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POWER QUALITY IMPROVEMENT USING UNIFIED POWER QUALITY CONDITIONER (UPQC)

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Abstract: The preferential use of power electronics devices introduces harmonics into the supply system and causes problems with the quality of the energy supplied. Good network quality is very important for the daily use of devices in both the industry and the home. Researchers have tried and implemented many useful techniques to eliminate all harmonic problems related to voltage and current. This improves the quality of the energy supplied to the power grid. The main focus of this work is control strategies such as SRF theory and instantaneous power (p-q) for the operation of Unified Power Quality Conditioner (UPQC), one of the latest technologies including both series and shunt active power filters simultaneously. Is an implementation of. This helps reduce total harmonic distortion (THD) while improving all current and voltage related issues such as voltage sagging/expansion andflicker. This paper shows how to use the UPQC model to reduce the% THD of source voltage, source current, and load voltage waveforms resulting from non-linear / sensitive loads by MATLAB simulation.

Keywords: Active power filter (APF), harmonic compensation, power quality, reactive power compensation, unified power quality conditioner (UPQC), voltage sag and swell compensation.

1. Introduction

In the current scenario, non-linear loading has become extremely important and people are becoming dependent on it. Few of these non-linear loads are televisions, printers and fax machines, rectifiers, inverters, frequency converters, ACs, etc. Harmonics are introduced into the lines due to the extensive use of these loads in our daily lives. The stability of any electrical device depends on its voltage and current flow. If the fundamental waveform is sinusoidal and its harmonics are also sinusoidal, then these harmonics occur in integer multiples of the fundamental waveform. As a result of this harmonic distortion caused by the non-linear load, the appliances used for our purpose experience several problems such as: motor overheating, increase of several types of losses, in the worst case, permanent damage to the equipment, high reading error, etc. Eliminating these harmonics or mitigating the harmonics from voltage and current curves are therefore a big problem for electrical engineers. Due to the introduction of harmonics into the line by non-linear loads, other problems are related to voltage rise, voltage drop, flicker occurring in the voltage, etc., and thus disrupting the overall power supply.

In earlier times, passive filters using tuned LC components were widely used to improve power quality by removing voltage and current harmonics. But due to high cost, resonance problems, large dimensions and many more, these filters are not widely used nowadays. All these problems are now improved by the use of active power filters (APF) and more advanced hybrid filters using several new technologies. A series active filter is used to mitigate voltage quality problems and a shunt active filter (SAF) is useful for removing disturbances present in the current curves.

Power quality (PQ) issues

Very important is the quality of the voltage that the consumer gets for the operation of the load or

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given by a particular company. The PQ problem deals with the deviation of voltage/current from their ideal sinusoidal waveforms. Energy quality has deteriorated mainly in those typical places where we connect loads to the network. Energy quality has its different definitions and importance according to its use by which we define it in the process. From a designer's point of view, PQ is defined so that there should be no voltage changes and no noise in the ground system. From a network engineer's point of view, it is voltage availability or outage minutes. For end users, the power quality is defined as the amount of available power to drive different types of loads.Voltage Sag is the rms voltage drop of the supply frequency over a time span of half a cycle to 1 minute. Voltage sag is a serious and drastic PQ problem, especially for voltage-sensitive sensitive loads such as control processing devices, adjustable speed drives (ASDs). It can also be manipulated as a short duration reduction in voltage as a consequence of a sudden abrupt increase in current value. Few of the common industrial situations where voltage sags couldbe visible are energizing of transformer, starting process of motor, and typical faults.

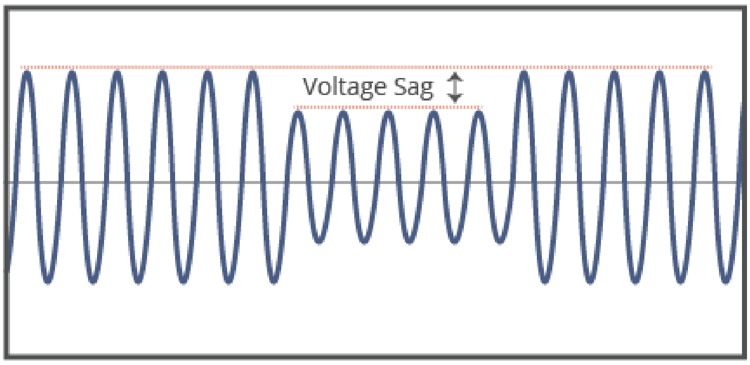

Fig. 1.1 Voltage sag found in supply voltage

Effects:

Few drastic effect found due to voltage sag problems includes relay getting tripped, loads ,malfunctioning, damage or complete failure of the equipment found in load end.

