Review on Power Quality Solution Technology

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Abstract–This paper presents a comprehensive study of various possible solutions for power quality improvement in common applications and supply system. This includes improved power quality converters (IPQC), multi-pulse converters, active compensation, passive compensation and their hybrid configurations. Various configurations and topologies of custom power devices such as DSTATCOM (Distribution Static Compensator), DVR (Dynamic Voltage Restorer) and UPQC (Unified Power Quality Compensator) are also described in detail. Main applications of these devices are for reactive power compensation, harmonic elimination, voltage sag/swell mitigation, voltage regulation, load balancing, neutral current reduction etc. Many such cases of power quality problems have been taken up and suitable solutions have been identified for those cases. As an example, a model of DSTATCOM is developed and its performance is presented for a distribution system feeding nonlinear loads.

Keywords–Custom power devices, hybrid filters, IPQC, passive filters, reactive power compensators, multi-pulse converters, power quality

I. Introduction

Electrical distribution system is facing undesirable power quality disturbances due to different types of linear/non-linear loads on supply system. Some of these power quality disturbances and problems include waveform distortion, high reactive power burden, unbalanced currents in the three phases, excessive neutral current, voltage sag/swell, imbalances in supply voltage, flicker and notching etc [1]. Due to the proliferation of power converter based non-linear loads in the distribution system, power quality related problems are on the rise; further, as these converters which actually cause these power quality problems are also vulnerable to them. Voltage quality in a distribution system very much depends on various phenomena of the network disturbances and the quality of power coming from the distribution network; on the other hand, current quality mostly depends upon the nature of connected loads [2-4]. AC–DC conversion of electric power is required in adjustable-speed drives (ASDs), switch-mode power supplies (SMPSs), uninterrupted power supplies (UPSs), arc furnaces, welding systems and utility interface with non-conventional energy sources such as wind, solar PV etc. One of the major culprits causing power quality problems lies in these AC-DC uncontrolled converters. With the emphasis on electric vehicles to reduce green house gas emission, the battery charging for electric vehicles is likely to form a major chunk of the load on the distribution system. Similarly, mobile phone users are on a steep rise which makes the requirements of telecom towers to shoot up; hence telecom tower power supplies are also contributing to a huge non-linearity in the distribution system. In all these systems of medium power rating (10-15 kW), conventional AC-DC converters can be replaced by improved power quality converters (IPQCs) and multi-pulse converters to grossly improve the power quality situation [5, 6].

The choice of IPQC depends upon number of phases in AC mains (single-phase, three-phase), required level of power quality at input (permitted power factor-PF, crest factor-CF and Total Harmonic Distortion-THD), type of output DC voltage required (constant, variable, etc.), direction of power-flow (unidirectional and bi-directional), number of quadrants of operation in the V-I plane (one, two or four), requirement of DC output (buck, boost and buck-boost) etc. Very often active power factor correction (PFC) techniques are used for improving power factor in an AC-DC converter. Sometimes VAR compensators and harmonic filters are also used for power quality improvement and voltage regulation [7-10]. Proper wiring and grounding are equally important in industrial and domestic sectors especially from the safety point of view. With the help of proper grounding and wiring, safety can be sustained and equipment damage and malfunctions may be reduced [11]. The power quality at the point of common coupling (PCC) is governed by several international standards such as IEEE-519, IEC-61000-3-2, IEEE 1531 etc [12-14]. A review on improved power quality AC–DC converters for power factor correction and reduction of harmonics at the utility interface is presented in [15-16] which describe control strategies, selection of components and selection of specific converters such as buck, boost and buck–boost etc for specific applications. Multi-pulse AC–DC converters (MPC) are also used for improving the power quality to reduce harmonics at the three phase ac mains and ripples in dc output. It is mostly used in the applications of drives and telecom sectors [17].

Increased use of power converters for accurate control and improved energy efficiency have caused increase in voltage and current harmonic contents in the distribution sector. Passive and active power filters are used as solutions for harmonic filtering and reactive power compensation. In a passive filter, its components are passive elements such as capacitor, inductor and resistor. Many research publications discuss the classification of active and passive filters, their combinations and applications as solutions to different power quality problems [18-27].

Compared to traditional passive filtering, active filtering technology can have one or more of the functions as harmonic filtering, damping, isolation, voltage regulation, voltage-flicker reduction, load balancing and reactive-power control for power factor correction. The advent of

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powerful digital signal processors and their cost reduction have inspired manufactures to put active filters on the global power market. Many researchers use the term power conditioning rather than harmonic filtering, because the term "power conditioning" encompasses all the power quality solutions such as harmonic damping, reactive power control, harmonic elimination, load balancing, voltage flicker etc [28-30].

