Approach for Control of a three Phase AC-DC Power Converter Without Grounded Conductor of Capacitators

T. Jonkov, K. Hristov

***Abstract*— Three-phase controlled rectifiers have a wide range of applications such as motor control, DC drives, cycloconverters. AC/DC converters consist a transformer following the input filtering, which passes to a rectifier to produce Direct Currents. Many AC/DC converters are using multistage conversion due to advantages of smaller transformer requirements. Converters steer an alternating current, as its voltage also alternates, into reactive impedance elements, such as inductors or capacitors, where it is stored and integrated. Filters are widely used to smoothen the energy stored, resulting in creation of a DC source for other circuits.**

***Index Terms*—AC-DC converter, energy exchange, power rectifier**

I. Introduction

An AC to DC converter is an integral part of any power supply unit used in the all electronic equipments. High efficiency power supplies can use active devices like MOSFETs or IGBTs working in switch mode in such circuits. The reason for using topologies that are more complex is usually for efficiency improvement, to lower noise or to act as a power control. The voltage output will change over time as power drains from these elements and may also have variance caused by the non-ideal characteristics of the devices – like series resistance or parasitic capacitance [1], [3], [6]. There are two modes of control for the power converters – continuous or discontinuous mode of operation. A continuous mode of operation is one where the inductor current never falls to zero. This is a lower output ripple and therefore lower noise mode of operation, but as the inductor is always conducting, it is always dissipating some energy in its non-ideal series conduction losses. In discontinuous mode, the inductor current is allowed to go to zero, causing the load to obtain energy from the storage capacitors [2], [5], [4], [7].

II. Modeling of Impulse Step-up Converter

Based on the structure of the model shown in figure 1 and according to dependencies (1) between the variables of states of the coordinate systems x_{abc} и $x_{\alpha-\beta}$ the model in coordinate system $0\alpha\beta$ could be expressed as equation 2:

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \sqrt{2/3} & 0 \\ -\sqrt{1/6} & \sqrt{1/2} \end{bmatrix} \begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix} \quad (1)$$

$$\frac{d}{dt}\begin{bmatrix} i_\alpha \\ i_\beta \\ \upsilon_0 \end{bmatrix} = \begin{bmatrix} \frac{-R}{L} & 0 & \frac{-\gamma_\alpha}{L} \\ 0 & \frac{-R}{L} & \frac{-\gamma_\beta}{L} \\ A_{31}^\alpha & A_{32}^\alpha & A_{33}^\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \\ \upsilon_0 \end{bmatrix} + \begin{bmatrix} \frac{1}{L} & 0 & 0 \\ 0 & \frac{1}{L} & 0 \\ \frac{\gamma_\alpha R_c}{L} & \frac{\gamma_\beta R_c}{L} & \frac{-1}{C} \end{bmatrix} \begin{bmatrix} \upsilon_\alpha \\ \upsilon_\beta \\ i_0 \end{bmatrix} \quad (2)$$

where

$$A_{31}^\alpha = \gamma_\alpha\left(\frac{1}{D} - \frac{RR_c}{L}\right); \quad A_{32}^\alpha = \gamma_\beta\left(\frac{1}{D} - \frac{RR_c}{L}\right); \quad A_{33}^\alpha = \frac{-R_c\left(\gamma_\alpha^2 + \gamma_\beta^2\right)}{L}$$

Model (2) is time-dependent. Applying forward Park conversion (3) at frequency of the rotating system synchronized with the frequency of the supply (q-component is set to zero), the time-dependent model should be transformed to model that is in non-rotational independent coordinate system (4):

