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Review Article

VARIOUS METHODS FOR POWER QUALITY IMPROVEMENT AND THEIR FEASIBILITY ACCORDING TO DIFFERENT LOADS-A REVIEW

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ABSTRACT

In the modern electrical distribution system, there has been a sudden increase of nonlinear loads, such as power supplies, recti er equipment used in telecommunication networks, domestic appliances, adjustable speed drives, power electronic devices etc. These loads are responsible up to a great extent for deteriorating the efficiency and quality of the power. In this paper a number of different methods, controllers and logics are discussed which are already implemented like hybrid fuzzy logic proportional plus conventional integral derivative (fuzzy P +ID) controller, Takagi-Sugeno (TS)-type fuzzy logic controller, asymmetrical nine-level active power filter (APF), a novel modular multilevel series/parallel converter, a modulation strategy for n-phase neutral-point-clamped (NPC) converters, a Y-D multifunction balance transformer (YD-MFBT) based power quality control system (MBT-PQCS) and a variable forgetting factor recursive least square (VFFRLS)-based control algorithm. In general it was seen that total harmonic distortion (THD) was appreciably reduced and efficiency of the system was improved. Multilevel-THSeAF eliminates source harmonic currents and improves power quality of the grid without the usual bulky and costly series transformer. APLC/FPIC Spectrum analysis measurements showed that the line voltage typically had a THD of approximately 3%. A comparison between the THD in output of Proportional (P), Proportional plus Integral (PI) and Proportional plus Integral plus Derivative (PID) controllers for different linear as well as non linear loads is further going to be discussed in upcoming work.

INTRODUCTION

Power quality is defined as the degree to which the power supply approaches the ideal case of stable, uninterrupted, zero distortion and disturbance supply. Power quality is a combination of voltage profile, frequency profile, harmonics content and reliability of supply. In general, it is useful to consider power quality as the compatibility between what comes out of an electric outlet and the load that is plugged into it. The term is used to describe electric power that drives an electrical load and the load's ability to function properly. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power.

The increasing demand of power-electronics-based nonlinear loads has raised several power quality problems. The uneven distribution of dynamically changing single-phase loads gives rise to the additional problems of excessive neutral current and current unbalance [1]. These power-electronic-based loads offer highly nonlinear characteristics. These nonlinear loads draw non sinusoidal currents from ac mains and cause reactive power burden and excessive neutral current [2]. Power quality (PQ) monitoring is important for measuring the effectiveness of smart grid implementations and trial projects. Wide-scale monitoring is increasingly feasible, and these schemes can provide utilities and customers with information regarding the operation of converter-connected devices, non-conventional loads, energy storage, and novel automation and control systems [3]. The increase of charging stations in a residential neighborhood and commercial buildings becomes crucial to monitor and evaluate their power quality characteristics [4]. Nonlinear loads are mainly two types of current-source and voltage-source fed loads. The examples for current-source-type nonlinear loads are a phase-controlled thyristor recti er with dc-link inductance and voltage-source-type loads are the diode recti er that has a smooth dc capacitor [5]. The consequence of these harmonics genera ting loads is a malfunction of equipment connected at the point of common coupling (PCC). The shunt passive filters are most commonly used to filter harmonics current, but the disadvantage of these filters is that

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they resonate with the power supply when the impedance of the system changes [6]. Control techniques play a vital role in the overall performance of the power conditioner. The rapid detection of the disturbance signal with high accuracy, fast processing of the reference signal, and high dynamic response of the controller are the prime requirements for desired compensation [7]. The constant increase in power electronic devices, used by industrial and commercial consumers, has deteriorated seriously electric power systems. More transmission losses, power-transformer and neutral-conductor overheating, power factor correction-capacitor overloading, and induced noise in control systems are only a few of the problems that harmonic distortion may bring into home and industrial installations, generating considerable economic losses to distribution companies [8]. In the next section a review of a number of methods used for improving the quality of power are discussed.

