SIMULATION OF UNIFIED POWER QUALITY CONDITIONER FOR ENHANCEMENT OF POWER QUALITY ISSUES

[1]Konidena N V Sai Tejaswi, [2]K K Vasishta Kumar and [3]P Bapaiah
[1]PG Scholar (JNTUK), [2]Asst Professor (VVIT), [3]Asst Professor (ASIST)
[1]Department of EEE, Amrita Sai Institute of Science & Technology, Vijayawada, India.

Abstract— In recent days, most of the equipment is based on power electronics and often leads to power quality problems. Conventional equipments for power quality enhancement are not sufficient to meet the increasing applications and so it is very important to develop a dynamic solution to power quality problems. Hence, to meet both supply voltage imperfections and load current abnormalities a custom power device unified power quality conditioner (UPQC) is employed. It is a combination of series and shunt converters connected together with a common direct current (DC) link capacitor. This paper deals with the simulation of UPQC system through synchronous reference theory for series converter control and instantaneous active and reactive power theory or PQ theory for shunt converter control. The simulation is carried out using MATLAB/SIMULINK tool and results are presented under distorted source conditions, voltage sag and swells conditions.

Index Terms—UPQC, synchronous reference frame (SRF), PQ theory, point of common coupling (PCC).

I. INTRODUCTION

In true sense, a large portion of the electrical loads have non linear behavior when subjected to AC power supply. Because they draw different types of harmonic currents like unbalanced current, fluctuating current, reactive component of current, characteristic and non-characteristic current harmonics from AC supply. Majority of the rotating machines and magnetic devices are behaves with non linear nature due to its saturation, geometry and asymmetry in airgap. The nonlinear loads comprising of solid state converters and they can draw considerable amount of harmonic current and reactive current from the supply mains. In three phase systems, these nonlinear loads can cause unbalance in load voltage and sometimes draws excessive neutral current under the system with three phase four wire supply. These power quality problems results in low system efficiency, poor power factor and also cause distortion in the supply voltage.

Generally power quality problems are classified into two classes: due to poor quality of current drawn from non linear loads and voltage disturbances that can cause faults in the power system. The very common but critical power quality problems are voltage sags, voltage swells and harmonic currents. These problems may cause from temporary interruption to permanent shutting down of the sensitive equipment connected to the system.

Recent research efforts are mostly concentrating on the full utilization of UPQC for all the power quality abnormalities for both voltage and current related. It is a versatile device similar to Unified Power Flow Controller (UPFC) but differs in control objectives and applications. UPQC has the ability to mitigate all the power quality problems there by enhance the quality of power transfer on the distribution systems at the point of common coupling (PCC).

II. UPQC CONFIGURATION

The UPQC is being used as a Universal active power conditioning device used to mitigate both current and voltage related abnormalities in the distribution system. It is a combination of series and shunt filters connected through a common link dc voltage. The series filter is connected in series with the supply voltage through a transformer and shunt filter is connected across the load. The series filter can be used to attenuate current harmonics by injecting a series voltage which is proportional to the line current. This injected voltage is added to the distribution system at the point of common coupling to eliminate any voltage sag, swell and flicker.

The shunt filter provides a path to flow real power to aid the operation of series filter. It draws or injects active power fluctuating at low frequency from or into the system. In addition it is used to deliver the reactive VARs demanded by load and also it is used to mitigate current harmonics and common link dc voltage regulation. The UPQC structure is shown in the figure 1 with sensitive load/critical load on the distribution system. The control strategies are explained in the next section.

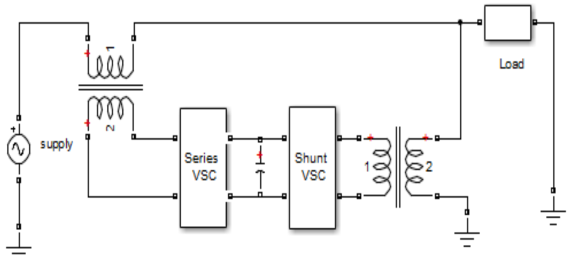


Fig.1: Schematic Layout of UPQC

III. CONTROL STRATEGIES OF UPQC:

As mentioned in the above section, UPQC have two filters, series and shunt. The control strategies are different for both series and shunt filters.

The shunt connected converter has the following control objectives:

1. To balance the source currents by injecting negative and zero sequence components required by the load.
2. The compensation for the harmonics in the load current by injecting the required harmonic currents.
3. To control the power factor by injecting the required reactive current (at fundamental frequency)
4. To regulate the DC bus voltage.

