REVIEW ON DIFFERENT CONTROL TECHNIQUES OF UNIFIED POWER QUALITYCONDITIONER (UPQC)

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Abstract- Better power quality is required for various electronics and electrical devices to perform efficiently. Various devices are available for power quality improvement. Different devices are suitable for different power quality disturbances or deviations such as Distribution Static Synchronous Compensator (DSTATCOM), Static VAR Compensator (SVC), Dynamic Voltage Restorer (DVR) and Unified Power Quality Compensator (UPQC) for the improvement of power quality in manufacturing industries. UPQC is the recent versatile device which can correct different power quality disturbances simultaneously such as harmonics, voltage sag, voltage swell, voltage regulation, load unbalancing and power factor improvement in 3-phase distribution system. UPQC is one of the best power device used to compensate both source and load side problems, which is a combination of series Active power filter (APF) and shunt APF. Various control techniques are utilised for proper operation of UPQC such as p-q theory, d-q theory, fuzzy logic control, PI control, hysteresis control etc. This paper presents different control techniques of UPQC.

Index Terms: Dynamic Voltage Restorer (DVR), Static VAR Compensator (SVC), Unified Power Quality Conditioner (UPQC), Distribution Static Compensator (DSTATCOM), Active Power Filter (APF), p-q theory, d-q theory, fuzzy logic control, PI control, hysteresis control.

1. INTRODUCTION

Power quality is a very important issue in distribution system. Power quality is simply defined as a quality of electricity i.e. it is a concept thatis use to describe the purity of the transferred energy[1]. Electrical power system is design to provide high quality power for satisfactory operation of various electrical equipments[2]. Over the recent years, power quality has been given attention due to the intensively use of power electronic controlled applications in all branches of industry, such as controlling or converting AC power to feed electrical loads. The non-linear loads have led to the concerns over the allowable amounts of harmonic distortion injected into the supply system[3].With the increasing application of nonlinear loads, the appearance of power quality problems is inevitable. Many of harmonic sources are single-phase loads, such as computers, fluorescent compact led to the concerns over the allowable amounts of harmonic distortion injected into the supply system.Lamps, copiers, printers and other home and office electronic equipments. In addition to this the power-factor of the loads are generally poor. On the other hand modern equipments of domestic and commercial uses are very sensitive to power quality problems. In the past, the solutions to mitigate these identified power quality problems were through using conventional passive filters. But their limitations such as, fixed compensation, resonance with the source impedance and the difficulty in tuning time dependence of filter parameters have ignited the need of active and hybrid filters.

One of the effective approaches is to use a unified power quality conditioner (UPQC) at Point of Common Coupling (PCC) to protect the sensitive loads. A UPQC is a combination of shunt and series APFs, sharing a common dc link. It is a versatile device that can compensate almost all power quality problems such as voltage harmonics, voltage unbalance, voltage flickers, voltage sags & swells, current harmonics, current unbalance, reactive current, etc. The Unified Power Quality Conditioner (UPQC) has evolved to be one of the most comprehensive custom power solutions for power quality issues relating to non-linear harmonic producing loads and the effect of utility voltage disturbance on sensitive industrial loads[4]. To obtain the proper operation from UPQC, we need to control power filters of UPQC. To control them, there are different topology has been introduce.Control strategy plays a vital role in the overall performance of the power conditioner. Rapid detection of disturbance signal with high accuracy, fast processing of the reference signal and high dynamic response of the controller are the prime requirements for desired compensation. Generation of appropriate switching Pattern or gating signal with reference to command compensating signal determines the control strategy of the UPQC[2]. Since derivation of reference signal from the measured distorted signal plays the main role, many theories and techniques were proposed or practiced over the years. Some of them are described in this paper.

2. UNIFIED POWER QUALITY CONDITIONER

Unified power quality conditioners (UPQC) also known as universal active filters are ideal devices to improve power quality[2].It is an advanced version of unified power flow controller (UPFC). The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived. The UPQC mitigates harmonics and provides reactive power to the power systems network so as to improve the power factor close to unity[6].The UPQC is a combination of shunt active and series active power filters connected through a dc link capacitor[2].The shunt active filter of UPQC acts as a current source for injecting compensating current through a shunt transformer, whereas, the series active filter acts as a voltage source for feeding compensating voltage through a series transformer[6].