Active power filters can be categorized into shunt and series compensating devices. For e.g. distribution static compensator (DSTATCOM) is a shunt device whereas dynamic voltage restorer (DVR) is a series device. UPQC (unified power quality conditioner) is a combination of shunt and series compensating devices. Design, classification, and various topologies of different custom power devices are available in the literature [31-39]. Typical loads in a three-phase four-wire distribution system may be computer loads, lighting ballasts, small rating adjustable speeds drives (ASD) in air conditioners, fans, refrigerators and other domestic and commercial appliances etc. Because of these distributed loads on three-phases, the distribution system has a significant portion of the third harmonic current component. The iron-cored inductive ballasts as well as electronic ballasts in fluorescent lighting also contribute to third harmonic currents. One survey in the United States has revealed that in a typical distribution system, neutral currents can be as high as 1.73 times the phase current [40]. It is also revealed that 22.6% of the sites that have been surveyed have neutral currents exceeding the full load phase currents and this scenario is becoming worse in the recent years due to the proliferation of many nonlinear single-phase loads. Some of the neutral current mitigation techniques are use of a Scott or T-connected transformer, star-hexagon transformer, star polygon transformer and a zig-zag transformer. These techniques are passive in nature and can be used in combination with custom power devices [41].

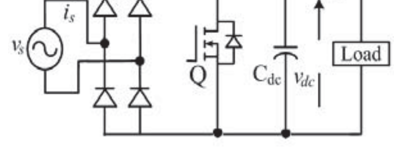
Some of the practical applications of power quality solutions in industrial and domestic sectors are IPQCs (Improved Power Quality Converters) as a power factor corrected (PFC) AC-DC converter for rectifier fed loads [42], autotransformer-based 24-pulse AC–DC converter for variable frequency drives [43], PFC Cuk converter-based PMBLDCM drive for air-conditioner application [44], boost PFC electronic ballast for compact fluorescent lamps (CFL) in lighting system application [45], application of PFC converter in special motor drives as switched reluctance motor [46], installation of SVC for arc furnaces to eliminate voltage and current harmonics distortion, flicker and unbalance elimination [47-49] by using a DSTATCOM at wood saw machine. These custom power devices are installed for eliminating flicker and offering reactive power compensation in arc and induction furnaces [50]. Following section gives a brief outline of various power quality solutions available as reported in the literature.

II. SOLUTIONS FOR POWER QUALITY IMPROVEMENT

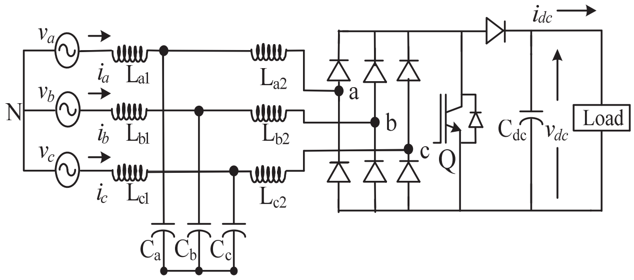
Increasing pollution in supply lines has drawn the attention of power engineers and many researchers are working for its prevention and suppression. In this regard, many standards such as IEEE-519, IEEE-1531 and IEC61000 have been developed and enforced to limit the power quality problems in industrial and domestic sectors [12-14]. There are power quality standards available from the view point of utilities and distribution companies as well. Power Quality problems can be effectively eliminated in two ways: first one is prevention- i.e., designing the upcoming power electronic systems in such a way as to make them to draw sinusoidal current in phase with the supply voltage; the other one is suppression, by means of employing power conditioners in already existing non-linear systems to nullify harmonics, to take the reactive power burden off the power supply and to eliminate imbalance. Some of the practical solutions for power quality problems are described below.

A. Application of IPQC for Power Quality Improvement [5-6, 15-17]

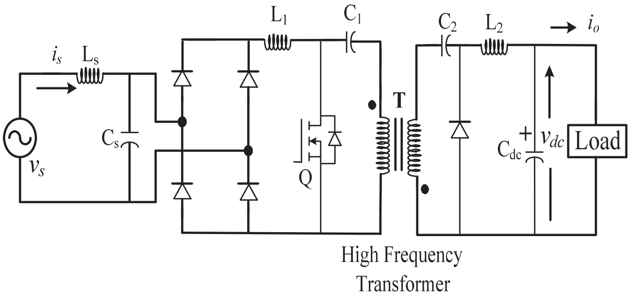
Low and medium power domestic and commercial applications are equipped with voltage source converters fed from single or three phase AC-DC converter connected with smoothing DC capacitor. These equipments draw nonlinear current from the supply which causes many power quality problems such as low power factor, heavy harmonic distortion in AC mains current and its high crest factor (CF). For mitigation of these problems various converter configurations are reported in the literature that are classified as IPQCs [5, 15-16]. IPQCs can be categorized based on various aspects as single phase and three phase, isolated and non-isolated converters. Various type of IPQCs are buck, boost, buck-boost and multilevel in non-isolated topologies and in isolated topologies such as flyback, forward, push-pull, Cuk, SEPIC, Zeta, half-bridge and full-bridge converters. Most of these converters are employed in DC power supplies, telecommunication power supplies, improved power factor ballast, multiple output power supplies for equipment like computers, medical electronic systems, printers and scanners etc. Many non-isolated AC-DC converters such as multi-pulse and multi-phase converters are used in drives and welding applications [17]. Figs. 1(a-c) show the schematic diagrams of single phase unidirectional boost converter, three phase unidirectional boost converter and single-phase buck-boost Cuk AC-DC converter respectively. In Fig.1(c), inductances L_s, L_1, L_2 act as boost/filter inductors, C_o, C_1, C_2 act as filter and charging storage capacitors. The inductive element in parallel with capacitor connected in the supply side acts as passive filters. Elements of power circuit such as semiconductor device, transformer are shown by symbols Q and T respectively



