Simple Control Strategies of the Active Filters within a Unified Power Quality Conditioner (UPQC)

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***Abstract*— Unified power quality conditioner (UPQC) consists of combined shunt and series active power filters for improving both the power quality on the source side and on the load side. The paper presents a simple method for controlling the series filter under unbalanced and distorted load conditions by using a three phase locked loop (PLL). Two methods for controlling the shunt filter are analyzed. The model of the entire system is presented and considerations on the starting procedure are highlighted. The simulation is performed by using the Matlab-Simulink environment. The improvements of the power quality are analyzed by comparing the THD on the source side before and after use of the UPQC.**

***Keywords*— Active power filter (APF), phase locked loop (PLL), unified power-quality conditioner (UPQC)**

I. INTRODUCTION

At the end of the low voltage distribution systems, due to the limited power and other loads influences, distortions of the voltage can occur which negatively influence the supplied load. There could be not only alterations of the rated value, but alterations of the sinusoidal waveform. On the other hand, the loads themselves can be sources of distortions, especially when we consider the currents drawn from the source. The development of the power electronics increases the nonlinear loads. Unified Power-Quality Conditioner (UPQC) systems could be a solution in order to increase the power quality [1, 3]. This type of system are capable not only to increase the power quality on the load side, but also on the source side, in the same time with the reactive power compensation. Mainly, this type of systems consists of two active filters which share a common DC circuit. The series active filter is responsible for correction of the source voltage while the parallel (shunt) active filter locally supplies the load current harmonics specific to the load, compensates the source side reactive power and controls the common DC voltage.

There are many ways to control the two active filters [2, 4]. The paper presents a simple method for controlling the series filter, based on a three phase locked loop (PLL). In what concerns the shunt filter, two methods will be presented: the Czarnecki method, based on the load admittance and the pq method based on instantaneous active and reactive powers.

The general behavior will be analyzed by using a Matlab Simulink model.

II. FILTERS CONTROL

A. Series filter control

The series filter begins to operate only after the DC voltage reaches the rated value. Responsible for this is the shunt filter.

Considering that the start procedure, described later, was fulfilled, the firing pulses of the series active filter switches are obtained as results of three hysteresis comparators which compare on each phase the instantaneous values of the voltages across the filter's transformers V_{Tabc} with the reference values. These reference values are obtained as difference between the voltages supplied to the load V_{Labc} and an ideal three phase system with rated voltage amplitude V_L. The phase of this ideal three phase system is given by a three phase locked loop (PLL) which gives the *sin* and *cos* functions corresponding to the position of the first phase of the source V_{sabc} (Fig. 1).

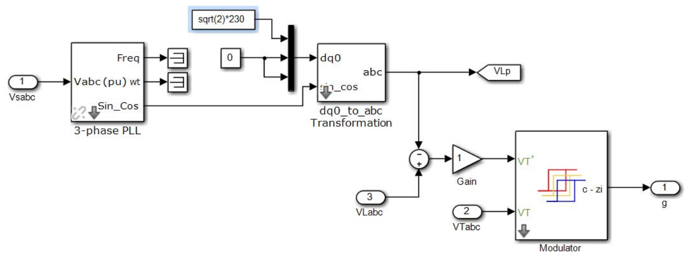

Fig. 1. Control of the series active filter

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In the case of voltages disturbances of the source, this control allows to supply to the load a symmetrical voltages system with the rated voltage amplitude. Fig. 2 exemplifies the operation of the series filter when the source voltage drops to 300 V. The last plot shows the currents in the primary windings of the series filter transformers.