Voltage Swell

Voltage swell is a sudden increase in the rms supply voltage varying in a range from 1.1p.u.to 1.7 p.u., with a approximate time range of from half a cycle to 1 min. These appear due to largeloads sudden shutdown, capacitor banks getting energized, or due to few faults produced inside the power system. Its occurrence probability appear when compared to voltage sags is very muchless, but these are more harmful to sensitive equipment/non-linear loads.

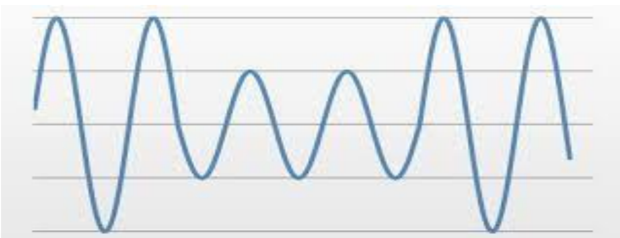

Fig. 1.2 Voltage swell found in supply voltage

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Effects:

The effects are similar like voltage sag such as damage or equipment relay tripping whichleads to failure of complete system in operation.

Active Power Filters

APF's are the electrical equipment which are connected sometimes as series model or shunt model and sometimes as a combination of both series and shunt filters. UPQC is a model where both series and shunt APF connected via a common dc link capacitor are implemented in one circuit only and they help to solve all voltage and current harmonics problems simultaneously. Series APF are used for solving only voltage harmonics problems like voltage sag, swell, flickering etc.

whereas shunt APF is used for solving only current harmonics problems and hence improves power factor by supplying reactive power continuously regulates DC link voltage. Hence service reliability is achieved with the combination of series and shunt filter in the form of UPQC.

2.UNIFIED POWER QUALITY CONDITIONER

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and critical load. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously.

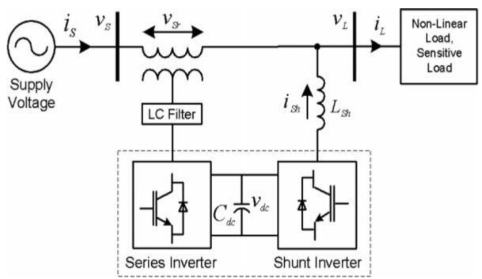


Fig 2: Hardware structure of UPQC

The main purpose of a UPQC is to compensate for supply voltage power quality issues, such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems, such as, harmonics, unbalance, reactive current, and neutral current.

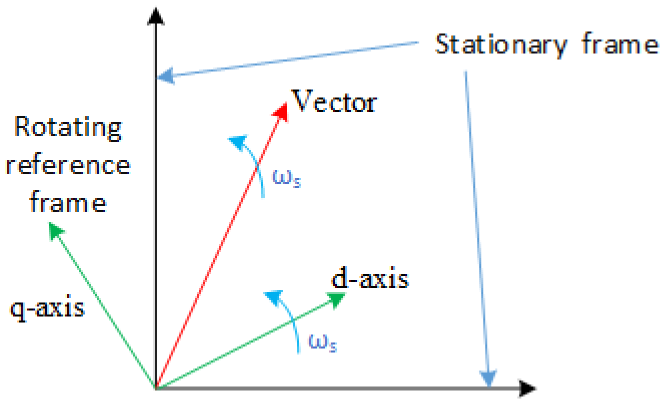
The key components of this system are as follows.

1) Two inverters -one connected across the load which acts as a shunt APF and other connected in series with the line as that of series APF.
2) Shunt coupling inductor Lsh is used to interface the shunt inverter to the network. It also helps in smoothing the current wave shape. Sometimes an isolation transformer is utilized to electrically isolate the inverter from the network.
3) A common dc link that can be formed by using a capacitor or an inductor. In Fig. 2, the dc link is realized using a capacitor which interconnects the two inverters and also maintains a constant

selfsupporting dc bus voltage across it.
4) An LC filter that serves as a passive low-pass filter (LPF) and helps to eliminate high-frequency switching ripples on generated inverter output voltage.
5) Series injection transformer that is used to connect the series inverter in the network. A suitable turn ratio is often considered to reduce the voltage and current rating of series inverter

