An Efficient iUPQC Controller to Supply Additional Voltage Using Neural Network

Aradhana Sontake[1], Prof. Devendra Sahu[2]

PG Student (Electrical Device & Power System Engg), Dept. of EEE, CSVTU University, C.G. India[1]

Assistant Professor, Dept. of EEE, DIMAT College, CSVTU University, C.G. India[2]

ABSTRACT: In this paper the dual topology of improved unified power quality conditioner (iUPQC) is studied. The iUPQC can mitigate the power quality problems by mitigation of voltage sag and swell, voltage and current harmonics compensation, power factor compensation, grid side voltage regulation and load bus voltage regulation for the combination of linear and non linear loads. It also gives fast dynamic response. The iUPQC controller composes of PLL and PWM controller which is used for generating reference signal for shunt converter and also the Neural Network which is used for generating reference signal for series converter. This method provides better power quality and also the reduction of total harmonic distortion (THD). Simulation results are provided to verify the functionality of this equipment.

KEYWORDS: iUPQC, Microgrids, Power quality, STATCOM, Unified Power Quality Conditioner (UPQC), Neural Network.

I.INTRODUCTION

The main objective of electric utility companies is to supply uninterrupted sinusoidal voltage of constant magnitude to their consumers. But, this is becoming difficult day by day because of the increased applications of power electronics based instruments at industrial and domestic purposes. These are non-linear loads, which draw non-linear current and reduce electric power quality. The quality degradation occurs low power factor, low efficiency, overheating of transformers and so on. The power quality has find out the most important issue for power engineers. In the past, passive filters were used to mitigate power quality problems. It has some advantages such as reliability, simplicity, efficiency and cost. However, the performance of passive filter is limited to a few harmonics and it can insert resonance in the power system. Therefore, a new technology called custom power (CP) appeared for mitigation of different power quality problems. The CP devices are helpful for optimizing the reliability and quality of the power supply. The compensating type custom power devices mainly composite the shunt connected device (called DSTATCOM), series connected device (called DVR), and combination of series and shunt connected device (called UPQC). Generally, the DSTATCOM is used for the mitigation of current based distortions, while DVR is used for the mitigation of voltage based distortions.

The Unified Power Quality Conditioner (UPQC) is one of the CP device, which is used for compensating both current and voltage related problems, simultaneously. It suppresses current and voltage based distortions as well as improves the power factor by compensating reactive component load current. Here an improved unified power quality conditioner (iUPQC) is used which similar to UPQC. The main difference between the iUPQC and UPQC is that the kind of source emulated by the series and shunt power converters. Within the UPQC approach, the series converter is controlled as a non sinusoidal voltage source and therefore the shunt one as a non sinusoidal current source. On the other hand, in the iUPQC approach the series converter behaves as controlled, sinusoidal, current source and the shunt converter as a controlled, sinusoidal, voltage source. . This means it's not necessary to work out the harmonic voltage and current to be compensated, since the harmonic voltages seem naturally across the series current source and also the harmonic currents flow naturally into the shunt voltage source.

The power rate capability is reduced with increasing of the switching frequency in actual power converter. Therefore the iUPQC offers better solutions in case of high power applications than UPQC. Since the compensating references of iUPQC are pure sinusoidal waveforms at the fundamental frequency. Furthermore, the UPQC has higher switching

losses on account of higher switching frequency. This efficient iUPQC controller contains all functionalities of UPQC including the voltage regulation at the load side bus, and also providing voltage regulation at the grid side bus, like a STATCOM to the grid.

