Syst. 78 (2016) 194–206.

[172] G. Shahgholian, A. Movahedi, J. Faiz, Coordinated design of TCSC and PSS controllers using VURPSO and genetic algorithms for multi-machine power system stability, Int. J. Control, Autom. Syst. 13 (2) (2015) 398–409.

[173] G.D. Shivalingswamy, P. Anjali, A review on improvement of power quality and performance using LVRT for grid connected solar farms with split TCSC, in: In2019 1st International Conference on Advanced Technologies in Intelligent Control, Environment, Computing & Communication Engineering (ICATIECE), IEEE, 2019, pp. 369–371.

[174] P. Dhawale, D. Gowda, S.M. Sandeep, Design and implementation of TCSC in renewable energy.

[175] A.Q. Al-Shetwi, M.Z. Sujod, F. Blaabjerg, Y. Yang, Fault ride-through control of grid-connected photovoltaic power plants: a review, Solar Energy 180 (2019) 340–350.

[176] L. Piyasinghe, Z. Miao, J. Khazaei, L. Fan, Impedance model-based SSR analysis for TCSC compensated type-3 wind energy delivery systems, IEEE Trans. Sustain. Energy 6 (1) (2014) 179–187.

[177] S. Biswas, P.K. Nayak, A new approach for protecting TCSC compensated transmission lines connected to DFIG-based wind farm, IEEE Trans. Ind. Inform. 17 (8) (2020) 5282–5291.

[178] C. Yao, X. Wang, C. Bi, The analysis and modeling of TCSC in the low-frequency oscillation suppression of electrified railway, in: 2019 IEEE 3rd International Electrical and Energy Conference (CIEEC), IEEE, 2019, pp. 2123–2126.

[179] C. Yao, X. Wang, C. Bi, Y. Zhang, C Jin, An approach to suppress low-frequency oscillation in electrification railway based on TCSC impedance control, in: 2018 IEEE 2nd International Electrical and Energy Conference (CIEEC, IEEE, 2018, pp. 110–113.

[180] H. Amootaghi, S. Shojaeian, E.S. Naeini, Enhancing low frequency oscillations damping of a power system by a TCSC controlled with sliding mode method, Majlesi J. Electr. Eng. 12 (1) (2018) 31–37.

[181] B.R. Reddy, Performance of fractional order robust controller for LFC of EVs integrated three area deregulated power system, in: 2021 2nd International Conference for Emerging Technology (INCET), IEEE, 2021, pp. 1–7.

[182] A. Mohanty, M. Viswavandya, D. Mishra, P. Paramita, S.P. Mohanty, Intelligent voltage and reactive power management in a standalone PV based microgrid, Procedia Technol. 21 (2015) 443–451.

[183] S. Singh, S.P. Jaiswal, Enhancement of ATC of micro grid by optimal placement of TCSC, Mater. Today: Proceedings 34 (2021) 787–792.

[184] Z. Luburić, H. Pandžić, M. Carrión, Transmission expansion planning model considering battery energy storage, TCSC and lines using AC OPF, IEEE Access. 8 (2020) 203429–203439.

[185] S. Padhan, R.K. Sahu, S. Panda, Automatic generation control with thyristor controlled series compensator including superconducting magnetic energy storage units, Ain Shams Eng. J. 5 (3) (2014) 759–774.

[186] P. Jena, A.K. Pradhan, Directional relaying in the presence of a thyristor-controlled series capacitor, IEEE Trans. Power Deliv. 28 (2) (2013) 628–636.

[187] T. Nireekshana, J. Bhavani, Y. Venu, B. Phanisaikrishna, Power transmission congestion management by TCSC Using PSO, in: In2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC), IEEE, 2020, pp. 491–497.

[188] A.H. Elmetwaly, A.A. Eldesouky, A.A. Sallam, An adaptive D-FACTS for power quality enhancement in an isolated microgrid, IEEE Access. 8 (2020) 57923–57942.

[189] J. Urquizo, P. Singh, N. Kondrath, R. Hidalgo-León, G. Soriano, Using D-FACTS in microgrids for power quality improvement: a review, in: In2017 IEEE Second Ecuador Technical Chapters Meeting (ETCM), IEEE, 2017, pp. 1–6.

[190] Z.H. Saleh, Z.H. Ali, R.W. Daoud, A.H. Ahmed, A study of voltage regulation in microgrid using a DSTATCOM, Bull. Electr. Eng. Inform. 9 (5) (2020) 1766–1773.

[191] C.T. Lee, C.C. Chu, P.T. Cheng, A new droop control method for the autonomous operation of distributed energy resource interface converters, IEEE Trans. Power Electron.. 28 (4) (2012) 1980–1993.

[192] I. Zunnurain, Y. Sang, A stochastic optimization model for distributed static series compensator allocation to mitigate transmission congestion, in: 2020 52nd North American Power Symposium (NAPS), IEEE, 2021, pp. 1–6.

[193] Z. Shuai, W. Huang, X. Shen, Y. Li, X. Zhang, Z.J. Shen, A maximum power loading factor (MPLF) control strategy for distributed secondary frequency regulation of islanded microgrid, IEEE Trans. Power. Electron. 34 (3) (2018) 2275–2291.

[194] M. Anand, A. Kumar, R. Dev, P. Kumar, Integration of DSTATCOM and distributed generation with nonlinear loads, in: Computational Advancement in Communication Circuits and Systems, Springer, Singapore, 2020, pp. 15–24.

[195] N.H. Baharudin, M.A. Ridzwan, T.M. Mansur, R. Ali, K. Ananda-Rao, E.C. Mid, S. M. Suboh, A.M. Abdullah, Design and performance analysis of Grid Connected Photovoltaic (GCPV) based DSTATCOM for power quality improvements, J. Phys.: Conf. Ser. 1878 (1) (2021) 012032. IOP Publishing.

[196] N. Patel, N. Gupta, B.C. Babu, Photovoltaic system operation as DSTATCOM for power quality improvement employing active current control, IET Gen., Transm. Distrib. 14 (17) (2020) 3518–3529.

[197] V.K. Kannan, N. Rengarajan, Investigating the performance of photovoltaic based DSTATCOM using I cos Φ algorithm, Int. J. Electr. Power Energy Syst. 54 (2014) 376–386.

[198] A. Kumar, V.M. Mishra, R. Ranjan, Fuzzy distribution static compensator based control strategy to enhance low voltage ride through capability of hybrid renewable energy system, Energy Sources, Part A: Recov., Utiliz., Environ. Effects (2021) 1–8.

[199] S.N. Duarte, P.M. Almeida, P.G. Barbosa, Voltage compensation in multi-grounded distribution network with a three-phase five-wire DSTATCOM.☆, Electr. Power Syst. Res. 197 (2021) 107310.

[200] A.M. Eltamaly, Y.S. Mohamed, A.H. El-Sayed, A.N. Elghaffar, AG. Abo-Khalil, D-STATCOM for distribution network compensation linked with wind generation, Control Oper. Grid-Connect. Wind Energy Syst. (2021) 87–107.

[201] M. Aly, E.M. Ahmed, M. Shoyama, Thermal and reliability assessment for wind energy systems with DSTATCOM functionality in resilient microgrids, IEEE Trans. Sustain. Energy 8 (3) (2016) 953–965.

[202] G.S. Chawda, A.G. Shaik, Adaptive reactive power control of dstatcom in weak ac grid with high wind energy penetration, in: 2019 IEEE 16th India Council International Conference (INDICON), IEEE, 2019, pp. 1–4.