LITERATURE REVIEW

A hybrid fuzzy logic proportional plus conventional integral derivative (fuzzy P +ID) controller in an incremental form is designed by using an incremental fuzzy logic controller in place of the proportional term in a conventional PID controller. According to condition, the Ziegler and Nichols' approach to design the fuzzy P +ID controller are modified. The stability of the system remains unchanged after the PID controller is replaced by the fuzzy P+ID controller without modifying the original controller parameters. It is used to control a nonlinear system. Numerical simulation results demonstrate the effectiveness of the fuzzy P+ID controller in comparison with the conventional PID controller, especially when the controlled object operates under uncertainty or in the presence of a disturbance [1]. A switch-mode active power line conditioner (APLC) that uses fuzzy logic to control the semiconductor switches is described. Frequency-domain analysis is used to determine the desired compensation current, and a rule-based piecewise-linear fuzzy proportional-integral controller (FPIC) provides the appropriate switching pattern of the APLC to generate the actual compensation current. MATLAB simulations and experimental measurements shows that the APLC produces excellent results despite the use of a relatively low switching frequency, which is necessary to minimize semiconductor switching losses and shows that the APLC/FPIC system significantly improves line current total harmonic distortion (THD) and power factor during both steady-state and transient operating conditions [2]. Takagi–Sugeno (TS)-type fuzzy logic controller is described to control a three-phase shunt active power filter for the power-quality improvement and reactive power compensation required by a nonlinear load. Mamdani-type fuzzy logic controller has the limitation of a larger number of fuzzy sets and rules. TS fuzzy controller is designed by using a lower number of rules and classes. The hysteresis current control mode of operation is implemented for pulse width-modulation switching signal generation. Computer simulation results shown that the dynamic behaviour of the TS fuzzy controller is better than the conventional proportional-integral (PI) controller and is found to be more robust to changes in load and other system parameters [3]. To improve fuel economy and reducing emissions, hybrid electric vehicles (HEVs) are proposed. A power-split hybrid system, which is a complex hybrid power train, exhibits great potential to improve fuel economy by determining the most efficient regions for engine operation and thereby high-voltage (HV) battery operation to achieve overall vehicle efficiency optimization. An approach is developed to intelligently control engine power and speed behaviour in a power-split HEV using the fuzzy control paradigm for better performances by using fuzzy gain scheduling to determine appropriate gains for the PI controller based on the system's operating conditions. It results in elimination of the overshoots as well approximate 50% faster response and settling times in comparison with the conventional linear PI control approach [4]. An analysis is done on the dynamics of a dc bus split-capacitor boost converter used as an active filter and a control system which guarantees the desired closed loop performance (unity power factor and load-current harmonics and reactive-power compensation). This controller is hierarchically decomposed into two control loops, one in charge of shaping the network current and the other in charge of assuring the power balance. The analytical design of the controller and its performance is determined by some experimental results that show the good performance of the closed loop system [5]. An industrial controller, specifically designed for two- and three-level converters, was adapted to work on an asymmetrical nine-level active power filter (APF). The controller is now able to make all required tasks for the correct operation of the APF, such as current-harmonic elimination and removal of high-frequency noise. Switching losses were significantly reduced. The filter was designed to work as voltage source and operates as harmonic isolator, improving the filtering characteristics of the passive filter. The control strategy for detecting current harmonics is based on the "p-q theory" and the phase-tracking system in a synchronous reference frame phase-locked loop. Simulations for this application are displayed and experiments in a 1-kVA prototype, using an industrial controller, were tested, validating the effectiveness of this application [6]. A novel reference signal generation method for the unified power quality conditioner (UPQC) is adopted to compensate current and voltage-quality problems of sensitive loads. The UPQC consists of a shunt and series converter having a common dc link. The shunt converter eliminates current harmonics originating from the nonlinear load side and the series converter mitigates voltage sag/swell originating from the supply side, and is based on an enhanced phase-locked loop and nonlinear adaptive filter. The efficacy is tested through simulation studies using the Power System Computer Aided Design/Electromagnetic Transients dc analysis program and results in superior capability of mitigating the effects of voltage sag/swell and suppressing the load current harmonics under distorted supply conditions [7]. A PI, PID and Fuzzy Logic Controller (FLC) based shunt active filter for power line conditioners (PLC) is proposed to improve the power quality in the distribution network and is implemented with current controlled cascaded multilevel voltage source inverter (VSI). It is connected at the point of common coupling for compensating harmonic and reactive power by injecting equal but opposite harmonic compensating currents. The PI or PID or fuzzy logic controller is used to estimates the peak reference current by controlling the dc-bus capacitor voltage of the cascaded inverter. This system is validated through extensive simulation under steady state and transient conditions with different non-linear loads which reveals that the cascaded active power filter performs perfectly in conjunction with PI or PID or FLC [8]. A comparative study and implementation of UPQC is presented to eliminate harmonics and reactive power compensation in a single-phase to three-phase converter system in order to eliminate typical problems encountered in remote rural area applications, where only a single-phase supply is available and there is a demand for three-phase supply. A suitable control