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos(\omega t) - \sin(\omega t) \\ \sin(\omega t)\cos(\omega t) \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \quad (3)$$

$$\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \\ \upsilon_0 \end{bmatrix} = \begin{bmatrix} \frac{-R}{L} & \omega & \frac{-\gamma_d}{L} \\ -\omega & \frac{-R}{L} & \frac{-\gamma_q}{L} \\ A_{31}^d & A_{32}^d & A_{33}^d \end{bmatrix} \begin{bmatrix} i_d \\ i_q \\ \upsilon_0 \end{bmatrix} + \begin{bmatrix} \frac{1}{L} & 0 & 0 & 0 \\ 0 & \frac{1}{L} & 0 & 0 \\ \frac{\gamma_d R_c}{L} & \frac{\gamma_q R_c}{L} & \frac{-1}{C} & -R_c \end{bmatrix} \begin{bmatrix} \upsilon_d \\ \upsilon_q \\ i_0 \\ \frac{di_0}{dt} \end{bmatrix} \quad (4)$$

where

$$A_{31}^d = \gamma_d\left(\frac{1}{C} - \frac{RR_c}{L}\right); \quad A_{32}^d = \gamma_q\left(\frac{1}{C} - \frac{RR_c}{L}\right); \quad A_{33}^d = \frac{-R_c\left(\gamma_d^2 + \gamma_q^2\right)}{L}$$

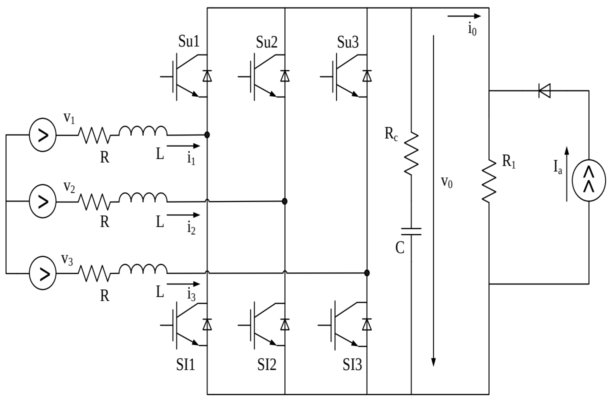

Fig. 1. Scheme of a three-phase converter

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The control in current mode does not use linearization of the modulator which simplifies it's modeling [8],[9]. The measured values are being compared to the ones from the voltage regulator. The current mode scheme could be applied in systems working in continuous mode providing better characteristics and low order of the system [10],[11]. Structure scheme of the current mode with constant frequency is shown on figure 2.

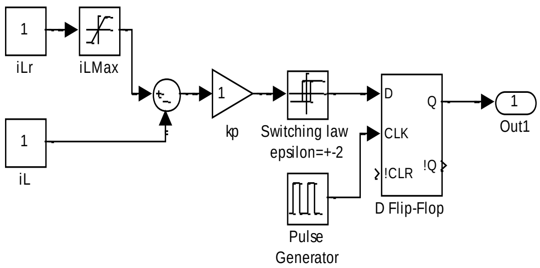

Fig. 2. Structure scheme of current mode with constant frequency

III. EXPERIMENTAL RESULTS

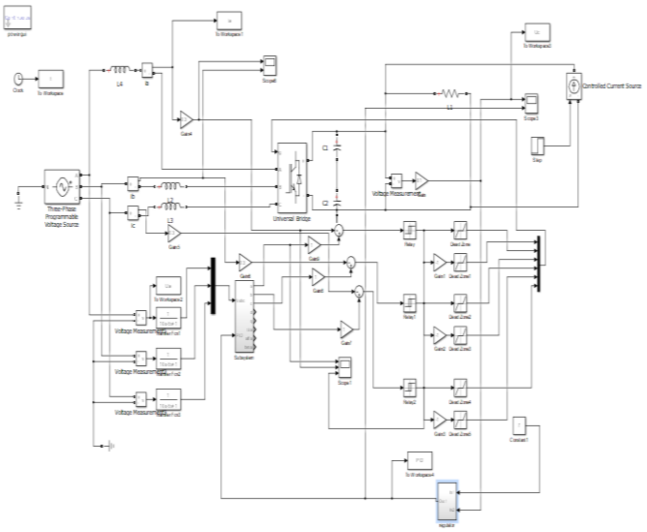

Fig. 3. Scheme of a three-phase AC-DC converter in Simulink

Simulation results are achieved using SimPowerSystems tool in Simulink for modeling of the power converter, voltage supply, phase inductance and capacitor batteries. Reducing and avoiding of peak currents in charging mode of the capacitor is achieved by serial conducted resistor gaining smooth charging and being switched off from control switches shown on figure 3. Apart from the conventional methods of control in that particular case the zero conductor of the capacitor batteries is removed which allows the system to reach faster the mode of returning energy.