(a) Single-phase unidirectional boost converter



(b)Three-phase single switch unidirectional boost converter



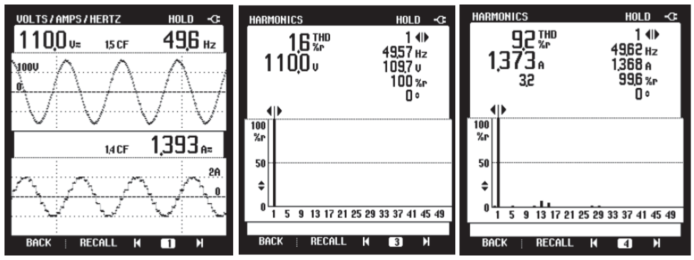
(c) Single-phase buck-boost Cuk AC-DC converter

Fig. 1: Schematic of various improved power quality converters [15-16]

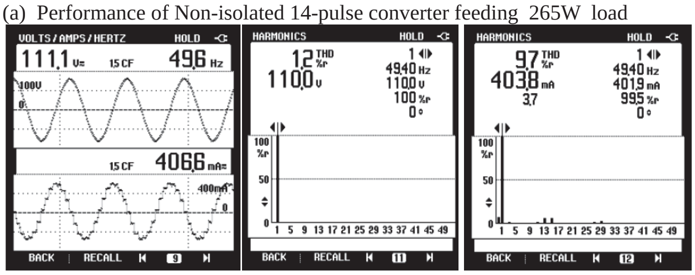
B. Application of Multipulse Converter for Power Quality Improvement

Multipulse technique involves connection of many six-pulse converters in series or parallel such that the harmonics generated by one converter are canceled by the other converter. It is one of the simplest and most effective techniques for reducing power converter harmonics [6, 17]. These have been widely used in high power drive applications and in electro-chemical industries. The expanding the use of power converters for adjustable frequency ac motor drives has stimulated the development of multipulse converters in lower power rating as well. Major advantages of multipulse converter technique are simple uncontrolled structure, reduction of AC input line current harmonics and reduction of DC output voltage ripple. These are also used in high voltage direct current (HVDC) transmission, telecommunication power supplies, battery charging, uninterruptible power supplies (UPS) of high-capacity, magnet power supplies, high-power induction heating equipments, aircraft converter systems and plasma power supplies [17]. Multipulse converters can be classified as 6, 12, 18, 24, 30 …. pulse etc. Harmonic level in supply line may be decreased further as the number of pulses increases.

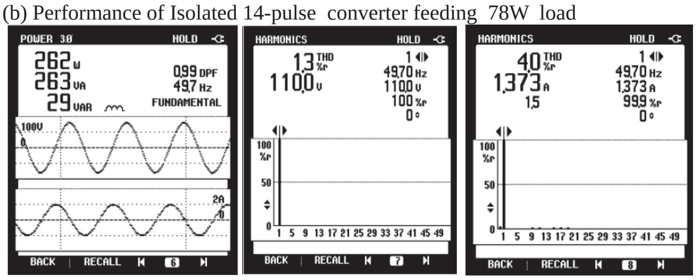
Large power rating rectifiers in 12-and 18-pulse configurations are commonly used in several important processes such as DC arc furnaces, plasma torches and so on. Sometimes, non-conventional pulse numbers (not a multiple of six) are also used in multi-pulse converters. The prototypes of 14 pulse and 28 pulse converter have been developed using diode bridge rectifiers and transformer connection. These converters are connected to three phase ac supply and feeding varying loads. A Fluke (43B) power analyzer is used for recording of steady state results on a developed converter. Waveforms of uncontrolled 3-phase 14-pulse and 28-pulse bridge rectifiers are shown in Fig.2. The input current THD is found to be around 10% in both isolated and non isolated 14-pulse converter and around 4% in 28-pulse converter.



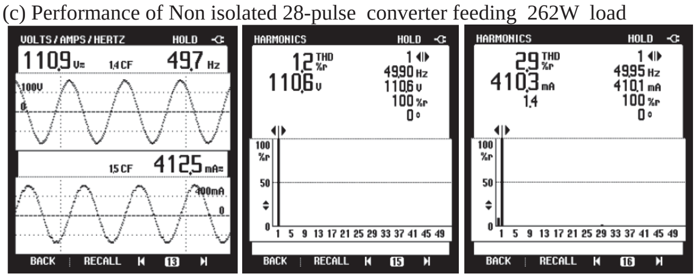
(a) Performance of Non-isolated 14-pulse converter feeding 265W load