The series connected converter has the following control objectives

1. To balance the voltages at the load bus by injecting negative and zero sequence voltages to compensate for those present in the source.
2. To isolate the load bus from harmonics present in the source voltages, by injecting the harmonic voltages
3. To regulate the magnitude of the load bus voltage by injecting the required active and reactive components (at fundamental frequency) depending on the power factor on the source side
4. To control the power factor at the input port of the OPEN UPQC (where the source is connected.

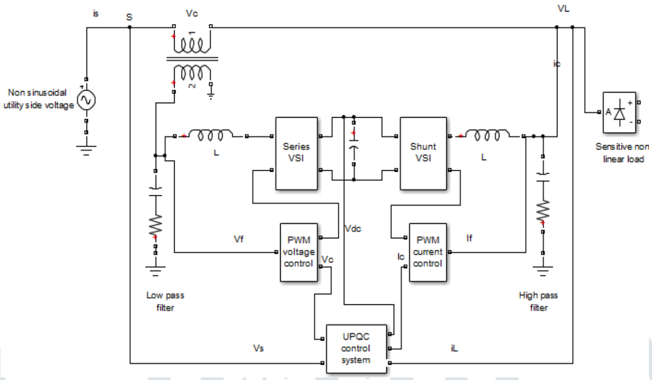


Fig.2: Control strategies of UPQC

Note that the power factor at the output port of the OPEN UPQC (connected to the load) is controlled by the shunt converter.

a. Series control strategy:

The control strategy for the unified power quality conditioner is based on the synchronous reference frame (SRF) theory. In this theory controlling of the three-phase converters using the rotating frame theory by converting the source voltage and current to αβ and then again it converted to direct and quadrature axis. The three phase voltages may be converted the following two phase system for convenience. The forward (abc to ab) and (ab to abc) are given below. It is assumed that there is no neutral connection [(Va+Vb+Vc) = 0]. The three phases to two phase transformation above simplifies the system equations by taking advantage of the redundancy present in the three phase system.

b. Shunt control strategy

The shunt converter has the function of compensating the current related problems. Along with the shunt controller, DC link voltage is maintained. The abc to dq0 transform is inversed and converted to abc; that signal is given as the reference signal and the measured signal is given to the Pulse generation algorithm produce the pulse signals for the operation of shunt converter. The simulation diagram for shunt controller is shown in Fig 3

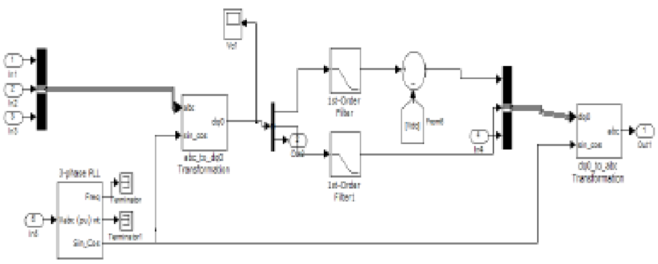


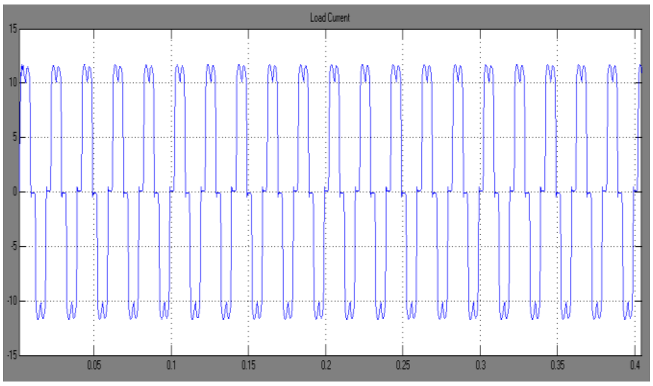
Fig 3 Shunt converter SRF control Strategy

