International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 04, April-2015

Power Quality Improvement using UPQC with Non-Linear Load

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***Abstract* — the unified power-quality conditioner (UPQC) is used to mitigate the current and voltage-related power-quality (PQ) problems simultaneously in power distribution systems. Among all of the PQ problems, voltage sag is a crucial problem in distribution systems. Sags are most often caused by fuse or breaker operation, motor starting, or capacitor switching. Voltage sags typically are non-repetitive, or repeat only a few times due to recloses operation. UPQC consists of back to back connected series and shunt active filters. The shunt active power filter compensates the source current harmonics and also it maintains the dc link voltage unchanged in steady state, while the series active power filter compensates the load voltage harmonics.**

A MATLAB based model for the UPQC has been simulated for R-L load using synchronous reference frame based technique

Keywords— UPQC ,shunt filter,series filter SRF Theory

I. INTRODUCTION

The present power distribution system is usually configured as a three-phase three-wire or four-wire structure featuring a power-limit voltage source with significant source impedance, and an aggregation of various types of loads. Ideally, the system should provide a balanced and pure sinusoidal three-phase voltage of constant amplitude to the loads; and the loads should draw a current from the line with unity power factor, zero harmonics, and balanced phases. To four - wire systems, no excessive neutral current should exist. However, with a fast increasing number of applications of industry electronics connected to the distribution systems today, including nonlinear, switching, reactive, single-phase and unbalanced three-phase loads, a complex problem of power quality evolved characterized by the voltage and current harmonics, unbalances, low power factor (PF). Some active circuits were developed to compensate unbalanced currents as well as limit the neutral current. Voltage-source converter based custom power devices are increasingly being used in custom power applications for improving the power quality (PQ) of power distribution systems. The term electric power quality broadly refers to maintaining a nearly sinusoidal power distribution bus voltage at rated magnitude and frequency. In addition, the energy supplied to a consumer must be uninterrupted from reliability point of view. Though power quality is mainly a distribution system problem, power transmission system may also have impact on quality of power It can also regulate the voltage of a distribution bus. A DVR can compensate for voltage sag/swell and distortion in the supply side voltage such that the voltage across a sensitive/critical load terminal is perfectly regulated. A unified power-quality conditioner (UPQC) can perform the functions of both DSTATCOM and DVR .The UPQC consists of two voltage-source converters (VSCs) that are connected to a common dc capacitor. One of the VSCs is connected in series with a distribution feeder, while the other one is connected in shunt with the same feeder. It is possible to connect two VSCs to two different Feeders in a distribution system (IUPQC) and also possible for multi bus/multi feeder system (MC-UPQC).

II. UPQC TOPOLOGY

A. *Basic configuration of UPQC*

Fig shows the basic configuration of a general UPQC consisting of the combination of a series active and shunt active filter. Fig 2.1 Inverter 1 (Series Inverter SE) is connected in series with the incoming utility supply through a low pass filter and a voltage injecting transformer. Inverter 2 (Shunt Inverter SH) is connected in parallel with the sensitive load, whose power quality needs to be strictly maintained.

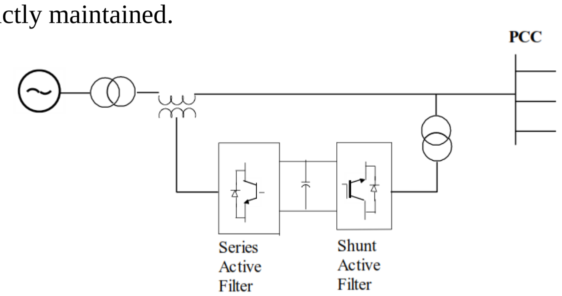

Fig 2.1 Basic Configuration of UPQC

The main purpose of the series active filter is harmonic isolation between a sub transmission system and a distribution system. In addition the series active filter has the capability of voltage flicker/imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer point of common coupling (PCC). The main purpose of the shunt active filter is to absorb current harmonics, compensate for reactive power and negative sequence current, and regulate the dc link voltage between both active Filters.

B.SPECIFICATION OF UPQC

Fig 2.1 shows the configuration of a specific UPQC. The aim of specific UPQC is not only to compensate for the current harmonics, but also to eliminate the voltage flicker/imbalance contained in the receiving terminal voltage V_R from the load terminal voltage VL. The receiving terminal in Fig 2.1 is often corresponding to the utility-consumer point of common coupling in high power applications. The operation of series active filter greatly forces all the current harmonics produced by the load into an existing shunt passive filter.

It also has the capability of damping series/parallel resonance between the supply impedance and the shunt passive filter.