(b) Performance of Isolated 14-pulse converter feeding 78W load



(c) Performance of Non isolated 28-pulse converter feeding 262W load



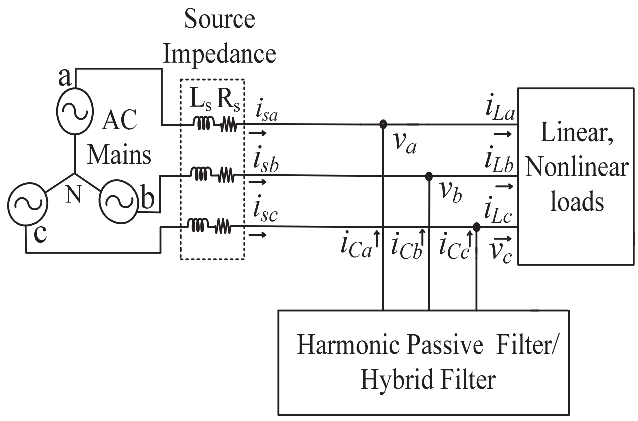
(d) Performance of Non isolated 28-pulse converter feeding 80W load

Fig. 2: Voltage and current waveforms and harmonic spectra of controlled 3-phase 14-pulse and 28-pulse bridge rectifiers

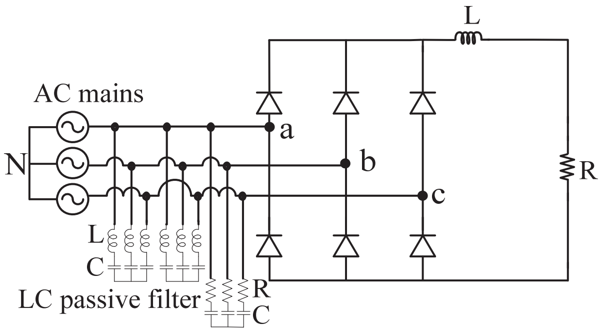
C. Application of Passive Filter for Power Quality Improvement [3-4, 18- 27]

Harmonic filtering using passive and active filters is one of the solutions to prevent the problem causing harmonics from entering the rest of the distribution system. Basically harmonic filters are two types. First is passive, where filter components are passive elements such as capacitor, inductor and resistor; second is active, where filter has a current source inverter (CSI) or voltage source inverter (VSI). Among the passive filter, there are two approaches to suppress undesired harmonic currents: first is, using a series impedance to block them; second is, diverting them by means of a low impedance shunt path. The former is called a series filter and the latter is called a shunt filter. In comparison with series filter, shunt filter carries only a fraction of the current and is also less expensive. Harmonic filter comes in many "shapes and sizes". Most of the times, harmonic filters are "shunt" filters because they are connected in parallel with the power system and provide low impedance path to suck for harmonics currents at one or more harmonic frequencies. Shunt filters are designed in different basic categories as single-tuned filters, multiple (usually limited to double) tuned filters, high pass damped and undamped filter (first order, second, or third order) and bypass filter etc [3, 4]. The single and double tuned filters are usually used to filter specific frequencies, while the damped filters are used to filter a wide range of frequencies. Key point for the passive filter design is reactive power (kVAR) requirement, harmonic distortion and normal system condition, inclusive of load and source impedances. The major advantages of a passive filter are it is simple, easy to build at higher power levels, capable of providing reactive power compensation. The disadvantages of passive filter are problems associated with resonance, poor filtering characteristics resulting in power factors other than unity, dependence on source impedance, being bulky etc [21].

Passive filters can also be classified based on topology, connections and the number of phases. The topology can be tuned and damped to act as low pass and high pass for shunt filters or to act as low block and high block for series filters. These passive power filters may be connected in shunt, series or a combination of both for compensating different types of nonlinear loads. Third classification is based on the number of phases such as two wire (for single-phase) and three or four wire (for three-phase nonlinear loads). Passive filters are widely used to limit harmonic propagation, to improve power quality, to reduce harmonic distortion and to provide the reactive power compensation [22, 23]. Many such filters are in operation for HVDC transmission systems, large industrial drives, static VAR compensators etc. Passive filters are the best and viable choice in high voltage and high current applications. Figs. 3(a) and (b) show the schematic of passive filter connection in three phase three wire system and actual structure of the filter with a diode rectifier. A combination of series and shunt filter configuration is known as a hybrid filter. These individual components can be active or passive. It provides cost effective solution to problems of compensation of harmonics in current and voltage [24-27]. Hybrid filter can be classified based on the number of elements in the circuit topology and supply system. The supply system can be single phase (two-wire), three-phase three-wire and three-phase four-wire to feed a variety of nonlinear loads.



(a) Schematic of Passive filter connection in three phase three wire system



(b) Three phase diode bridge rectifier with passive filter

Fig 3: Schematic of passive filter with supply system

The type of converters can be voltage source inverter (VSI) or current source inverter (CSI) to realize active filter part of hybrid filter with appropriate control. The number of elements in topology can either be two, three or more, which may either be active filters or passive filters. Here, the main classification is made on the basis of supply system with further sub-classification on the basis of filter elements. Fig.4. shows the classification of hybrid filters based on number of phases in the supply system and further sub-classification based on topology and passive and active filter combination. Some example of hybrid filters are unified power quality conditioner (UPQC), combination of passive and active filters and their topologies. These are most effective solution for compensation/suppression of power quality problems in various power levels.