[203] O.P. Mahela, A.G. Shaik, Power quality improvement in distribution network using DSTATCOM with battery energy storage system, Int. J. Electr. Power Energy Syst. 83 (2016) 229–240.

[204] S.R. Ghatak, S. Sannigrahi, P. Acharjee, Optimised planning of distribution network with photovoltaic system, battery storage, and DSTATCOM, IET Renewable Power Gen. 12 (15) (2018) 1823–1832.

[205] J. Hussain, M. Hussain, S. Raza, M. Siddique, Power quality improvement of grid connected wind energy system using DSTATCOM-BESS, Int. J. Renewable Energy Res. 9 (3) (2019) 1388–1397.

[206] M. Bagheri, V. Nurmanova, O. Abedinia, M.S. Naderi, Enhancing power quality in microgrids with a new online control strategy for DSTATCOM using reinforcement learning algorithm, IEEE Access 6 (2018) 38986–38996.

[207] M. Goyal, B. John, A. Ghosh, Harmonic mitigation in an islanded microgrid using a DSTATCOM, in: 2015 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), IEEE, 2015, pp. 1–5.

[208] A.V. Jayawardena, L.G. Meegahapola, D.A. Robinson, S. Perera, Low-voltage ride-through characteristics of microgrids with distribution static synchronous compensator (DSTATCOM), in: 2015 Australasian Universities Power Engineering Conference (AUPEC), IEEE, 2015, pp. 1–6.

[209] T.L. Lee, S.H. Hu, Y.H. Chan, Design of D-STATCOM for voltage regulation in microgrids, in: 2010 IEEE Energy Conversion Congress and Exposition, IEEE, 2010, pp. 3456–3463.

[210] P. Prabhakar, H. Vennila, Power quality improvement in microgrid using custom power devices, Int. J. Enterprise Network Manage. 8 (4) (2017) 327–339.

[211] G. Kumar, C.A. Babu, A zig-zag transformer and three-leg VSC based DSTATCOM for a diesel generator based microgrid, Procedia Technol. 21 (2015) 310–316.

[212] K.B. Kumar, A.K. Eedara, V.L. Sastry, V. Ramakrishna, Modeling & simulation of DSTATCOM for power quality improvement of diesel generator stand alone system, Int. J. Innov. Res. Dev. 1 (8) (2012) 643–657.

[213] A. Bala, G. Thakur, L. Matthew, Design and implementation of three phase three level inverter based DSTATCOM, in: 2017 4th International Conference on Power, Control & Embedded Systems (ICPCES), IEEE, 2017, pp. 1–5.

[214] V. Vivek, S. Krishnakumar, Cascaded multilevel H-Bridge inverter based DSTATCOM for voltage compensation, in: In2014 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), IEEE, 2014, pp. 348–352.

[215] J.I. Ota, Y. Shibano, H. Akagi, A phase-shifted PWM D-STATCOM using a modular multilevel cascade converter (SSBC)—Part II: zero-voltage-ride-through capability, IEEe Trans. Ind. Appl. 51 (1) (2014) 289–296.

[216] M.S. Mahmoud, N.M. Alyazidi, M.I. Abouheaf, Adaptive intelligent techniques for microgrid control systems: a survey, Int. J. Electr. Power Energy Syst. 90 (2017) 292–305.

[217] M.I. Mosaad, H.S. Ramadan, Power quality enhancement of grid-connected fuel cell using evolutionary computing techniques, Int. J. Hydrogen Energy 43 (25) (2018) 11568–11582.

[218] A. Krama, L. Zellouma, B. Rabhi, S.S. Refaat, M. Bouzidi, Real-Time implementation of high performance control scheme for grid-tied PV system for power quality enhancement based on MPPC-SVM optimized by PSO algorithm, Energies 11 (12) (2018) 3516.

[219] H. Bevrani, F. Habibi, P. Babahajyani, M. Watanabe, Y. Mitani, Intelligent frequency control in an AC microgrid: online PSO-based fuzzy tuning approach, IEEe Trans. Smart. Grid. 3 (4) (2012) 1935–1944.

[220] U. Sultana, S.H. Qazi, N. Rasheed, M.W. Mustafa, Performance analysis of real-time PSO tuned PI controller for regulating voltage and frequency in an AC microgrid, Int. J. Electr. Comput. Eng. 11 (2) (2021) 1068.

[221] M.G. Abdolrasol, R. Mohamed, M.A. Hannan, A.Q. Al-Shetwi, M. Mansor, F. Blaabjerg, Artificial neural network based particle swarm optimization for microgrid optimal energy scheduling, IEEe Trans. Power. Electron. (2021).

[222] M.Z. Efendi, F.D. Murdianto, R.E. Setiawan, Modeling and simulation of MPPT sepie converter using modified PSO to overcome partial shading impact on DC microgrid system, in: 2017 International Electronics Symposium on Engineering Technology and Applications (IES-ETA), IEEE, 2017, pp. 27–32.

[223] J. Song, A. Xu, W. Hou, Y. Zhang, Y. Jiang, Q. Wang, Z. Mao, H. Wen, Economic optimization of electricity generation and sales in microgrid system based on PSO, J. Phys.: Conf. Ser. 1646 (1) (2020) 012139. IOP Publishing.

[224] S. Mahaboob, S.K. Ajithan, S. Jayaraman, Optimal design of shunt active power filter for power quality enhancement using predator-prey based firefly optimization, Swarm. Evol. Comput. 44 (2019) 522–533.

[225] A.I. Omar, S.H. Aleem, E.E. El-Zahab, M. Algablawy, Z.M. Ali, An improved approach for robust control of dynamic voltage restorer and power quality enhancement using grasshopper optimization algorithm, ISA Trans. 95 (2019) 110–129.

[226] A. Almadhor, H.T. Rauf, M.A. Khan, S. Kadry, Y. Nam, A hybrid algorithm (BAPSO) for capacity configuration optimization in a distributed solar PV based microgrid, Energy Rep. (2021).

[227] G.K. Suman, J.M. Guerrero, O.P. Roy, Optimisation of solar/wind/bio-generator/diesel/battery based microgrids for rural areas: a PSO-GWO approach, Sustain. Cities. Soc. 67 (2021) 102723.

[228] M. Mohanty, S.K. Sahu, M.R. Nayak, A. Satpathy, S. Choudhury, Application of salp swarm optimization for pi controller to mitigate transients in a three-phase soft starter-based induction motor, in: Advances in Electrical Control and Signal Systems, Springer, Singapore, 2020, pp. 619–631.

[229] S. Choudhury, B. Sen, N. Khandelwal, A. Satpathy, Novel collecting decision optimization algorithm for enhanced dynamic performance of hybrid power source-based SOFC and supercapacitor for grid integration, in: Advances in Electrical Control and Signal Systems, Springer, Singapore, 2020, pp. 147–166.

[230] S. Choudhury, P.K. Rout, Design of fuzzy and HBCC based adaptive PI control strategy of an islanded microgrid system with solid-oxide fuel cell, Int. J. Renewable Energy Res. 7 (1) (2017) 34–48.

[231] S. Choudhury, B. Sen, S. Kumar, S. Sahani, A. Pattnaik, T. Dash, Improvement of performance and quality of power in grid tied SOFC through crow search optimization technique, in: 2020 5th International Conference on Communication and Electronics Systems (ICCES), IEEE, 2020, pp. 68–73.

