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The Unified Power Quality Conditioner (UPQC) : The Principle, Control and Application

Prof. S. S. Khalse
Faculty, Electrical Engineering Department, CSMSS CHH Shahu College of Engineering, Aurangabad, India

***Abstract*— This paper deals with unified power quality conditioners (UPQC's), which aim at the integration of series-active and shunt-active filters. The proposed system can compensate the sag, swell and unbalance voltage, harmonics and also the reactive power. In other words, UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. In this paper, we present the compensation principle using PI and Fuzzy control strategies of the UPQC. The results of simulation in MATLAB/SIMULINK are listed for comparison. The Fuzzy controller presents more interesting results according to THD values.**

***Index Terms*—Active filters, harmonics, power conditioners, power quality, voltage flicker, voltage imbalance.**

I. INTRODUCTION

The term "power quality" (PQ) has gained significant attention in the past few years. The advancement in the semiconductor device technology has made it possible to realize most of the power electronics based devices/prototypes at commercial platform. The development of power electronic technology makes it possible to realize many kinds of Flexible Alternating Current Transmission Systems devices to obtain high quality electric energy and enhance the control over power system. UPQC is one of them. This paper deals with unified power quality conditioners (UPQC"s) [1-6] which aim at the integration of series active and shunt active filters. The main purpose of a UPQC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC, therefore, is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance.

This paper presents a general UPQC for power distribution systems. It consists of a series active and shunt-active filter. The series-active filter eliminates supply voltage flicker/imbalance from the load terminal voltage. The shunt-active filter performs dc-link voltage regulation, thus leading to a significant reduction of capacity of the dc capacitor.

II. GENERAL UPQC

The UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC, therefore, is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance. With ideal compensation, the voltage at PCC is the fundamental positive sequence sinusoidal voltage of the power source side. The currents of the source are sinusoidal current and the phase angles of them are the same as the fundamental voltage in phase respectively. In another words, with the function of the, UPQC, the load is equal to a resistance. As the UPQC is a combination of series and shunt active filters, two active filters have different functions. The series active filter suppresses and isolates voltage-based distortions. The shunt active filter cancels current-based distortions.

Unified power quality conditioner (UPQC) is the powerful tool to settle the power quality problem. The general configuration of the UPQC is shown below.

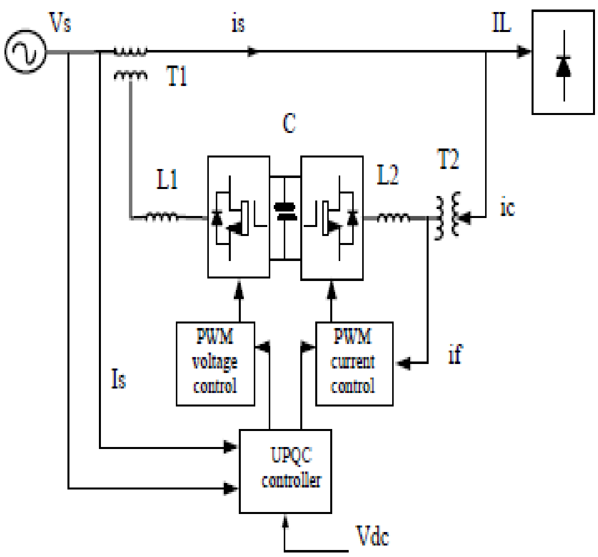


Fig. 1. General configuration of the UPQC

At the same time, it compensates reactive current of the load and improves power factor. There are many control methods to determine the reference value of the voltage and the current, the most famous is the instantaneous active and reactive power theory (the *pq* theory) that Akagi proposed in and now the most popular is the *dq0* method developed from the instantaneous reactive power theory. But the method of them needs Transformation like Clarke Transformation (*abc* to ab), Park transformation (*abc* to *dq0*) and the control circuits are more complex, the calculation is huger. The simpler, the more robust to the control system, so the new methods are developed incessantly in recent years.

III. THE UPQC CONTROL STRATEGY

The control strategy can be separated to shunt strategy, series control strategy and DC capacitor control.