Fig. 5 shows a typical hybrid filter configuration. This hybrid filter is formed by series connection of passive filter and a small capacity active filter. The passive filter suppresses harmonic currents produced by the load, whereas the active filter improves the filtering characteristics of the passive filter. As a result, the hybrid filter system can solve the problems inherently by using only a passive filter. The series connected active filter is controlled to act as a harmonic compensator for the load by constraining all the harmonic currents to sink into passive filters. This eliminates the possibility of series and parallel resonances. By actively improving the compensation characteristics of the tuned passive filters, the need for precise tuning of the passive filters is greatly reduced and the design of the passive filter becomes insensitive to the supply impedance. This topology is suited for the harmonic compensation of the load connected to a stiff supply. This configuration effectively provides compensation for current harmonics and limited supply voltage distortions, since it acts as a harmonic voltage source, compensating for the voltage drop in passive filters at harmonic frequencies at PCC. However, the distortions in the utility voltage are added to the required voltage injected, and hence the required rating of the active filter may increase. Unlike hybrid filters having active filter in series with AC mains, these are less susceptible to problems under short circuit condition in the utility line and do not increase voltage harmonics any further. Selection of hybrid filter configuration depends upon the nature of load (voltage fed, current fed or mixed), type of supply system (single-phase, three phase three wire, three phase four wire), compensation required in current (harmonics, reactive power, balancing, neutral current) or voltage (harmonic flicker, unbalance, regulation, sag, swell, spikes, notches) and pattern of loads (fixed, variable, fluctuating) etc.

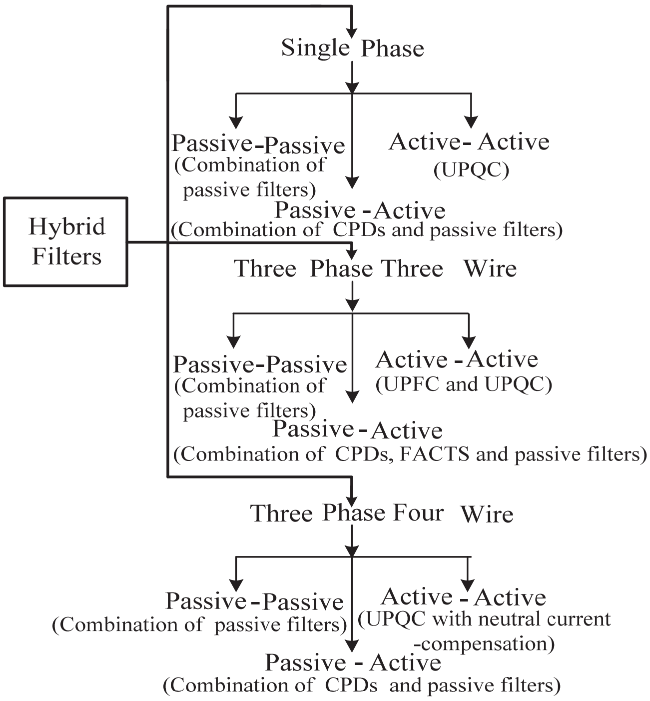


Fig. 4: Classification of hybrid filters for power quality improvement [24]

D. Application of Active Filter and Custom Power Devices [1, 2, 7, 8, 28-49]

In order to overcome the problems associated with passive filters, active power filters have been developed since early 1970's. The operation of an active filter is based on continuous monitoring and conditioning of the distorted current created by the nonlinear loads. The same harmonic currents, but with a 180º phase shift are generated by the filter, so that harmonic components are cancelled and only fundamental component flows from the point of common coupling (PCC) towards the source. Functions of active filter are to cancel out harmonics, block resonance, reactive power management etc [28-30].