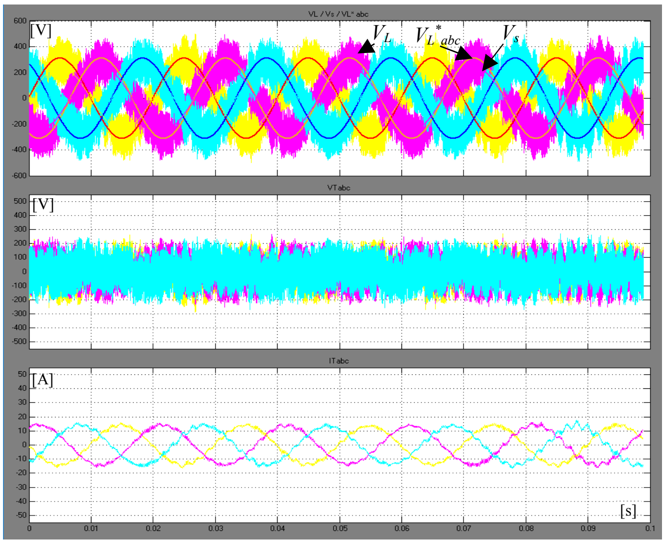

Fig. 2. Operation of the series active filter: a) source V_s, load V_L and reference load $V_L{}^*_{abc}$ voltages; b) primary windings of the series filter voltages V_{Tabc}; c) currents in the primary windings of the series filter transformers I_{Tabc}

B. Shunt filter control

For computing the reference values of the shunt active filter currents, two methods were tested.

The first is based on the Czarnecki theory. The instantaneous powers on the three phases of the load are computed and the total average P over one period of their sum is computed. This is used for computing the load admittance by division to the sum of the squared RMS values of the preset phases voltages

$$G = \frac{P}{\sum_1^3 U_{ef}^2} \tag{1}$$

Then, the active components of each phase current I_{La} is computed as product of the supplying voltage and the admittance (1), Fig. 3.

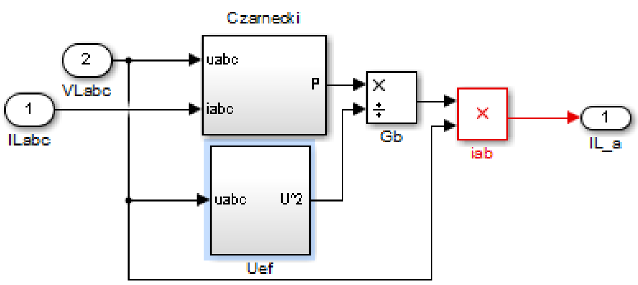

Fig. 3. The calculus of the active component of the phase currents

The preset phase currents of the shunt filter I_C^* are computed as difference between the instantaneous load currents I_L and the corresponding active components I_{La} determined as above,

$$I_C^* = I_L - I_{La}. \tag{2}$$

The final preset values of the shunt filter are obtained as sum between (2) and the components necessary for sustaining the DC voltage at the reference value. The final results are applied to the hysteresis modulator which compares these inputs with the actual shunt filter currents and supplies the gate signals to the shunt filter switches.

The second tested method is based on the *pq* theory. This consists in computing the instantaneous active and reactive components of the load powers based on the α, β components of the load voltage and currents

$$p = V_\alpha I_\alpha + V_\beta I_\beta, \tag{3}$$

$$q = -V_\alpha I_\beta + V_\beta I_\alpha. \tag{4}$$

The alternative component of the active power is computed as difference between (3) and the average active power

$$p_\sim = p - P. \tag{5}$$

The α, β components of the shunt filter preset currents are computed as

$$i_{p\alpha} = (V_\alpha p_\sim + V_\beta q)/(V_\alpha^2 + V_\beta^2) \tag{6}$$

$$i_{p\beta} = (V_\beta p_\sim - V_\alpha q)/(V_\alpha^2 + V_\beta^2) \tag{7}$$

The resulted components are converted in three phase components, by considering null the zero component. The results are added to the components necessary for sustaining the DC voltage at the reference value, as in the first method. As previously, the final results are applied to the hysteresis modulator which compares these inputs with the actual shunt filter currents and supplies the gate signals to the shunt filter switches (Fig.4).

The diagram of the entire procedure is presented in Fig. 5.