[232] S. Choudhury, N. Khandelwal, A novel weighted superposition attraction algorithm-based optimization approach for state of charge and power management of an islanded system with battery and supercapacitor-based hybrid energy storage system, IETE J. Res. (2020) 1–4.

[233] A.S. Nayak, D.P. Acharya, S. Choudhury, Photovoltaic cell with shunt active power filter for harmonic cancelation using modified PSO-based PI controller, in: Advances in Electrical Control and Signal Systems, Springer, Singapore, 2020, pp. 455–467.

[234] S. Choudhury, P. Bhowmik, P.K. Rout, Seeker optimization approach to dynamic PI based virtual impedance drooping for economic load sharing between PV and SOFC in an islanded microgrid, Sustain. Cities. Soc. 37 (2018) 550–562.

[235] S. Choudhury, S. Nayak, T.P. Dash, P.K. Rout, A robust control approach based on seeker optimization for power quality enhancement in a grid connected diesel generator, in: In2018 Technologies for Smart-City Energy Security and Power (ICSESP), IEEE, 2018, pp. 1–6.

[236] H. Shayeghi, A. Safari, H.A. Shayanfar, PSS and TCSC damping controller coordinated design using PSO in multi-machine power system, Energy Convers. Manage 51 (12) (2010) 2930–2937.

[237] A. Askarzadeh, A memory-based genetic algorithm for optimization of power generation in a microgrid, IEEE Trans. Sustainable Energy 9 (3) (2017) 1081–1089.

[238] B. Dey, B. Bhattacharyya, Dynamic cost analysis of a grid connected microgrid using neighborhood based differential evolution technique, Int. Trans. Electr. Energy Syst. 29 (1) (2019) e2665.

[239] X. Qian, Y. Yang, C. Li, S.C. Tan, Operating cost reduction of DC microgrids under real-time pricing using adaptive differential evolution algorithm, IEEE Access. 8 (2020) 169247–169258.

[240] M.M. Awan, A.B. Asghar, M.Y. Javed, Z. Conka, Ordering technique for the maximum power point tracking of an islanded solar photovoltaic system, Sustainability 15 (4) (2023) 3332.

[241] M.M. Awan, M.Y. Javed, A.B. Asghar, K. Ejsmont, Performance optimization of a ten check MPPT algorithm for an off-grid solar photovoltaic system, Energies 15 (6) (2022) 2104.

[242] M.M. Awan, M.Y. Javed, A.B. Asghar, K. Ejsmont, Economic integration of renewable and conventional power sources—a case study, Energies 15 (6) (2022) 2141.

[243] M.M. Awan, A technical review of MPPT algorithms for solar photovoltaic system: SWOT analysis of MPPT algorithms, Sir Syed Univ. Res. J. Eng. Technol. 12 (1) (2022) 98–106.

[244] M.M. Awan, T. Mahmood, Modified flower pollination algorithm for an off-grid solar photovoltaic system, Mehran Univ. Res. J. Eng. Technol. 41 (4) (2022) 95–105.

[245] M.M. Awan, Strategic perturb and observe algorithm for partial shading conditions: SP&O algorithm for PSC, Sir Syed Univ. Res. J. Eng. Technol. 12 (2) (2022) 26–32.

[246] M.M. Awan, M.J. Awan, Adapted flower pollination algorithm for a standalone solar photovoltaic system, Mehran Univ. Res. J. Eng. Technol. 41 (4) (2022) 118–127.

[247] M.M. Awan, T. Mahmood, Optimization of maximum power point tracking flower pollination algorithm for a standalone solar photovoltaic system, Mehran Univ. Res. J. Eng. Technol. 39 (2) (2020) 267–278.

[248] M.M. Afzal Awan, T Mahmood, A novel ten check maximum power point tracking algorithm for a standalone solar photovoltaic system, Electronics 7 (11) (2018) 327.

[249] M.M. Awan, F.G. Awan, Improvement of maximum power point tracking perturb and observe algorithm for a standalone solar photovoltaic system, Mehran Univ. Res. J. Eng. Technol. 36 (3) (2017) 501–510.

[250] M.J. Awan, M.M. Awan, A.U. Khan, M. Umer, M. Zia, M. Bux, Frequency limited impulse response Gramians based model reduction, Mehran Univ. Res. J. Eng. Technol. 42 (2) (2023) 71–74.

[251] M.M. Awan, A.U. Khan, M.U. Siddiqui, H. Karim, M. Bux, Optimized hill climbing algorithm for an islanded solar photovoltaic system, Mehran Univ. Res. J. Eng. Technol. 42 (2) (2023) 124–132.

[252] V.M. De Jesus, A.F. Cupertino, L.S. Xavier, H.A. Pereira, V.F. Mendes, Operation limits of grid-tied photovoltaic inverters with harmonic current compensation based on capability curves, IEEE Trans. Energy Convers. (2021).

[253] A. Saim, A. Houari, M. Ait-Ahmed, M. Machmoum, J.M. Guerrero, Active resonance damping and harmonics compensation in distributed generation based islanded microgrids, Electr. Power Syst. Res. 191 (2021) 106900.

[254] W.N. Chang, C.M. Chang, S.K. Yen, Improvements in bidirectional power-flow balancing and electric power quality of a microgrid with unbalanced distributed generators and loads by using shunt compensators, Energies 11 (12) (2018) 3305.

[255] J.M. Pattery, S. Jayaprakasan, E.P. Cheriyan, R. Ramchand, A composite strategy for improved power quality using micro compensators in secondary distribution systems, IEEE Trans. Power Deliv. (2021).

[256] H.K. Morales-Paredes, C. Burgos-Mellado, J.P. Bonaldo, D.T. Rodrigues, J. S. Quintero, Cooperative control of power quality compensators in microgrids, in: In2021 IEEE Green Technologies Conference (GreenTech), IEEE, 2021, pp. 380–386.

[257] E.V. Liberado, F.P. Marafão, M.G. Simões, W.A. de Souza, J.A. Pomilio, Novel expert system for defining power quality compensators, Expert. Syst. Appl. 42 (7) (2015) 3562–3570.

[258] O.P. Mahela, B. Khan, H.H. Alhelou, S. Tanwar, S. Padmanaban, Harmonic mitigation and power quality improvement in utility grid with solar energy penetration using distribution static compensator, IET Power Electron. 14 (5) (2021) 912–922.

[259] E. Hamatwi, I.E. Davidson, M.N. Gitau, Rotor speed control of a direct-driven permanent magnet synchronous generator-based wind turbine using phase-lag compensators to optimize wind power extraction, J. Control Sci. Eng. 2017 (2017).

[260] C. Mosca, F. Arrigo, A. Mazza, E. Bompard, E. Carpaneto, G. Chicco, P. Cuccia, Mitigation of frequency stability issues in low inertia power systems using synchronous compensators and battery energy storage systems, IET Gen., Transm. Distrib. 13 (17) (2019) 3951–3959.

[261] K. Kehelpannala, T. Herath, N. Nadeekumari, J.B. Ekanayake, K.M. Liyanage, Distribution networks with renewable sources, electric vehicles and reactive power compensators, in: National Energy Symposium, 2015 (p. 102).

[262] V. Bezhenar, D. Mykolaets, V. Mykytyuk, T. Tereshchenko, Multilevel inverter as var-compensator, in: 2013 IEEE XXXIII International Scientific Conference Electronics and Nanotechnology (ELNANO), IEEE, 2013, pp. 370–372.

