CHAPTER - 2

REVIEW OF LITERATURE

2.1 Reviews of Power Quality Improvement in ASD

Back in the 1970s, the definition of the power quality included limits applied to the fluctuations of frequency and voltage, the voltage unbalance, voltage transients, voltage harmonics and power cuts. Moreover, the purpose of quality control was intended to reduce consumer complaint and increment the electric power use value as well as to obtain data for better monitoring and planning of power supply systems (Hilger 1972).

Colding *et al*. (1982) has mentioned the International Union of Producers and Distributors of Electrical Energy (UNIPEDE) and issued one of the first standards for power quality. It is a report that outlines the quality of the electricity supply regarding noise spikes, variation of voltage levels and audio and radio frequency contents.

Alex DomijanJr *et al.* (1990) explained the Harmonic mitigation techniques for the improvement of power quality of adjustable speed drives (ASDs). An electronic motor drive classification based on the motor type is provided. Included are circuit configurations, a table of features of the main ASD, and a list of benefits of ASD. A brief recap of some of the harmonic effects and an overview of some harmonic mitigation techniques is presented.

MC Eachem (1993) has claimed the need for standards regarding power quality to determine the power quality status of distribution systems. Many different groups have been working towards this goal, including the ANSI (American National Standards Institute), Institute of Electrical and

Electronics Engineer (IEEE), CBEMA (Computer and Business Equipment Manufacturers Association), IEC (International Electro technical Commission).

IEEE Std 1100 defines power quality as "the concept of powering and grounding sensitive equipment in a matter that is suitable for the operation of that equipment." Despite this definition, the term power quality is used in a more general way in the IEEE (Bollen 2000). IEC has adopted, instead of power quality, the concept of electromagnetic compatibility defined as "the ability of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment."

A historical review of the standards related to power quality at the IEEE is given below:

IEEE Std 1100-1999 "IEEE recommended practice for powering and grounding electronic equipment" IEEE Standard 1159-1995, "IEEE recommended practice for monitoring electric power quality."

IEEE Standard 1250-1995 "IEEE guide for service to equipment sensitive to momentary voltage disturbances" IEEE Standard 1346-1998, "IEEE recommended practice for evaluating electric power system compatibility with electronic process equipment." IEEE Standard 1564 draft, 6, "Recommended Practice for the Establishment of Voltage Sags Indices."

The nature of power quality problems, their frequency and the problems they cause have been reported Melhom *et al*. (1995). The increased concern for power quality has resulted in measuring power quality variations, studying the characteristics of power disturbances and providing solutions to the power quality problems (Oliver *et al*. 2002). There are many solutions in

mitigating the power quality problems at a distribution system, such as using surge arresters, active power filters, isolation transformer, uninterruptible power supply and static Var compensator.

Osborne *et al*. (1992) have reported that the environmental effects also give an impact to the power quality and its reliability. Major concerns on industrial power quality problems are that they affect the production, due to sensitive equipment in the industries. When power quality problems occur equipment may misoperate, or machine may shut down. Installations by industries such as ASD switch mode power supplies and high-frequency switching also affect the power quality.

Bollen (2000), have explained that ASD is generally utilized in modem processes. The high dynamic performance, increased flexibility, and possible energy conservations are among the most important features driving the ASD-market. In any case, the reliable operation of these ASDs has to be ensured to avoid malfunctioning or interruption of the process. ASDs have shown to be very vulnerable towards voltage dips with a considerable financial impact, especially in continuous processes.

Deswal *et al*. (2008) has mentioned some common symptoms of PQ problems in ASD systems. They are premature tripping or shut down of the ASD, ASD resetting or restarting the motor which it operates, requirement of frequent repairs or replacements, erratic control of process parameters, unexplained fuse blowing and component failures, frequent motor overheating trip and continuous operation of the motor cooling system.

P. M. Balasubramaniam *et al.*(2015) explained the Power Quality Issues, Solutions and Standards . This paper presents a review of the main power quality (PQ) problems with their associated causes and solutions with

codes and standards. This paper concludes with some solutions to mitigate the Power Quality Problems are presented.

J. Seeralan. *et al.* (2015) discussed a power system power quality enhancement by dual voltage source inverter. These features make the DVSI scheme a promising option for micro grid supplying sensitive loads. Dual voltage source inverter (DVSI) scheme to heighten the power quality and reliability of the micro grid system. The suggested system is made up of two inverters, which enables the micro grid to exchange power generated by the distributed energy resources (DERs) and likewise to cover the local unbalanced and the nonlinear load

Kavya Mittal *et al.* (2015) compared the Different Filters for the Improvement of Power Quality**.** The proposed filter estimates and mitigates the harmonics in power transmission systems because of non-linear loads. Thus, by using the Hybrid Power Filter, THD will be delayed and is compared with the THD obtained without using filters

C. Subbaramireddy *et al.* (2015) explained the Power Quality and Characteristic Analysis of Multilevel Pulse width-Modulation Methods for Three-Level Diode-Clamped Medium-Voltage Industrial Drives**.** In this report, two multilevel pulse width-modulation schemes; phase disposition (PD) and selective harmonic elimination (SHE) up to the 29th and 17th harmonics correspondingly, are evaluated. In the SHE method has decreased CMV as compared with the PD algorithms. Eradication of up to the 29th harmonic attains the best harmonic presentation without requiring an output filter, at the cost that the losses are superior with a lower efficiency.

PooyaDavari *et al* (2016), an Electronic Inductor (EI) technique has been used in single drives to overwhelm the existing challenges in conventional front-end rectifiers even at partial loading conditions. Moreover, the effectiveness of the EI technique along with a phase-shifted current control in conditions of improved grid current quality in multi-drive configurations are addressed. Furthermore, novel DC-link current modulation schemes for multi-drive arrangements are offered.

Domínguez-Ibarvo *et al* (2016) proposed an advanced DC-DC Luo converter for low-power applications using a single high efficiency photovoltaic cell. In this paper is submitted with a different alternative to power-conditioning of environmental sources of energy through an advanced DC-DC converter, with the purpose to explore another efficient way to improve energy harvesting. In particular, it was used a 1-W high-efficiency solar mono crystalline cell and, as a base of the power conditioning structure, an enhanced self-lift positive output Luo converter (ESLPOLC) is provided. A 1 F super capacitor array is used to salt out the accumulated energy, which can be applied in low-power devices as wireless sensors and other low-power applications.

