Single Phase to Three Phase Unified Power Quality Conditioner

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Abstract- **Mitigating power quality issues in distribution systems is of utmost importance to both electricity consumers and suppliers as it improves the distribution system's efficiency, reduces electricity costs, maintains continuous supply, and diminishes the requirement for frequent maintenance. Custom power devices were introduced to eliminate power quality issues like voltage sags, swells, transients, imbalances, and current harmonics arising in distribution systems. Unified power quality conditioner (UPQC) is one such frequently used custom power device that enhances the power quality of distribution systems. Now days the usage of three phase loads is increasing gradually, therefore it is much required to get access to the three-phase distribution system. UPQC 1-ph-to-3-ph uses dual compensation principle makes possible to draw sinusoidal current, in phase with the grid voltage, from the single-phase grid to improve the power quality. The system compensates the voltage disturbances such as voltage sag, voltage swell and other voltage unbalances. The proposed system allows the balanced and regulated voltage with lower harmonic content. The present paper analyzes the compensation and control strategies using PI controller. The control strategies are simulated using MATLAB/SIMULINK.**

Keywords— Power quality (PQ), unified power quality conditioner (UPQC), Series and Shunt active power filter.

I. INTRODUCTION

Electricity is the most famous form of energy which becomes compromised due to power quality problems. In this era of industrialization, the power quality is important for any power distribution company. Basically, the characteristic of voltage (like frequency, waveform, amplitude etc.) are in power quality concerns . On the bases of modern digital devices like microcontroller, microprocessor-based equipment has great concern about Power Quality issues. Poor power quality is major problem for both customers as well as power suppliers.

Power quality refers to maintain a sinusoidal waveform of bus voltages at bus voltages at rated voltage and frequency. You should have a constant frequency and proper sinusoidal voltage and current with constant magnitude and then only you say that, you are getting a good quality of power. The waveform of electric power at generation stage is purely sinusoidal, apart from their diagnostic and generally if you find that issues like some broken rotor or so are coming then generally those are being replaced and repaired. Power quality (PQ) is defined as the measure, analysis, and improvement of voltage and/or current to maintain a sinusoidal waveform at a rated frequency and voltage within a certain power system. As a result, there is a significant rise in power quality issues that arise in distribution systems. Some of the most frequently occurring power quality disturbances are voltage, interruptions, sags, swells, flickers, imbalances, spikes, and current harmonics. A variety of techniques and devices were introduced to eliminate power quality issues in distribution systems in recent years.

The initial concept of UPQC which involved integrating properties of both series and shunt filters was introduced by Akagi and Fujita in the late 1990s. As mentioned in the previous section, the significance of this custom power device is its capability to mitigate both voltage and current quality problems like voltage sags, swells, flickers, interruptions, and harmonics arising within a distribution system simultaneously. Also, UPQCs can balance the reactive power in the distribution system. References an introduced a power conditioning system known as Universal Power Quality Conditioning System (UPQS) that uses the same principles of the original UPQC model but has more capability in power factor correction and harmonic compensation in current type loads.

UPQC is a combination of a Shunt Active power filter and Series Active power filter. Here Shunt Active power filter (APF) is used to compensate for load current harmonics and make the source current completely sinusoidal and free from harmonics and distortions. Shunt APF is connected parallel to transmission line. Here Series APF is used to mitigate for voltage distortions and unbalance which is present in supply side and make the voltage at load side perfectly balanced, regulated, and sinusoidal. Series APF is connected in series with transmission line. UPQC consists of two voltage source inverters connected back-to-back through a DC link capacitor in a single phase, three phase-three wire, three phase-four wire configuration. The inverter in shunt APF is controlled as a variable current source inverter and in series APF is controlled as a variable voltage source inverter. Earlier passive filters where also used for compensation of harmonics and voltage distortion but due to their many disadvantages they are not used nowadays.

II. TYPICAL STRUCTURE OF SINGLE PHASE TO THREE PHASE UPQC

Fig. 1. shows the Unified power quality conditioner (UPQC) which is a combination of back-to-back connected series active power filter and shunt active power filter attached to a common DC link voltage is one of the progressed forms of

power conditioning device as shown in fig.1.