II. METHODOLOGY

An efficient iUPQC controller consists two buses, bus A and bus B. Bus A supplies sensitive loads and works as a point of coupling for microgrid. Bus B contains linear and non-linear loads, which requires premium quality power supply. For proper supplying to sensitive loads and the non-linear loads, the voltages of bus A and bus B must be regulated. The STATCOM provides voltage regulation at bus A but it cannot mitigate harmonic currents drawn by the non-linear loads.
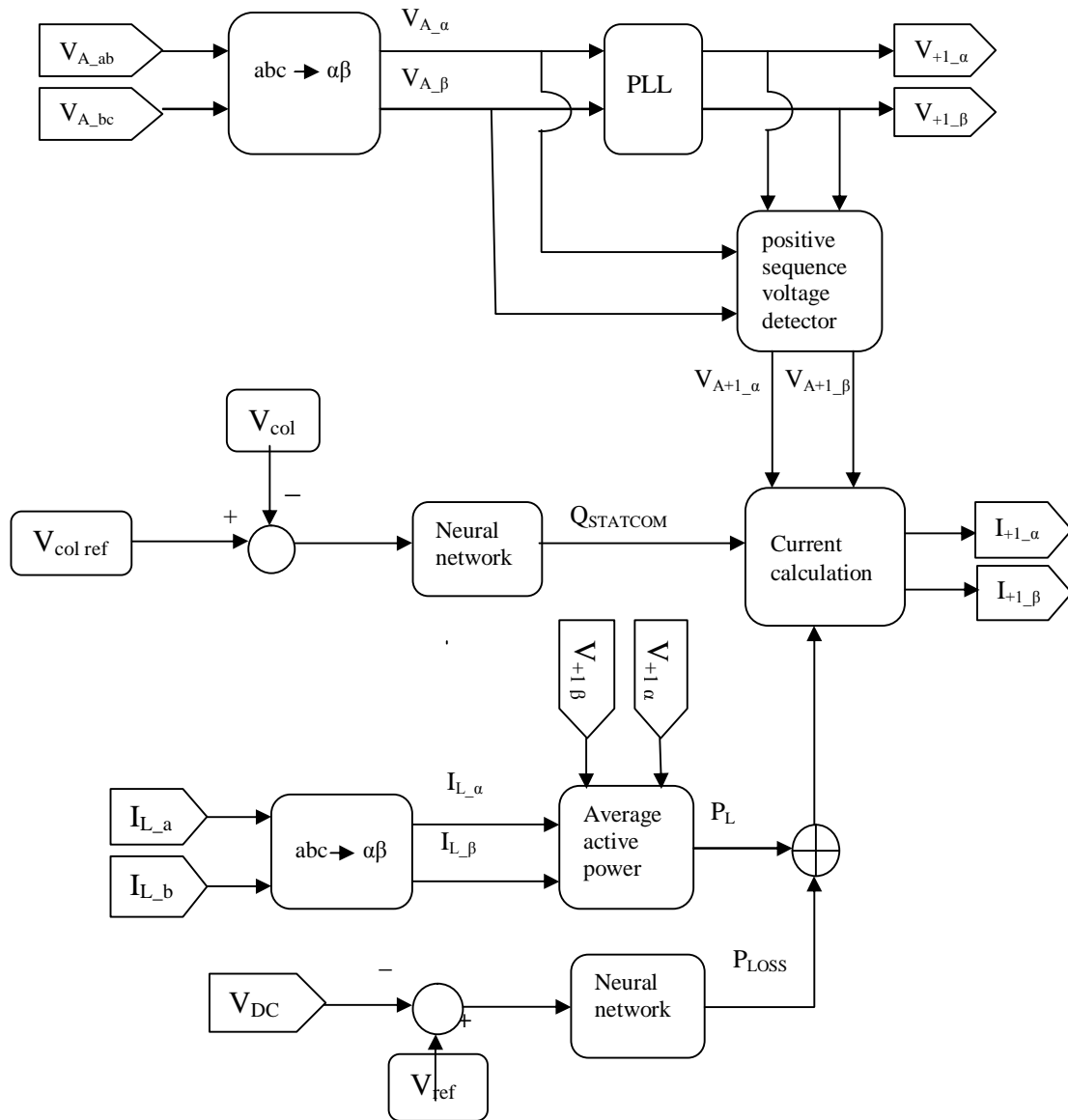

Fig 1: iUPQC Controller

On the other hand, the UPQC between bus A and bus B, can diminish the harmonic currents of the non-linear loads and regulate the voltage at bus B, but it cannot regulate the voltage at bus A. Hence, to accomplish all the required goals, a STATCOM at bus A and a UPQC between bus A and bus B should be applied. The cost of this solution would become high. Fig.1 shows the working iUPQC controller.

