The Synthesis of a Control System of the Active Rectifier

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***Abstract*— The paper is dedicated to an issue of efficiency of the three phase controlled rectifiers. The aim of the work is to identify the benefits of using active rectifier in comparison with uncontrolled diode rectifier. The first part reviews the synthesis of a control system of the uncontrolled diode voltage rectifier. The second part is the synthesis of a control system of the active rectifier and the description of the control strategy for phase controlled rectifiers named as periodical sampling. The article includes the results of the computer simulation of two types of rectifiers (controlled and uncontrolled) to show the benefits of using the first one.**

Keywords— active voltage rectifier; uncontrolled diode voltage rectifier; computer simulation

I. INTRODUCTION

The most common used rectifiers are uncontrolled diode rectifiers. These rectifiers consume currents with a large number of high harmonic components from ac voltage supply, and the presence of a phase shift between voltage and current significantly reduces the power factor.

For the analysis of power electronics circuits widely used simulation modeling using the software package Matlab+Simulink.

II. COMPUTER SIMULATION OF THE UNCONTROLLED DIODE VOLTAGE RECTIFIER

Fig.2 shows a virtual model for the investigation of the uncontrollable diode voltage rectifier.

The harmonic distortion of the phase current shows the presence of a large proportion of high harmonics in the consumed current. Total harmonic distortion is equal to 13.16% (Fig.1).

From the waveforms it can be clearly seen that the shape of consumed currents is non-sinusoidal. In the Fig.3 it is also seen the presence of the phase shift between consumed currents (red coloured) and phase voltage (blue coloured) (about 30°).

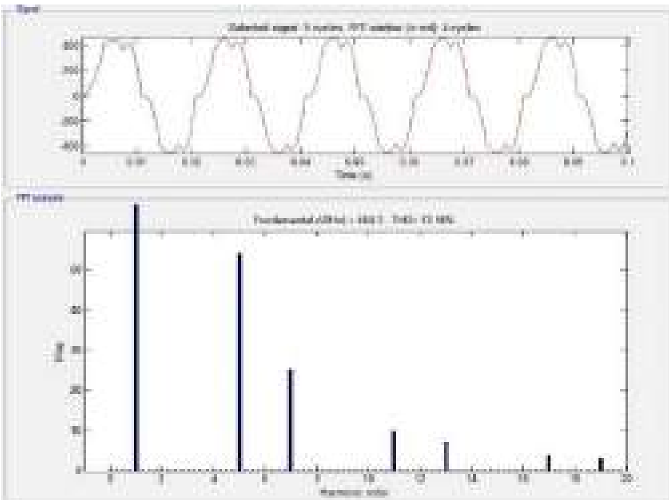

Fig.1. The harmonic distortion of the consumed currents (uncontrolled rectifier)

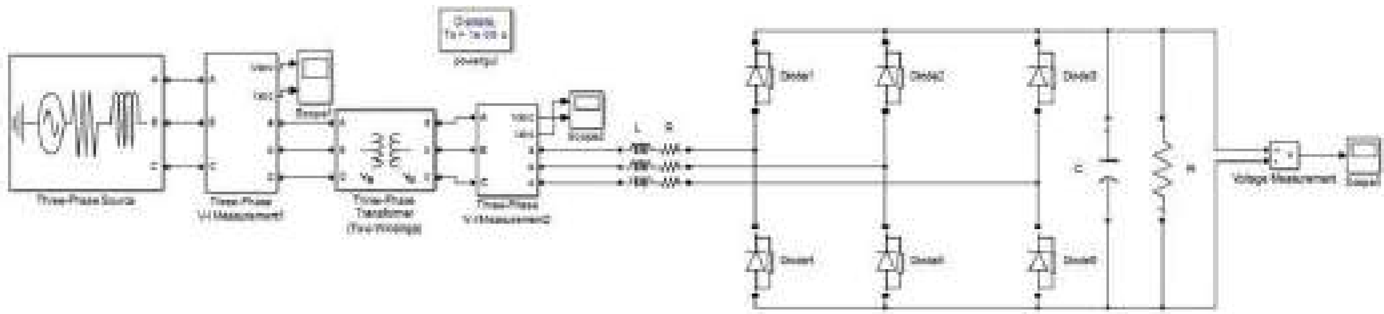

Fig.2. Simulation model of the uncontrolled diode voltage rectifier

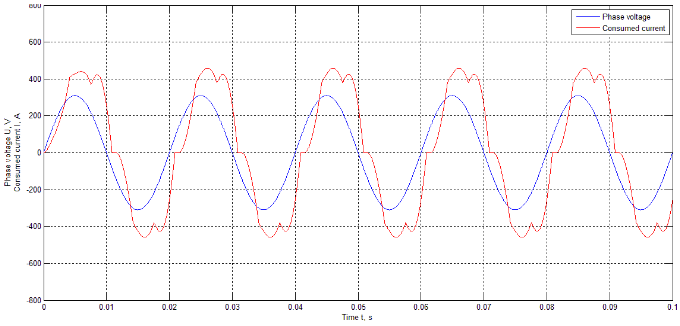

Fig.3. The phase shift between the phase voltage and the consumed current (diode rectifier)