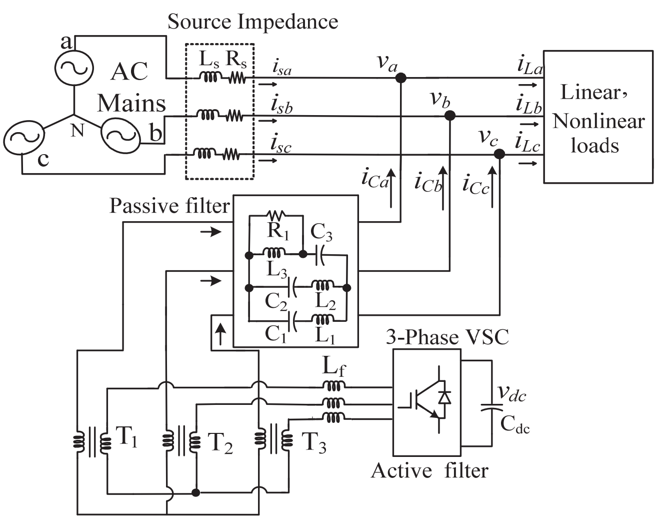


Fig. 5: Block diagram of a typical hybrid filter configuration

Improved versions of active filters are known as custom power devices (CPDs) that are used in low and medium power distribution systems. The term custom power pertains to the use of power converters in a distribution system, especially, these devices make sure that the customers get pre-specified quality and reliability of supply. This pre-specified quality may have specifications like no power interruptions, low flicker, less reactive power demand, balanced operation, low harmonic distortion, magnitude and duration of over-voltages/ under-voltages within specified limits, zero voltage regulation and less neutral current. These can be achieved on the basis of a large individual customer or industrial/ commercial parks or a supply for a high tech community on a wide area basis. Custom power technology is a general term for equipment capable of mitigating numerous power quality problems. Basic functions of these devices are fast switching converters with current or voltage injection for correcting anomalies in supply voltages or load currents, by injecting or absorbing reactive and active powers, respectively. The power electronic controllers that are used in the custom power solution can be network reconfiguring type or compensating type. The network re-configuration devices are usually called switch gears which include current limiting, current breaking and current transferring devices. It includes solid state current limiter (SSCL), solid state breaker (SSB), and solid state transfer switch (SSTS). The compensating devices either compensate a load, i.e. its power factor, unbalance conditions or improve power quality of supplied voltage, etc. These devices are either connected in shunt or in series or a combination of both. This class of devices includes the distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR), and unified power quality conditioner (UPQC) [1,7-9]. Among compensating devices, a DSTATCOM can mitigate current related power quality problems in power factor and voltage regulation mode whereas DVR can solve voltage sags and swells which are considered to have a severe impact on manufacturing industries such as plastics and semiconductor device manufacturing plants, food processing and paper mills. UPQC can be used to solve both types of problems in critical and sensitive loads such as hospitals, banks etc. Details of these devices are given below.

1) Distribution Static Compensator (DSTATCOM): This provides load current compensation in the form of reactive power compensation, load balancing and/or harmonic elimination and neutral current mitigation. Performance of DSTATCOM system depends on the algorithm used for control of the system so that dynamic compensation of the load can be provided. The important requirement for the control algorithm is that it should be simple, easy to implement and work well with non-sinusoidal and unbalanced ac mains, which is a practical situation in the present day distribution system. Depending upon supply system, the topologies of DSTATCOM are shown in Fig. 6(a, b). Power circuit of DSTATCOM includes voltage source inverter with DC bus voltage (v_{dc}) supported by a DC bus capacitor (C_{dc}) and AC inductors (L_f). Three phase supply currents, compensating currents, load currents, supply neutral current, load neutral current are shown by (i_{sa}, i_{sb}, i_{sc}), (i_{Ca}, i_{Cb}, i_{Cc}), (i_{La}, i_{Lb}, i_{Lc}), i_{sn} and i_{Ln} respectively. Circuit parameters such as high value of source inductance (L_s) distort the supply voltage, smooth the current waveform and effect the mean output voltage. Diode bridge rectifier with series connected inductor and resistance is presented as current fed type nonlinear loads where maximum percentage harmonics are 31.08% and 48.34% in three wire and four wire systems respectively. In case of voltage fed type nonlinear loads, maximum percentage of harmonics is decided by value of parallel connected capacitor. For reducing ripple components in compensating currents, proper tuned valued of interfacing inductors (L_f) are connected at ac output of the VSC. A three phase series combination of capacitor (C_f) and a resistor (R_f) represent the shunt passive ripple filter which is connected at point of common coupling (PCC) for reducing the high frequency switching noise during DSTATCOM operation.

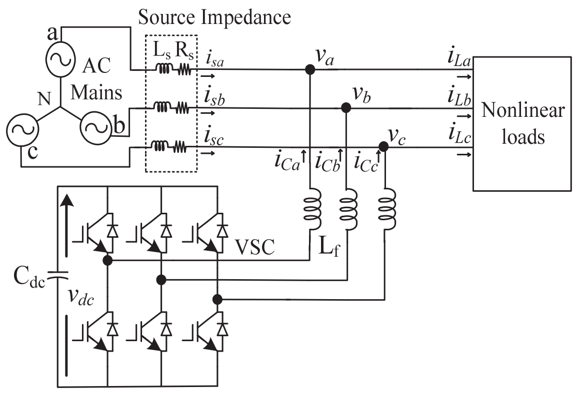
Fig 7 shows a block diagram of synchronous reference frame (SRF) theory based control algorithm for DSTATCOM. Where i_{sd}* and i_{sq}* are the total active and reactive components of the reference supply currents. SRF algorithm is used for generation of reference supply currents (i_{sa}*, i_{sb}*, i_{sc}*) using Park's and inverse Park's transformation from distorted three load currents (i_{La}, i_{Lb}, i_{Lc}). The sensed supply currents (i_{sa}, i_{sb}, i_{sc}) and reference supply currents (i_{sa}^*, i_{sb}^*, i_{sc}^*) are compared and extracted current errors are amplified through PI current controller and output of these controllers are fed to comparator to generate the gating signals of VSC. DSTACOM is connected to a three phase supply feeding three phase nonlinear loads with internal grid impedance for test purpose. Three phase diode based rectifier with resistive load is modeled as nonlinear load. A Fluke (43B) power analyzer is used for recording steady state results on a developed DSTATCOM. Fig. 8 shows the performance of three-phase VSC based DSTATCOM system under nonlinear loads in power factor correction mode. After power factor correction, %THD of phase 'a' supply current and load current are 3.1% and 27.7 % respectively. It shows that supply currents are maintained balanced and sinusoidal in phase with the supply voltages even under highly distorted load currents.