Sheik Mohammed Mukassir *et al* (2016) explained a Power quality improvement using a novel D-STATCOM-control system for analog and non-linear loads. In this proposed scheme Static-Compensator (STATCOM) is joined at the point of common coupling (PCC) along with sinusoidal conventional energy source. This scheme also mitigates the issues of power quality when are due to non linear load, Adjustable Speed Drives (ASD), UPS system, and also improves the voltage profile along is reducing Total Harmonic Distortion (THD).

Sanjana. S. Patil *et al*. (2016) explained a Power Quality Improvement using SSSC. It mitigates voltage sag and voltage swell caused by generating source such as wind power plants are tied to the power system. If the voltage supplied to the equipment is less than the rated, it will not work or either it will puzzle out at very low efficiency and if the voltage supplied is above the rated windings get damaged. In this paper SSSC is explained with its operation, Mathematical Modelling and modes of performance.

SK. Ershad Sameeer *et al.* (2016*)* discussed the Power Quality Improvement with a Shunt Active Power Filters using Fuzzy Logic. APF can easily eliminate unwanted harmonics, improve power factor and overcome voltage sags and eliminate any harmonic frequencies

Vishakha V *et al*. (2016) reviewed the Power Quality Improvement Using Active Power Filters. There are numerous advancements to diminish power quality issues so for this study is done on various setups and topologies for force quality change utilizing dynamic force filters.AF innovation is presently having characteristic development for giving pay to music, receptive force, and/or non-parties an current in air conditioning systems. These distinctive arrangements of APFs have been proposed to repay different force quality issues.

Lakkakula Durga Rani, *et al.* (2016) discussed a grid connected voltage source inverter with power quality improvement features. This theme reveals a dual voltage source inverter (DVSI) design to heighten the energy quality and trustworthiness of the micro grid system. The suggested scheme is made upwards of two inverters, which permits the micro grid to switch power made by the sent out energy resources (DERs) and to pay the neighbourhood unbalanced and nonlinear weight. The control algorithms are developed

predicated on the instantaneous symmetrical aspect theory (ISCT) to use DVSI in grid posting and grid injecting settings.

R. Saravana *et al.* (2016) explained multilevel inverter based UPQC for power quality improvement. In this paper, a 9-level based UPQC system is developed to maintain the system voltage and current profile at the grid as well as the load. The power quality of the proposed systems is progressed by controlling the MLI switches using a firefly algorithm (FFA) based pulse width modulation (PWM) scheme. The synchronization of UPQC with proposed 13 bus system is done with same FFA algorithm.

Laszlo Mathe *et al* (2017) proposed a Resonance Reduction for AC Drives With Small Capacitance in the DC Link. These drives are fed from a weak grid a resonance between the line side impedance and the DC-link capacitor appears. Due to this resonance, the THD and the partially weighted harmonic distortion of the line currents are increased, which may raise compatibility problems with the AC line harmonic standards. This report offers a novel DC-link voltage compensation method, which can thin out the amplitude of the above mentioned oscillation, while the big DC-link voltage variation, had by the rectification can be eradicated from the motor current.

Wajahat Ullah Tareen *et al* (2017) explained an Active power filter (APF) for mitigation of power quality issues in the grid integration of wind and photovoltaic energy conversion system. The highly unstable devices coupled with the rising need for nonlinear loads and renewable energy resources influence the power networks and system operation in terms of force quality. The effective solutions to these problems are passive filters (PFs), static var generators, and active power filters (APFs). However, the use of PFs in a high-power system increases its price, size, and weight. This work helps to trim back the number of power switches and focus on the reduction of cost, size, and weight of grid-connected inverters. The current techniques and their

limitations for developing advanced inverter-based devices for renewable energy systems are discussed with justifications.

Nikhil Gujar *et al* (2017) explained *a* Power Quality Monitoring and Mitigation in induction furnaces for steel making**.** In this composition, harmonic measurement at the level of common coupling of two industries having induction furnaces is discussed, in terms of current and voltage harmonics (when there is no load and when load increases and reaches maximum). The measurements were carried out for an entire load cycle to identify current demand distortion and voltage harmonic distortion. To mitigate the harmonics, passive filter is designed and simulated using ETAP software.

Sambasivaiah Puchalapalli *et al* (2017) discussed the Control Strategies for Shunt Active Power Filter for Harmonics Suppression**.** This report gives a comprehensive study of three control strategies, namely instantaneous reactive power (p – q) theory, synchronous reference frame (SRF) theory and instantaneous active and reactive current (id - IQ) component method for SAPF in a three phase three wire distribution system. These three control methods, aims to compensate harmonics, reactive power and load unbalance under sinusoidal balanced supply voltage conditions.

Yashi Singh *et al* (2017) explained the Power Quality Improvement in Single Phase Grid Tied Solar PV-APF Based System using Improved LTI-EPLL Based Control Algorithm**.** This paper deals with an improved LTI-EPLL (Linear Time Invariant-Improved Enhanced Phase Lock Loop) based control algorithm for a single-stage solar PV (Photovoltaic) power generating system (PVGS) with the power quality improvement. The proposed PVGS comprises of a PV array, a single phase voltage source converter (VSC), a nonlinear load and the grid. The VSC is used as a link between the PV array and the grid. The VSC provides the multi-functional capabilities in PVGS.

Pranay Kumar Alladi *et al.* (2017) proposed *a* conductance factor based control method for Distribution static compensator (DSTATCOM) to improve power quality**.** The proposed control algorithm extracts fundamental in-phase and quadrature components of load currents using conductance factor and voltage unit vectors at the Point of Common Coupling (PCC) to calculate the reference source currents during the normal and distorted supply conditions. The compensator with this control technique will cause the organization operate in either Unity Power Factor (UPF) mode or Zero Voltage Regulation (ZVR) mode.

Archana Sharma *et al* (2017) explained the power quality improvement at the conclusion of a permanent magnet synchronous motor (PMSM) based adjustable speed drive (ASD). In the input a typical ASD the current harmonic distortion has been found to be 288% due to the less conduction period of rectifier diodes. Shunt active power filter has been controlled using the Anti-Hebbian control algorithm. Posting out of Anti-Hebbian algorithm has been verified by comparing its performance with Synchronous Reference Frame (SRF) based control algorithm. Total harmonic distortion (THD) in source stream has been cut up to 4.98% using Anti-Hebbian control algorithm as compared to 12.86% in the case of SRF based control algorithm.