[263] M. Farhoodnea, A. Mohamed, H. Shareef, Optimum active power conditioner placement for power quality enhancement using discrete firefly algorithm, in: Proceedings of the World Congress on Engineering and Computer Science 1, 2013.

[264] M. Farhoodnea, A. Mohamed, H. Shareef, H. Zayandehroodi, Optimum placement of active power conditioner in distribution systems using improved discrete firefly algorithm for power quality enhancement, Appl. Soft. Comput. 23 (2014) 249–258.

[265] J.L. Afonso, J.G. Pinto, H. Gonçalves, Active power conditioners to mitigate power quality problems in industrial facilities, InTech (2013).

[266] C.Y. Tang, C.J. Tsai, Y.M. Chen, Y.R. Chang, Dynamic optimal AC line current regulation method for three-phase active power conditioners, IEEE J. Emerg. Sel. Top. Power. Electron. 5 (2) (2017) 901–911.

[267] J.G. Pinto, M. Tanta, V.D. Monteiro, L.A. Barros, J.L. Afonso, Active power conditioner based on a voltage source converter for harmonics and negative sequence components compensation in electrified railway systems.

[268] I.A. Channa, M.A. Koondhar, N.M. Mughal, M.S. Bajwa, S.A. Bukhari, M.I. Jamali, Simulation and analysis of active power filter for mitigation of power quality problems in a wind based distributed generation, J. App. Emerg. Sci. 11 (1) (2021) 11.

[269] A. Marini, M.S. Ghazizadeh, S.S. Mortazavi, L. Piegari, A harmonic power market framework for compensation management of DER based active power filters in microgrids, Int. J. Electr. Power Energy Syst. 113 (2019) 916–931.

[270] M. Moghbel, S. Deilami, M.A. Masoum, Optimal siting and sizing of multiple active power line conditioners to minimize network THD considering harmonic couplings, in: 2019 9th International Conference on Power and Energy Systems (ICPES), IEEE, 2019, pp. 1–6.

[271] S. Mukherjee, S. Mazumder, S. Adhikary, Harmonic compensation for nonlinear loads fed by grid connected solar inverters using active power filters, in: 2020 IEEE VLSI Device Circuit and System (VLSI DCS), IEEE, 2020, pp. 1–6.

[272] M.S. Khadem, M. Basu, M.F. Conlon, UPQC for power quality improvement in dg integrated smart grid network-a review, Int. J. Emerg. Electr. Power Syst. 13 (1) (2012).

[273] S.S. Bhosale, Y.N. Bhosale, U.M. Chavan, S.A. Malvekar, Power quality improvement by using UPQC: a review, in: In2018 International conference on control, power, communication and computing technologies (ICCPCCT), IEEE, 2018, pp. 375–380.

[274] N. Hedaoo, M. Gupta, Reactive power compensation through unified power quality conditioner: a review, IUP J. Electr. Electron. Eng. 10 (4) (2017).

[275] Q.N. Trinh, H.H. Lee, Improvement of unified power quality conditioner performance with enhanced resonant control strategy, IET Gen., Transm. Distrib. 8 (12) (2014) 2114–2123.

[276] K. Palanisamy, D.P. Kothari, M.K. Mishra, S. Meikandashivam, I.J. Raglend, Effective utilization of unified power quality conditioner for interconnecting PV modules with grid using power angle control method, Int. J. Electr. Power Energy Syst. 48 (2013) 131–138.

[277] S. Devassy, B. Singh, Design and performance analysis of three-phase solar PV integrated UPQC, IEEE Trans. Ind. Appl.. 54 (1) (2017) 73–81.

[278] M.A. Mansor, K. Hasan, M.M. Othman, S.Z. Noor, I. Musirin, Construction and performance investigation of three-phase solar PV and battery energy storage system integrated UPQC, IEEe Access. 8 (2020) 103511–103538.

[279] S. Lakshmi, S. Ganguly, Multi-objective planning for the allocation of PV-BESS integrated open UPQC for peak load shaving of radial distribution networks, J. Energy Storage 22 (2019) 208–218.

[280] M. Gangadharam, G. Lovaraju, Performance analysis of three-phase solar PV integrated UPQC using space vector technique.

[281] Y. Yang, X. Xiao, S. Guo, Y. Gao, C. Yuan, W. Yang, Energy storage characteristic analysis of voltage sags compensation for UPQC based on MMC for medium voltage distribution system, Energies 11 (4) (2018) 923.

[282] Z. Liu, S. Miao, Z. Fan, K. Chao, Y. Kang, Coordinated power allocation and robust dc voltage control of UPQC with energy storage unit during source voltage sag, in: 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5. IEEE.

[283] B.S. Goud, B.L. Rao, Power quality enhancement in grid-connected PV/wind/battery using UPQC: atom search optimization, J. Electr. Eng. Technol. 16 (2) (2021) 821–835.

[284] C.P. Kumar, S. Pragaspathy, V. Karthikeyan, K.D. Prakash, Power quality improvement for a hybrid renewable farm using UPQC, in: 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS), IEEE, 2021, pp. 1483–1488.

[285] U.S. Vadivu, B.K. Keshavan, Power quality enhancement of UPQC connected WECS using FFA with RNN, in: In2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), IEEE, 2017, pp. 1–6.

[286] M. Habbab, B. Cherif, A wind turbine energy storage system based on a new UPQC configuration, Electrotehnica, Electronica, Automatica 65 (4) (2017).

[287] P. Oza, Power quality enhancement in DFIG based wind power system using fuzzy controlled UPQC, in: IJRAR-International Journal of Research and Analytical Reviews (IJRAR) 6, 2019, pp. 70–74.

[288] G. Mallesham, C.S. Kumar, Enhancement of power quality using UPQC for hybrid PEMFC and DFIG based wind energy system connected to weak grid, in: In2017 International Conference on Technological Advancements in Power and Energy (TAP Energy), IEEE, 2017, pp. 1–6.

[289] G. Mallesham, C.S. Kumar, Power quality improvement of weak hybrid PEMFC and SCIG grid using UPQC, in: Advances in Decision Sciences, Image Processing, Security and Computer Vision 2020, Springer, Cham, 2019, pp. 406–413.

[290] C. Gong, R. Shi, Z.J. Chi, B.Q. Zhang, L.F. Ma, R. Jiao, Research on application of UPQC in electric vehicle charging equipment. In, in: Applied Mechanics and Materials 734, Trans Tech Publications Ltd., 2015, pp. 852–857.

[291] Y. Zhong, M. Xia, H.D. Chiang, Electric vehicle charging station microgrid providing unified power quality conditioner support to local power distribution networks, Int. Trans. Electr. Energy Syst. 27 (3) (2017) e2262.

[292] V. Vinothkumar, R. Kanimozhi, Power flow control and power quality analysis in power distribution system using UPQC based cascaded multi-level inverter with predictive phase dispersion modulation method, J. Ambient. Intell. Humaniz. Comput. 12 (6) (2021) 6445–6463.

[293] X. Xiao, J. Lu, C. Yuan, Y. Yang, A 10kV 4MVA unified power quality conditioner based on modular multilevel inverter, in: 2013 International Electric Machines & Drives Conference, IEEE, 2013, pp. 1352–1357.

[294] V. Velmurugan, N. Chellammal, R. Abirami, Power quality conditioning using hybrid multilevel inverter as UPQC, in: 2013 International Conference on Circuits, Power and Computing Technologies (ICCPCT), IEEE, 2013, pp. 43–48.