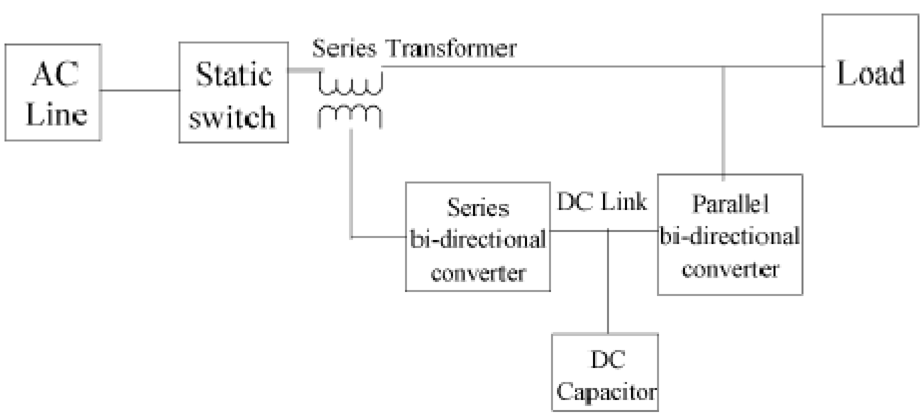

Fig. 2 UPQC basic Structure.

There are many control strategies reported in theliterature to control the UPQC for power quality improvements,the most common of which are the instantaneousactive and reactive power theory (PQ method) proposed byFujita and Akagi, symmetric component transformation,synchronous reference frame (SRF) theory, and unittemplate technique (UTT) etc[4]. The compensation effectiveness of the UPQC depends on its ability to follow with a minimum error and time delay the reference signals to compensate the distortions, unbalanced voltages or currents or any other undesirable condition.

3. CONTROL STRATEGY

Control strategy plays the most significant role in any power Electronics based system. It is the control strategy which decides the behavior and desired operation of a particular system. The effectiveness of a UPQC system solely depends upon its control algorithm. The UPQC control strategy determines the reference signals (current and voltage) and thus, decides the switching instants of inverter switches, such that the desired performance can be achieved[2]. There are several control strategies/technique available in the existing paper those have successfully applied to UPQC systems.

3.1 DIRECT DETECTION METHOD

A number of methods proposed where the instantaneous active and non-active power s are calculated directly from the a-b-c phase voltages and line currents. It eliminates the need for complicated X-coordinate transformation, thus reducing the computation volume and improving the detection speed. However, this method requires low pass filter like X-transformation.in method proposed in, the exact sinusoidal waveform of the voltage is stored in the memory (EPROM).

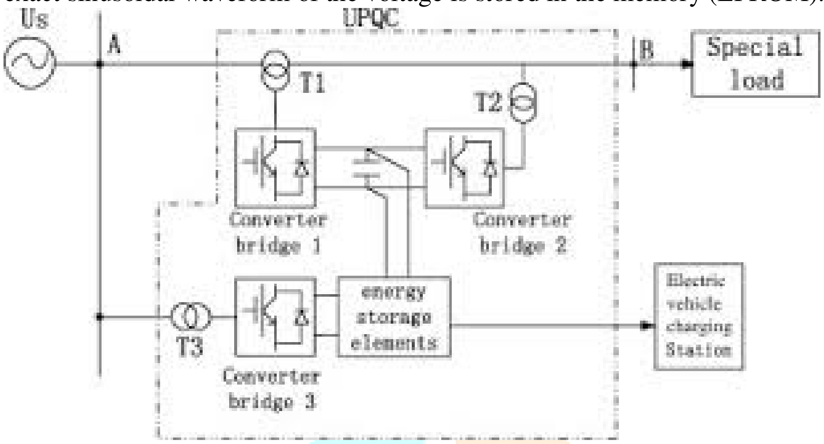

Fig.3.1The main configuration of UPQC

A microcomputer system reads the voltage values sequentially from the EPROM and compares it with the measured waveform and gives the reference values instantaneously. This method does not require calculation of an active current or voltage component and in this way a delay in compensator response is avoided[2].