3. SYNCHRONOUS REFERENCE FRAME (SRF) THEORY

Synchronous Reference Frame (SRF) Theory is coined long back. The main concept as the name suggests is to have a frame which rotates at a synchronous speed. Now the question comes that with what speed this reference frame should rotate and how do we determine that. To understand that we need to understand the usefulness of this theory. This theory finds its valuable application in 3-phase control applications. A 3-phase quantity (voltage/current) rotates in space with a speed. If the system is at 50 Hz then the corresponding angular speed will be 2*pi*50 = 314 radians/second. Now, to put individual controllers in all the three phases is a bit costly approach. SRF theory helps us to eliminate controller for each three phases instead, keeping 2 controllers (For P and Q control ability) for all the three phases. What we do in this SRF theory is that, we consider two axis namely d and q axis. q axis leads the d axis by 90 degrees. So, this becomes our reference frame (dq axis). Also, we consider that this reference frame is rotating synchronously same as that of system frequency. If we refer below the image, phasor is rotating at speed" w". The reference frame rotates with the same speed "w". Therefore, relative speed between the rotating phasor and the frame is Zero (0). Hence, we observe a dc quantity and can be resolved along the d and q axis. The benefit what we achieve here using SRF is we deal with dc quantities. For control applications, dc quantities are easily controllable without having steady state errors.



4.SIMULATION RESULTS

Single phase shunt active power filter:

System Parameters:

Supply voltage (single phase): 165 volt; Frequency:

50Hz , DC capacitor: 2000μF Source Rs= 1ohm &

Ls=25mH

Filter parameters: R=0.5ohm & L=2.4mH.

Non-linear rectifier load: R_1= 10ohm & L_1 =100mH.

The results of the simulation model for source current with and without shunt APF are shown below:

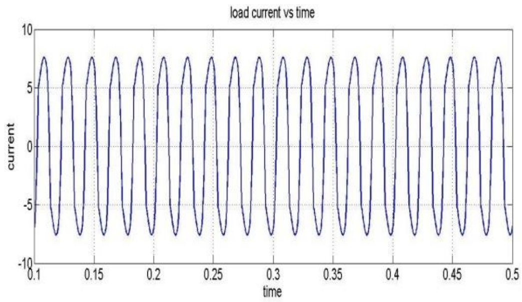


Fig 4.2 Load current without shunt APF

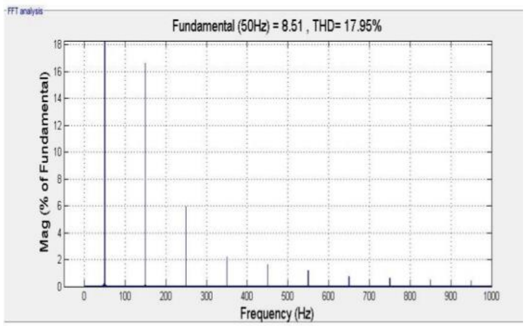


Fig:4.3 Load current Harmonic Spectrum without shunt APF

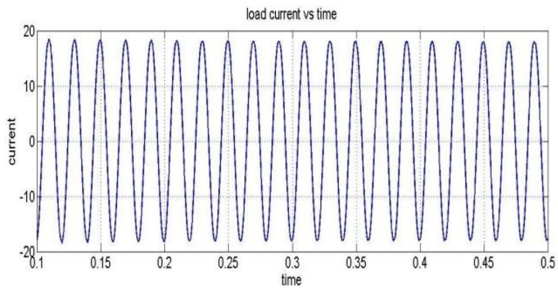


Fig: 4.4 Load current with shunt APF

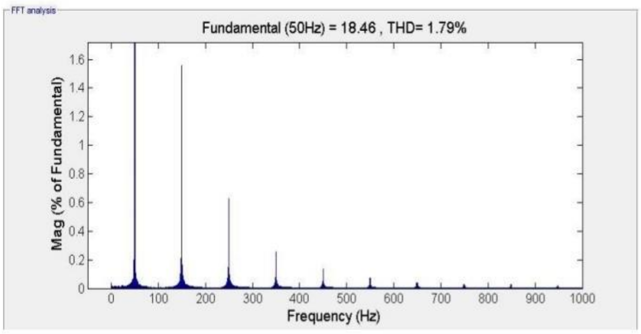


Fig4.5 Load current Harmonic Spectrum with shunt APF

The load current of system with non linear load in absence of shunt APF is seen in Fig4.2 and thetotal harmonic distortion (THD) in load current as shown in Fig 4.3. without the use of shunt activepower filter(SAPF) is found to be 17.95% .Now after introducing shunt APF the new improved load current with the use of shunt active power filter its THD is found to be 1.79% which is within the harmonic limits.