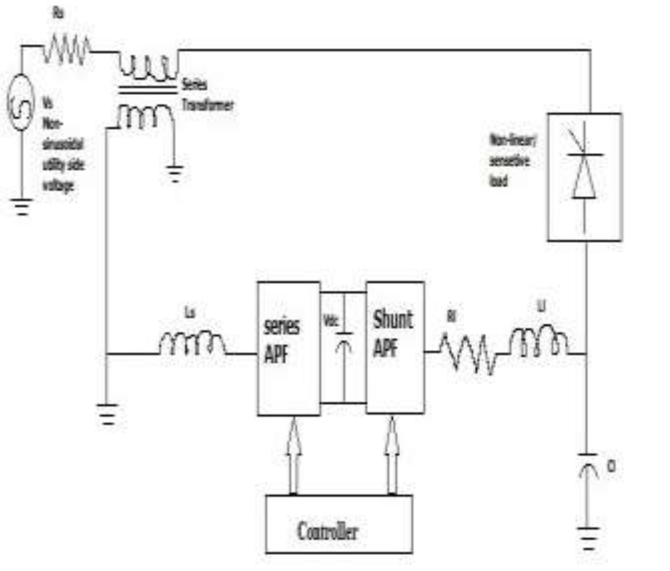

Fig. 1. Typical Structure Of Single Phase To Three Phase UPQC

This topology will be getting better for the power quality and facilitates this equipment to have a reduced dc-link voltage without reducing its compensation capability. Because of the increase of nonlinear loads attached to the electrical power system causing distortions in the utility voltages at the point of common coupling the demand for power quality (PQ) improvement.

Unified power quality conditioner used to compensate both source and load side problems is one of the best custom power devices. Power quality problems have received a great attention because of their impacts on both utilities and customers. PQ problems on the proper operation of sensitive equipment causing defect such as voltage sags/swells and voltage unbalances. Furthermore, additional procedures should be taken under consideration in order to overcome PQ problems linked to harmonic currents generated by nonlinear loads, load unbalances and reactive power demanded by the load.

The Block diagram shown in fig. 1. has single phase three-wire power supply system. The UPQC is a custom power device which joins the series and shunt active filters attached back-to-back on dc side and dividing a common DC capacitor. This dual performance makes the UPQC as one of the most proper devices that could solve the issues of both consumers as well as of utility. The voltage distortions can be compensated by the series filter and the reactive power and counteract the harmonic current injected by the load can be compensated by shunt filter and the voltage of the DC link capacitor is composed to a desired value by the shunt active filter.

UPQC is composed of two Voltage Source Converters (VSC) and is attached in series with the feeder and the other is connected in parallel to a similar feeder. Whenever the supply voltage undergoes sag and then series converter injects correct voltage with supply. The series filter suppresses and isolates voltage-based distortions, although the shunt filter cancels current-based distortions. It is composed of a series voltage-source converter attached in series with the AC line and acts as a voltage source to decrease voltage distortions. It is used to eliminate supply voltage flickers or imbalance from the load terminal voltage and forces the shunt branch to absorb current harmonics generated by the nonlinear load. Control of series converter output voltage is usually performed by pulse-width modulation (PWM).

III. SIMULATION OF SYSTEM IN MATLAB

The system shown in fig.2. is implemented in MATLAB Simulink model with the following parameter and the component values tolerance. The results are as discussed below.