An efficient iUPQC controller provides beside all those functionalities of this equipment and also reactive power support to bus A. The modified iUPQC can provide the following functionalities:-

   a)   It controls the energy and power flow between the grid and the microgrid.
   b)   It provides voltage/frequency support at bus B of the microgrid.
   c)   It provides reactive power support at bus A of the power system.
   d)   It provides harmonic voltage and current isolation between bus A and bus B.
   e)   It provides "smart" circuit breaker as an intertie between the grid and the microgrid.
   f)   It provides voltage and current imbalance compensation

The shunt converter provides a controlled, sinusoidal voltage at bus B, which represents the above mentioned functionality (b). Whereas, the series converter of an efficient iUPQC uses only an active power control variable, p, for synthesize a fundamental, sinusoidal current drawn from the bus A, relevant with the active power demanded by bus B. The DC link of the iUPQC has no large energy storage system, the control variable p also attend as an additional active power reference to the series converter to maintain the energy inside the dc link of the iUPQC. Inputs of the controller are voltages at bus A and B, the current demanded by bus B, I_L and the voltage V_{DC} of the common dc link. Outputs of the controller are shunt voltage reference and the series current reference. For calculating the grid voltage in αβ-reference frame, the clark transformation is applied to the measured variables. The input of PWM controller is the output of Phase-Locked-Loop (PLL). Since the modified iUPQC can regulate the grid voltage, therefore both the buses will be regulated independently to obtain their reference values. The series converter synthesizes the current drawn from the grid bus. This current can be calculated by adding the average active power required by the loads P_L, and the power loss P_{Loss}. The load active power can be calculated by:

$$P_L = V_{+1\,\alpha} * i_{L\,\alpha} + V_{+1\,\beta} * i_{L\,\beta}$$

Where $i_{L\,\alpha}$, $i_{L\,\beta}$ are the load currents and $V_{+1\,\alpha}$, $V_{+1\,\beta}$ are the voltage references for the shunt converter. The low pass filter gives average active power (P_L). The power loss signal P_{Loss} is determined by using a Neural Network, by comparing the measured dc voltage V_{DC} with its reference value. An additional control loop is employed to regulate the voltage at the grid bus like a STATCOM, which is represented by the control signal $Q_{STATCOM}$. This control signal is obtained by the Neural Network. The error between the reference value and actual aggregate voltage of the grid bus is applied to the Neural Network.
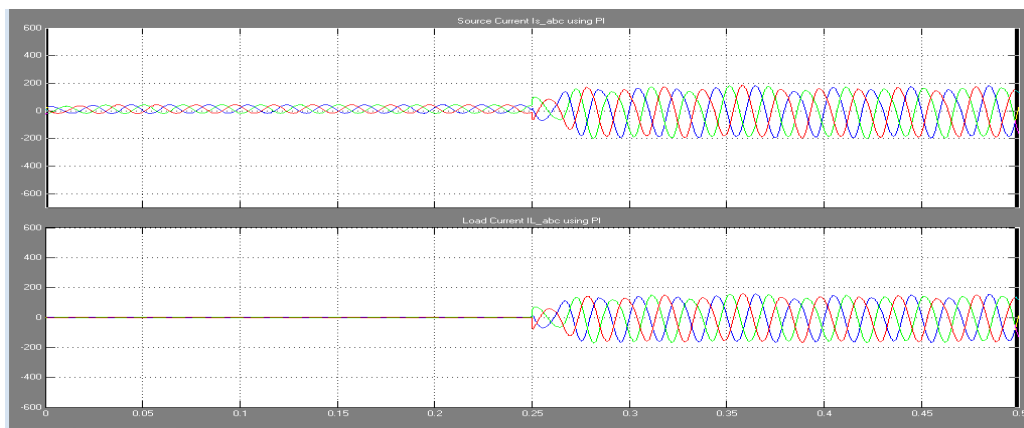
III. EXPERIMENTAL RESULTS

