## EXPERIMENTAL STUDY OF THE POWER FACTOR COMPENSATION CONVERTER

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*Abstract* – The conventional power converters determine harmonic pollution of the alternative power grid, leading to a non-economically functioning and a reduced power factor. A solution of the problem could be the insertion of some auxiliary elements, named power factor compensators, between the power grid and converter. These elements force a sinusoidal current from the power grid. The aim of this paper is to study, using modeling and simulation, a single-phase rectifier with symmetrical command of the commutation devices toward the maximum voltage value.

*Keywords:* power factor compensation, power converter, peak current control, control of the permanent conduction limit

### **1. INTRODUCTION**

Most of the converters, supplied by the A.C. network, absorb a non-sinusoidal current, which generates harmonics, leading to a sub-unit power factor. To improve its achievements, an auxiliary converter, named power factor compensator, is connected between the network and this converter, which is created to transform the non-sinusoidal waveform of the absorbed current into the sinusoidal waveform. The current is in phase with the voltage. [1], [2], [3] The most spreading diagram represents a boost structure (lifter) as it is shown in Figure 1, which is made of an un-commanded rectifier, followed by a power factor compensator converter. This compensator is actually a variable continuous voltage regulator parallel, voltage lifter, so that the absorbed current is forced to develop a sinusoidal waveform. The D.C. voltage from the variator output is controllable, having a value greater than the peak value of the network voltage. Through this method, the waveform of the current absorbed by the rectifiers, variable continuous voltage regulators or inverters with D.C. circuit, is improved.

The diagram presented in the Figure 1 is working in dial I and it doesn't ensure a galvanic insulator.



Figure 1: Internal schematic of the power factor boost compensator.

To maintain the sinusoidal waveform of the current and the null phase-shift between the current and the supply voltage, there are known many techniques to command and control the variable continuous voltage regulator: [3], [4], [5], [6].

- Control of the peak current
- Control of the average current
- Control at the permanent conduction limit
- Command with non-linear carrier
- Integrative command.

Combinations of power factor compensators with special technical commands are used in some specific applications (remarkable performances required, higher or reduced powers, etc.) [7], [8].

In this paper, we will review two control methods for the monophase diagram from the Figure 1, and these will be implemented by the authors in a computer programme.

#### 2. EXPERIMENTAL STUDY OF THE PEAK CURRENT CONTROL METHOD

The following figure represents the internal schematic for the power factor compensator and the control for the peak current.

The static switch is commanded by a signal with a constant frequency and it is blocked when the sum between the increase current of the inductivity (similar with the switch) and a compensator external signal with a variation of the increase ramp, (synchronized with the signal) becomes equal with the sinusoidal waveform of the absorbed current. In order to assure a natural synchronization and an adequacy of the signal with the network voltage, the signal is generated as a product between the rectifier

voltage and the output voltage of the error amplifier of the current. As it is shown in the Figure 2, the converter works in permanent conduction and the current is not cancelled during a half-period.



Figure 2: Internal schematic for the power factor compensator with the control of the peak and the waveform of the absorbed current

The advantages of this control technique are:

- commutation frequency is constant;

- it is necessary to measure only the switch current, which can be realized with a transformer of simple current, removing the imminent damages due to the measurements with resistive shunt, thus simplifying the protection of the over-current commutation device;

- it is not necessary to use the error amplifier of the current (with the compensation network);

- due to the permanent conduction:

• dynamic application of the device is reduced;

• conditions assessed to the filter are more easily;

• diodes of the rectifier bridge commute to the network frequency, so they can be slow devices (fated to the natural commutation);

• leakage diode must be fast because it works in forced commutation, causing losses increasing and the level of the generated perturbations.

This control technique has the following disadvantages:

- necessity of an extern compensation signal with the variation of the increase ramp, in order to eliminate the sub-harmonic oscillations of the space factor lower than 50%;

- sinusoidal waveform of the input current is twisted at high network voltages and low charges, and also it is twisted due to the presence of the compensation signal;

- higher sensitivity to the perturbations.

The block diagram of this converter is lent oneself to the integration, thus more producers' make integrated circuits specialized for this control technique.

2.1. Experimental results. Control method for the peak current

The converter for the power factor compensation using the control method for the peak current was designed. The command function of the converter is carried out by the integrated circuit ML4812 from the Fairchild Semiconductor [9].

In the figure 3 is shown the internal schematic for the power factor compensation converter, based upon the control method of the peak current, using the integrated circuit ML4812.





The photo of the built converter and the experimental set used to test the power factor compensator is presented in figure 4.



Figure 4: Photo of the built converter and the experimental set

The compensator (PFC block) powers a D.C. variable voltage regulator (CC/CC block). The regulator powers either a resistive load R, either a load with an electromotive source – the D.C. motor denoted by M. The combination of the K switches makes possible the changes in the circuit topology. Therefore, the regulator can be powered directly from the mains (the rectification of the grid's voltage is achieved by the rectifier bridge placed inside the power factor compensator). In this case, the regulator absorbs a non-sinusoidal current. For another combination of the switches, the regulator can be powered from the compensator's output, and this way it absorbs a sinusoidal current.



Figure 5: Oscillograms of the current absorbed by the D.C. VVR without compensation of the power factor and with compensation of the power factor.

#### **3. EXPERIMENTAL STUDY OF THE CONTROL METHOD AT THE PERMANENT CONDUCTION LIMIT**

The power factor compensator's schematic, that controls the current at the permanent conduction limit, is given in figure 6.