A. Shunt control strategy:

The shunt active power filter is provided the current and the reactive power (if the system need) compensation. It acts as a controlled current generator that compensated the load current to force the source currents drained from the network to be sinusoidal, balanced and in phase with the positive-sequence system voltages.

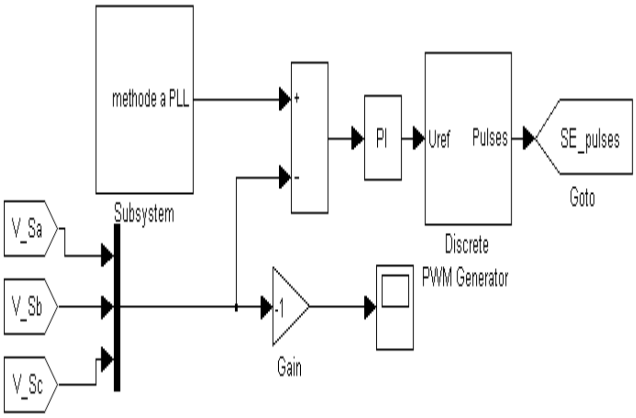


Fig. 2. The control system of the PAPF

B. Series control strategy:

The series active power filter is provided the voltage compensation. It generates the compensation voltage that synthesized by the PWM converter and inserted in series with the supply voltage, to force the voltage of PCC to become sinusoidal and balanced.

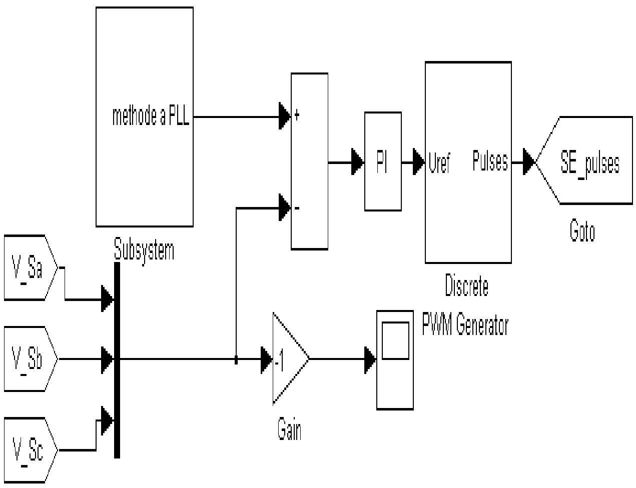


Fig. 3. The control system of the SAPF

C. The DC voltage regulator:

In compensation process, the DC side voltage will change because UPQC compensates the active power and the losses of switches, etc. If the DC voltage is not the same as the rating value, the output voltage of the series active filter will not equal to the compensation value. The compensation will not correct. It is the same with the shunt active filter. The DC voltage regulator shown in Fig.4 is used to generate a control signal to keep the voltage be a constant. It forces the shunt active filter to draw additional active current from the network.

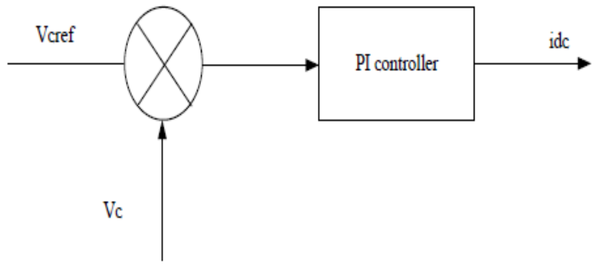
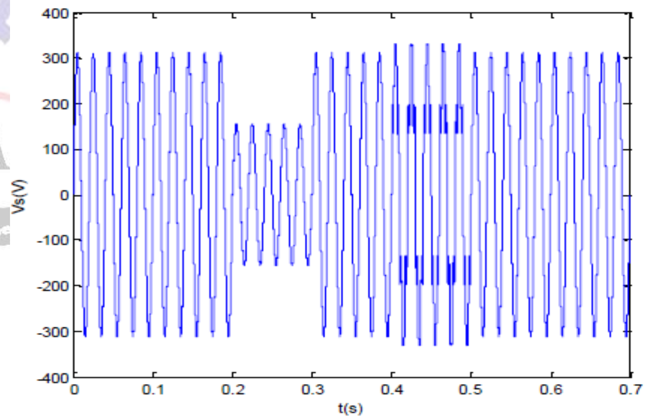