IV. SIMULATION RESULTS

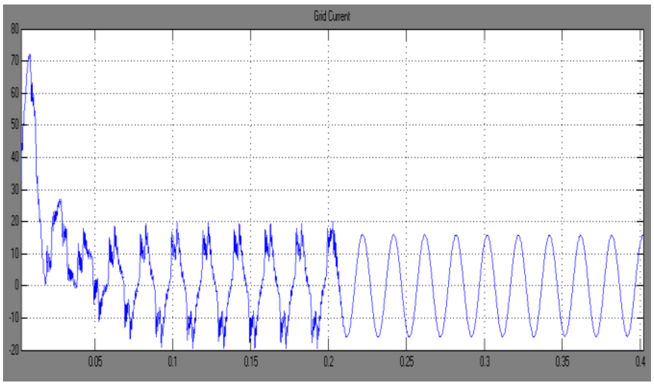
In this section the simulation analysis of OPEN UPQC is described. In this two filters are used i.e. shunt and series so called as DSATCOM and DVR. The developed model of OPEN UPQC in MATLAB/SIMULINK environment and the control circuits for this model are same as shown in Fig. 2. The shunt active power filter compensates current disturbances and also maintains the dc link voltage to reference value. While series active power filter compensates voltage related problems for maintaining required load voltage.

a. Current Harmonic Compensation

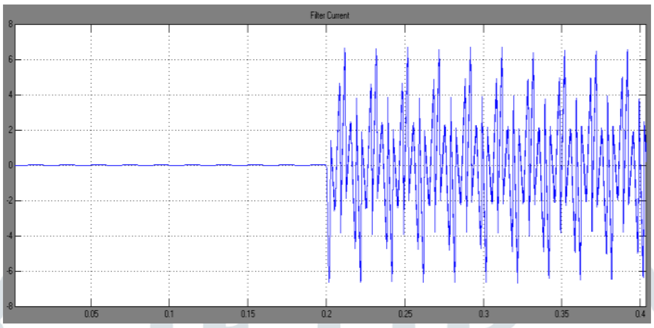
Fig. 4 shows the simulation results for OPEN UPQC working as current harmonics compensator. In this case, the terminal voltages are assumed pure sinusoidal, the OPEN UPQC is put into the operation at instant 0.1sec. In addition to this the DSTATCOM also helps in compensating the current harmonics generated by the non-linear load. The load current is shown in Fig. 4(a). The DSTATCOM injects a current (Fig.4(c)) in such a manner that the source current becomes sinusoidal. At the same time, the DSTATCOM compensates for the reactive current of the load and improves power factor. The improved source current profile is shown in Fig. 4(b).



(a)



(b)



(c)

Fig. 4: Simulated results of UPQC (a) Load current (b) Source current (c) DSTATCOM current

Fig 5(a-b) shows the harmonic spectrum of distorted source current and compensated source current for phase-a after DSTATCOM is put in operation. THD of source current is 28.49%. With DSTATCOM in operation there is a significant reduction in THD at source side current, from 28.49% to 0.41 %. Shunt inverter is able to reduce the current harmonics entering into the source side.

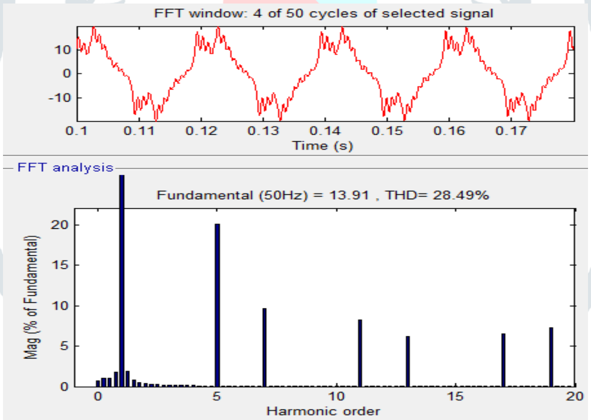


Fig. (a)