Mohit Srivastava *et al* (2017) reviewed mathematical modelling, of a Dynamic Voltage Restorer (DVR) systems using MATLAB Simulink. In this paper, PI controller and Discrete PWM pulse generator are used for the controlling purpose of the system. Here, several methods are used to control of the DVR system. The voltage injection method to control DVR system. In this way, the application of DVR to compensate the problem of starting voltage dip for induction motor is also probe.

Karthik Thirumala *et al* (2017) explained the hardware implementation of empirical wavelet transform (EWT) for the estimation of the IEEE Standard 1459 - 2000 definitions. The estimation of single-phase power quality indices (PQIs) using the EWT technique is extended away on a floating point digital signal processor TMS320F28377S.

Kumar Saliganti, *et al.* (2017) explained to solve the power quality problems with the help of the combined system of shunt and active series filters like unified power quality conditioner which aims at attaining a low cost under highly efficient command.

Milton K, et *al.* (2017) explained a Three Level Inverter Based Dynamic Voltage Restorer for Power Quality Improvement. The use of multilevel inverters in DVR improves the harmonic performance of the System. The synchronous reference frame based control applied to the DVR control.

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Ronak Mistry *et al.* (2017) explained the Control of Shunt Active Power Filter for Improvement of Power Quality. This sensitive equipment will introduce more problems due to the built in compensation and sometimes lack of enforced regulations. Therefore, Power quality improvement is becoming a more important factor as a point of view for reliable & continuous Power System operation.

Parthasarathy *et al.*(2016) proposed an enhancement of power quality in an ac-dc interconnected system using improved current injection technique. Mitigation of line current harmonics produced by a controlled converter as a nonlinear load using improved current injection technique is proposed in this

paper. The improved current injection technique is illustrated on a three-phase AC-DC interconnected system. Though the system may have many applications, it suffers from very high line current harmonics were mitigation becomes more necessary. In this case, the proposed method shows effective, sensitive variations in the THD of the line current variations whereas than the other techniques available. This effective system is simulated in PSIM platform.

2.2 Reviews of Multilevel Inverter

Multilevel Inverter Technology (MLI) has been developed recently as a very significant alternative in the area of medium and high power applications. Jose Rodriguez *et al*. (2002) presented the most important topologies like flying capacitor inverter; diode clamped inverter, cascaded multi-cell with separate DC sources. The emerging topologies are soft-switched multilevel inverters and asymmetric hybrid cells. The multilevel selective harmonic elimination, multilevel sinusoidal pulse width modulation, and space vector modulation were also discussed. For conveyor belts, laminators and unified power flow controllers much consideration given. Finally, the peripherally developing areas such as high-voltage, high-power devices, optical sensors and other opportunities for future development were addressed.

Leon Tolbert *et al*. (2002) presented transformer less MLI for the applications of high power Hybrid Electric Vehicle (HEV). MLI could generate nearly sinusoidal voltages with fundamental frequency switching. It did not have electromagnetic interference or common-mode voltage problem. These features made an HEV more accessible and safer. Cascaded MLI used several levels of DC voltage sources, which will be available from batteries, ultra-capacitors or fuel cells. So, it was fit for large automotive hybrid electric

drives. Simulation and experimental results displayed how to operate this inverter to maintain equal charging and discharging operations from the DC sources in hybrid electric vehicles.

Zhong Du *et al.* (2006) proposed a cascaded MLI which is executed utilizing only a single DC power source and capacitors. Typical cascaded MLI required n number of DC sources for 2n+1 levels. The proposed scheme utilized the use of a single DC power source without transformers and the remaining (n -1) DC sources being capacitors. In this proposed system, the DC voltage level of the capacitors was kept up, and also a fundamental switching frequency pattern was used to create a nearly sinusoidal output voltage. The switching angles were selected to eliminate harmonics in the output voltage waveform.

Rajesh Gupta *et al.* (2007) proposed a Distributed Static Compensator (DSTATCOM), based on cascaded transformer MLI. The proposed scheme needed a common DC storage capacitor. Two level ramp comparison current control methods were extended for the MLI using phase shifted multi-carrier PWM Technique. In this strategy, equal switching stress and same power handling for all the cascaded units can be accomplished. There is a decrease in ripple magnitude, causing the feed forward gain to increase, leading to a higher bandwidth of the control loop with increased net switching frequency. An expression for the feed forward gain had been determined which demonstrated that the use of proportional plus a resonant controller with proposed multilevel modulation makes the tracking characteristics to get improved in fundamental frequency. A seven-level inverter based DSTATCOM was proposed for application to the three-phase medium voltage distribution system, and results was verified by Power System Computer Aided Design (PSCAD)/ Electromagnetic Transients Including DC (EMTDC) simulation.

Jose Rodriguez *et al*. (2007) described a technology review of voltage source converter topologies for medium-voltage industrial drives. They had discussed many inverter topologies like diode clamped, cascaded H-bridge and flying capacitor converters. The operating principle of each topology with related modulation methods was employed. It is concluded that the selection of topology and modulation method were closely related to a particular application and also gave the solution to the problems like voltage level, dynamic performance, reliability, costs, and the other technical specifications.

Dietmar Krug *et al*. (2007) compared the component count and the expense of active and passive components of the different multilevel inverter topologies for 2.3 kV, 2.39 MVA industrial medium voltage drives. Diode-clamped MLI is one of the competitive topologies for a large variety of low and medium switching frequency (1000Hz) applications. The high capacitance values and stored energies of the flying capacitors limit the use of the flying capacitor multilevel inverter to high switching frequency (1200Hz) applications. Cascaded H-bridge MLI is an attractive topology for various medium voltage drives because it required lowest installed switch power and stored energy of the LC sine filter. IGBT based MLI was recommended for medium voltage drives.