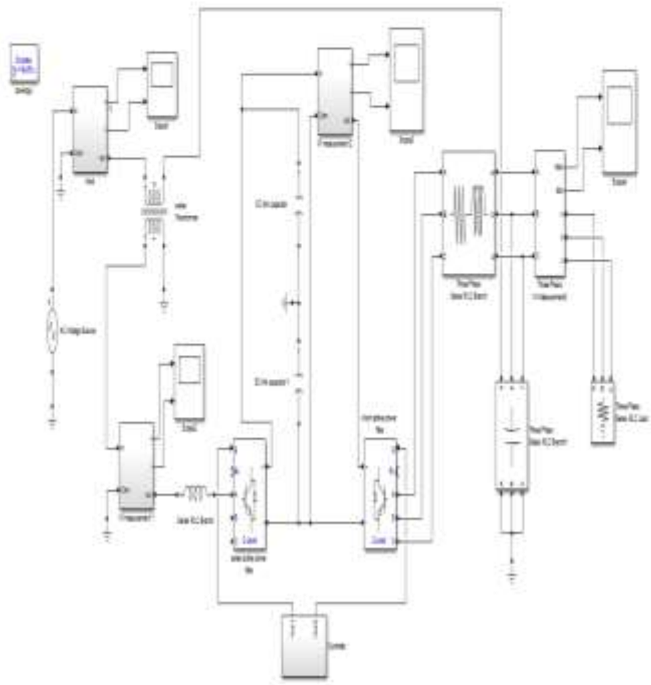

Fig. 2. MATLAB/Simulink Model Of 1 Phase To 3 Phase UPQC

IV. RESULT AND DISCUSSION

As Shown in fig. 2. during an voltage swell a parallel compensator phase A will act as a rectifier and absorb the excessive voltage and series controller also work as a rectifier and transfer the energy to phase B and C. During normal condition the series converter will be inactive and parallel converter will control and supply the total load. During abnormal condition the series converter injects voltage into the system to compensate for the sag and the parallel converter will supply phase b and c.