The shunt active filter is connected in parallel to the supply by the step up transformer. The only objective of the shunt active filter is to regulate the dc link voltage between both active filters. Thus, the dc link is kept at a constant voltage even when a large amount of active power is flowing into or out of the series active filter during the flicker compensation. Although the shunt active filter has the capability of reactive power compensation, the shunt active filter in Fig 2.1 provides no reactive power compensation in order to achieve the minimum required rating of the shunt active filter.

Therefore, it should be connected downstream of the series active filter acting as a high resistor for harmonic frequencies. In Fig 2.1 the shunt active filter draws or injects the active power fluctuating at a low frequency from or into the supply, while the existing shunt passive filter absorbs the current harmonics. To avoid the interference between the shunt active and passive filters, the shunt active filter should be connected upstream of the series active filter.

III. UPQC CONTROL STRATEGY

A. Vector control of UPQC with synchronous reference frame theory

There is different vector control strategies used to perform the control of the grid side converter. They all are focused on the same topic: i.e. control of DC-link voltage, ac link current, active and reactive power control of grid, power quality.

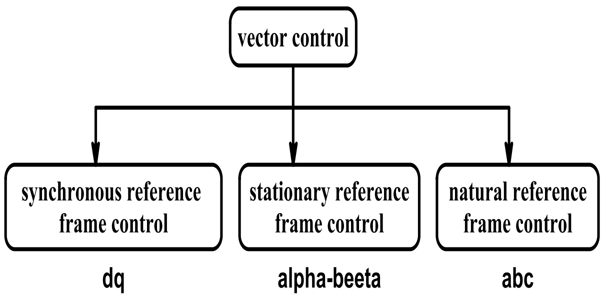

Fig 3.1 Classifications of grid side converter control strategies

These control strategies are classified depending on the reference frame used in the control structure. In this project the main part is on the stationary reference frame control strategy and PI control. Brief introduction of synchronous reference frame is also including in literature.

B. *Series control startegy*

Synchronous reference frame control strategy as show in figure. In Series Converter the mains voltages and line currents are transformed into d-q reference frame.

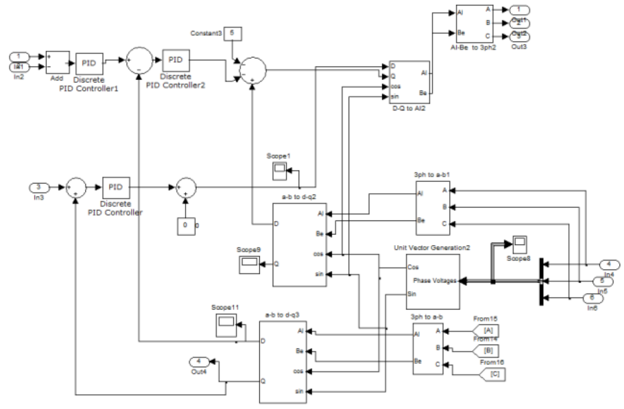

Fig 3.2 Series converter SRF control Strategy

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.

C. *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 3.3.

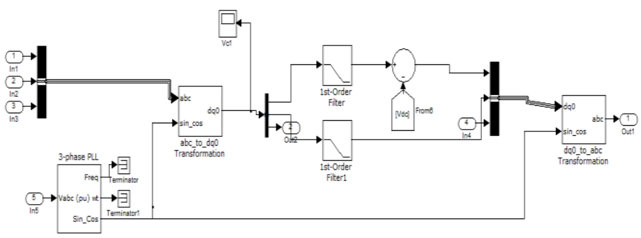

Fig 3.3 Shunt converter SRF control Strategy

IV. SIMULATION RESULT ANALYSIS OF UPQC

A UPQC simulation model as shown in figure has been created in MATLAB/Simulink so as to investigate UPQC circuit waveforms, the dynamic and steady –state performance and voltage and current rating.

The following typical case studies have been simulated and the result are presented