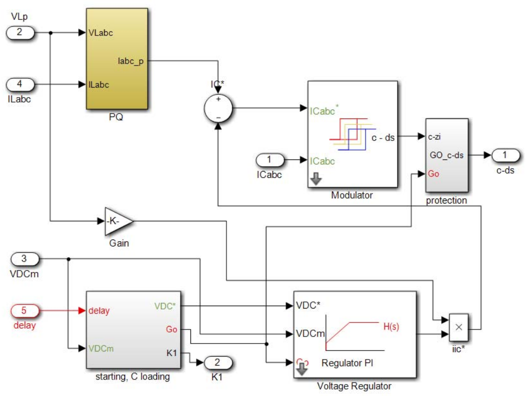

Fig. 4. The firing signals obtained with *pq* method

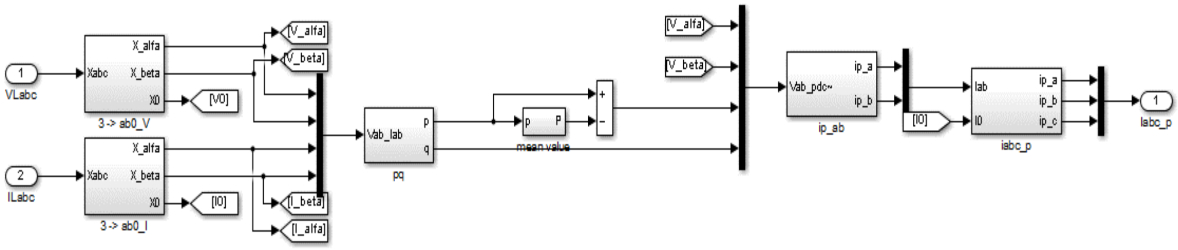

Fig. 5. The pq method for computing the preset values of the shunt filter currents

It may be noticed that the results of the simulations show no significant differences between the two methods. In the same time, it can be remarked that the first method is significantly simpler and less time consumer.

III. Simulation of the UPQC

Fig. 6 presents the Simulink diagram of the whole UPQC system. As load is considered a three phase controlled rectifier.

The two filters are controlled as described in the previous section, but some consideration must be done concerning the starting procedure.

The system is started in no load conditions, K3 open respectively and the secondary windings of the series filter are short circuited (KS1-3 closed). By closing K_APF, the DC capacitor is “naturally” charged through the limitation resistor RDC, in order to limit the charging current during the very first moments. After RDC is short circuited (short time after start), the shunt filter starts to be controlled in order to ensure the charge of the DC capacitor at the rated voltage. The currents of the shunt filter during the entire starting process are plotted in Fig. 7.