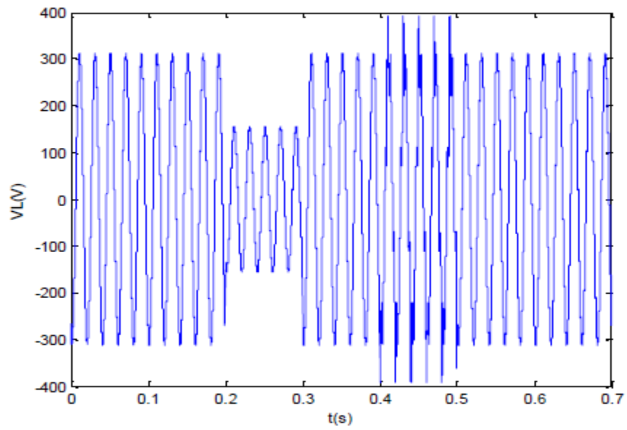
Fig. 4. The DC voltage regulator

The study of the regulation of the continuous voltage at the boundaries of the storage capacity showed that a compromise must be done between filtering and the speed in the control of this voltage. For that, the studied regulator, proportional integrator (PI) is more suited to assure an optimal filtering characteristic and an optimal cost.

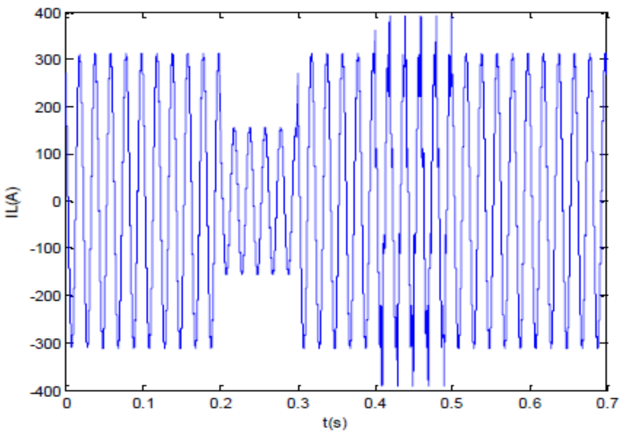
IV. SIMULATION RESULTS



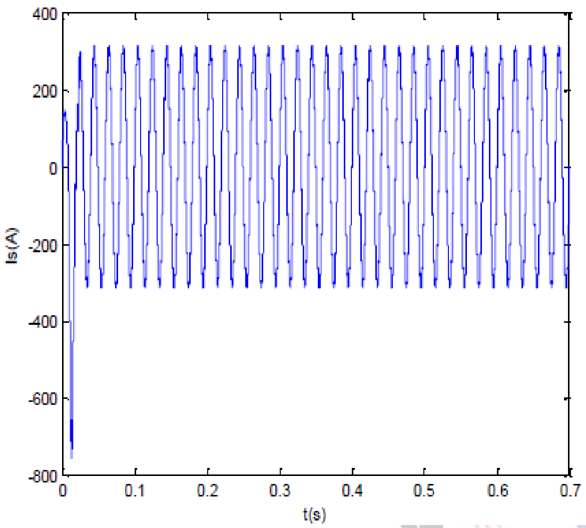
(a)