Fig.2 Performance of iUPQC using PI controller, source current, load current

The performance of iUPQC using PI controller is shown in fig.2, where the circuit breaker closes at 0.25sec. The waveforms of source current, load current, are shown. In the improved unified power quality conditioner (iUPQC) using PI controller, the load current is zero before 0.25 sec. The magnitude of load current is less.
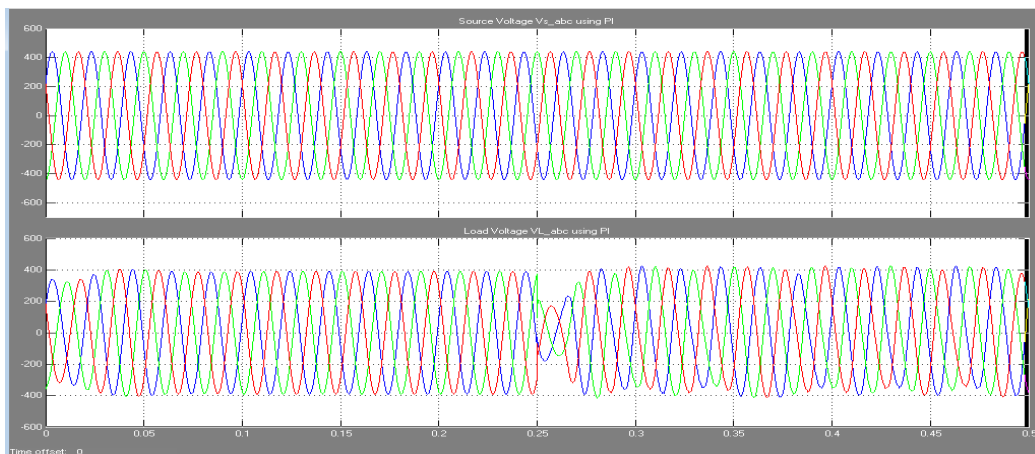

Fig.3 Performance of iUPQC using PI controller, source voltage, load voltage

The performance of iUPQC using PI controller is shown in fig.3, where the circuit breaker closes at 0.25sec. The waveforms of source voltage, load voltage are shown. In the improved unified power quality conditioner (iUPQC) using PI controller, the load voltage is not exactly balanced after 0.25 sec. Which has been improved in iUPQC using Neural Network.
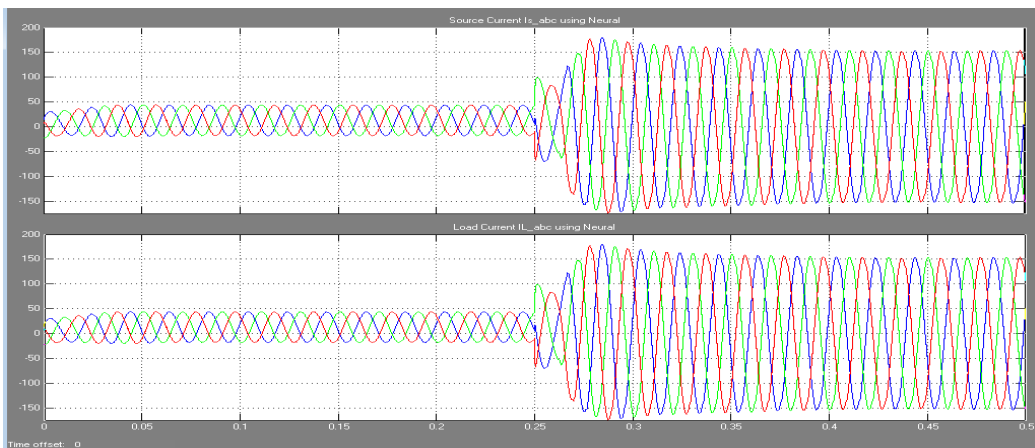

Fig.4 Performance of iUPQC using Neural Network, source current, load current

The performance of iUPQC using Neural Network is shown in fig.4, where the circuit breaker closes at 0.25sec. The waveforms of source current, load current are shown. In the improved unified power quality conditioner (iUPQC) using Neural Network, there is some load current before 0.25 sec. The magnitude of load current is greater than the iUPQC uning PI controller.
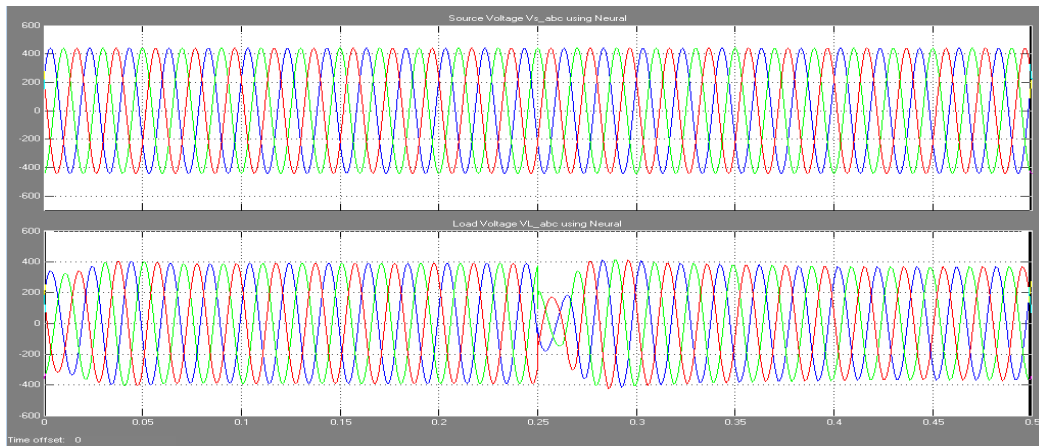
Fig.5 Performance of iUPQC using Neural Network, source voltage, load voltage