Alireza Nami *et al.* (2011) presented a series connection of a high voltage diode clamped inverter with H-bridge multilevel pulse width modulation converter topology and a low voltage conventional inverter, to make a maximum number of output voltage levels with the aid of adjacent switching vectors between dc link voltage levels. With less number of power components, 15 level hybrid converters were made. The output voltage of THD got in the 15 level hybrid inverter is 7.2%. The performance of the proposed converter was compared, and it was proved by simulation as well as hardware.

Banaei & Salary (2011) proposed a new MLI that operated both in symmetric and asymmetric states. This inverter generates DC voltage levels with the least number of switching devices. As a result, reduction in losses, converter cost, and installation area was achieved. The number of gate driver circuits were also reduced in this topology. From this topology, a nearly sinusoidal output voltage with low harmonic distortion can also be achieved. Voltage injection capabilities of the proposed converter were verified by applying this topology in Dynamic Voltage Restorer (DVR). Their operation and performance were confirmed by MATLAB/Simulink and experimental results.

Anup Kumar Panda &Yellasiri Suresh (2012) proposed Cascaded MLI which employed a single DC source and three phase transformers. Proposed Cascaded MLI has the attractive features of low switching frequency, increased utilization rate which allowed to achieve high-quality output voltages and input currents. The proposed MLI was reliable, cost effective and compact due to less number of components which were proved by prototype experiments. Voltage THD obtained in the proposed seven-level inverter was 10.23%. Because of these, the proposed architecture was superior to the conventional methods. These features made the proposed converter applicable for grid-connected photovoltaic systems, wind power generator systems and Flexible Alternating Current Transmission Systems (FACTS).MLI had been proposed to handle high power and high voltage in the flexible power systems. They had advantages over conventional two level converters, out of which high quality of the output voltage was most important.

Ebrahim Babaei *et al*. (2012) proposed symmetric and asymmetric multilevel inverter topologies with less number of switching devices compared to other topologies. Hybrid topologies are operated at high voltage levels, and their simulation results were obtained with Power System Computer Aided

Design (PSCAD)/ Electromagnetic Transients Including DC (EMTDC) software and the experimental results were presented.

Banaei & Salary (2012) proposed a novel cascaded multilevel inverter, which employed two DC sources, single phase transformers, and semiconductor switches. This inverter operates in both symmetric and asymmetric modes and gives a number of voltage levels. Gate driving circuits required for this inverter were less, lead to reduced circuit size and lower power consumption. Several methods available for the determination of the turns ratio had been given. A theoretical analysis was done, and simulation results were verified using MATLAB/Simulink software. The output voltage THD obtained for the twenty-seven level inverter was 2.91%. Experimental results were provided to verify the simulation results.

Venkatachalam Kumar Chinnaiyan *et al*. (2013) proposed power semiconductor switches with a three phase multilevel inverter to minimize the power quality issues in solar power conversion system. The developed prototype 3φ CMLI performance was analyzed for solar energy conversion. Because of low voltage stress, low THD in output voltage waveform, These MLIs are popular.

Krishna Kumar Gupta & Shailendra Jain (2013) proposed a new MLI topology was developed by adding and subtracting the combinations of input DC levels at the output voltage waveform; the levels depends on the arrangement of DC source. Proposed and classical multilevel topologies were compared by some levels in the output voltage and device count. In addition to that, the appropriate modulation scheme applied and detailed study was made on the proposed topology. This concept was verified through hardware and simulation.

Ebrahim Babaei *et al*. (2013) proposed a cascaded MLI topology with less number of switching devices which also offered provisions to design the desired MLI. Optimization of the proposed cascaded MLI considering some factors such as some semiconductor switching devices, the number of output voltage levels and the voltage across each switch was given. The important reason for improved output power quality was that the multilevel inverters generate a nearly sinusoidal output voltage. Cascaded H-Bridge (CHB) MLI can also be derived from the proposed inverter. Performance parameters related to conventional CHB inverters were analysed with thirteen level inverter by the simulation and experimental setup.

M. Makoschitz *et al*.(2015) presented a topology survey of DC-side-enhanced passive rectifier circuits for low-harmonic input currents and improved power factor. For applications which require high input current quality active three-phase rectifiers have to be used which in general are dedicated systems entirely replacing the passive rectifier stage. For specific applications (e.g., AC drives) now a concept is attractive which opens the opportunity that an existing B6 rectifier optionally can be upgraded to high-quality main currents if required. This paper gives a succinct topology review and proposes several new circuits regarding DC-side found extra options for standard B6 rectifiers. All proposed topologies (introduced and also new circuits) depend on the third harmonic injection principle. The most attractive ideas are analyzed in detail concerning the injection inductor design, DC- link capacitor design and voltage/current stress of the required switching semiconductor components.

Krishna Reddy *et al* (2015) proposed a new seven inverter with lesser number of switches fed to BLDC motor drive. In this proposed topology, power cells linked in cascade using two inverter legs in series, as an alternative of two parallel inverter legs, lay up in CHB power cells,

conventionally. In this proposed topology input voltage is $V_{dc}/2$ only. So that severity of the detonation is brought down to half and results in an increase of the reliability of the system and cost effective. Detailed analyses of the proposed structure with five tiers are taken out using pulse width-modulation phase-shifted multicarrier modulation.

Saravana sankar *et al* (2015) explained the cuckoo optimization method for harmonic elimination in a cascaded multilevel inverter. The primary aim is to eliminate 3rd, 5th, 7th, 13th harmonics using the Selective Harmonic Elimination Pulse Width Modulation strategy order by solving nonlinear equations, while the fundamental factor is filled. In this report, the cuckoo algorithm (CA) is applied to a 7level inverter for solving the equations. The algorithm based on the parasitic behaviour of the cuckoo bird and levy flights used for random walks (or) Brownian motions also the it starts with an initial population.

Dhanamjayulu *et al* (2015) verified the Novel Cascaded Multilevel Inverter (CMLI) performance with reduced number of replacements. The CMLI comprises of an enactment of sub inverter levels. The fundamental and PWM switching of 11 level CMLI is analyzed. The harmonic levels of both PWM and fundamental are compared.

Md. Didarul Islam *et al* (2015) proposed the 5-level Hybrid H-bridge Multilevel Inverter Fed DTC-IM Drive. Although DTC is very popular for its simplicity, but it suffers from some disadvantages like- high torque ripple and uncontrollable switching frequency. To compensate these shortcomings conventional DTC strategy is modified for five levels, voltage source inverter (VSI). Multilevel hysteresis controller for both flux and torque is used. Optimal voltage vector selection from precise lookup table utilizing 12

sectors, 9 torque level and 4 flux level is projected to improve DTC performance.