3.2 HYSTERESIS CONTROL ALGORITHM

The hysteresis band control technique is used to generate the switching pattern of the inverter. The hysteresis control method is the best among other control methods, as it is quick controllable, easy to implement and unconditioned stability and easy to understand. It gives excellent dynamics and fastest control and requires minimum hardware[11]. The basic of the hysteresis current control is based on an error signal between injections current and a reference current of APF (I ref.) which produces proper control signals. The hysteresis band current controller decides the switching pattern of APF. There are bands above and under the reference current. When the error reaches to the upper limit, the current is forced to decrease. When the error reaches to the lower limit, the current is forced to increase.

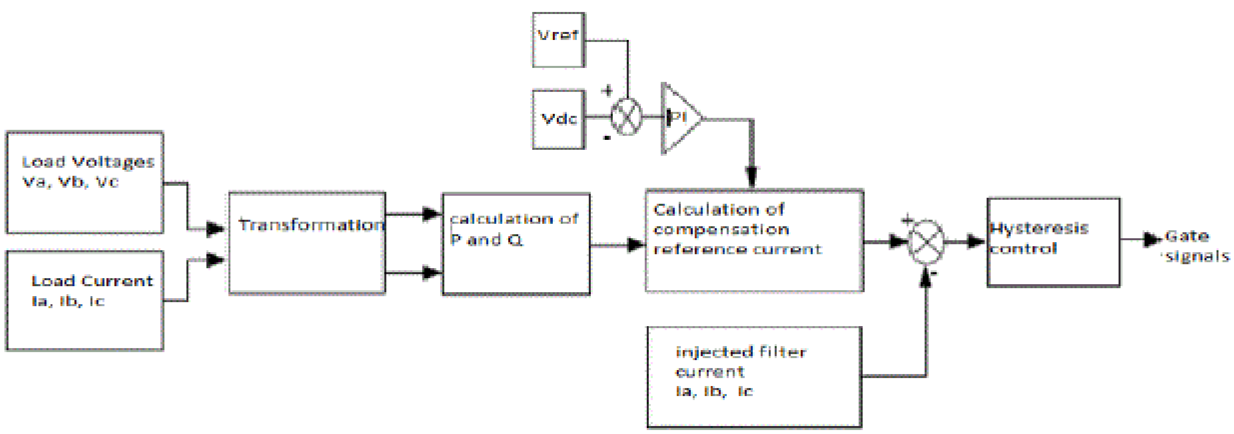

Fig. 3.2 control system of shunt APF

Some significant advantages of hysteresis controllers over other types of controllers designed nonlinear control techniques for APF applications are as follows:

1. Switching behaviour of the power inverter can be directly taken into account at the design level.
2. Robustness to load parameters variation can be proved.
3. Almost static response is achieved (the dynamics are obviously bounded by the DC-link voltage and by the actual switching frequency).
4. Simple hardware implementations based on logical devices are possible according to Boolean nature of controller input/output variables[12].

3.3 P-Q-R INSTANTANEOUS POWER THEORY

H.Akagi has defined a theory on the basis of instantaneous power in three phase system either in the presence or absence of neutral wire. This p-q approach is valid for operation under all conditions namely transient and steady state operation. This theory makes use of some famous transformation models defined like Clarkes Transformation. Here the voltage and current waveforms are sensed and then made to transform from a-b-c coordinates to $\alpha - \beta - 0$ coordinates. After this transformation, based on a certain set of equation we calculate active and reactive power and then eliminate the power components having harmonics in it by passing through a certain suitable low pass filter of suitable frequency. This new set of power and already derived new voltages in a different coordinate namely $\alpha - \beta - 0$ coordinates ,we again find out the reference source current in this frame only and then using Inverse Clarkes Transformation we convert this reference source current again back to a-b-c coordinates. This new reference source current is then compared against actual sensed source current waveforms and the error is driven through a hysteresis controller with a certain band for getting the different gate pulse for the operation of inverter[9]. A simple block diagram explaining the complete operation of this important p-q theory is given below:-