The performance of iUPQC using Neural Network is shown in fig.5, where the circuit breaker closes at 0.25sec. The waveforms of source voltage, load voltage are shown. In the improved unified power quality conditioner (iUPQC) using Neural Network, the load voltage is balanced after 0.25 sec.
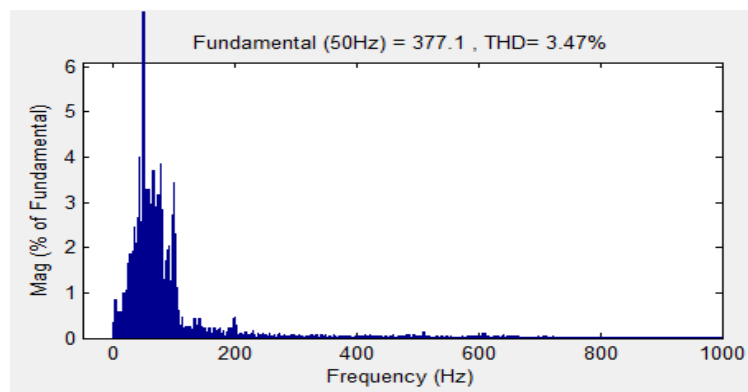

Fig.6 Total Harmonic Distortion of iUPQC using PI controller

Fig.6 shows the Total Harmonic Distortion (THD) of the iUPQC using PI controller. Where the Total Harmonic Distortion of iUPQC using PI controller is 3.47% at fundamental frequency (50Hz).
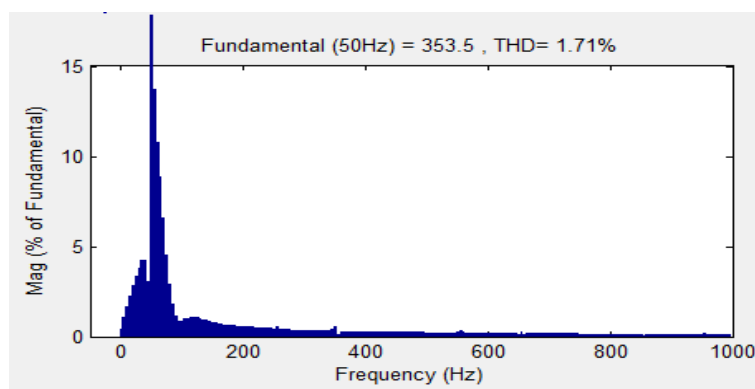

Fig.7 Total Harmonic Distortion of iUPQC using Neural Network

Fig.7 shows the Total Harmonic Distortion (THD) of the iUPQC using Neural Network. Where the Total Harmonic Distortion of iUPQC using Neural Network is 1.71% at fundamental frequency (50Hz). Hence, the iUPQC using PI controller gives low Total Harmonic Distortion, voltage sag/swell compensation, voltage and current harmonic compensation, power factor compensation and fast dynamic response.

IV. CONCLUSION

An efficient iUPQC controller has been presented and tested in simulation. The structure of the proposed technique allows the compensation of reactive power, voltage and currents harmonics simultaneously and mitigates voltage sag and swell. Overall it improves the quality of power supply and also compensate the Total Harmonic Distortion. It gives fast dynamic response. This technique raise the applicability of the iUPQC and endows new resolutions in future scenarios. It provides grid voltage regulation which reduces the inner loop circulating power inside the iUPQC.

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