[295] R.P. de Lacerda, C.B. Jacobina, E.L. Fabricio, P.L. Rodrigues, Six-leg single-phase AC–DC–AC multilevel converter with transformers for UPS and UPQC applications, IEEe Trans. Ind. Appl. 56 (5) (2020) 5170–5181.

[296] M.R. Sindhu, G.N. Manjula, T.N. Nambiar, Development of LabVIEW based harmonic analysis and mitigation scheme with shunt active filter for power quality enhancement, Int. J. Recent Technol. Eng. (IJRTE) 2 (5) (2013) 71–78.

[297] J. Chen, T. Tang, Power quality analysis based on LABVIEW for current power generation system, in: International Symposium on Power Electronics Power Electronics, Electrical Drives, Automation and Motion, IEEE, 2012, pp. 865–870.

[298] C.F. Nascimento, A.A. Oliveira Jr, A. Goedtel, A.B Dietrich, Harmonic distortion monitoring for nonlinear loads using neural-network-method, Appl. Soft. Comput. 13 (1) (2013) 475–482.

[299] H.R. Baghaee, M. Mirsalim, G.B. Gharehpetian, H.A. Talebi, Unbalanced harmonic power sharing and voltage compensation of microgrids using radial basis function neural network-based harmonic power-flow calculations for distributed and decentralised control structures, IET Gen., Transm. Distrib. 12 (7) (2018) 1518–1530.

[300] B. Adineh, M.R. Habibi, A.N. Akpolat, F. Blaabjerg, Sensorless voltage estimation for total harmonic distortion calculation using artificial neural networks in microgrids, IEEE Trans. Circuits Syst. II: Express Briefs (2021).

[301] H.R. Baghaee, M. Mirsalim, G.B. Gharehpetan, H.A. Talebi, Nonlinear load sharing and voltage compensation of microgrids based on harmonic power-flow calculations using radial basis function neural networks, IEEE Syst. J. 12 (3) (2017) 2749–2759.

[302] A. Heydari, D.A. Garcia, F. Keynia, F. Bisegna, L. De Santoli, A novel composite neural network based method for wind and solar power forecasting in microgrids, Appl. Energy 251 (2019) 113353.

[303] I. Grcić, H. Pandžić, D. Novosel, Fault detection in DC microgrids using short-time Fourier transform, Energies 14 (2) (2021) 277.

[304] A. Ezzat, B.E. Elnaghi, A.A. Abdelsalam, Microgrids islanding detection using Fourier transform and machine learning algorithm, Electr. Power Syst. Res. 196 (2021) 107224.

[305] D.K. Asl, A. Hamedi, M. Shadaei, H. Samet, T. Ghanbari, A non-iterative method based on fast Fourier transform and least square for fault locating in DC microgrids, in: 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), IEEE, 2020, pp. 1–5.

[306] T.K. Das, A. Banik, S. Chattopadhyay, A. Das, FFT based classification of solar photo voltaic microgrid system, in: 2019 Second International Conference on Advanced Computational and Communication Paradigms (ICACCP), IEEE, 2019, pp. 1–5.

[307] H.J. Choi, J.H. Jung, Enhanced power line communication strategy for DC microgrids using switching frequency modulation of power converters, IEEE Trans. Power Electron.. 32 (6) (2017) 4140–4144.

[308] D.R. Nair, S. Devi, M.G. Nair, K. Ilango, Tariff based fuzzy logic controller for active power sharing between microgrid to grid with improved power quality, in: In2016 International Conference on Energy Efficient Technologies for Sustainability (ICEETS), IEEE, 2016, pp. 406–409.

[309] P.K. Barik, G. Shankar, P.K. Sahoo, Power quality assessment of microgrid using fuzzy controller aided modified SRF based designed SAPF, Int. Trans. Electr. Energy Syst. 30 (4) (2020) e12289.

[310] S. Newaz, M. Naiem-Ur-Rahman, Voltage control of single phase islanded microgrid by fuzzy logic controller for different loads, in: 2020 IEEE Region 10 Symposium (TENSYMP), IEEE, 2020, pp. 1560–1563.

[311] Y. Teekaraman, R. Kuppusamy, H.R. Baghaee, M. Vukobratović, Z. Balkić, S. Nikolovski, Current compensation in grid-connected VSCs using advanced fuzzy logic-based fluffy-built SVPWM switching, Energies 13 (5) (2020) 1259.

[312] P. Nanda, C.K. Panigrahi, A. Dasgupta, Phasor estimation and modelling techniques of PMU- a review, Energy Procedia 109 (2017) 64–77.

[313] S.R. Samantaray, I. Kamwa, G. Joos, Phasor measurement unit based wide-area monitoring and information sharing between micro-grids, IET Gener. Transm. Distrib. 11 (5) (2017) 1293–1302.