The waveforms obtained after the application of UPQC in the given system compensated the harmonics introduced in the source voltages, source current and load voltage due to the presence of non-linear load. The results of the improved waveform due to UPQC operation for the considered A-phase is shown in the following figures:-

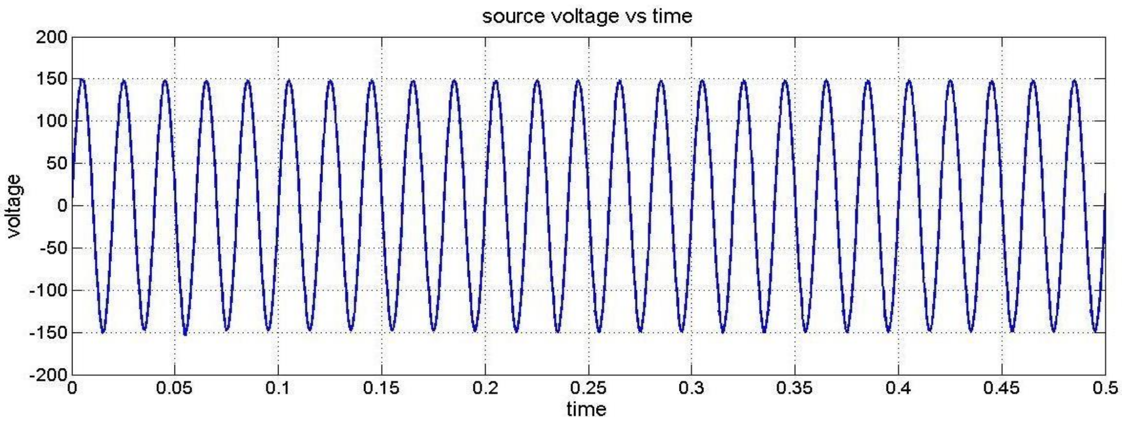


Fig4.6 source voltage(a-phase) after UPQC compensation in non-linear load

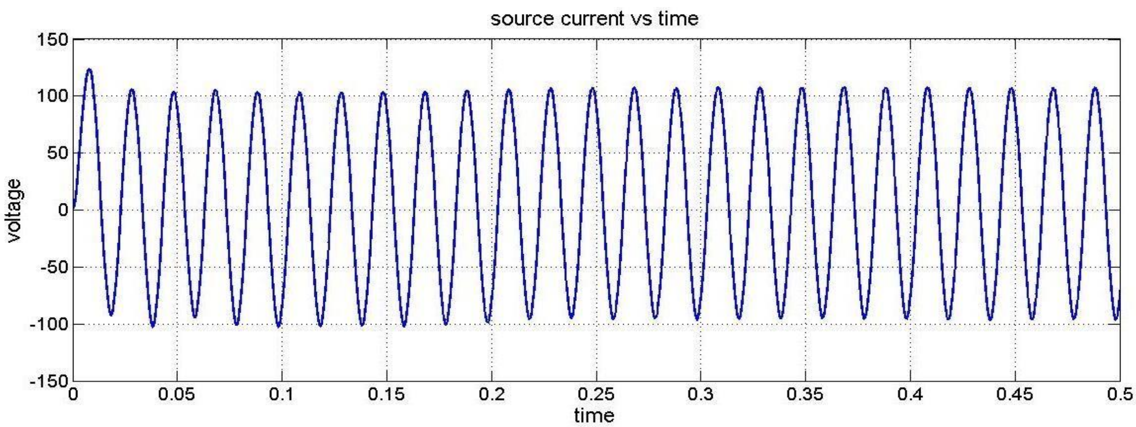


Fig4.7source current(a-phase) after UPQC compensation in non-linear load

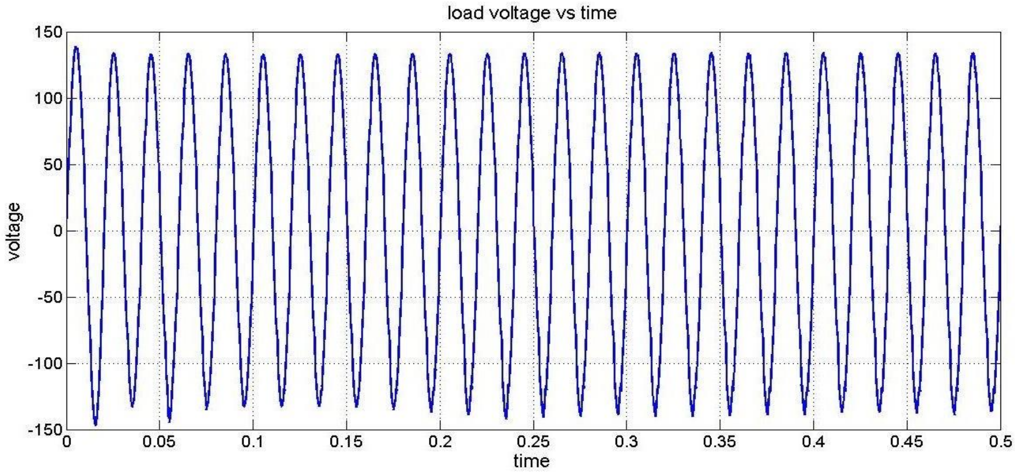


Fig4.8 Load voltage(a-phase) after UPQC compensation in non-linear load

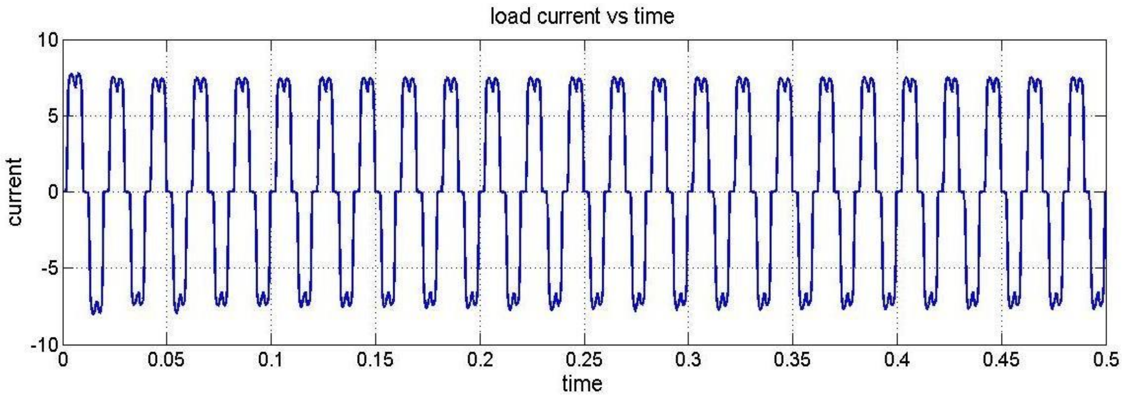


Fig4.9: Load current(a-phase) after UPQC compensation in non-linear load

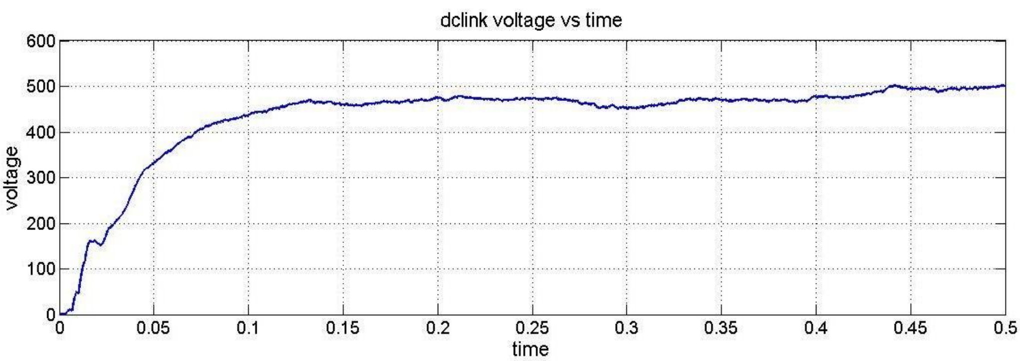


Fig 4.10: DC link voltage across capacitor

5. Conclusion & Future Work

This thesis describes an improved control strategy for the operation of UPQC system. Several control strategy is studied like p-q theory, SRF based approach, unit vector template generation for the APF operation. The UPQC model is simulated in MATLAB using instantaneous power theory. Shunt part of UPQC removes all the current related harmonic problems in the system and series connected APF of UPQC system removes all voltage harmonics which comes up due to the use of nonlinear load. The overall THD is now improved in the system which is clearly observed from the waveforms the resultant THD before and after UPQC operation.

Preventing the harmonics due to presence of nonlinear load is difficult but its controlling is possible and many research work is still going on for the same. Sliding Mode(SM) and feedback linearization strategy of control is an advanced method for the operation of UPQC due to their ease in implementation and robust in external disturbance. Further dSPACE software which is a good interface between real time hardware and computer, it can be used to implement UPQC model using a further new strategy called Fuzzy control method.

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