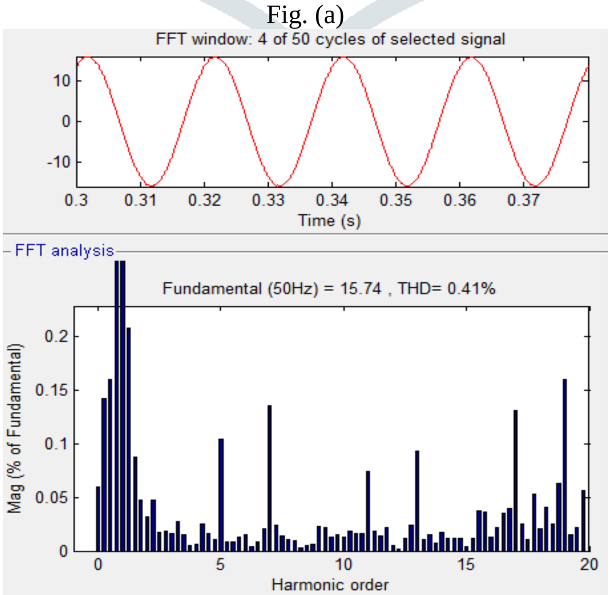
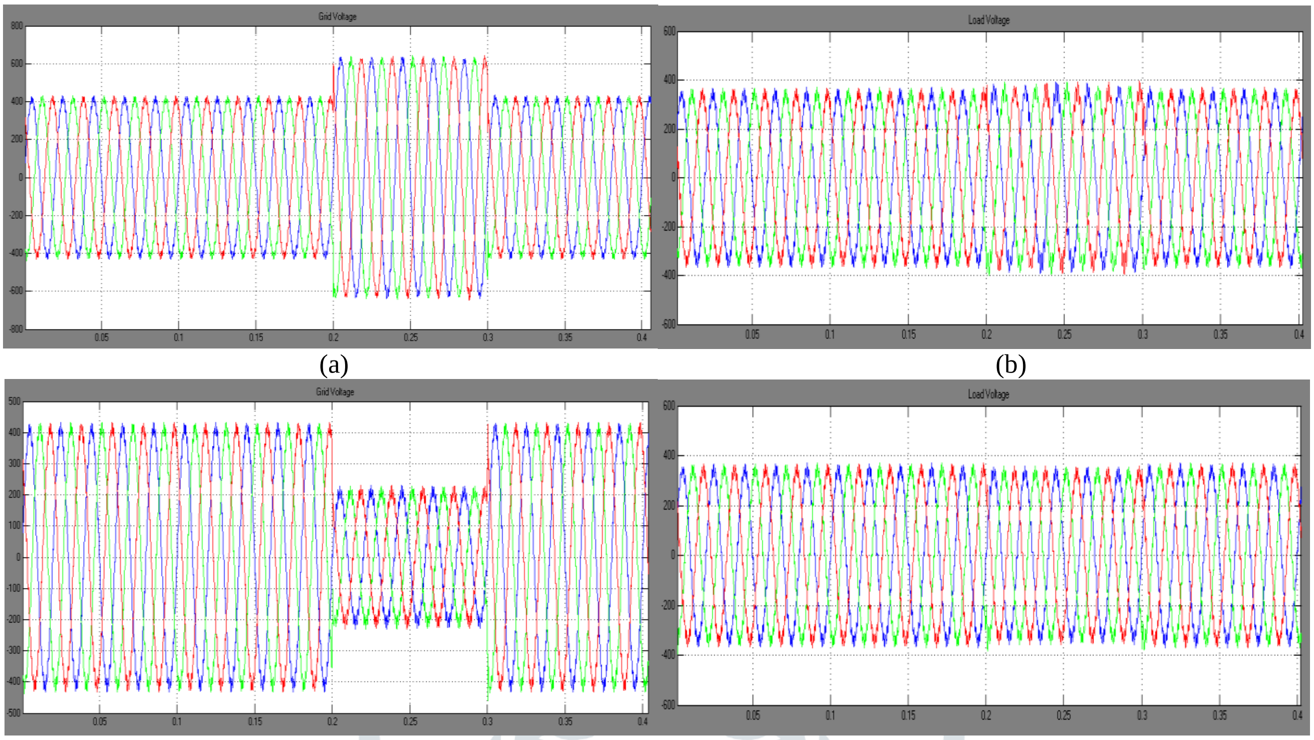


Fig. (b)

Fig.5: THD analysis of (a) distorted source current (b) compensated source current

b. Voltage Sag and Swell

Fig.6 shows the simulation result of OPEN UPQC for voltage sag and swell. Voltage swell is observed from 0.2s to 0.3 s as shown in Fig. 6(a). Fig 6(c) shows the voltage sag which is observed in between 0.2s and 0.3s. The DVR solves the problems of voltage sag and swell. The load voltage profiles can be observed in Fig. 6(b) and (d) respectively which is free from supply voltage sag and swell.



(a) (b)

(c) (d)

Fig. 6: Simulated results of UPQC (a) voltage swell (b) load voltage (c) voltage sag (d) load voltage

V. CONCLUSION

In this paper, work has been done to simulate UPQC by treating shunt and series converters as DSTATCOM and DVR respectively. Performance analysis has been done by comparing the power quality of each compensator. UPQC is proved to compensate current and voltage harmonics which has been reduced considerably. Current harmonics generated at source side has THD of 28.49% which has been compensated to 0.41% at PCC. Voltage Harmonics generated at load side has THD of 26.8% which has been compensated to 0.50% at load end. All the work has been done under the conditions distorted source, voltage sag and swells with the help of custom power device UPQC by using MATLAB/Simulink software and results were obtained satisfactorily under all worked conditions.

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