approach is used to minimize the voltage and current harmonics simultaneously. A simulation model is developed using MATLAB - Simulink with PI and Neural Network controller. The results in terms of THD are compared for PI and Neural Network controller and the prototype model is developed using dsPIC30F4011 controller, for the one which provides better results in comparison. The effectiveness of the proposed system is validated from the experimental results [9]. A single-step non-iterative optimized algorithm for a three-phase four-wire shunt active power filter under distorted and unbalanced supply conditions is proposed to optimally determine the conductance factors to maximize the supply-side power factor subject to prede ned source current THD limits and average power balance constraint by considering separate limits on odd and even THDs. The effectiveness is evaluated through comparison with an iterative optimization-based control algorithm and the validated using a real-time hardware-in-the-loop experimental system. The real-time experimental results demonstrate that the proposed method is capable of providing load compensation under steady-state and dynamic load conditions, thus making it more effective for practical applications [10]. An enhanced current control approach is proposed which integrates system harmonic mitigation capabilities with the primary DG power generation function. It has two well decoupled control branches to independently control fundamental and harmonic DG currents. A closed-loop power control scheme is employed to directly derive the fundamental current reference without using any phase-locked loops (PLL). It effectively eliminates the impacts of steady-state fundamental current tracking errors in the DG units. Simulated and experimental results from a single-phase DG unit validate the correctness of the proposed methods [11]. A fast-transient repetitive control strategy for a three-phase shunt active power filter is presented to improve dynamic performance without sacrificing steady-state accuracy which requires one-sixth of the fundamental period required by conventional repetitive control methods. A fast dynamic response is achieved and the program occupies minimal storage space. A proportional-integral regulator is also added to the current control loop to eliminate arbitrary order harmonics and ensure system stability under severe harmonic distortion conditions. The LCL filter resonance problem is avoided by the appropriately designed corrector, which increases the margin of system stability and maintains the original compensation current tracking accuracy [12]. A novel modular multilevel series/parallel converter is introduced that allows switching modules dynamically not only in series, as in the traditional modular multilevel converter (M2C), but also in parallel. Semiconductor voltages do not exceed the module capacitor voltage for any module state. Whereas in M2C many modules are bypassed if the instantaneous converter voltage is lower than the system's peak voltage, the parallel connectivity enables these modules to contribute to the current load, thus reduces the conduction losses. Parallel configuration of modules is used for balancing the modules' state of charge (SOC) and enables stable operation of a multilevel converter and is appropriate for low-power systems [13]. An implementation of distribution static compensator (DSTATCOM) for the three-phase distribution system is discussed whose functions are harmonics elimination, compensation of reactive power, and load balancing in power factor correction and voltage regulation modes. A variable forgetting factor recursive least square (VFFRLS)-based control algorithm is proposed for effective operation of DSTATCOM to estimate weighted values of active and reactive power components of load current. This control algorithm is fast in convergence and has quick response. A prototype of DSTATCOM is developed in the laboratory using a digital signal processor (dSPACE 1104) and voltage-source converter and tested for various operating conditions under nonlinear load. The performance of DSTATCOM is found satisfactory in mitigating various power-quality problems with the VFFRLS-based control algorithm [14]. The control of a synchronous reluctance generator (SyRG) is presented which is driven by a biogas/biomass diesel engine as a prime mover in a distributed power generating system. This generator is used as a source to feed linear and nonlinear loads. A three-leg voltage source converter (VSC)-based distribution static compensator (DSTATCOM) is implemented using an adaptive neural network-based control algorithm for harmonic suppression, load balancing, and voltage regulation in a three phase SyRG system with a battery energy storage system. This control algorithm is used for extraction of active and reactive power components of distorted load currents. These components of load currents are used for estimation of reference source currents to generate the gating pulses of VSC used as DSTATCOM and its performance under balanced and unbalanced loads [15]. A flexible control technique is discussed power electronics converters, which can function as an active power filter, as a local power supply interface, or perform both functions simultaneously, hence it compensate current disturbances while simultaneously injecting active power into the electrical grid, transforming the power converter into a multifunctional device. Orthogonal current decomposition of the Conservative Power Theory is applied to maximize the benefits. Each current component is weighted by compensation coefficients (k_i), which are adjusted instantaneously and independently, in any percentage, by means of load conformity factors (λ_i), thus providing online flexibility with respect to the objectives of compensation and injection of active power [16]. Passive filters along with capacitor banks are widely used in electrical system for power quality improvements. Both of them have their demerits which makes the passive filter and the capacitor bank incapable to keep the system operating within acceptable level of power quality. So a solution is provided in which the passive filter and the capacitor bank remains installed and unchanged. It consists of installing two shunt compensators specially designed for performing what the passive filter and the capacitor bank are incapable to do. The result is a reduced processed power in the compensators. The generation of the references is based on Conservative Power Theory [17]. A study, analysis and practical implementation of a versatile UPQC