2) Series connected DVR (Dynamic Voltage Restorer)

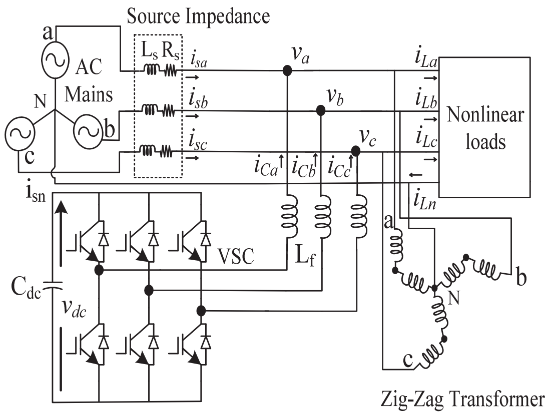
A DVR is connected between the supply and sensitive load, so that it can inject required compensating voltage into the distribution line [38]. Therefore, the DVR can provide an effective solution for compensating voltage sag, swell, harmonics and unbalance in supply voltages. Depending upon supply system, its topologies are depicted in Fig. 9, where (i_{sa}, i_{sb}, i_{sc}), (v_{ca}, v_{cb}, v_{cc}), (i_{La}, i_{Lb}, i_{Lc}) are shown as three phase supply currents, compensating voltages and load currents respectively. Power circuit elements as interfacing inductor and series transformer are represented as L_r and T_r.

3) Unified power Quality Conditioner (UPQC)

It is a combination of DSTATCOM and DVR. If any consumer can afford the cost, then a hybrid of these two compensators provides the best solution and thus it is known as unified power quality conditioner (UPQC) or universal active filter. Therefore, the development of hybrid filter technology has been from a hybrid of passive filters to a hybrid of active filters to provide a cost-effective solution and optimal compensation for voltage related power quality problems. For systems based on diode bridge converters with high DC link capacitive filters, series active or hybrid filter configurations are preferred. In general, when a UPQC is used in a power distribution system, the series filter is installed ahead of the shunt filter. Functions of UPQC are a hybrid of shunt and series compensators that take care of both current quality and voltage quality problems. The shunt compensator converts the load currents to balanced sinusoids, the series compensator converts the load voltages to balanced sinusoids; thus, it can mitigate the load current quality problems and the source voltage quality problems. But, it is an expensive device, as it requires two sets of power inverters. Fig. 10 shows the schematic diagram of UPQC [1, 9, 39]. It shows three phase supply currents (i_{sa},i_{sb},i_{sc}), compensating voltages (v_{ca},v_{cb},v_{cc}), compensating currents (i_{Ca},i_{Cb},i_{Cc}), load currents (i_{La},i_{Lb},i_{Lc}), interfacing inductor (L_r) and series transformer (T_r).



(a) Three phase three- wire, 3-Leg VSC Topology of DSTATCOM system



(b) Three phase four- wire, 3-Leg VSC with Zig-zag transformer topology of DSTATCOM system

Fig. 6: Supply system based DSTATCOM topologies [34, 36]

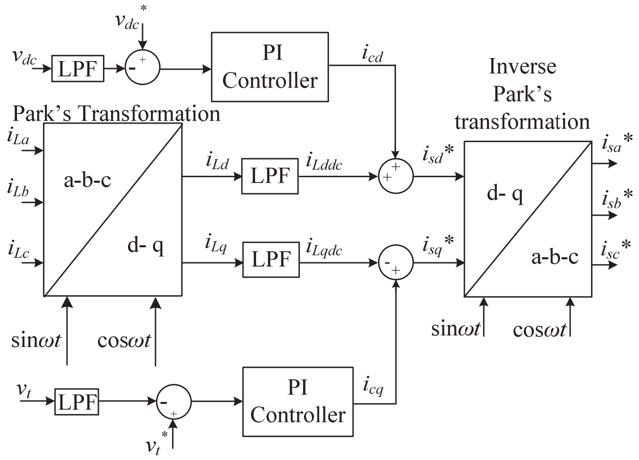
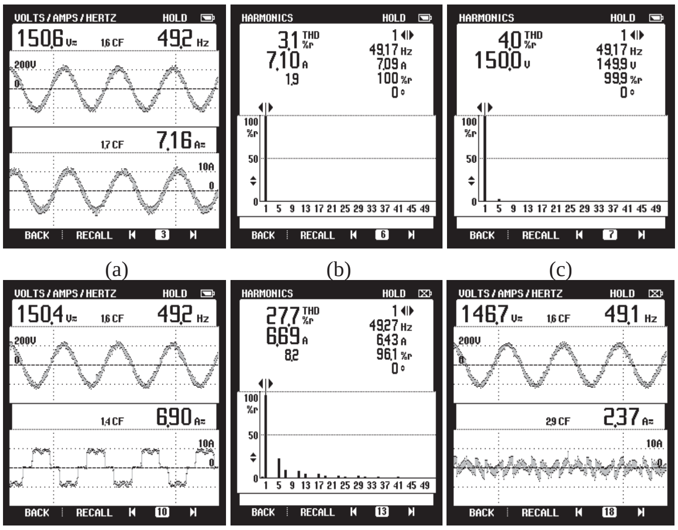