This approach of the control method commands the commutation device to tip from the blocked state to conduction every time the current through the coil drops to zero. The device remains in conduction until the current rises to the reference value, when it is blocked again. This way, the converter functions at the limit between permanent and discontinue conduction. Due to this fact, the commutation of the leakage diode is facilitated and therefore the losses are reduced. On the other hand, large current peaks affect the commutation device and lead to significant losses on the coil. Also, large current undulations require severe conditions for the input filter.



Figure 6: Schematics of the power factor compensator that controls the current at the permanent conduction limit and the Waveform of the absorbed current

The reference current, here as well as for the previous method, is generated as the product between the rectified voltage and the output voltage of the error amplifier of the voltage loop.

As one can see in figure 6, the converter functions at the limit between permanent and discontinue conduction. During a half-period, the current has periods when it reaches zero.

The advantages of this control technique are the following:

- it doesn't require an external compensation signal;

- the current error amplifier is not necessary (with its afferent compensation grid);

- low losses on the leakage diode;

- since the current through the commutation device must be measured, the protection of the commutation device to over currents is simplified;

- due to permanent conduction:

- the dynamic stress on the commutation device is lower;

- the requirement from the input filter ale less severe;

- the diode from the rectifier bridge commute at the grid frequency there for can be slow-devices (meant for natural commutation);

- on the other hand the leakage diode should be a quick one since it is working for forced commutation which leads to increase losses and high perturbation level.

This control technique has the following disadvantages:

- the commutation frequency is not constant;

- we need to notice when the current through the coil becomes zero;

- the currents undulations are large which leads to:

- large losses on the coils
- larger input filter
- increased sensibility to perturbations.

# 3.1. Experimental results. The method of control at the permanent conduction limit

We build a converter used for power factor compensation based on the peak-current control method. The command function of the converter is achieved by the integrated circuit L65-61 produced by STMmicroelectronics [10].

In figure 7 is presented the internal schematic of the converter, built using the integrated circuit L6561.



Figure 7: Internal schematic of the power factor compensator converter using the control method of the peak current

Figure 8 shows de testing scheme of the converter. The connected load to the converter output is a source in commutation, which doesn't have any improving power factor devices. The measurement of the grid voltage and absorbed current was made with the Lab-PC-1200 PCB through a transducers unit. The measurement was made through the commutation source charged directly from the power grid and charged through the power factor compensation converter in static and transient operating regime (open circuit operating, on-load operating, coupling and decompression of the load).



Figure 8: Testing scheme of the power factor compensator using the method of control at the permanent conduction limit

Data presented in Figures 9 to 12 was obtained in static regime functioning.

Figure 9 represent a data acquisition for the commutation source charged directly from the onload operation power grid. It observed that characteristically pulses of the rectifier which discharges on the capacitive load. The current spectrum contains many components. Figure 10 represent a data acquisition for the same source, with the same load but supplied by the rectifier power factor converter. It is obviously the improving of the current spectrum to.

The acquisition presented in Figure 11 was made in other sampler conditions and emphasis the commutation spectrum component which are not observable on the previous figures. Data from the figure 12 was acquisitioned in the same sampler conditions as the datum afferent to figure 10 but the functioning of the commutation source was in opencircuit operation. One could see that the rectifier converter operate adequate in this regime.



Figure 9: The characteristics quantities of the source, working in on-load commutation, without power factor compensation



Figure 10: The characteristics quantities of the source, working in on-load commutation, with power factor compensation.



Figure 11: The characteristics quantities of the source, working in on-load commutation, with power factor compensation



Figure 12: The characteristics quantities of the source, working in open-circuit commutation, with power factor compensation

Data presented in figures 13-14 was acquisitioned in transient conditions load.

Figure 13 represent a data acquisition during the switching between the open circuit regime and on-load regime. The regime change involve apparition of some parasite spectral component.



Figure 13: The characteristics quantities of the source, during the switching between the open-circuit and onload commutation, with power factor compensation

Figure 14 emphases a data acquisition during the switching between the on-load regime and open circuit regime. This operating change involve apparition of some spectral component, too.



Figure 14: The characteristics quantities of the source, during the switching between the on-load and opencircuit commutation, with power factor compensation

#### 4. CONCLUSIONS

The conventional power converters determine harmonic pollution of the alternative power grid, leading to a non-economically functioning and a reduced power factor.

A solution of the problem could be the insertion of some auxiliary elements, named power factor compensators, between the power grid and converter. These elements force a sinusoidal current from the power grid.

The power factor compensators could be passive or active.

The passive methods use only passive circuit elements, which are connected around the converter in order to improve the absorbed current waveform. The line voltage is not controlled and it solves the power factor correction only for certain conditions of functioning.

The active methods use commutation devices with reactive elements, in order to improve as well it is possible the line current waveform and to control the output voltage.

Experimental realization of two power factor compensator based on different control techniques (peak current control technique and the technique of control to the permanent conduction limit) and the experimental study of these, confirm the viability of the methods. An advantage of the compensators consists in the possibility of attaching them to the existing converters therefore giving a relative cheap solution to obtain an ecologically energy consumption.

Another possibility to improve the power factor, consists in realization of the converters which assures a better power factor trough its functioning principles.

Using modeling and simulation to study a singlephase rectifier with symmetrical command of the commutation devices toward the maximum voltage value, could lead to a fundamental current power factor very closely to the unitary value.

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