is carried out, which can be connected in both three-phase three-wire or three-phase four-wire distribution systems for performing the series-parallel power-line conditioning. This UPQC employs a dual compensation strategy, such that the controlled quantities are always sinusoidal. Thereby, the series converter is controlled to act as a sinusoidal current source, whereas the parallel converter operates as a sinusoidal voltage source. As the controlled quantities are sinusoidal, it is possible to reduce the complexity of the algorithms used to calculate the compensation references. Hence the voltage and current controllers are implemented into the synchronous reference frame, their control references are continuous, decreasing the steady-state errors when traditional proportional-integral controllers are employed. Static and dynamic performances, as well as the effectiveness of the dual UPQC are evaluated by means of experimental results [18]. A modulation strategy for n-phase neutral-point-clamped (NPC) converters is proposed which is able to control and completely remove the low-frequency neutral-point (NP) voltage oscillations for any operation point and load types. Even when unbalanced and/or nonlinear loads are considered, the NP voltage remains under total control and enables the use of low-capacity film capacitors in NPC converters. It is formulated following a generalized approach that makes it expandable to n-phase NPC converters and the NP voltage is controlled directly using a closed-loop algorithm that does not rely on the use of the linear control regulators or the additional compensators used in other modulation algorithms. Therefore, no tuning of parameters is required and it performs optimally for any operating conditions and kind of loads, including unbalanced and nonlinear loads [19]. A Y-D multifunction balance transformer (YD-MFBT) based power quality control system (MBT-PQCS) is proposed to deal with the power quality problems in the single-phase power system which mainly consists of a YD-MFBT and a three-phase full-bridge converter (FBC). It fully explores the inherent negative sequence current (NSC) suppressing the ability of YD-MFBT, which makes the power flow transformed by FBC less than that of the conventional transformer-based compensating system. The initial investment cost, installing difficulties and covering space of the whole compensating system, is reduced significantly. Both the simulation and the experiment are used to verify the effectiveness of the proposed system [20]. Use of wind and solar energy for generating electrical power suffers from the power quality issues from grid and generator side. A control strategy is discussed for achieving maximum benefits from this grid-interfacing inverter when installed in 3-phase 4-wire distribution systems. The inverter is controlled to perform as a multi-function device and to be utilized as: 1) power converter to inject power generated from RES to the grid and 2) shunt APF (Active Power Filter) to compensate current unbalance, load current harmonics, load reactive power demand and load neutral current. This combination appears as balanced linear load to the grid. A 500kW Type I Wind Generation System 250kW each with Four Leg Inverter Controlled by d-q technique operated as DSTATCOM connected to 415V 4 wires Grid is proposed which reduces the %THD of system to 1.97% from 24.12% where Unit Vector Control is of 3.94% which was on higher side, this is simulated in MATLAB/SIMULINK [21]. Improvements are shown in Direct Torque control of induction motor using Fuzzy logic switching controller (FDTC). The conventional DTC (CDTC) and FDTC drive performance is compared using Conventional PI, Fuzzy controller and Neural Network controllers. The presence of hysteresis bands is the major reason for high torque and flux ripples in CDTC. In FDTC the hysteresis band and switching table are replaced by Fuzzy logic switching controller. Artificial intelligence based fuzzy controller and neural network controller are compared with PI controller for both CDTC and FDTC of Induction machine. Simulation results shows reduction in torque and flux ripples in FDTC and dynamic performance of the drive at low speeds and sudden change in load torque was improved using Fuzzy logic controller compared to PI and neural network controller [22]. A study is done on the basis of comparison between different kinds of controllers based on a speed tracking problem inside an electrical vehicle using an axial-flux permanent-magnet traction motor. Basically the outline is the control of the power train of electric vehicles which is a great challenge to ensure driving comfort. To do so, the vehicle's performances are carried out using an established simulation platform implemented on Matlab-Simulink environment. Then, obtained results are compared for the three synthesized controllers. It has been found that required speed levels are reached with a clear advantage of the adaptive Fuzzy-PI controller versus the PI and the fuzzy counterparts, from the points of view of rise and settling times [23]. A process is described for automatically detecting and correcting errors in PQ monitoring data, which has been applied in an actual smart grid project. It is demonstrated how to: unambiguously recover from various device installation errors; enforce time synchronization between multiple monitoring devices and other events by correlation of measured frequency trends; and efficiently visualize PQ data without causing visual distortion, even when some data values are missing. This process is designed to be applied retrospectively to maximize the useful data obtained from a network PQ monitoring scheme, before quantitative analysis is performed. A case study of a UK smart grid project is also discussed [24]. A Multilevel Transformer-less Hybrid Series Active Filter (Multilevel-THSeAF) is proposed to enhance the power quality of a single-phase residential household which reflects new trends of consumers towards electronic polluting loads and integration of renewable sources. A proportional resonant (P+R) regulator is implemented in the controller to prevent current harmonic distortion s of various non-linear loads to flow into the utility. Its main feature is the great capability to correct the power factor as well as cleaning the grid simultaneously, while protecting consumers from voltage disturbances, sags, and swells during a grid perturbation. It investigates aspects of harmonic compensation and assesses the influence of the controller's choice and time delay during a real-time implementation [25].