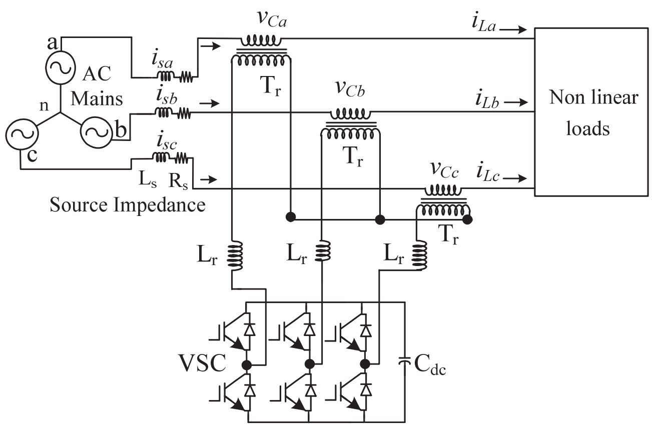
Fig.7: Block diagram of extracting reference source currents using SRF control algorithm [8, 32].



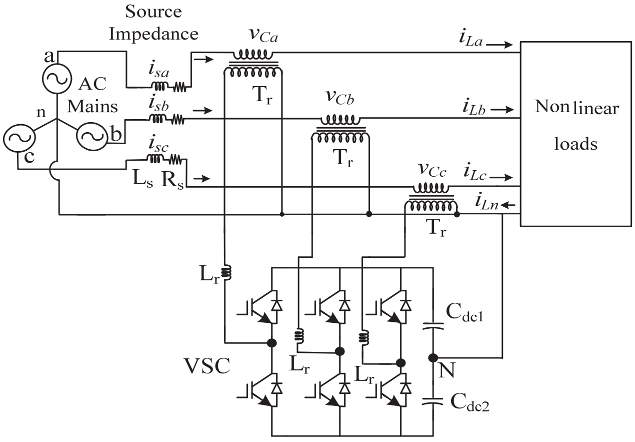
(a) (b) (c)

(d) (e) (f)

Fig. 8: Performance of DSTATCOM under nonlinear loads (a) v_{ab}, i_{sa} (b) Harmonic spectrum of i_a (d) Harmonic spectrum of v_{ab} (d) i_{La} (e) Harmonic spectrum of i_{La} (f) i_{Ca}



(a) Schematic of 3-phase 3-wire DVR system



(b) Schematic of 3-phase 4-wire DVR system

Fig. 9: Supply system based DVR topologies [38]

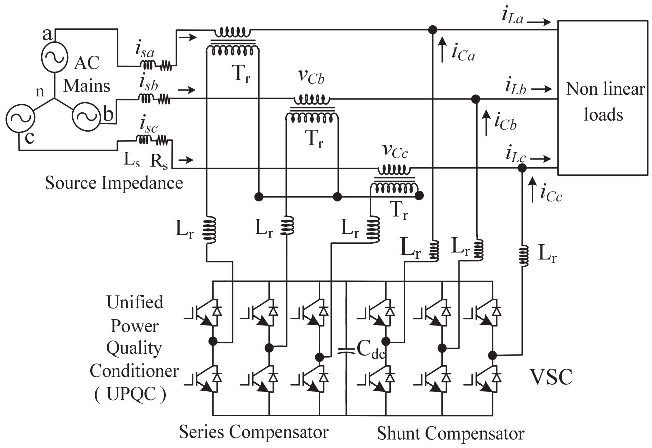


Fig. 10: Schematic diagram of UPQC [39]

V. Conclusion

Different types of converters and compensators have been proposed for the improvement of power quality. Some of these power quality mitigation devices have been illustrated as passive, active or hybrid filters, multi-pulse converters and IPQCs. Passive filters are not adaptable and remain fixed once they are installed in particular application also a special switching is required to avoid the switching transients but active filter eliminates limitation of passive filter. Active filter is equally well applicable for reactive power compensation, harmonic elimination etc without any resonance problem. Major problem with active filter are cost and high rating so its applications are limited. To reduce these problems, different topologies of hybrid filters are more effective solution. Selection of these equipments depends upon requirements of the system under consideration. Passive filter and hybrid filters have been more useful in very large power applications.

IPQCs and multi-pulse converters have been found very useful in both industrial and domestic sectors such as lighting, air conditioners, SMPS and telecommunication power supplies etc. They have also been extensively used in the areas of power supplies and adjustable speed drives. For low and medium voltage domestic and commercial sectors, custom power devices have been found more suitable as compared to passive filters. DSTATCOM which is the shunt connected custom power devices is the most popular compensating devices for harmonic elimination, reactive power compensation, load balancing and neutral current compensation in power factor correction and voltage regulation mode. It is more suitable for current fed type loads. DVR is another custom power devices which is used for series compensation to protect critical loads from ac supply main disturbances. Generally, series filter is better suited are more suitable for voltage fed type loads because its rating is less compared to shunt filters.

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