[314] Y. Liu, L. Wu, J. Li, D-PMU based applications for emerging active distribution systems: a review, Electr. Power Syst. Res. 179 (2020) 106063.
[315] N.K. Sharma, S.R. Samantaray, Assessment of PMU-based wide-area angle criterion for fault detection in microgrid, IET Gener. Transm. Distrib. 13 (19) (2019) 4301–4310.
[316] G. Frigo, A. Derviskadic, P.A. Pegoraro, C. Muscas, M. Paolone, Harmonic phasor measurements in real-world PMU-based acquisitions, in: 2019 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), IEEE, 2019.
[317] H. Liu, T. Bi, J. Li, S. Xu, Q. Yang, Inter-harmonics monitoring method based on PMUs, IET Gener. Transm. Distrib. 11 (18) (2017) 4414–4421.
[318] Y. Sun, S. Li, Q. Xu, et al., Harmonic contribution evaluation based on the distribution-level PMUs, IEEE Trans. Power Deliv. 36 (2) (2021) 909–919.
[319] D. Granados-Lieberman, Global harmonic parameters for estimation of power quality indices: an approach for PMUs, Energies 13 (9) (2020) 2337.
[320] Y. Tan, R. Chen, M. Wang, M. Zhang, M. Hou, High-accurate estimation method of sub-synchronous and super-synchronous harmonic parameters on PMU, J Eng 2017 (13) (2017) 1275–1279.
[321] M. Loper, T. Trummal, J. Kilter, Analysis of the applicability of PMU measurements for power quality assessment, in: 2018 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe). IEEE, 2018.
[322] A. Derviškadić, M. Paolone, Design and experimental validation of an FPGA-based PMU simultaneously compliant with P and M performance classes, Electr. Power Syst. Res. 189 (2020) 106650.
[323] Y. Wang, C. Lu, I. Kamwa, C. Fang, P. Ling, An adaptive filters based PMU algorithm for both steady-state and dynamic conditions in distribution networks, Int. J. Electr. Power Energy Syst. 117 (2020) 105714.
[324] M. Monadi, H. Hooshyar, L. Vanfretti, Design and real-time implementation of a PMU-based adaptive auto-reclosing scheme for distribution networks, Int. J. Electr. Power Energy Syst. 105 (2019) 37–45.
[325] J. Zhao, S. You, H. Yin, J. Tan, Y. Liu, Data quality analysis and solutions for distribution-level PMUs, in: 2019 IEEE Power & Energy Society General Meeting (PESGM), IEEE, 2019.
[326] S. Li, Y. Sun, S. Qin, et al., PMU-based harmonic phasor calculation and harmonic source identification, in: 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), IEEE, 2018.
[327] P. Garanayak, R.T. Naayagi, G. Panda, A high-speed master-slave ADALINE for accurate power system harmonic and inter-harmonic estimation, IEEE Access. 8 (2020) 51918–51932.
[328] M. Sujith, S. Padma, Optimization of harmonics with active power filter based on ADALINE neural network, Microprocess. Microsyst. 73 (2020) 102976.
[329] M.M. Zainuri, M.M. Radzi, A.C. Soh, et al., Photovoltaic integrated shunt active power filter with simpler ADALINE algorithm for current harmonic extraction, Energies 11 (5) (2018) 1152.
[330] G.S. Chawda, A.G. Shaik, Performance evaluation of adaline controlled dstatcom for multifarious load in weak AC grid, in: 2019 IEEE PES GTD Grand International Conference and Exposition Asia (GTD Asia), IEEE, 2019.
[331] S. Devassy, B. Singh, Performance analysis of proportional resonant and ADALINE-based solar photovoltaic-integrated unified active power filter, IET Renew. Power Gener. 11 (11) (2017) 1382–1391.
[332] X. Nie, Detection of grid voltage fundamental and harmonic components using Kalman filter based on dynamic tracking model, IEEE Trans. Ind. Electron. 67 (2) (2020) 1191–1200.
[333] S.K. Singh, N. Sinha, A.K. Goswami, N. Sinha, Several variants of Kalman Filter algorithm for power system harmonic estimation, Int. J. Electr. Power Energy Syst. 78 (2016) 793–800.
[334] A. Bagheri, M. Mardaneh, A. Rajaei, A. Rahideh, Detection of grid voltage fundamental and harmonic components using Kalman filter and generalized averaging method, IEEe Trans. Power. Electron. 31 (2) (2016) 1064–1073.
[335] R. Ferrero, P.A. Pegoraro, S. Toscani, Dynamic fundamental and harmonic synchrophasor estimation by Extended Kalman filter, in: 2016 IEEE International Workshop on Applied Measurements for Power Systems (AMPS), IEEE, 2016.
[336] R. Haider, C.H. Kim, T. Ghanbari, S.B.A. Bukhari, Harmonic-signature-based islanding detection in grid-connected distributed generation systems using Kalman filter, IET Renew. Power Gener. 12 (15) (2018) 1813–1822.
[337] R. Panigrahi, B. Subudhi, Performance enhancement of shunt active power filter using a Kalman Filter-based ${{\rm H} _\infty} $ control strategy, IEEE Trans. Power. Electron. 32 (4) (2017) 2622–2630.
[338] Y. Xi, X. Tang, Z. Li, Y. Cui, X. Zeng, Detection of power quality disturbances based on residual analysis using Kalman filter based on maximum likelihood, Electr. Power Components Syst. 47 (9–10) (2019) 861–875.
[339] S.K. Prince, K.P. Panda, V.N. Kumar, G. Panda, Power quality enhancement in a distribution network using PSO assisted Kalman filter - based shunt active power filter, in: 2018 IEEMA Engineer Infinite Conference (eTechNxT), IEEE, 2018.
[340] A.A. Abdelsalam, A.Y. Abdelaziz, M.Z. Kamh, A generalized approach for power quality disturbances recognition based on Kalman filter, IEEE Access. 9 (2021) 93614–93628.
[341] I. Molina-Moreno, A. Medina, R. Cisneros-Magaña, O. Anaya-Lara, J.A. Salazar-Torres, Enhanced harmonic state estimation in unbalanced three-phase electrical grids based on the Kalman filter and physical scale-down implementation, Int. J. Electr. Power Energy Syst. 123 (2020) 106243.
[342] M.E. Abdulmunem, A.A. Badr, Hilbert transform and its applications: a survey, Int. J. Sci. Eng. Res. 8 (2) (2017).
[343] M. Klingspor, Hilbert transform: mathematical theory and applications to signal processing.
[344] P. Li, J. Gao, D. Xu, C. Wang, X Yang, Hilbert-Huang transform with adaptive waveform matching extension and its application in power quality disturbance detection for microgrid, J. Mod. Power Syst. Clean. Energy 4 (1) (2016) 19–27.
[345] C. Xiaojing, Detection of power quality disturbances using empirical wavelet transform and Hilbert transform, J. Electr. Electron. Eng. 5 (5) (2017) 192.
[346] J.R. Razo-Hernandez, M. Valtierra-Rodriguez, D. Granados-Lieberman, G. Tapia-Tinoco, J.R. Rodriguez-Rodriguez, A phasor estimation algorithm based on Hilbert transform for P-class PMUs, Adv. Electr. Comput. Eng. 18 (3) (2018) 97–104.
[347] H. Pan, T. Wei, C. Deng, H. Long, Y. Zhang, A novel PQ control strategy for non phase-locked loop based on Hilbert transform, in: 2018 IEEE Energy Conversion Congress and Exposition (ECCE), IEEE, 2018.
[348] I. Urbina-Salas, J.R. Razo-Hernandez, D. Granados-Lieberman, M. Valtierra-Rodriguez, J.E. Torres-Fernandez, Instantaneous power quality indices based on single-sideband modulation and wavelet Packet-Hilbert transform, IEEE Trans. Instrum. Meas. 66 (5) (2017) 1021–1031.
[349] V.K. Tiwari, A.C. Umarikar, T. Jain, Measurement of instantaneous power quality parameters using UWPT and Hilbert transform and its FPGA implementation, IEEE Trans. Instrum. Meas. 70 (2021) 1–13.
[350] R. Zamani, M.P. Moghaddam, M. Imani, H.H. Alhelou, M.E.H. Golshan, P. Siano, A novel improved Hilbert-Huang transform technique for implementation of power system local oscillation monitoring, in: 2019 IEEE Milan PowerTech. IEEE, 2019.
[351] M. Bueno-López, M. Molinas, G. Kulia, Understanding instantaneous frequency detection: a discussion of Hilbert-Huang Transform versus Wavelet Transform. InInternational Work-Conference on Time Series Analysis-ITISE, University of Granada, Granada, 2017, pp. 474–486. Vol. 1.
[352] A. Moradzadeh, A. Mansour-Saatloo, M. Nazari-Heris, B. Mohammadi-Ivatloo, S. Asadi, Introduction and literature review of the application of machine learning/deep learning to load forecasting in power system, Appl. Mach. Learn. Deep Learn. Methods Power Syst. Probl. (2021) 119–135.
[353] M.M. Forootan, I. Larki, R. Zahedi, A. Ahmadi, Machine learning and deep learning in energy systems: a review, Sustainability 14 (8) (2022) 4832.
[354] E. Mohammadi, M. Alizadeh, M. Asgarimoghaddam, X. Wang, M.G. Simões, A review on application of artificial intelligence techniques in microgrids, IEEE J. Emerg. Sel. Top. Ind. Electron. 3 (4) (2022) 878–890.
[355] M. Fayyazi, P. Sardar, S.I. Thomas, R. Daghigh, A. Jamali, T. Esch, H. Kemper, R. Langari, H. Khayyam, Artificial Intelligence/machine learning in energy management systems, control, and optimization of hydrogen fuel cell vehicles, Sustainability 15 (6) (2023) 5249.
[356] W. Guo, N.M. Qureshi, M.A. Jarwar, J. Kim, D.R. Shin, AI-oriented smart power system transient stability: the rationality, applications, challenges and future opportunities, Sustainable Energy Technol. Assess. 56 (2023) 102990.
[357] N.M. Kumar, A.A. Chand, M. Malvoni, K.A. Prasad, K.A. Mamun, F.R. Islam, S. S. Chopra, Distributed energy resources and the application of AI, IoT, and blockchain in smart grids, Energies 13 (21) (2020) 5739.
[358] V. Franki, D. Majnarić, A. Višković, A comprehensive review of artificial intelligence (AI) companies in the power sector, Energies 16 (3) (2023) 1077.
[359] M.L. Zulu, R.P. Carpanen, R. Tiako, A comprehensive review: study of artificial intelligence optimization technique applications in a hybrid microgrid at times of fault outbreaks, Energies 16 (4) (2023) 1786.
[360] C. Francisco do Nascimento, A.J. Sguarezi Filho, A. Flamarion Querubini Gonçalves, A. Matheus dos Santos Alonso, L. Gustavo Reis Bernardino, P. Fernando Silva, W Angelino de Souza, Active Power Filters Applied to Smart Grids: Harmonic Content Estimation Based On Deep Neural Network. InSmart Grids—Renewable Energy, Power Electronics, Signal Processing and Communication Systems Applications, Springer International Publishing, Cham, 2023, pp. 325–358.
[361] D. Razmi, T. Lu, B. Papari, E. Akbari, G. Fathi, M. Ghadamyari, An Overview on Power Quality Issues and Control Strategies for distribution networks with the presence of distributed generation resources (DGs), IEEE Access. (2023).
[362] E. Hernández-Mayoral, M. Madrigal-Martínez, J.D. Mina-Antonio, R. Iracheta-Cortez, J.A. Enríquez-Santiago, O. Rodríguez-Rivera, G. Martínez-Reyes, E. A. Mendoza-Santos, Comprehensive review on power-quality issues, optimization techniques, and control strategies of microgrid based on renewable energy sources, Sustainability 15 (12) (2023) 9847.
[363] A. Kharrazi, V. Sreeram, Y. Mishra, Assessment techniques of the impact of grid-tied rooftop photovoltaic generation on the power quality of low voltage distribution network-a review, Renewable Sustainable Energy Rev. 120 (2020) 109643.
[364] C. Sunil Kumar, C. Puttamadappa, Y.L Chandrashekar, Power quality improvement in grid integrated PV systems with soa optimized active and reactive power control, J. Electr. Eng. Technol. 18 (2) (2023) 735–750.
[365] T. Pidikiti, B. Gireesha, M. Subbarao, V.M. Krishna, Design and control of Takagi-Sugeno-Kang fuzzy based inverter for power quality improvement in grid-tied PV systems, Measurement: Sensors 25 (2023) 100638.
[366] H. Raziq, M. Batool, S. Riaz, F. Afzal, A. Akgül, M.B. Riaz, Power quality improvement of a distribution system integrating a large scale solar farm using hybrid modular multilevel converter with ZSV control, Ain Shams Eng. J. 14 (7) (2023) 102218.
[367] A. Hassan, O. Bass, Y.M. Al-Abdeli, M. Masek, M.A. Masoum, A novel approach for optimal sizing of stand-alone solar PV systems with power quality considerations, Int. J. Electr. Power Energy Syst. 144 (2023) 108597.
[368] S.S. Dheeban, N.B Muthu Selvan, ANFIS-based power quality improvement by photovoltaic integrated UPQC at distribution system, IETE J. Res. 69 (5) (2023) 2353–2371.