IV. DATA VALIDATION

Reaching the mode of returning energy to the supply voltage the active load is replaced by a controllable current source shown on Figure 4. In order to analyze experimental results and data the amplitude of the voltage signal is reduced by 90%. When charging the capacitor a negative current is applied to the current source with the value of -8A. Figure 5 represents the charging voltage of the capacitor. The process of charging the battery is set to 0.3s. At the time period of 0.27 s there is overcharging of the capacitator which is mark of exchanging energy. In the time range of 0 to 0.2s the capacitor is being charged. At the time of 0.27 s there is dephasing between the signals of the supply voltage and current shown on figure 4. The provided simulation results are for a single phase of the power converter.

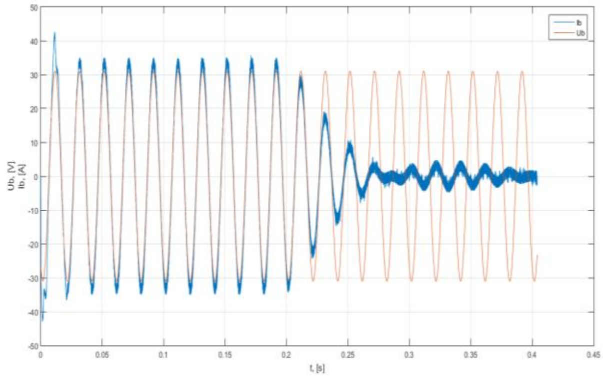

Fig. 4. Voltage and current signals of a single phase

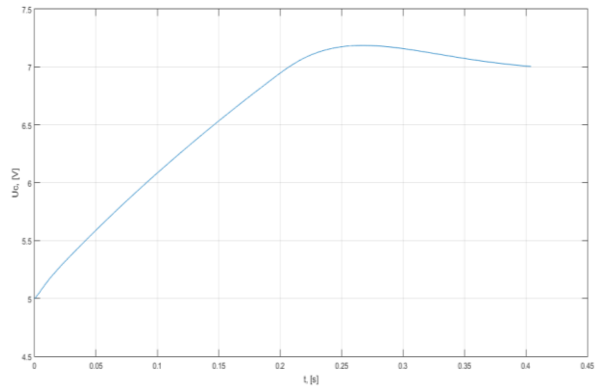

Fig. 5. Voltage of the capacitors in charginf mode.

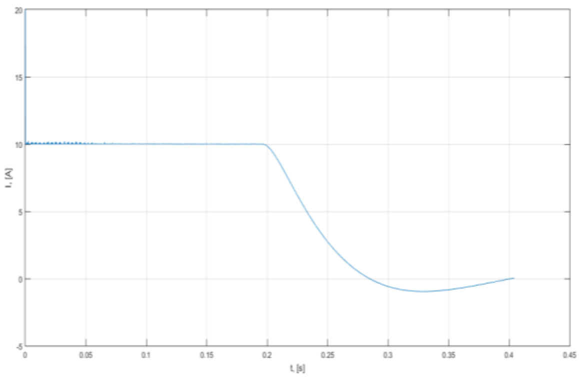

Fig. 6. Reaction of the PID controller

V. CONCLUSION

In conclusion of the previous states and experimental data some peculiar properties should be pointed out. The main difference in the model comes by removing the grounded conductor of the capacitator battery. That allows faster charging and turning into mode of energy exchange. Taking into account the derivative part of the PID regulator and absence of the zero conductor, that particular moment comes in the time of 0.27 second which is 0.1 second faster than the model with zero conductor. The overregulation in charging mode is set to 4.8% which is in the rates of the theoretical overregulation.

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