Objectives

The main objective of this paper is to present a technological aspect by virtue of which the quality of power can be enchanced in an efficient manner. For doing so, a nunmber of research papers have been reviewed and it is found that many different approaches have been employed which result in improving the efficiency of the system hence improving the

Table 1 Summary of the whole literature review along with results

Author (s) & Year of Publication	Solution Approaches / Methodologies	Result/ Limitation
Wei Li *et al*, 1998	Fuzzy Proportional Integral-Derivative Controller (PID) controller	Stability of system remains unchanged after the PID controller is replaced by the fuzzy P+ID controller without modifying the original controller parameters.
Phumin Kirawanich *et al*, 2004	Rule-based Piecewise-linear Fuzzy Proportional-Integral Controller (FPIC)	The uncompensated line current THDs fluctuate between around 78% and125%, respectively, for Loads A and B, APLC, takes approximately two cycles in the case of Load A and one cycle in the case of Load B to compensate the line current and reduce the THD.
C. N. Bhende *et al*, 2006	TS Fuzzy logic controller.	TS fuzzy controller was better than the conventional PI controller under various load conditions as well as filter parameter variations. The dc-link voltage settled approximately within two cycles for the large change in load and also the excursion in voltage was less compared to the PI controller
Ahmet Teke *et al*, 2011	Fuzzy-logic controller used in dc link control strategy.	A nonlinear load current with 24% THD is approximately reduced to 4% with a PI controller and 3.7% with FLC.
H. Sudheer *et al*, 2016	Fuzzy logic DTC (Direct Torque control)	FDTC the torque ripples are reduced by 90% and flux ripples are reduced by 40% compared to CDTC. Rise time 0.015 sec, 0.01 sec and 0.01 sec and Peak overshoot 39%, 0% and 9.09% Settling time 0.025 sec, 0.015 sec and 0.013 sec by using PI controller, Fuzzy controller and Neural controller.
Alaeddine Ben *et al*, 2016	Adaptive Fuzzy-PI controller versus the PI and the fuzzy counterparts	Required speed levels are reached with a clear advantage of the adaptive Fuzzy-PI controller versus PI and the fuzzy counterparts, from the points of view of rise and settling time.
Ramon Costa *et al*, 2009	A single-phase shunt active filter	Active filter operation with no load its THD = 6.8% and active filter operation with non linear load THD = 0.6% and active filter operation with linear load THD = 0.9%.
Ramon Costa *et al*, 2009	Hybrid-series active Power Filter	The proposed hybrid-series APF was simulated in MATLAB/Simulink, using a source impedance of 2% p.u. For the experiments, a 1-kVA/110-V 50-Hz system using an IGBT-based multilevel inverter was implemented.
Karuppanan P *et al*, 2011	PI, PID and FLC based cascaded shunt active power filter	THD conditions Source Current without APF Source and Current with APF source and PI controller and PID controller and Fuzzy logic controller Steady state 25.38% ,2.61% ,2.58% and 2.53% Transient 25.32%, 2.59% ,2.59%and 2.48% Power factor 0.8772 ,0.9733, 0.9721 and 0.9829.
Zheng Zeng *et al*, 2014	three-phase LCL Filter-based Active Power Filter (APF)	The harmonic currents are effectively compensated and the grid current is almost sinusoidal with a low THD of approximately 3.7%. This result proves that the repetitive controller has a better steady filtering capability compared with the traditional PI controller.
Tiago Davi Curi Busarello *et al*, 2015	Active power compensators to replace the passive filters and capacitor banks	Authors described a active power compensators and the CPT is a time-domain theory applicable to any periodic signal, single or poly-phase system with or without neutral conductor. THD before and after the compensator began to operate are 20.9% and 9.0%.