1. Steady state and three phase fault condition
2. Non-linear load and three phase fault condition

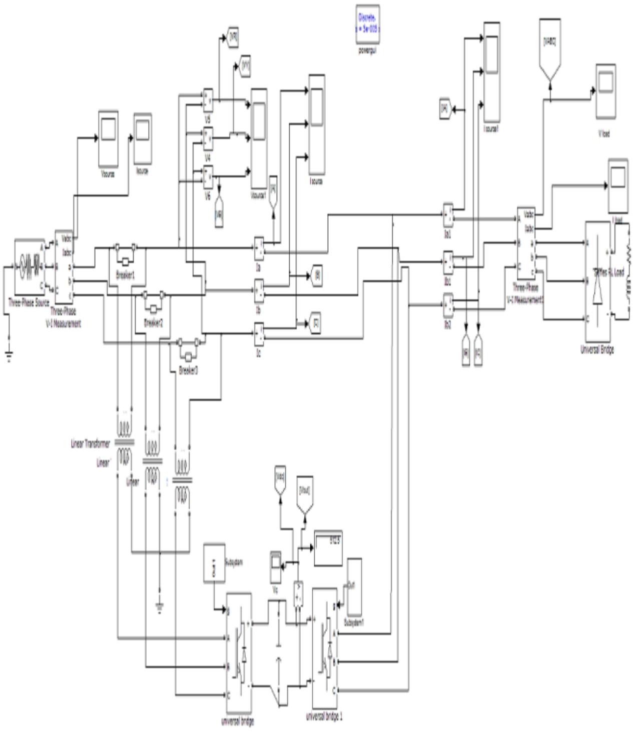

Fig 4.1 MATLAB model for unified power quality conditioner (UPQC)

