RESEARCH ARTICLE OPEN ACCESS

A Synchronizing Devicefor Power Electronic Converters

MihailH. Antchev*,MintchoS. Mintchev**, KostadinG. Milanov***, HristoM.Antchev****

*(Department of Power Electronics, Faculty of Electronic Engineering and Technologies, Technical University-Sofia, Bulgaria)
**(Department of Electrical Apparatus, Faculty of Electrical Engineering, Technical University-Sofia, Bulgaria)
***(Department of Electrical Apparatus, Faculty ofElectrical Engineering, Technical University-Sofia, Bulgaria)
****(Department of Power Electronics, Faculty of Electronic Engineering and Technologies, Technical University-Sofia, Bulgaria)

ABSTRACT
In this paper we introduce a synchronizing device for power electronic converters with single-phase or three-phase AC input voltage. The voltage synchronizing transformer in this device has been replaced by a current transformer and a double galvanic isolation has been realized by means of optical media. Results from computer simulation and experimental studies have been brought out.

Keywords- power electronic converters, high AC voltage, synchronizing device.

I. INTRODUCTION

The proper operation of power electronic converters with AC input voltage requires the use of synchronizing devices to accurately determine the moment when the supply voltage passes through zero [1]. This group of power electronic converters includes thyristor and transistor controlled rectifiers, ACregulators, converters for active power factor correction, matrix converters.

The common synchronizing devices use mostly voltage synchronizing transformer [2,3]. A new synchronization method under significant supply voltage distortions has been described in [4]. At high levels of voltage power supply the power electronic converter endures increasing problems related to providing appropriate insulation voltages for the voltage transformer. The dimensions and weight of the voltage synchronizing transformer are quite big compared to the minimum power required for the electronic synchronizing steps activation. As it is known, the electromagnetic power of thevoltage measuring transformers (the so called limit power, determined by the heating conditions) is on the average $10 \div 15$ times higher than their nominal output power, ensuring error-free operation [5].

The present paper introduces a synchronizing device, in which the voltage synchronizing transformer has been replaced by a current one. The main advantage of the proposed solution is based on the fact that the current transformers' inaccuracies are determined solely by the parameters (active and inductive impedance) of the secondary coil only. The voltage transformers' inaccuracies are determined by both secondary and primary coils parameters. At high voltage levels the active and especially the inductive impedanceof the primary coil are rather high, which leads to the problems stated above. From this perspective the current transformer solution has greater advantages. An optical pair transmitter - receiver in the examined synchronizing device provides additional galvanic isolation and conversion to square wavesignal. The circuit is applicable to single-phase and three-phase AC voltage. The use of current transformers is also common for control of serially connected thyristors [6-8].

II. BASIC BLOCK DIAGRAM

Fig.1 shows a basic block diagram of the synchronizing device. The value of the current through the transformer's primary coil CTr - I_{HVAC} is set by the resistors $R_{1H}, R_{2H} ... R_{NH}$ depending on the AC voltage V_{HVAC} value. The network is of predominantly active character, therefore the phase shift between V_{HVAC} and I_{HVAC} is minimal. It can be possibly compensated withthe help of the capacitor $C1^*$. The circuit in the secondary part of the current transformer CTr is in current generator power mode. During the positive half wave the capacitor $C2$ is charged from this current through diode $VD3$ and the voltage value on the capacitor is limited by $VD4$. This voltage is used as power supply for the transmitter $HFBR15XX$. During the negative half wave the current flows through $VD1$ and $VD2$. Stabilitrons $VD2$ and $VD4$ have the same voltage stabilization value. The value of the current passing through the transmitter's LED $HFBR15XX$ and through the transistor $VT1$ is set by resistor $R1$. The transistor $VT1$ is conducting during the positive half wave, while the transmitter's LED - during the negative. Rectangular pulses between $+5V$ (conditional logical 1) and $0V$ (conditional logical 0) are received at the output V_{OUT} of the receiver $HFBR25XX$. The logical 1 corresponds to a positive half wave of the voltage V_{HVAC}, and the logical 0 – to a negative half wave. The unspecified digits XX in the transmitter and receiver designations depend on the optical fibre housing and length. [9].

For three-phase system supply voltage, the power electronic converter should use three identical channels from the described diagram.