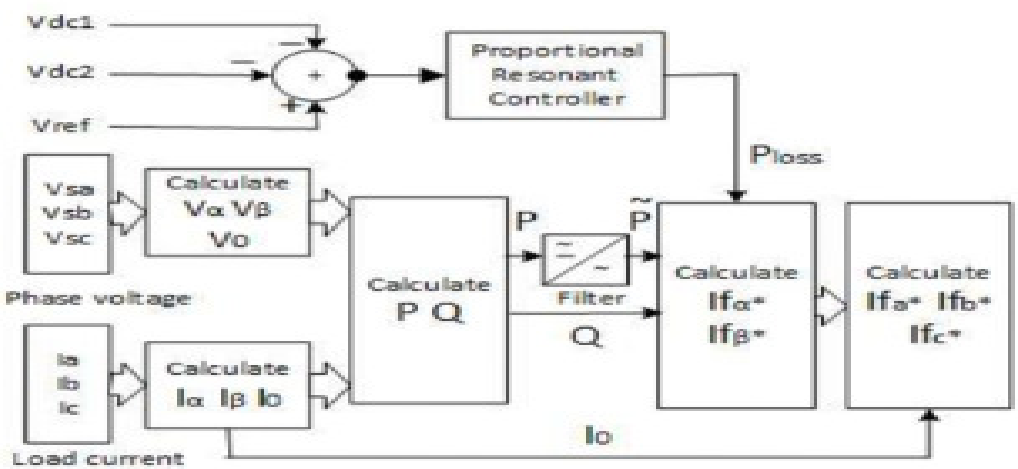

Fig.3.3 p-q control strategy to generate reference current

3.4 SYNCHRONOUS 'D-Q' REFERENCE BASETHEORY

This algorithm relies on the Parks transformation where three-phase voltage and current signals are transformed to a synchronously rotating frame. The active and reactive components of the system are represented by the direct and quadrate component, respectively. In this approach, fundamental quantities become d-q quantities which can be separated easily through filtering. To implement the synchronous reference frame some kind of synchronizing system PLL should be used. The system is very stable since the controller deals mainly with the d- q quantities.

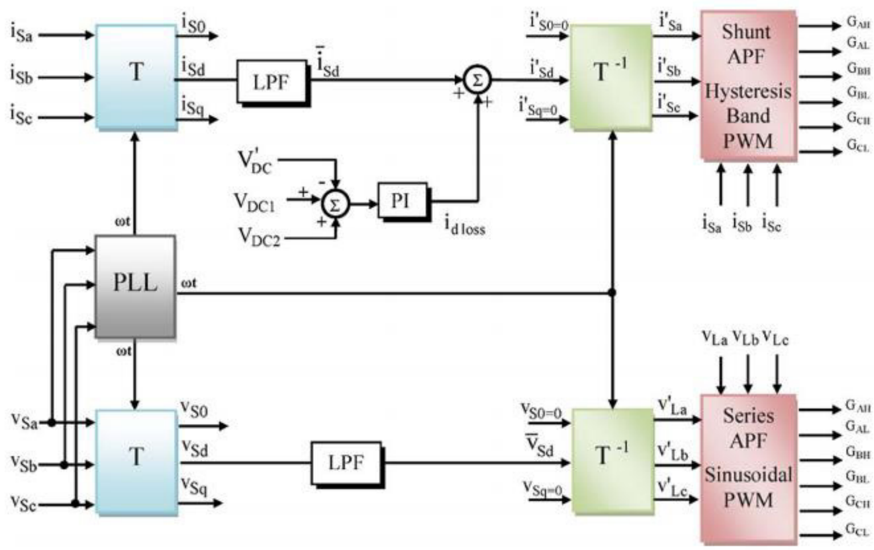

Fig .3.4 SRF control for UPQC operation

The computation is instantaneous but incurs time delays in filtering the d-q quantities. This method is applicable only for three-phase systems. The modified synchronous reference frame, named as 'instantaneous id-iq method' is also proposed. This method is similar to synchronous reference frame method Except that the transformation angle is obtained from the voltage X~ components. The speed referential is no longer constant but it varies instantaneously depending on the waveform of the three-phase voltage system. In this method, no synchronizing circuit is needed[2].

3.5 SPWM BASED CONTROL

SPWM controller is used to operate the voltage source inverter in such a way that the difference between the inverter voltage and the line voltage is widely adjusted so that the shunt APF generates or absorbs reactive power. The measured three phase voltages are fed to PLL to detect the phase angle of voltages. The measured voltage is passed through a first order low pass filter to attenuate voltage transients. This signal is then compared with a reference voltage and the voltage error is fed to the lag-lead function block, the output of which is fed to a PI controller. The output of PI controller is the angle representing the shift between the system voltage and the shun inverter voltage required to adjust the voltage of the dc link capacitor.