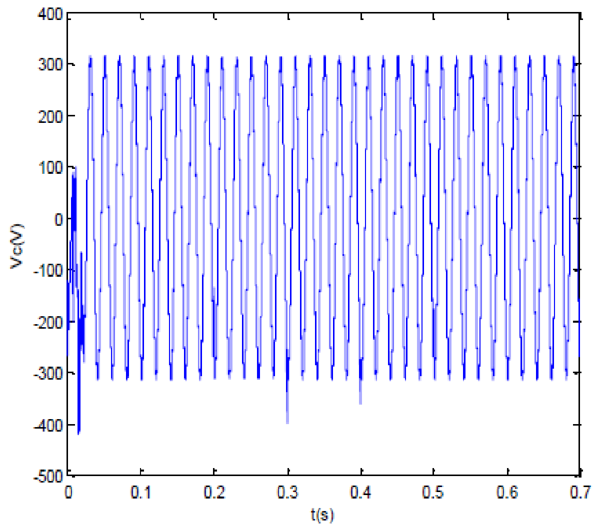
(b)



(c)



(d)



(e)

A. Compensation of the three phase-voltage sags

In this part of simulation, one will analyze the robustness in terms of speed and precision of the UPQC compensating for the three-phase voltage sags applied in an interval of the time from *0.2s* to *0.3s*. It is noticed that at the moment *t=0.2s* the amplitude of the tension source is reduced to *20%* compared to the fundamental tension. The UPQC through the transformer of the series active filter injects the compensating voltage necessary to satisfy the request voltage of the load.

B. Compensation of the three phase-voltage swell

This part of simulation will be carried out in the same way that the three-phase sag. One will use two programmable sources of tension applied from the moment *t=0.4s* until the moment *t=0.5s*. It is deduced that at the moment *t=0.4s* our UPQC starts to compensate for and correct perfectly the overvoltage, produced on the point of connection, by injecting through the transformer the compensating tensions which are well synchronized and in opposition of phase with the tension of the source. In this case the effective voltage at the boundaries of the load is maintained equal to the nominal value.

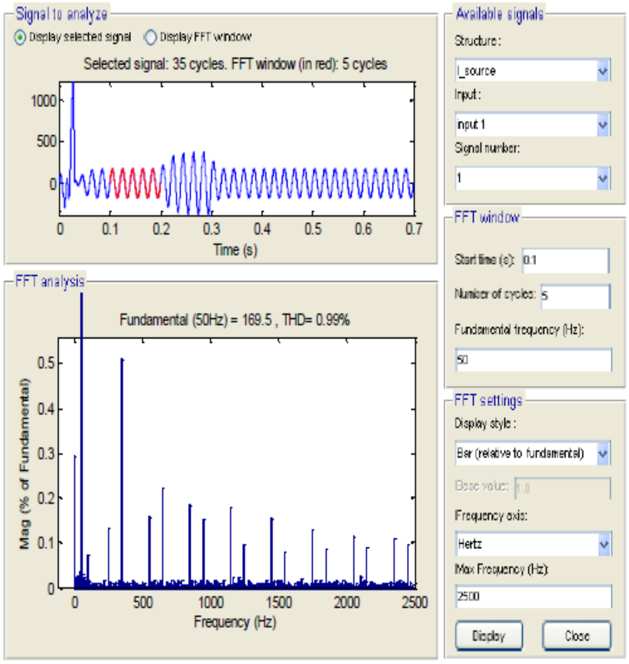


Fig. 6. Simulation Results of the harmonics.

C. Compensation of the harmonics of tension:

it is noted that at the moment *t=0.2s*, the UPQC through the active filter series starts to correct the harmonics of the tension, by injecting compensating tensions have forms of well synchronized waves and in opposition of phase with the tension of the source. In this case the current of source and that of the load do not undergo any more of the disturbances, and thus the UPQC only compensates for the disturbance in tension.

V. Conclusion

The work presented lies within the scope of the search for new solutions for the improvement of the power quality in the electrical supply network. The parallel active filter aimed to compensate for the harmonic, reactive and unbalanced interference currents. The active filter series its objective was the compensation of the harmonic disturbing voltage, and of the voltage sags and swells. Finally, the UPQC) was proposed as a general solution of the compensation of all the disturbances due to voltage or/and current. The obtained results of the simulations show that the UPQC is a FACTS equipment able to compensate all disturbances of voltage and/or current with a great efficiency.

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