III. Computer Simulation of the Active Voltage Rectifier

Fig.5 presents a model of the active voltage rectifier.

The rectifier of the voltage source works by maintaining the voltage of the DC link to a predetermined reference value using a feedback control unit (Subsystem). To accomplish this, the voltage in the DC circuit is measured and compared with a reference voltage source. The error signal is used to switch the six transistors of the rectifier.

When active rectifier starts to work in a rectifier mode, capacitor *C* is discharged and the error signal indicates to the control unit on the need for power from the AC power source. The control unit supplies power from the source, generating a corresponding PWM signal to the six transistors. Thus, the value of the current flowing from the supply to the load increases, and the voltage of the capacitor is set.

Conversely, when operating in an inverter mode, the capacitor *C* is charged and error signal sets the control signal to discharge the capacitor and return power to the AC main.

There is a potential to control not only an active power but also a reactive, allowing this type of rectifier to correct power factor. In addition, the form of consumed currents can be maintained very close to sinusoidal, which reduces the harmonic content of current in the mains supply.

Control is achieved by measuring the instantaneous values of phase currents, causing their values to approach the values of the reference sinusoidal current i_ref. The amplitude of the reference current $i_{\max}$ is determined by the expression [2]:

$$i_{\max} = Pe = P(u_{ref} - u_{dc}), \qquad (1)$$

where *P* – is the reaction of the PI-controller.

The reference sinusoidal signal is generated by multiplying the amplitude $i_{\max}$ with a sine wave with the desired value of the phase shift and the same frequency as the mains supply. Moreover, the reference values must be synchronized with the values of the ac currents. After creating a reference signal pulse width modulation is used to make the values of ac currents close to the reference sinusoidal current.

The control algorithm of the active rectifier is shown in the Fig.6.

With the inclusion of the feedback and controller *P* in the system and also with the small increments of the variables control system of the active rectifier can be represented as a diagram shown in Fig.4.