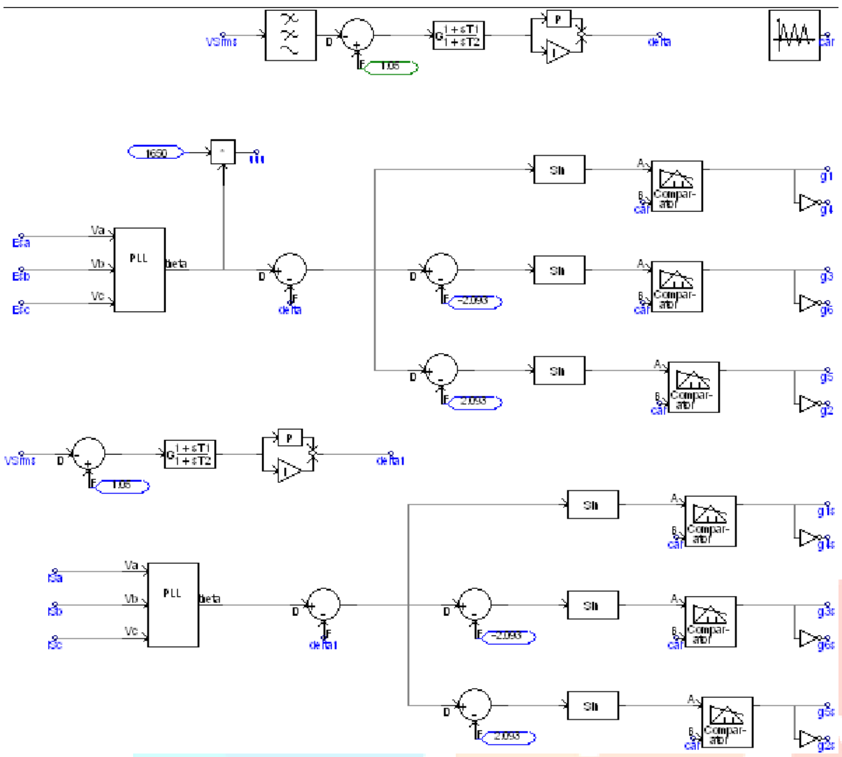

Fig.3.5 SPWM based Controller

This angle combined with the signal from PLL becomes the voltage modulating signal. The phase angle from the PLL is multiplied by a carrier, whose frequency is 33 times the operating frequency to generate the triangular signal whose amplitude is fixed between the extremities of unity. The triangular carrier is compared with the voltage modulating signal so as to obtain the firing pulses for the shunt APF[2].

3.6 SWITCHING CONTROL METHOD

In this method six single phase H-bridge inverters are used in the structure of UPQC connected to a common dc storage capacitor. Of these six inverters three of them are used for series voltage insertion and the other three are used for shunt current injection. The UPQC current and voltage references are generated based on Fourier series extraction of fundamental sequence components using half cycle running (moving) averaging.

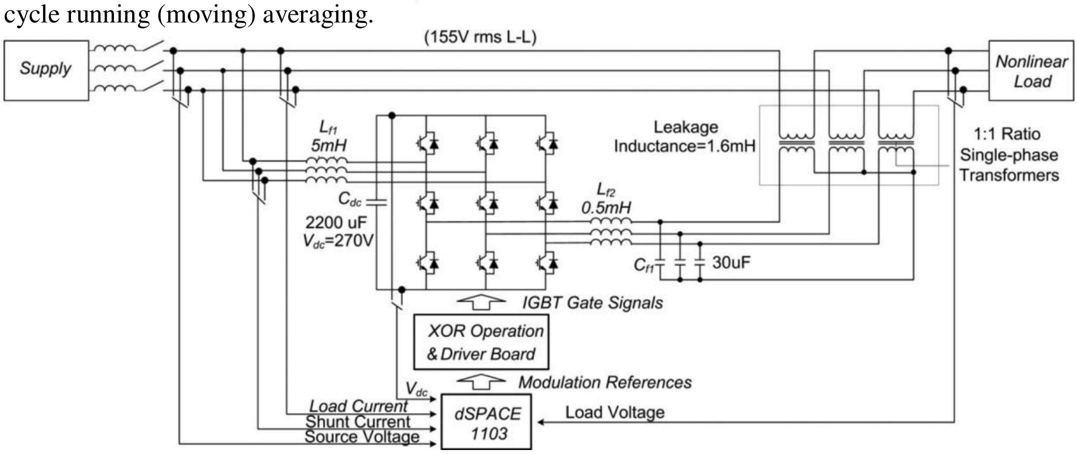

Fig.3.6 Experimental setup and parameters used for testing.