[369] A. Venkatesh, P.S. Kumar, Design of dynamic voltage restorer in the power quality improvement for voltage problems, Appl. Nanosci. 13 (4) (2023) 2985–2995.

[370] A.R. Vadavathi, G. Hoogsteen, J.L. Hurink, PV inverter based fair power quality control, IEEE Trans. Smart. Grid. (2023).

[371] O.P. Mahela, A.G. Shaik, N. Gupta, M. Khosravy, B. Khan, H.H. Alhelou, S. Padmanaban, Recognition of power quality issues associated with grid integrated solar photovoltaic plant in experimental framework, IEEE Syst. J. 15 (3) (2020) 3740–3748.

[372] A.A. Alkahtani, S.T. Alfalahi, A.A. Athamneh, A.Q. Al-Shetwi, M.B. Mansor, M. A. Hannan, V.G. Agelidis, Power quality in microgrids including supraharmonics: issues, standards, and mitigations, IEEE Access. 8 (2020) 127104–127122.

[373] K. Jha, A.G. Shaik, A comprehensive review of power quality mitigation in the scenario of solar PV integration into utility grid. e-Prime-Advances in Electrical Engineering, Electron. Energy (2023) 100103.

[374] T. Ahilan, Wind connected distribution system with intelligent controller based compensators for power quality issues mitigation, Electr. Power Syst. Res. 217 (2023) 109103.

[375] X. Zheng, Z. Gong, Z. Liu, Z. Li, D. Yuan, T Jin, Research on Start-stop standby energy storage element participating in wind power filtering under the influence of power quality disturbance, Int. J. Electr. Power Energy Syst. 145 (2023) 108631.

[376] A. Das, S. Dawn, S. Gope, T.S. Ustun, A strategy for system risk mitigation using FACTS devices in a wind incorporated competitive power system, Sustainability 14 (13) (2022) 8069.

[377] G.S. Chawda, A.G. Shaik, O.P. Mahela, S. Padmanaban, Performance improvement of weak grid-connected wind energy system using flsrf-controlled dstatcom, IEEE Trans. Ind. Electron. 70 (2) (2022) 1565–1575.

[378] B.S. Goud, B.L. Rao, Power quality enhancement in grid-connected PV/wind/battery using UPQC: atom search optimization, J. Electr. Eng. Technol. 16 (2021) 821–835.

[379] R.K. Beniwal, M.K. Saini, A. Nayyar, B. Qureshi, A. Aggarwal, A critical analysis of methodologies for detection and classification of power quality events in smart grid, IEEE Access. 9 (2021) 83507–83534.

[380] Y. Zhang, C. Klabunde, M. Wolter, Study of resonance issues between DFIG-based offshore wind farm and HVDC transmission, Electr. Power Syst. Res. 190 (2021) 106767.

[381] S.W. Ali, M. Sadiq, Y. Terriche, S.A. Naqvi, M.U. Mutarraf, M.A. Hassan, G. Yang, C.L. Su, J.M. Guerrero, Offshore wind farm-grid integration: a review on infrastructure, challenges, and grid solutions, IEEE Access. 9 (2021) 102811–102827.

[382] K. Hasan, M.M. Othman, S.T. Meraj, M. Ahmadipour, M.H. Lipu, M. Gitizadeh, A unified linear self-regulating method for active/reactive sustainable energy management system in fuel-cell connected utility network, IEEE Access. 11 (2023) 21612–21630.

[383] J.B. Basu, S. Dawn, P.K. Saha, M.R. Chakraborty, F. Alsaif, S. Alsulamy, T. S. Ustun, Risk mitigation & profit improvement of a wind-fuel cell hybrid system with TCSC placement, IEEE Access. (2023).

[384] X.Z. Yuan, C. Nayoze-Coynel, N. Shaigan, D. Fisher, N. Zhao, N. Zamel, P. Gazdzicki, M. Ulsh, K.A. Friedrich, F. Girard, U. Groos, A review of functions, attributes, properties and measurements for the quality control of proton exchange membrane fuel cell components, J. Power. Sources 491 (2021) 229540.