Fazal U. Syed *et al*, 2009	Linear control algorithm	In this test, the vehicle initially cruises at a constant speed of 30 mph at an altitude condition of 9000 ft above sea level, where the accelerator pedal is held depressed at 17% and then the accelerator pedal is depressed to 33%.
Parag Kanjiya *et al*, 2013	A non-iterative optimized algorithm	Algorithm is proposed for 3P4W shunt APF to achieve an optimum performance between power factor and THD. This approach does not require complex iterative optimization techniques. Only three conductance factors are sufficient to determine the desired reference source currents. It determines conductance factors in 10 µs.
Manoj Badoni *et al*,2015	variable forgetting factor recursive least square (VFFRLS)-based control algorithm	In this paper authors have proposed some value of pf, THD and then calculated by their algorithm. THD is found to be 2.32%, 3.68% and 4.72% at load currents 40.7, 40.72 and 40.35 ampere respectively. THD in supply current has been reduced to 3.5% from 22.9% in load current which is within the limits of the IEEE-519 standard.
Sabha Raj Arya *et al* , 2015	Adaptive neural network control algorithm	PCC voltage is regulated to the desired value after supplying extra reactive power from DSTATCOM. After voltage regulation, source current and load current THDs are 4.5%, 4.5%, 4.6% and 22.7%, 22.6%, 22.5%, respectively and harmonics are reduced to 1.5%, 7.9%, and 15.4%.
Iraide Lopez *et al*, 2016	Proposed algorithm NPC converter with the proposed modulation strategy	This work proposes an efficient n-phase neutral-point-clamped converters. The proposed modulation strategy is able to control and completely remove the low-frequency neutral-point voltage oscillations for any operation point and load types.
M.Vijayakumar *et al*, 2013	A three phase line interactive uninterruptible power supply system	The THD level of the load voltage and load current, which were approximately 14.7% and 29.9% respectively before compensation, were reduced to about 4.66% and 4.86% after compensation by using universal active power filter with PI controller.
R. Augusto Modesto *et al*, 2015	Unified Power Quality Conditioner (UPQC)	UPQC installed at a 3P3W system. For voltages V_{sa} and V_{La}, THD is 12.3% and 1.8% respectively. For currents i_{sa} and i_{La}, THD is 1.2% and 30.7% respectively.
Jinwei He *et al*, 2014	Active Harmonic Filtering Using Current-Controlled, Grid-Connected DG Units With Closed-Loop Power Control	DG current is sinusoidal and the local load harmonic currents are pushed to the main grid side. THDs of DG and grid currents are 5.16% and 41.73%, respectively. Local load harmonic current are compensated by DG unit, resulted in an improved main grid current (with 3.64% THD) at the same time, the DG current is polluted with 51.08% THD.
Sabha Raj Arya *et al*, 2015	Power Quality Improvement Using DSTATCOM	The generator current and PCC voltage total harmonic distortions (THDs) are 6.7% and 1.7%, respectively. Values of source and load kVAR are 1.90 kVAR (leading) and 1.64 kVAR (lagging), respectively, with constant frequency.
Stefan M. Goetz *et al*, 2015	M2SPC topology using 4-pole modules, extending the 2-pole M2C module structure	Output deviated from the previous one by no more than two module-voltage steps (2×100) V. The losses were controlled to 246 W on average which led to an average switching rate of 47.5 kHz.
Alireza Javadi *et al*, 2016	Power Quality improvement by a Multilevel-THSeAF	Proposed solution used a multilevel configuration to reduce dc side voltage for low level distribution system, which facilitates the integration of energy storage systems and renewable for modern households. It does not use the bulky series transformer which constitutes an economic key toward cost effective power quality improvement of future grids.