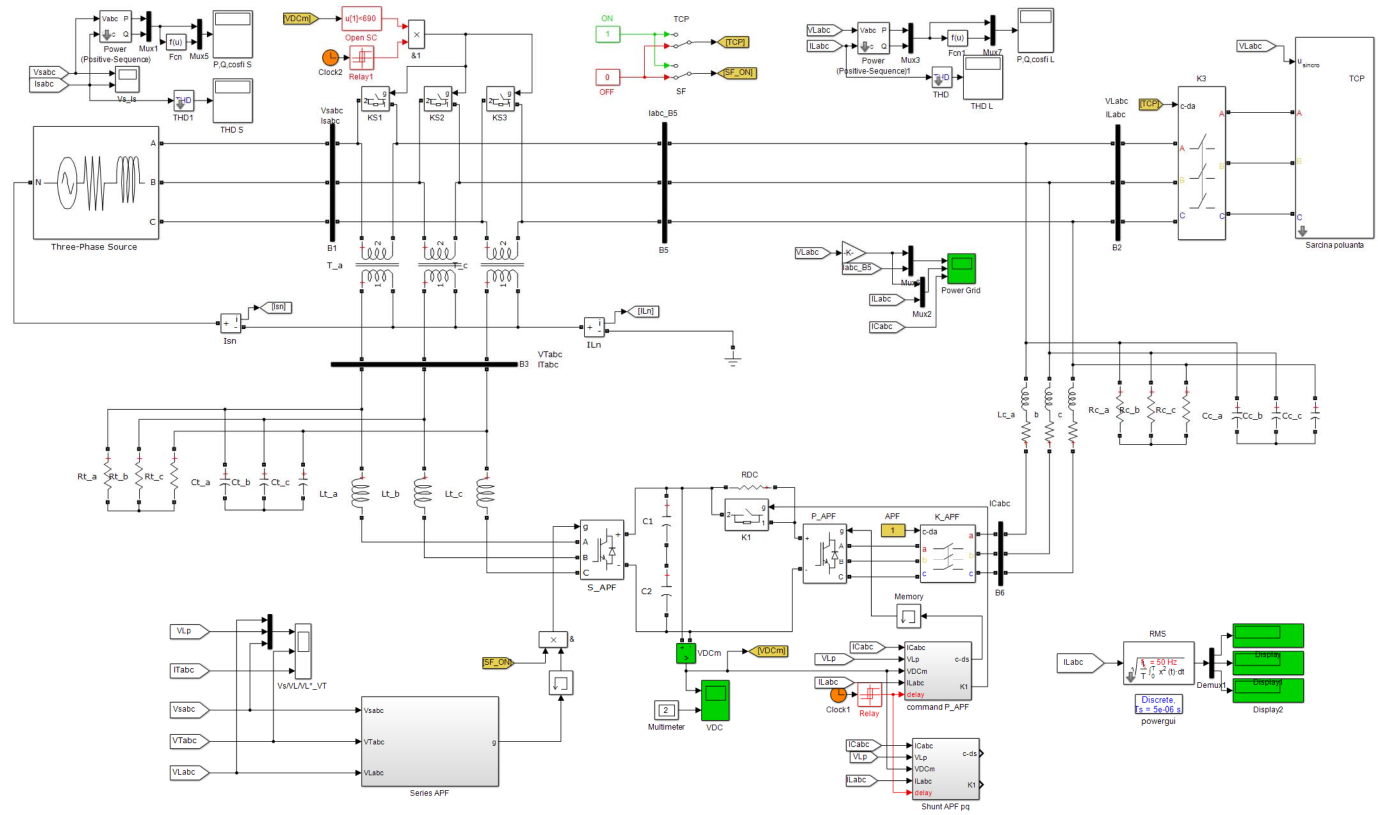

Fig. 6. The diagram for simulation of UPQC

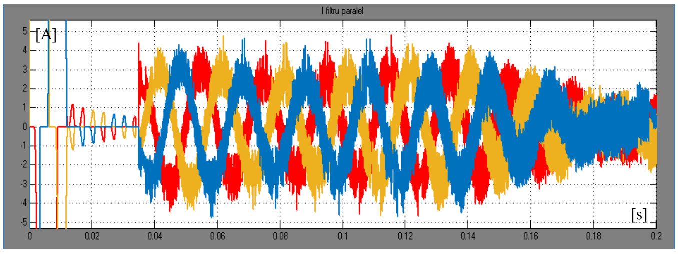

Fig. 7. The shunt filter currents during the start

It can be noticed the free charging period at the beginning of the procedure, then the controlled currents which brings the DC voltage at the rated value after about 180 ms. Now the KS1-3 can be opened and the series filter begins to operate. As the shunt filter already operates, the entire system is prepared to fulfill its functions and the load can be connected.

It will not be shown the waveforms in different points of the system, but overall operation parameters will be commented.

As the load is a controlled rectifier, we notice a very bad power factor of about 0.5 and the average THD of the current almost 0.18. These values would be recorded also on the source side in the absence of the UPQC system. When the presented system operates, on the source side we recorded the power factor greater than 0.99 and the current THD less than 0.07.

IV. Conclusions

The paper presents the basic principles of the control of the two active filters within a Unified Power Quality Conditioner (UPQC). Considerations on the starting procedure were also been presented.

The improvements of the overall parameters (power factor and currents THD) are quite important. On this basis, it is encouraging to test an experimental real system. This demarche is performed in this phase of the research.

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