They also propose a Linear Quadratic Regulator based switching controller scheme that tracks a reference using the proposed compensator. This method is suitable for both utilities and customers having sensitive loads. From the utility standpoint, it can make the current drawn balanced sinusoidal. To accomplish this, the voltage at the point of common coupling must be of similar nature and also must contain the same amount of harmonics as the source. From the customer point of view, the UPQC can provide balanced voltages to their equipment that are sensitive to Voltage dips. At the same time, the UPQC also filters out the current harmonics of the load. Therefore, the operation of UPQC is ideal from both viewpoints[2].

3.7 UNIT VECTOR TEMPLATE GNERATION

The control technique used here is Unit vector template generation technique In this case supply voltage is made distorted and Unit Vector Templates are extracted from it. The distorted input source voltage contains harmonic components in addition to the fundamental component. For extraction of these unit vectors**,** the supply voltage is first measured and the product of this and gain (1/ Vm) is done, Vm being the peak fundamental supply voltage. After this unit vector templates are generated by using a phase locked loop. Supply voltage is then multiplied with the unit vector templates and reference load voltage is generated.

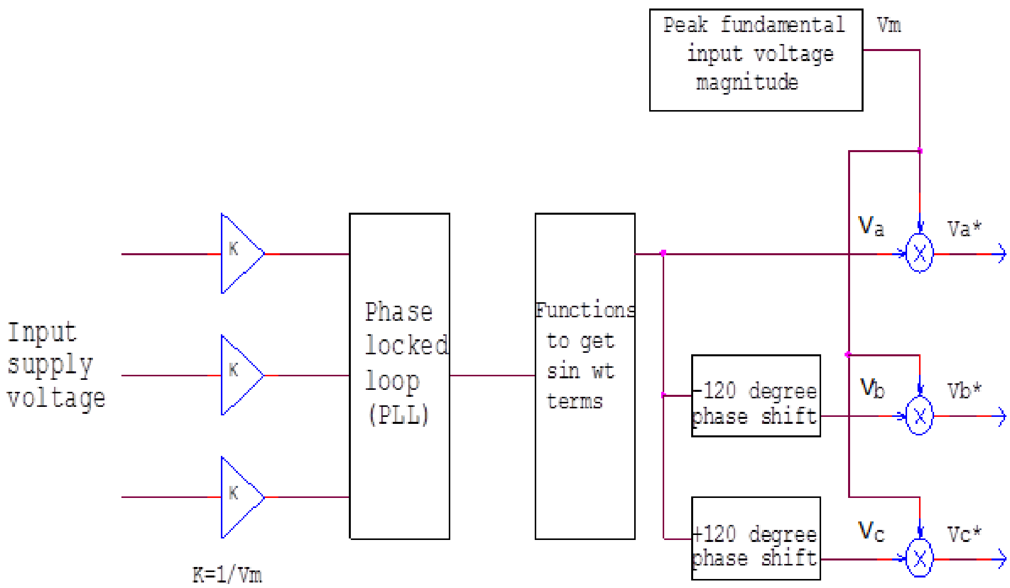

Fig. 3.8 Generation of Unit Vector Templates and reference Load Voltages

Then the comparison of actual load voltage and reference load voltage is done. Errors are calculated and send into a hysteresis band for generating the gate pulse for the series inverter. Shunt Active Power Filter is used for current harmonics compensation. Generation of pulses for the shunt inverter DC link voltage is then measured an it its comparison is done with the reference dc link voltage. After that error is processed by utilizing a PI controller, and to produce the reference current these results are multiplied by unit vector templates. Comparison of reference and actual source current is done and a hysteresis band controller is used for processing the error and production of gate pulses for parallel inerter circuit is completed[10].