Ranjitha *et al* (2016) introduced a new technique where the diode clamped multilevel inverter is being combined with switched inductor multilevel boost converter. In this case voltage unbalance problem is concentrated where the total system is stimulated and executed in PSIM software.

Nilay Ashok Sawalakhe *et al* (2016) proposed a fresh access of modular-cell inverter with a bargain amount of aerial capacitors (RFCI). The adduce RFCI will abate decidedly the basic counts, cost, and admeasurements of the convertor. The all-embracing achievement of RFCI will abundantly enhance as compared with the classical multilevel aerial capacitor inverter (FCI).

Rathinam Angamuthu *et al* (2016)described the Reduction of Components in New Family of Diode Clamp Multilevel Inverter Ordeal to Induction Motor. New topology requires only (N-1) switching devices and (N-3) clamping diodes compared to existing topology. A modified APO-PWM control method is applied to generate gate pulses for inverter.

Satheesh Kumar *et al* (2016) explained the switched inductor Z-source modified cascaded H-Bridge multilevel inverter. This topology is built up by replacing switched inductor cell instead of a normal inductor in Z source modified cascaded multilevel inverter. This set up provide high boost factor compared to the existing Z source cascaded H bridge multilevel inverter ZS CHB MLI. High voltage conversion ratio obtained by short shoot through

helping in improving the quality of the output force of the main proposed circuit.

Yogananda Reddy *et al* (2016) explained the MATLAB Implementation of a Various Topologies of Multilevel Inverter with Improved THD. Multilevel power converters provide more than two degrees of voltage to achieve a quieter and less distorted as to-DC, DC-to-Ac, and DC-to-DC power conversion. This report shows a generalized multilevel inverter (converter) topology with self voltage balancing. From this generalized multilevel inverter topology, several new multilevel inverter structures can be derived. In summation, the generalized topology has led to some new multilevel structures such as P3D and P3C.

Murugesan *et al* (2016) explained the different examples of multilevel inverter topologies. This paper presents a review and analysis of multilevel inverter topologies. In this work a new idea is developed to increase the level with less number of replacements. It is concluded that the topologies are closely related to each special application, depending on their singular features.

Mehta Prashant *et al* (2016) proposed the simulation of three phase multilevel inverters with reduced number of replacements. As the number of switches increases the voltage drop related to change increases. Moreover, switching loss as well as overall converter loss increases. The main focus of the study is to decrease power semiconductor switches for particular levels. A multilevel DC link using fixed DC voltage supply and cascaded half-bridge is connected in such a way that the new inverter outputs the required output voltage levels. For the purpose of increasing the number of voltage levels with

fewer number of power electronic components, the structure of the new topology has been built up.

Sangita Das Biswas *et al* (2016) proposed, an innovative approach to designing multilevel inverter is proposed, which can increase the generation of two-levels of output voltage by increasing only one switch. This paper explains nine-level single-phase multilevel inverter with this innovative approach, using only eight switches.

Pavan Prasad *et al* (2016) proposed a new form of a three-phase seven-level multilevel voltage source inverter. The proposed topology constitutes the conventional three-phase five-level bridge with three bidirectional switches.

Bolla Madhusudana Reddy *et al* (2016) proposed a 31-level cascaded multilevel inverter is with series connection of sub multilevel inverters and there after proposed topology is extended to a novel three phase 31-level cascaded multilevel inverter fed induction motor drive. As the number of levels increases the harmonics are decreased. This topology offers very less THD which is equal to THD=1.25.

Shery Grace Colaco *et al*(2016) explained the Simulation and performance analysis of simplified multilevel inverter. There are many topologies developed for multilevel converter each of them has various advantages and disadvantages. In this report a new topology is proposed which is a combination of conventional multilevel topology and H-bridge circuit having advantages of both.

Varsha Singh *et al* (2016) introduced a single-phase asymmetrical cascaded multilevel inverter with the goal of increasing power quality with the

reduction of power in insulated-gate bipolar transistor (IGBT) switches. In the present work, the proposed inverter topology is analyzed and generalized with respect to different proposed algorithms for choosing different voltage source values.

Mohammed Rasheed *et al* (2016) discussed a three-phase Cascaded H-bridge multilevel inverter (CHBMLI) based on the Modulation Index (Ma) for harmonic reduction. The proposed method had been comprised of a super capacitor SC with 5-level multilevel inverter, while the control organization was built on the Newton Raphson (NR) method. The experimental results showed that the proposed method had been effective in verifying the NR control in conditions of total harmonic distortion (THD).

Datar Singh Nathawat *et al* (2016) proposed a Symmetric 9 - Level Multilevel Inverter with minimum number of devices. Here the output level increased by shortening the number of power switches without any complexity in the circle. Multicarrier PWM based techniques used for controlling, firing circuit of switching device.

E. Barbed *et al* (2016) explained the Recent Advances in Multilevel Inverters and Their Applications. The paper focuses on a new general multilevel inverter topology based on cascaded connection of sub-multilevel units with reduced switching components, DC voltage sources and blocked voltage by switches is proposed. The proposed topology is optimized to generate any points with minimal number of factors and peak voltage on switches.

Asha Gaikwad *et al* (2016) presented a cascaded h-Bridge multilevel inverter with SPWM technique. This paper includes performance of 3-Level, 5-Level & 7-Level cascaded H-Bridge multilevel inverter with respect to the number of switches, total harmonic distortion, waveform pattern, harmonic

spectrum, output voltage, voltage stress across the switch & an input DC voltage with the help of simulation soft ware.

Sai Saritha *et al* (2016) explained to evaluate the functioning of an induction motor with hybrid cascaded multilevel inverter with DC source and further the DC source is replaced by a renewable energy source such as solar panels, fuel cell etc. and to moderate the focal ratio of the induction motor. The method can be easily extended to a m-level inverter.

S. Malathy *et al* (2016) proposed a new single phase cascaded multilevel inverter topology incorporating a new basic unit. Besides, seven different schemes are proposed to determine the magnitude of the dc sources. The proposed topology utilizes fewer power electronic components to generate a specific bit of output voltage points in comparison with the classical cascaded multilevel inverters resulting in compact and cost efficient design.