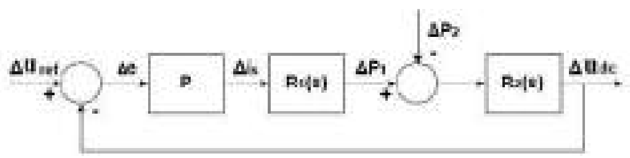

Fig.4. Block diagram of the control of a rectifier

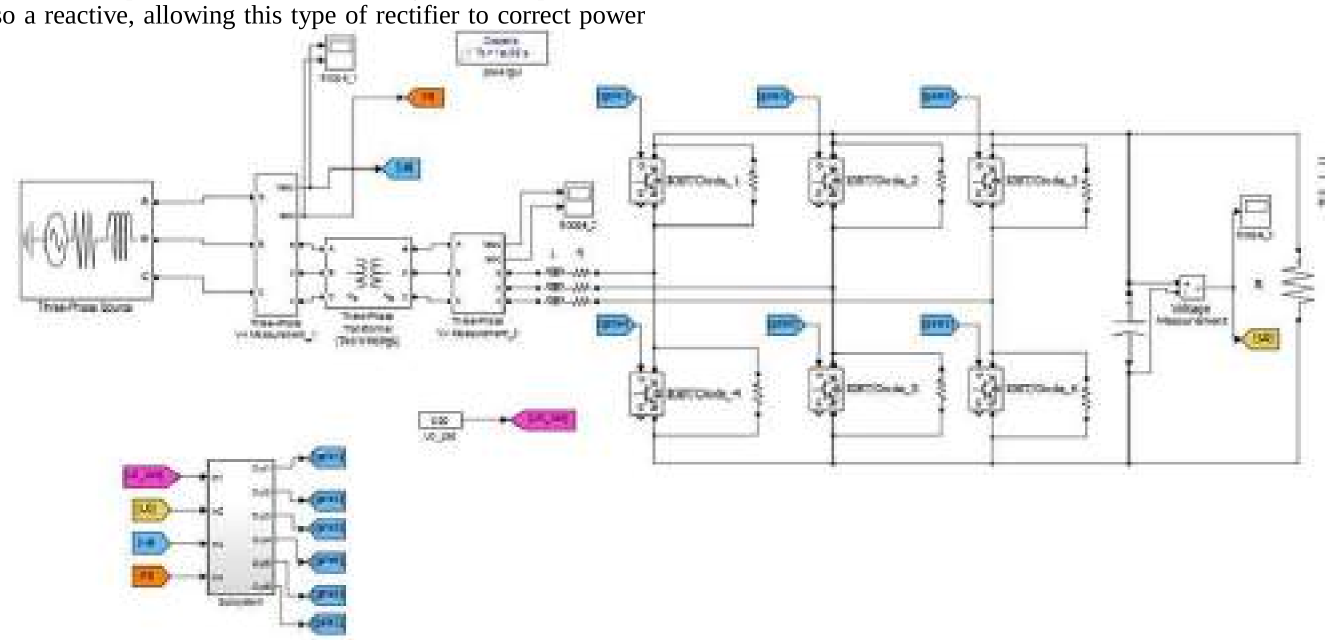

Fig.5. Simulation model of the active voltage rectifier

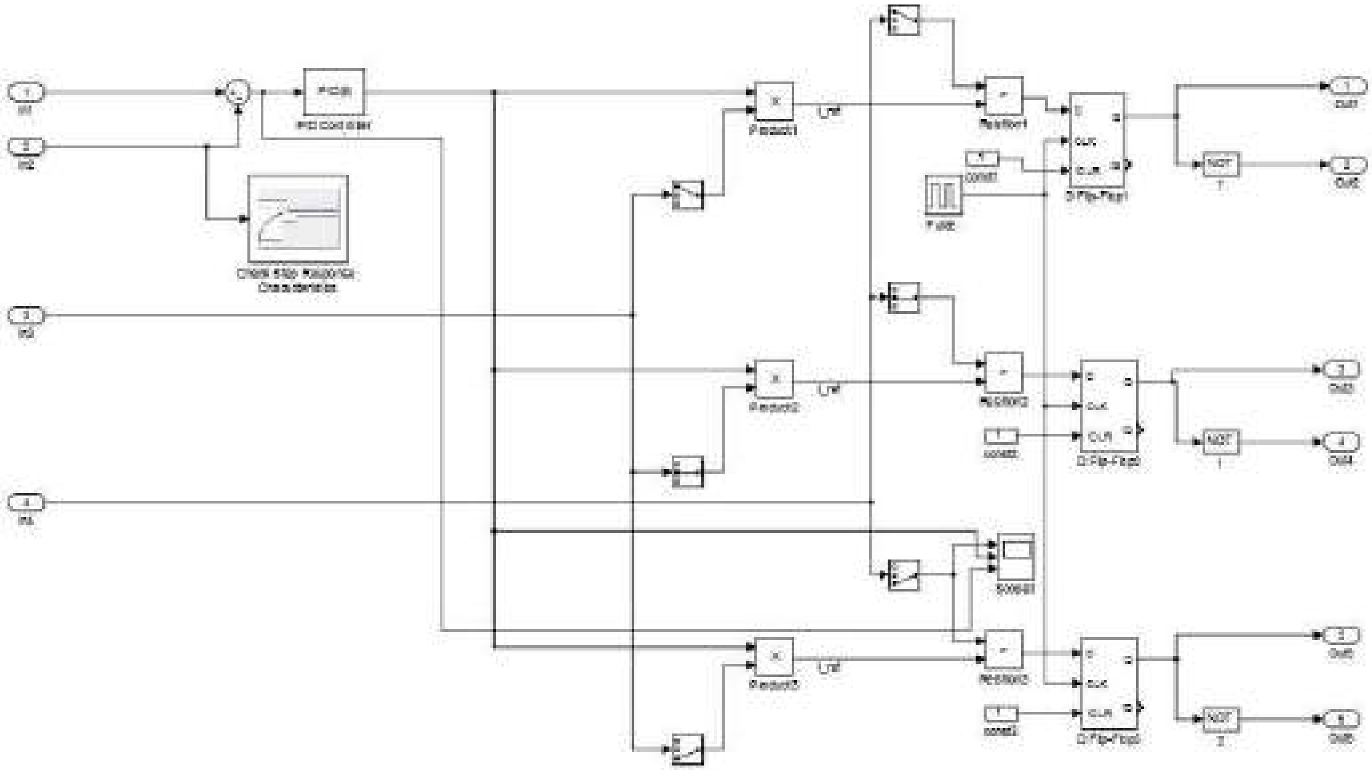

Fig.6. The control algorithm of the active rectifier

Block diagram in the Fig.4 is designed to linearize the control system of the active rectifier in the neighborhood of the operating point of the rms value of consumed current $\dot{i}_s$. Blocks $R_1(s)$ and $R_2(s)$ represent the transfer function of the active rectifier in the neighborhood of an operating point and transfer function of DC link respectively.