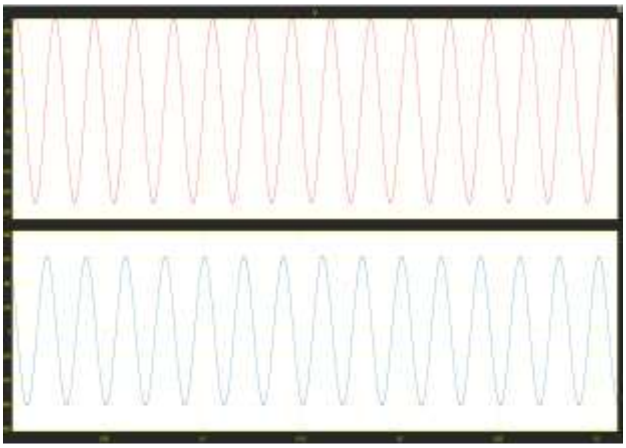

Fig.3. Single Phase Voltage And Current

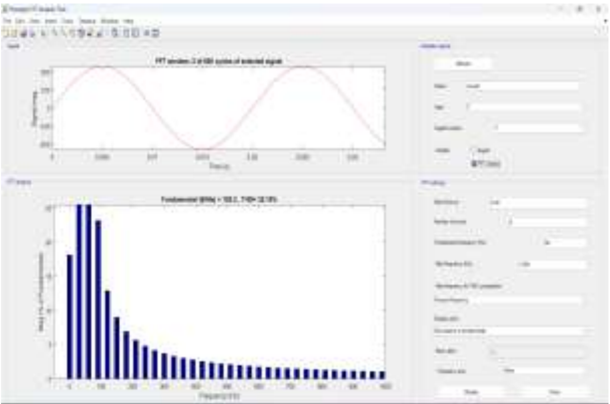

Fig.4. THD Of Single-Phase Voltage And Current

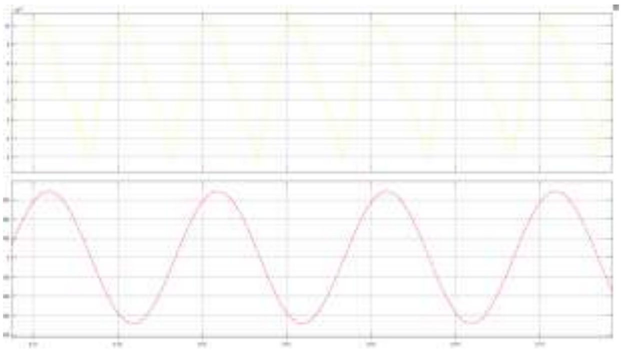

Fig. 5. DC bus voltage and current

Fig.6. THD Of DC Bus Voltage And Current

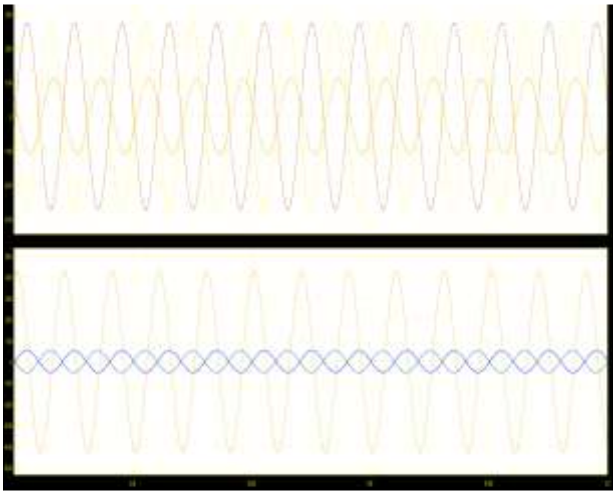

Fig.7. Three Phase Load Voltage And Current

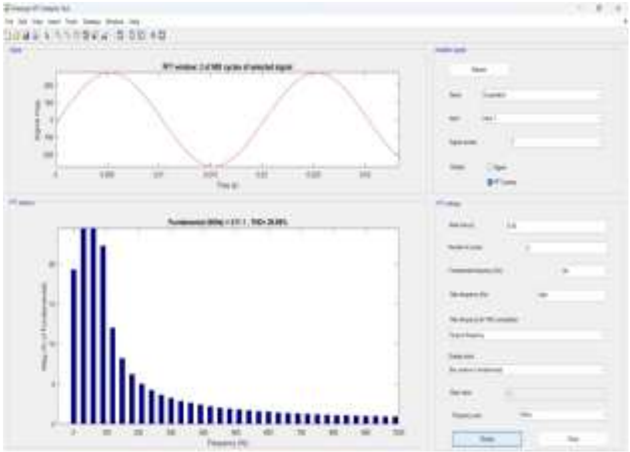

Fig.8. THD Of Three Phase Load Voltage And Current

TABLE I. RESULT TABLE

Figure name	**Total Harmonic Distortion**
Single Phase Voltage And Current	32.19 %
DC bus voltage and current	300.26 %
Three Phase Load voltage and current	29.89 %

As shown in above result table , in single phase load the total harmonic distortion (THD) is 32.19% and in three phase load the total harmonic distortion (THD)29.89%. When the conversion is done from Single phase to three phase the Total harmonic distortion (THD) get reduced and the power quality of the system is improved.

TABLE II. PARAMETER USED IN SIMULATION

Parameter	Values
1ph load 1	Sla=600, Slb=300, Slc=400VA
1ph load 2	Sla=Slb=Slc=538VA
3ph load 1	Sl=1860VA
3ph load 2	Sl=1372VA
Vrms 1ph grid	Vs =230v
Vrms 3ph load	Vlabc =230v
Grid Frequency	Fs=50Hz
Inverter switching frequency	Fch=50kHz
Inductor Parallel Converter	Lfpabc=2mH, Rfp=0.2m ohm
capacitor Parallel Converter	Cfpabc= 50uF
Inductor Series Converter	Lfsabc=2mH, Rfs= 0.2m ohm
Series Transformer	Ldt=0.2mH, Rdt=0.2mohm, N=1
Sampling Frequency	Fa=50 KHz

V. CONCLUSION

The paper shows the study and validation of a three phase four wire ground return distribution system. This system can be implemented in rural and agricultural areas where three phase load such as induction motors are connected and the three phase was conceived based on unified power quality conditioner functionalities. With UPQC ability and 1Ph-to-3Ph conversion. Using the dual compensation strategy, the simulated system is able to feeding linear and non-linear three-phase loads acting with universal active filtering capability, i.e. acting as SAPF and PAPF. The simulation has shown that the system is stable for both static and dynamic loads and behaviour of the UPQC achievable while 1Ph-to-3Ph conversion is also carried out and the system does not need any external source to regulate the dc bus, it has been verified through simulation results.

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