[385] M. İnci, M. Büyük, M.H. Demir, G. İlbey, A review and research on fuel cell electric vehicles: topologies, power electronic converters, energy management methods, technical challenges, marketing and future aspects, Renewable Sustainable Energy Rev. 137 (2021) 110648.

[386] J. Zhao, Z. Tu, S.H. Chan, Carbon corrosion mechanism and mitigation strategies in a proton exchange membrane fuel cell (PEMFC): a review, J. Power. Sources. 488 (2021) 229434.

[387] D. Thiruselvi, P.S. Kumar, M.A. Kumar, C.H. Lay, S. Aathika, Y. Mani, D. Jagadiswary, A. Dhanasekaran, P. Shanmugam, S. Sivanesan, P.L. Show, A critical review on global trends in biogas scenario with its up-gradation techniques for fuel cell and future perspectives, Int. J. Hydrogen. Energy 46 (31) (2021) 16734–16750.

[388] A.M. Abd El-Hameid, A.A. Elbaset, M. Ebeed, M Abdelsattar, Literature review and power quality issues, Enhancement Grid-Connect. Photovolt. Syst. Using Artif. Intell. (2023) 5–37.

[389] S.R. Shakya, I. Bajracharya, R.A. Vaidya, P. Bhave, A. Sharma, M. Rupakheti, T. R. Bajracharya, Estimation of air pollutant emissions from captive diesel generators and its mitigation potential through microgrid and solar energy, Energy Rep. 8 (2022) 3251–3262.

[390] A.G. Mustayen, M.G. Rasul, X. Wang, M. Negnevitsky, J.M. Hamilton, Remote areas and islands power generation: a review on diesel engine performance and emission improvement techniques, Energy Convers. Manage 260 (2022) 115614.

[391] S.R. Das, A.K. Mishra, P.K. Ray, S.R. Salkuti, S.C. Kim, Application of artificial intelligent techniques for power quality improvement in hybrid microgrid system, Electronics 11 (22) (2022) 3826.

[392] A. Riyaz, P.K. Sadhu, A. Iqbal, M. Tariq, Power quality enhancement of a hybrid energy source powered packed e-cell inverter using an intelligent optimization technique, J. Intell. Fuzzy Syst. 42 (2) (2022) 817–825.

[393] J. Hernandez-Alvidrez, R. Darbali-Zamora, J.D. Flicker, M. Shirazi, J. VanderMeer, W. Thomson, Using energy storage-based grid forming inverters for operational reserve in hybrid diesel microgrids, Energies 15 (7) (2022) 2456.

[394] A. Chauhan, S. Upadhyay, M.T. Khan, S.S. Hussain, T.S. Ustun, Performance investigation of a solar photovoltaic/diesel generator based hybrid system with cycle charging strategy using BBO algorithm, Sustainability 13 (14) (2021) 8048.

[395] J. Zhou, M. Zhu, L. Chen, Q. Ren, S. Su, S. Hu, Y. Wang, J. Xiang, Performance assessment and system optimization on supercritical CO2 double-path recompression coal-fired combined heat and power plants with MEA-based post-combustion CO2 capture, Energy 267 (2023) 126539.

[396] A.S. Alsagri, A.A. Alrobaian, Optimization of combined heat and power systems by meta-heuristic algorithms: an overview, Energies 15 (16) (2022) 5977.

[397] M. Razeghi, A. Hajinezhad, A. Naseri, Y. Noorollahi, S.F. Moosavian, An overview of renewable energy technologies for the simultaneous production of high-performance power and heat, Future Energy 2 (2) (2023), 1-1.

[398] S. Vijayalakshmi, R. Shenbagalakshmi, C.P. Kamalini, M. Marimuthu, R. Venugopal, Power quality issues in smart grid/microgrid. InPlanning of Hybrid Renewable Energy Systems, Electric Vehicles and Microgrid: Modeling, Control and Optimization, Springer Nature Singapore, Singapore, 2022, pp. 403–442.

[399] E. Gul, G. Baldinelli, P. Bartocci, Energy transition: renewable energy-based combined heat and power optimization model for distributed communities, Energies 15 (18) (2022) 6740.

[400] F. Calise, F.L. Cappiello, M.D. d'Accadia, M. Vicidomini, A novel smart energy network paradigm integrating combined heat and power, photovoltaic and electric vehicles, Energy Convers. Manage 260 (2022) 115599.

[401] C. Su, C. Yang, C. Tian, H. Hu, S. Dehan, Optimal economic operation of microgrids considering combined heat and power unit, reserve unit, and demand-side management using developed adolescent identity search algorithm, Int. J. Hydrogen Energy 47 (90) (2022) 38295–38310.

[402] Y. Tan, Y. Shen, X. Yu, X. Lu, Low-carbon economic dispatch of the combined heat and power-virtual power plants: a improved deep reinforcement learning-based approach, IET Renewable Power Gen. 17 (4) (2023) 982–1007.

Dr. Subhashree Choudhury graduated from Biju Patnaik University of Technology (BPUT), Odisha in Electrical Engineering in the year 2009, obtained Master's Degree from Siksha 'O' Anusandhan University in Electrical Engineering in 2012 and obtained Ph.D degree from Siksha O Anusandhan (Deemed to be University) in 2017 in the area of Power System Operation and Control. She has served almost 12 years to technical institutions. Currently, she holds the position of Associate Professor in the Department of Electrical and Electronics Engineering, Siksha O Anusandhan (Deemed to be University) Bhubaneswar, India.

Her major research interests include Microgrid control, Renewable Energy Integration to Microgrid, Energy Storage Systems and its Control, Multilevel Inverter Technology, Active Power Filters, FACTS Controllers, Soft Computing Methods and its application to power system planning, operation, and control. With more than 90 peer reviewed International Journals, Conference Proceedings and Book Chapters her research appeared in top power engineering journals such as Elsevier, Wiley, MDPI, Taylor & Francis etc. She has published 06 Indian patents at IPR and have published 01 Book to her credit. She has acted as a reviewer of many International Journals such as Sustainable Cities and Society-Elsevier, IEEE ACCESS, MDPI, Control Engineering and Practice-Elsevier, Journal of Hydrogen Energy-Elsevier, International Journal of Control- Taylor & Francis, Journal of Franklin Institute-Elsevier, IET Control Theory and Applications, ISA Transactions-Elsevier, LNEE Springer Book Series and many IEEE conferences.

She is one among the top 2% OF SCIENTISTS BY ELSEVIER B.V. AND STANFORD UNIVERSITY IN THE ENERGY DOMAIN, according to the report published on 4th Oct 2023. She has served as the Session Chair and core organizing committee for many international conferences in India and Abroad. She has been awarded as the YUVA MENTOR AS A CHANGEMAKER powered by YUVA INCUBATED & K.I.T.E.S EDUCATION in the year 2021. She is a Senior Member of IEEE Kolkata Section, Life Member of Indian Society of Systems for Science and Engineering (ISSE), Member of IEEE Young Professional, Member of IEEE Women in Engineering and Member of Smart Grid Community.

Mr. Gagan Kumar Sahoo graduated from Biju Patnaik University of Technology (BPUT), Odisha in Electrical Engineering, obtained Master's Degree and continuing Ph.D degreein Siksha O Anusandhan (Deemed to be University) since 2021 in the area of Power System Operation and Control. He has served more than 15 years to technical institutions. Currently, he holds the position of Principal in Maharaja Polytechnic, Bhubaneswar, India.