S V S Phani kumar *et al*, 2016	Controlling the inverter gate pulses	The proposed d-q method reduces the %THD of system to 1.97% from 24.12% where Unit Vector Control is of 3.94% which was on higher side; this is simulated in MATLAB/SIMULINK.
Sijia Hu *et al*, 2016	Y-D multifunction balance transformer (YD-MFBT)-based power quality control system (MBT-PQCS)	The dc-link voltage is controlled around 17.3 kV in steady state and shows the overshoot about1.156% (about 200 V) in the condition of load changes. The compensating system has a good dynamic performance, because the waveforms return to steady state from one working condition to another is in about 1–2 main grid periods.
Jakson P. Bonaldo *et al*, 2015	Flexible control technique for power electronics converters	The control approach was tested experimentally and by means of simulation, demonstrating its effectiveness in a scenario of practical interest. It was shown that, even when the PEC is used in a multifunctional manner, it is possible to obtain a virtually unitary power factor and low distortions of voltage at the PCC and of current in the grid.

CONCLUSION

A number of different technologies have been used which includes controllers like hybrid fuzzy logic proportional plus conventional integral derivative (fuzzy P +ID) controller, Takagi–Sugeno (TS)-type fuzzy logic controller. Some other methods are also used like active power line conditioner (APLC) that uses fuzzy logic, Asymmetrical nine-level active power filter (APF), A novel reference signal generation method for the UPQC, A PI, PID and Fuzzy Logic Controller (FLC) based shunt active filter for power line conditioners (PLC), A closed-loop power control scheme is employed to directly derive the fundamental current reference without using any phase-locked loops (PLL), A novel modular multilevel series/parallel converter, A modulation strategy for n-phase neutral-point-clamped (NPC) converters, A Y-D multifunction balance transformer (YD-MFBT) based power quality control system (MBT-PQCS), A Multilevel Transformer-less Hybrid Series Active Filter (Multilevel-THSeAF), A single-step non-iterative optimized algorithm for a three-phase four-wire shunt active power filter, A variable forgetting factor recursive least square (VFFRLS)-based control algorithm. The proposed algorithm can determine the conductance factors in 10 µs. and because of this it performs satisfactorily under dynamically changing load conditions. DC voltage excursion of the TS fuzzy controller found to be better than the conventional PI controller under various load conditions as well as filter parameter variations. Multilevel-THSeAF eliminates source harmonic currents and improves power quality of the grid without the usual bulky and costly series transformer. APLC/FPIC Spectrum analysis measurements showed that the line voltage typically had a THD of approximately 3%. In general it was seen that THD was appreciably reduced and efficiency of the system was greatly improved.

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