$$R_1(s) = \frac{\Delta P_1(s)}{\Delta i_s(s)} = 3(u_n * \cos(\varphi) - 2Ri_s - Li_s s), \quad (2)$$

$$R_2(s) = \frac{\Delta u_{dc}(s)}{\Delta P_1(s) - \Delta P_2(s)} = \frac{1}{u_{dc}Cs}, \quad (3)$$

where $\Delta P_1(s)$ and $\Delta P_2(s)$ represent the input and output power of the rectifier in Laplace dominion, u_n is the rms value of the voltage supply, $\dot{i}_s$ is the rms value of the input current being controlled by the template i_ref, $\cos(\varphi)$ – the input power factor, u_{dc} – is the voltage of the DC link, C – is the capacity of the output capacitor, L and R are the input inductance the input resistance respectively, s – is a complex variable.

The rectifier will maintain the value of the reference voltage on the capacitor for any load using PI-controller.

Shown in Fig.7 the harmonic analysis of the phase input current shows the presence of a small proportion of high harmonics in the consumed current. Total harmonic distortion (THD) equals to 3.17%.

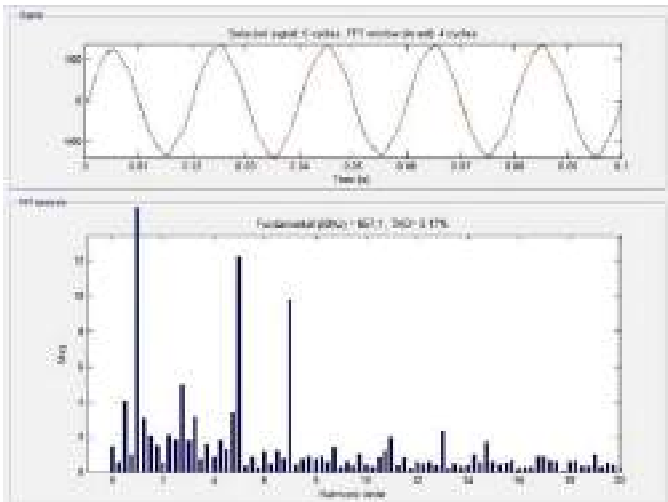

Fig.7. The harmonic distortion of the consumed currents (active rectifier)

From the waveforms it can be clearly seen that the shapes of the consumed currents are close to sinusoidal. And it is also shown the absence of phase shift between input current (red coloured) and phase voltage (blue coloured) in Fig.8.

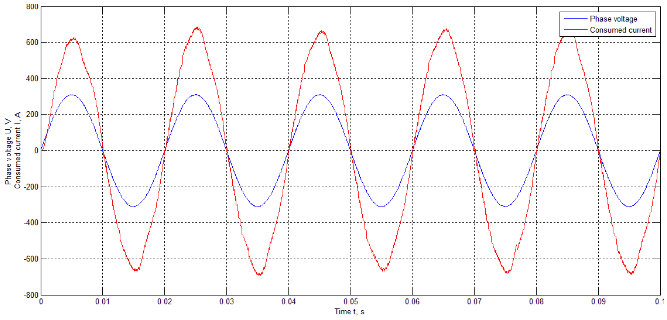

Fig.8. The phase shift between the phase voltage and the consumed current (active rectifier)

IV. Conclusions

The simulated results have shown the reasonability of using the active voltage rectifier than the uncontrollable diode rectifier for obtaining a higher power factor. The results of harmonic analysis of active voltage rectifier show that total harmonic distortion has reduced (THD= 3.17 %) compared with the uncontrollable diode rectifier (THD= 13.16 %). It can be clearly seen from the waveforms of the active voltage rectifier that the phase shift between the phase voltages and the input currents has disappeared.

Controlling transistors, the active rectifier maintains the value of the reference voltage on the capacitor, which allows getting the higher value of the rectified voltage than can generate a diode rectifier.

References

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