R Anjali Krishna *et al* (2016) reviewed the different multilevel inverter topologies. The different multilevel inverter topologies are: Cascaded H-bridges converter, Diode clamped inverter, and Flying capacitor multilevel inverter.

Amol K. Koshti *et al* (2016) discussed about a multilevel inverter topology with reduced number of switches, where sinusoidal pulse width modulation (SPWM) is used to produce a seven level output voltage. Also an L-C Filter is applied at the production of the inverter to suppress the ripples in the yield and produce the pure sinusoidal output voltage.

Pallakila Lakshmi (2016) presented a nine level inverted with reduced DC sources which is capable of obtaining all additive and subtractive

combinations of input DC levels. This topology requires less power switches compared to conventional multilevel inverter and less gate drives.

M. S. Sivagamasundari *et al* (2016) proposed a new approach for solving nonlinear transcendental selective harmonic elimination equations by the Newton Raphson method with any random, initial guess in a single phase cascaded h-bridge eleven level inverter. Selective harmonic elimination pulse width modulation (SHE PWM) technique is utilized to minimize lower order harmonics by solving nonlinear equations, while the fundamental is satisfied.

Tamilarasi Devaraj *et al* (2016) explained the Performance Evaluation of Nine Level Current Source Multilevel Inverter Using Pi and Fuzzy Controller. A Multilevel Current Source Inverter (MCSI) circuit with single rating inductor topology has taken in this work. The nine-level Current Source Inverter has been evaluated under symmetrical and asymmetrical modes of process and their performances are compared using PI and Fuzzy Gain Scheduled PI (FGSPI) controllers tuned with PWM strategy of Multicarrier PWM.

Chaitanya Vysyaraju *et al* (2017) discussed A Three-Phase Series-Parallel Converted Cascaded Switched Capacitor Multilevel Inverter for Induction Motor Drive. The Proposed multilevel inverter output voltage level increasing by using less number of switches driven by the multicarrier series-parallel techniques.

Summit Bhattacharya *et al* (2017) represented Multilevel Inverter (MLI) based Shunt Active Power Filter (APF) for improvement of power quality. Single MLI APF is used as both Interfacing converters for

improvement of Power Quality of the Whole system. Peak detection method of control strategy is employed in MLI-APF for power quality improvement.

Nilay Ashok Sawalakhe *et al* (2017) presented a simulation study of phase-disposition (PD-PWM) pulse width modulation strategies in 3 phases, seven level flying capacitor multilevel inverters (FCI) performed in MATLAB Simulink. Here we have applied a novel approach of modular cell inverter with a reduced number of flying capacitors.

Neeraj Seth *et al* (2017) surveyed the various recently developed three phase multilevel inverter topologies with different contours and control methodologies such that the number of components employed is reduced and finally emerge as techno economical design.

Khoukha Imarazene *et al* (2017) presented a new DC-link balancing algorithm for multilevel inverter in photovoltaic systems. The inverter is fed photovoltaic generator as DC source. 36 redundant vectors are making use of the 12 unbalance cases of four capacitor voltages instead of 24 cases presented in the former works. The obtained results show that the frequency of the PWM is unchanged

K. Aswini *et al* (2017) explained the 21-level of multilevel inverter using Asymmetrical Cascaded MLI topology. With the service of single phase with various different techniques, multilevel inverter is implemented. The technique used in this paper is sinusoidal pulse width modulation (SPWM).

Sayli Khadse *et al*, (2017) presented a single stage 5 level Flying Capacitor Multilevel Inverter. In order to obtain multilevel output voltage waveforms, a switching strategy based on calculating switching angles is explained. The one phase leg of five level Flying Capacitor Multilevel Inverter

is shown in this paper and the steps to synthesize the five level voltages is given.

Prarthana Nagle *et al* (2017) proposed a cascade H-bridge multilevel inverter employing selective harmonic elimination method. In selective harmonic elimination, a particular order of harmonic is selected and based on it, the breadth of the pulse is limited so that the output voltage will be free from that harmonic. The Selective Harmonics Elimination method is applied to thin out the Total Harmonics Distortion (THD) value and to eliminate the lower order harmonics.

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2.3 Current Injections

F.Peng, *et al.* (1990), suggested an active power filter using quad-series voltage-source, PWM converters to suppress ac harmonics by injecting compensating currents to the AC system is described. The calculation circuit for the compensating current references, the compensation characteristics, and the capability of the dc capacitor are discussed theoretically and experimentally in this literature.

D. Kimhi, *et al.* (1991), presented the operation of current mode PWM converters in continuous mode by SPICE simulation model and tested against analytical expressions and experimental data for buck and boost converters. In this literature, the recently suggested modification was compared with an earlier average model and to verify the effect of the gain factor in the current feedback path.

M. P. Kaimier kowski, *et al.* (1991), addressed current-controlled PWM transistor inverters with simple control strategies. In these methods, the three-level hysteresis comparators are used. These comparators which select

appropriate inverter output voltage vectors through the switching electrically programmable read-only memory (EPROM) table in this literature.

A. M. Hava, *et al. (*1996) introduced the waveform qualities of carrier-based PWM methods, and the over-modulation region voltage gain characteristics are investigated. The voltage-gain characteristics are extracted independently of carrier frequency through an analytical study in detail. In the literature, Minimum Pulse Width (MPW) control on the inverter gain characteristics and the influence of blanking time is analysed and presented.

Sadeq A. Hamed, *et al.* (1997), addressed PWM control of dc drive systems is considered as a challenge to the conventional phase controlled systems. This is a reality that is expected to be practically reinforced by the increasing availability and power capability of controlled-on and controlled-off power switching devices, such as Gate Turn-Off Thyristors (GTO's), Insulated Gate Bipolar Transistors (IGBT's), and MOS-controlled thyristors (MCT's) in this literature.

K.M. Rahman, *et al.* (1997), introduced for high-performance AC drives, hysteresis current controllers having fixed bands are used in inverters. The switching frequency varies over the fundamental period of the modulating signal of these controllers. These controllers were having high maximum switching frequency.The fixed carrier lockouts are usually incorporated to limit the MSF. The incorporation of carrier lockouts causes current distortion, and load currents do not confine within the fore-ordained band in this literature.