4. CONCLUSION

The confrontation in improving the power quality has become a promising area of research amongst power system and power electronic engineers and researchers. With the ever increasing advent of nonlinear loads and also due to high frequency switching characteristics, suitable conditioners are always a demand. Unified Power Quality Conditioner (UPQC) is one of the promising power electronic circuit modules to overcome voltage sag and total harmonic distortion problems, as the circuit is modeled using both series active and shunt-active power filters.

Most of the proposed or practiced control strategies for power quality conditioners have been reviewed with regard to performance and implementation. This work reveals that there has been a significant increase in interest of UPQC and associated control methods. This could be attributed to the availability of suitable power - switching devices at affordable price as well as generation of fast computing devices (microcontroller and DSP) at low cost. Each technique has its advantages and disadvantages.

5. REFERENCE

[1]. Pranjal M. Kadam, Prof.(Dr.) B.E. Kushare, "A Survey on Unified Power Quality Conditioner for Power Quality Improvement," *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE),in National Conference on Emerging Trends in Engineering & Technology(NCETET17)e-ISSN: 2278-1676,p-ISSN: 2320-3331, PP 15-22*,2017.

[2]. Aakash S. Shah, Professor Vishnu Patel, Professor Manish Patel, "Different Control Strategies for Unified PowerQuality Conditioner – A Review," *INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING Vol. 2, Issue 3, March 2014.*

[3]. NaimishZaveri, Ankit Mehta, and AjitsinhChudasama, "Performance Analysis of Various SRF Methods inThree Phase Shunt Active Filters," *Fourth International Conference on Industrial and Information Systems, ICIIS 2009, 28 - 31 December 2009, Sri Lanka*

[4] Salim CHENNAI, M-T BENCHOUIA,"Unified power quality conditioner based on a three-level NPC inverter using fuzzy control techniques for all voltage disturbances compensation", Higher Education Press and Springer-Verlag Berlin Heidelberg 2014.

[5] Vikas Singh,Nita.R.Patne, "Power Quality Problems Study On IEEE 14 Bus System And Their Mitigation Using UPQC With Different Control Schemes".

[6] Anil Bharti,RajatVarshney and DrS.K.Srivastva , "A Study of PI Controller Based Unified Power Quality Conditioner",International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 9, September 2012.

[7] H.Akagi, "New trends in active filters for power conditioning," IEEE Industry Applications., vol. 32, No-6, pp. 1312-1322, 1996.

[8] H. Akagi, Y. Kanazawa, and A. Nabae "Instantaneous reactive power compensators comprising switching devices without energy storage components," IEEE Trans. IndAppli.,Vol. IA-20, 1984.

[9] PiyushAnand, "POWER QUALITY IMPROVEMENT USING UNIFIED POWER QUALITY CONDITIONER (UPQC),"Department of Electrical Engineering National Institute Of Technology Rourkela May 2016.

[10] Shrutisnata Mishra, "Power Quality Improvement Using Unified Power Quality Conditioner," Department Of Electrical Engineering National Institute Of Technology Rourkela May 2016.

[11] Mr. JeevanJ.Inamdar and Mr.RahulS.Desai, "P-Q theory based design of Unified Power Quality Conditioner for tranquillization of voltage and current unbalance under Non Linear Load condition,"NOVATEUR PUBLICATIONS INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT] VOLUME 1, ISSUE 1 NOV--2014 22001144 2014

[12]CharanjeetMadan, PuneetPahuja, and Charu Jain, "ENHANCING VOLTAGE AND CURRENT CONTROL TECHNIQUES USING UNIFIED POWER QUALITY CONDITIONER," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 7, July 2013.

[13] Investigation on Rating of Shunt APF in Unified Power Quality Conditioner S. Srinath Second International Conference on Sustainable Energy and Intelligent System (SEISCON 2011) Tamil Nadu, India. July 20-22, 2011.

[14] P.vasudevanaidub.basavaraja, "design of a SRF based mc UPQC used for load voltage control in parallel distribution systems", ©2012 IEEE.

[15] Shafiuzzaman k khadem,malabikabasu, michael f conlon, "integration of UPQC for power quality improvement in distributed generation network – a review", IEEE.