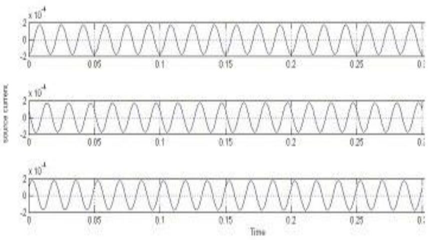

Fig 4.1.2 Source current with compensation

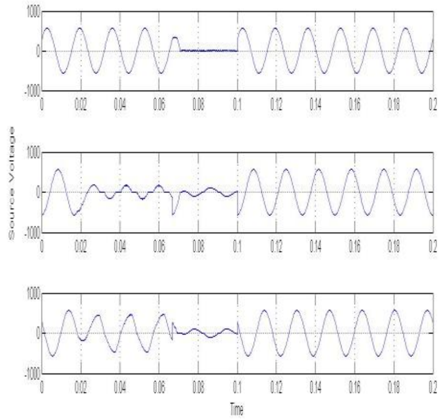

Fig 4.1.3 Source voltage with compensation

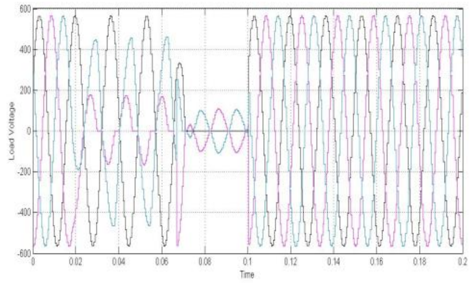

Fig.4.1.4 load voltage with compensation

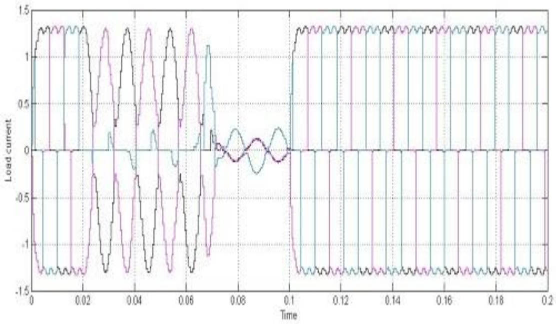

Fig 4.1.5 Load current with compensation

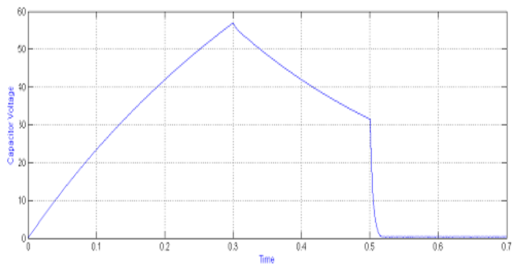

Fig 4.1.6 DC Capacitor with compensation

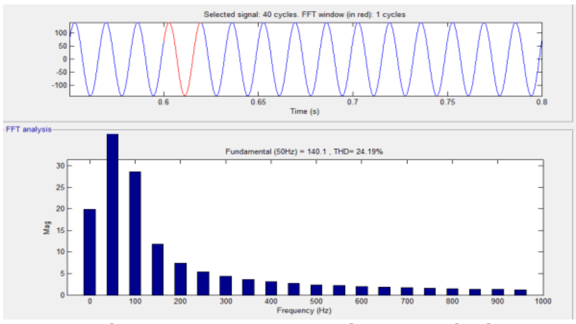

Fig 4.1.7 without compensation FFT analysis sourced voltage

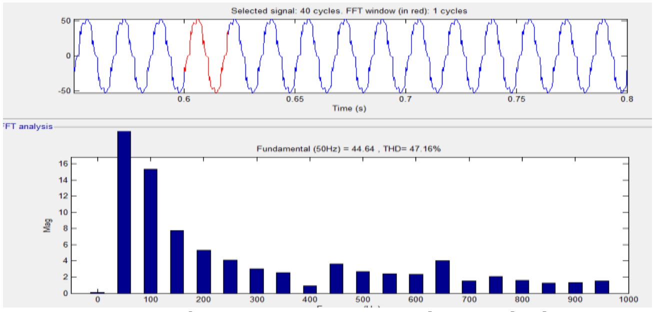

Fig 4.1.8 without compensation FFT analysis Load voltage

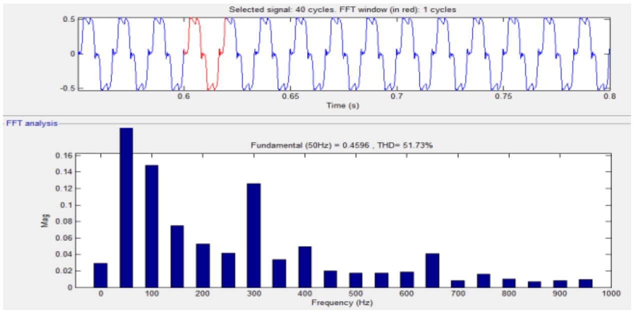

Fig 4.1.9 without compensation FFT analysis Load current

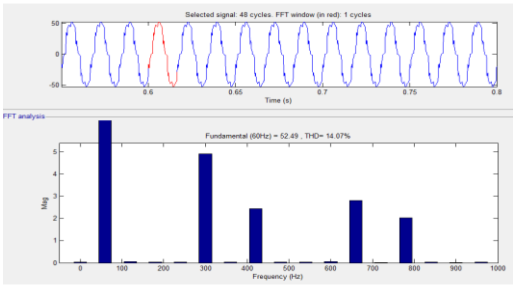

Fig 4.1.10 with compensation Load voltage

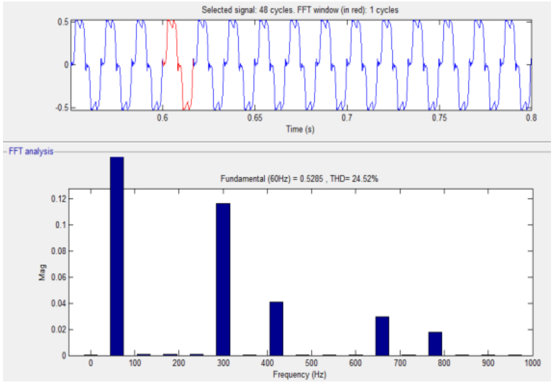

Fig 4.1.11 with compensation Source current

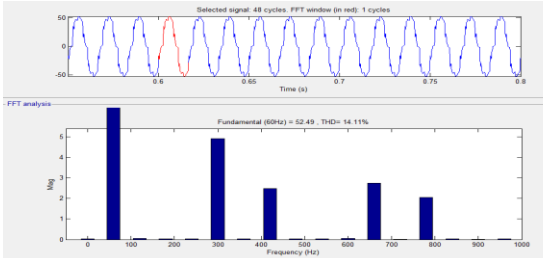

Fig 4.1.12 with compensation Load current

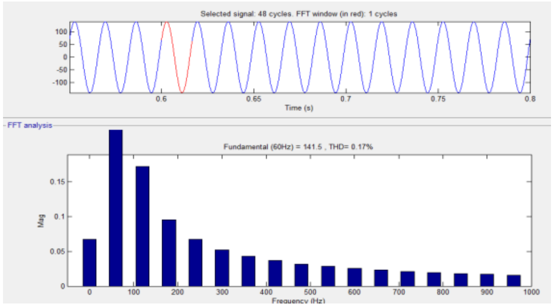

Fig 4.1.13 with compensation Source voltage

Fig. 4.1.1 to 4.1.13 shows the supply voltage, supply current and injected current wave forms of the line current after the shunt current injection. The overall simulation run time is 0.8 sec. The Breaker time is 0.4 to 0.6 s. the control strategy is started after 0.1 sec. It is observed that after the control strategy started the wave shape of the line current at the input side is improved in term of the waveform.

V. CONCLUSION

A MATLAB based model of the UPQC has been simulated for RL using the synchronous reference frame. The simulation results show that the input voltage harmonics and the current harmonics caused by non-linear load are compensated very effectively by using the UPQC. With a fast increasing number of applications of industry electronics connected to the distribution systems today, including nonlinear, switching, reactive, single-phase and unbalanced three-phase loads, a complex problem of power quality evolved characterized by the voltage and current harmonics, unbalances, low Power Factor (PF). The proposed control strategy uses only loads and mains voltage measurements for the series APF, based on the SRF theory. The conventional methods require the measurements of load, source, and filter currents for the shunt APF and source and injection transformer voltage for the series APF.

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