J.A. Pomilio, *et al.* (1997), presented a new soft-switched AC/DC PWM converter structure. It is useful for current fed inverters and PWM rectifiers. This structure is applicable for high-power AC motor drives, magnet

power supplies and active power filters with magnetic energy storage. When compared with usual hard-switching and soft switching, an expense is the limited increase of the circuit complexity.

M. Ohshima, *et al.* (1999), introduced the Error-Tracking Mode (ETM) in this literature, constantly sampled PWM technique for a voltage source power conversion system interconnecting with a utility network to regulate its AC waveform. It guarantees the AC actual current theoretically to be settled within an arbitrary target allowable error. Generated current harmonics can be restricted by a relatively small filter in this literature.

J. Chen, and P. Tang, *et al*. (1999), addressed a PWM brushless DC motor drives with a sliding mode current control scheme. In this scheme, an improved equivalent control method is used. A simple algorithm is proposed to estimate the load parameters, which differs from the original equivalent control method, which needs extensive calculation.

Y. Wei Li, *et al.* (1999), introduced an input of a PWM current source rectifier with inductor–capacitor (LC) filter. It is used to mitigate line current harmonics and to assist in the commutation of switching devices. An effective damping method is proposed in this literature, to damp the LC resonance introduced by the input filter, by using a hybrid combination of a three-step control signal compensator and virtual harmonic resistive damper.

M. Salo, *et al. (*2000), presented in this literature three-phase current-type PWM rectifiers are becoming increasingly popular as the front-end converter unit in power electronic systems due to electromagnetic compatibility (EMC) regulations. In this article, the control of the current source PWM rectifier in the synchronously rotating reference frame is discussed.

J.H. Seo, *et al.* (2001), presented a three-level inverter with new simplified SVPWM method. This method is based on the simplification of the space–vector diagram of a three-level inverter into that of a two-level inverter. The execution time is reduced greatly. All the remaining procedures necessary for the three-level SVPWM are done like conventional two-level inverter in the proposed system.

L.A.C. Lopes, *et al.* (2001), presented a variable reactance type series compensator with PWM capability. On a per-phase basis, it can be represented by a bidirectional force commutated switch in series with another bidirectional force-commutated switch and parallel with a combination of a capacitor. The equivalent reactance of the capacitor circuit varied continuously, with no risk of interrupting the line current.

G. Narayanan, *et al.* (2002) proposed a high power ASDs based on the space vector approach and two synchronized bus-clamping PWM strategies. By preserving the waveform symmetries, two strategies combined together can create PWM waveforms with any odd pulse number. The proposed methods work up to the six-step mode, keeping the proportionality between the reference magnitude and the fundamental voltage generated. These two techniques lead to less harmonic distortion and less peak current over the conventional space vector strategy (CSVS) in the high-speed ranges of ASDs.

D. S. Oliveira, *et al.* (2005), presented in this literature proposes the use of a three-phase version of the hybrid rectifier in the three-phase zero voltage switch (ZVS) DC/DC converter with asymmetrical duty cycle. The use of this new rectifier improves the efficiency of the converter because only three diodes are responsible for the conduction losses in the secondary side.

D.S. Oliveira Jr., *et al.*(2006), presents the theoretical analysis of the 3φ zero voltage switching pulse width modulation dc–dc converter associated with a double star connected rectifier, delta primary. To maintain equilibrium among the currents through the output filters, special switching scheme is used.

R. Ghosh *et al.* (2008), presented in this literature four-wire rectifier system was analyzed and designed. In this rectifier, split-capacitor topology control was used. Any input voltage sensing or complex transformations are not needed in the proposed controller. The distortions in the line and the neutral current analysis are given in detail.

Suryawanshi *et al*., (2008) proposed an International concern of power quality problems and pollution have brought the use of PFC converters to fed Induction motors which are used in numerous low power applications because of its high efficiency and the wide range of speed.

K. Marouani *et al.* (2008), To control the six-phase VSI-fed Dual Stator Induction Machines (DSIM) a new SVPWM technique is used. A DSIM has two sets of 3φ stator windings spatially shifted by 30 electrical degrees and fed by two three-phase VSIs.

Hiralal M. Suryawanshi *et al*.(2008) proposed a high power factor operation of a three-phase rectifier for an adjustable-speed drive. A high-frequency (HF) current injection technique is used to improve the PF and harmonic performance. The HF current at the same switching frequency is injected into the input of a front-end rectifier from the output of an HF inverter. The inverter driving the induction motor is operated using a sinusoidal pulse-width-modulation technique.

Gunwant A. Dhomane *et al*.(2009) proposed a mitigation of

harmonics in three-phase ac system using current injection method for an ac-to-dc converter. A new approach to eliminate harmonics and to improve the power factor of a three phase front-end uncontrolled rectifier is adopted. A high-power-factor is achieved by injecting high-frequency triangular current from the output of a three-phase inverter. The HF current modulates the rectifier input voltage resulting in the conduction of diodes into each switching cycle. The resulting ac input line current is continuous and sinusoidal in shape with a significant reduction in current harmonics. All the switches are operated at Zero-Voltage Switching (ZVS). The diodes of the rectifier are also operated with soft switching at turn-on as well as at turn-off. Varying switching frequency with a fixed duty ratio regulates the output voltage. The proposed AC/DC converter also maintains high-power-factor even for unbalanced input supply voltages. The analysis of the converter is carried out on a single-phase basis, using different operating modes in one switching cycle of injected current.

Nimrod Vázquez *et al*.(2009) proposed a circuit uses three bidirectional switches operating at low frequency. It also uses an inductor to make the current modulation, because only 3.7% of the total power delivered to the load is processed by the injection network. The proposed converter gives a high efficiency and not only a high power factor is obtained, but THD is also reduced.

S. Kim *et al.* (2010), addressed a matrix converter interface, which creates three different virtual DC-link voltages with three-phase AC voltage source. For this matrix converter, the new PWM method is proposed. The novel technique can produce the identical switching sequences to those generated by the conventional Space Vector Pulse Width Modulation (SVPWM) technique.

H. Akagi, *et al.* (2010), For energy savings purpose, a transformerless hybrid active filter integrated into a medium-voltage motor drive was introduced by the author. The hybrid filter is intended for line harmonic-current reduction of the 3φ diode rectifier used. It is based on the direct connection of an active filter using a 3-level PWM converter with the passive filter tuned to the 7^{th} harmonic frequency in series.

A.Z. Albanna, *et al.* (2010), presented an output harmonic spectrum of a single phase two level inverter with closed-form of analytical approximation derived from the action of hysteresis current control. It consists of first describing the error current as a triangular signal of variable duty cycle and frequency. The Fourier transform of the complex envelope modulated triangular signal is derived.

Rima Abi Rached *et al*. (2010) proposed a three-phase rectifier with an active current injection and a single high-frequency inductor. This topology uses two active networks: an injection network composed of three Bi directional switches operating at the low frequency and current shaping network consisting of two high-frequency switches and only one inductance. An input current total harmonic distortion (THD)of 8.6% and high power factor were obtained.

Amin *et al.* (2010) proposed a current harmonic reduction using current injection technique in a converter system. In this paper, a current injection technique has been introduced to mitigate current harmonics and to improve power factor present in a high power converter system. In a converter system using a current injection technique a passive resistance emulator circuit to be introduced in the current injection technique used to adjust the magnitude of injection current based on the load current variation

Lee *et al.* (2011) proposed a control of single-phase-to-three-phase AC/DC/AC PWM converters for induction motor drives. In this proposed converter topology, the number of switching devices is reduced to six from ten in the case of a full-bridge rectifier and three-leg inverter systems. Also, the source voltage sensor is eliminated with a state observer, which controls the deviation between the model current and the system current to be zero.

Pejovic *et al.* (2011) proposed a current injection technique in three-phase rectifier based on two boost converter. In this paper, the converter currents can be expressed regarding two mutually related auxiliary functions. Optimal auxiliary functions that eliminate harmonics of the input currents are derived. A method to generate reference signals for the optimal current programming is proposed.

Kazunori Hasegawa *et al.* (2011) introduced a new DC-voltage-balancing circuit including a single coupled inductor for a five-level diode-clamped PWM inverter. This circuit consists of two unidirectional choppers and a single coupled inductor with two galvanically isolated windings. The inductor produces no net DC magnetic flux because the individual DC magnetic fluxes generated by the two windings are cancelled out with each other. This makes the inductor compact by a factor of six, compared with the balancing circuit including two non-coupled inductors. Also, introducing phase-shift control with the new balancing circuit makes it possible to conform the midpoint voltage. Therefore, the DC mean voltage of all the four split DC capacitors can be adjusted, independent of inverter control.

Cross *et al.* (2012) proposed a modelling of single-phase to three-phase drive system using two parallel single-phase rectifiers. The proposed topology permits reduction of the rectifier switch currents, the harmonic distortion at the input converter side and presents improvements on the fault tolerance

characteristics. A suitable control strategy, including the PWM is developed.

Gunwant A. Dhomane *et al*.(2013) presented a high-power-factor ASD using diode clamped MLI. A diode clamped multilevel (3-level) inverter is utilized to perform a double task. It creates HF (high frequency) current to be injected at the input of the three-phase front-end rectifier thereby enhancing the power factor and harmonic spectra. It additionally drives the induction motor. The notable element of this paper is that it does not require additional converters for improving power factor and to drive induction motor. Besides, the inverter switches operate with ZVS, thus reducing the switching losses considerably. The voltage stress of the switches also has been decreased to half of the conventional 2-level converter.

N. Venkata Ramana *et al* (2015) suggested an A Novel DC-Side Current Injection Technique for 18-Pulse Converter System to Improve AC Line Condition. The goal of injecting currents at DC side is to improve the quality of the AC line currents. Compared to the conventional active filter deployed on the AC side, the three-phase inverter used in this paper is with lower KVA rating, and the 18-pulse converter draws nearly sinusoidal currents from the AC main by the proposed compensation strategy.

A. K. Pradhan *et al* (2016) suggested a current injection technique to find a Cable fault location in a DC microgrid. Calculating attenuation and damping frequency of the injected current the fault length is obtained. The proposed method is tested considering high fault resistance, different fault types and radial and looped network topologies.

Rahimi Baharom *et al* (2016) explained a high power factor three-phase AC-DC current injection hybrid resonant converter. The resonant conversion technique, involving two active soft switches that produce high frequency currents.

Yosuke Kondo *et al* (2016) suggested a technique to predict bulk current injection test using integrated circuit immunity macro model and electromagnetic analysis. Injected radio frequency disturbance that reaches to an integrated circuit is calculated by using electromagnetic analysis with a high accuracy injection probe model. 3D model of equipment under test can provide the terminal voltage of the IC which reference is the ground terminal of the IC, not BCI test setups reference ground plane.

Ali M. Eltamaly *et al* (2017) proposed novel current injection device for harmonic reduction of three-phase controlled converters in renewable energy utility interfacing. Injecting third harmonic current from the DC-bus to the line currents reduces its harmonic contents. Minimum THD for any firing angle of the controlled converter is a part of the phase-angle and amplitude of harmonic injection current that can be contained by a single-phase controlled converter and a boost converter, respectively. This scheme is used with a zigzag transformer to run close to the harmonic injection current to the line currents.

A. P. S. G. De Vas Gunawardena *et al* (2017) explained three phase asymmetrical power flow algorithm using current injection with full Newton-Raphson formulation.Three phase asymmetrical power flow studies are recommended for unbalanced power systems such as distribution networks

Markus Makoschitz *et al* (2016) proposed a control concepts for hybrid rectifiers utilizing a flying converter cell active current injection unit. This additional/optional circuit allows the upgrade of a standard B6 diode rectifier to a low harmonic input stage with unity power factor. To guarantee properly shaped sinusoidal mains input currents, dedicated current and voltage controllers of the active circuitry must be designed carefully. As the active current injection unit consists of an assembly of 3 individual converter stages,

the design procedure of both current and superimposed voltage controllers results in fairly high complexity. It is discussed in detail in this work. Based on the analysis of the rectifier system an appropriate control concept is developed which is implemented using a digital signal processor. It is furthermore shown that the midpoint voltage of the Flying Converter Cell (FCC) can advantageously be used for balancing of the DC capacitor stage of the cell without deteriorating THD of mains input currents.