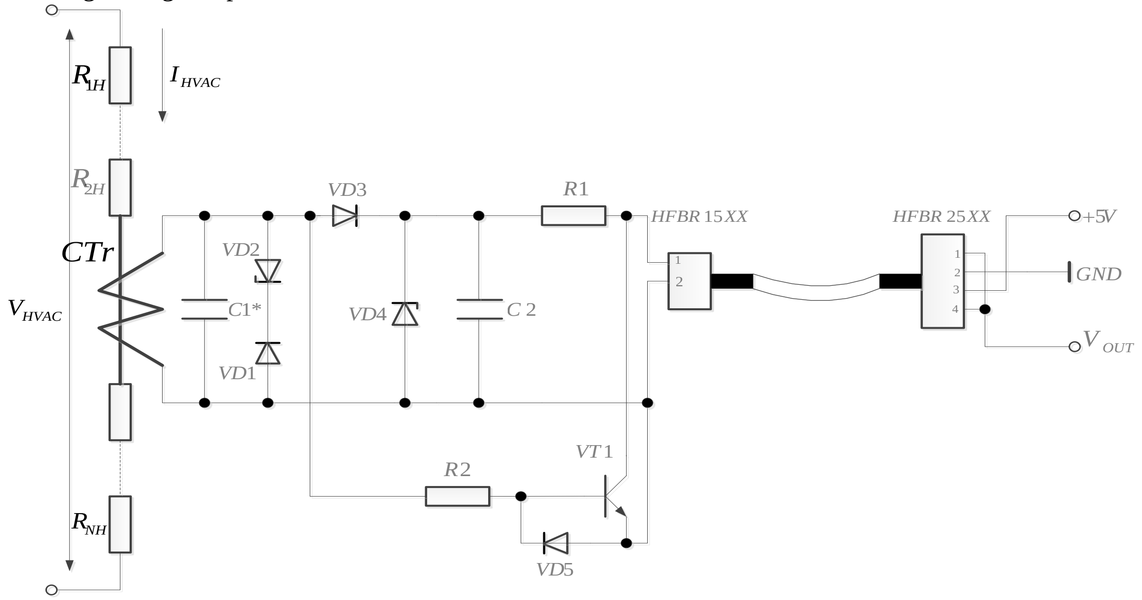

Fig.1. Basic block diagram

III. COMPUTER SIMULATION

The program PSIM has been used for the computer simulation [10]. The simulation diagram is shown on fig.2.

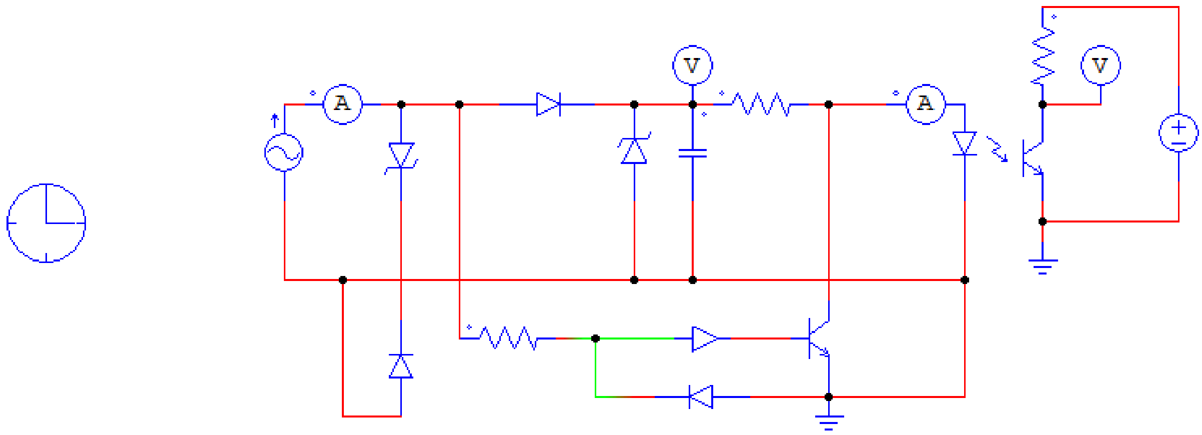

Fig.2. Computer simulation diagram.

The circuit behaviour after the secondary coil of the current transformer CTr on fig.1 has been examined. The current transformer has been represented by a current generator. The system transmitter $HFBR15XX$ - receiver $HFBR25XX$ on fig. 1 has been simulated by the optocoupler from fig.2.

Fig.3 shows the results from the computer simulation. At the top is the generator current $I2$. As it can be seen, the supply voltage for the transmitter (the voltage on the capacitor $C2$), represented on fig.3 as $V1$, reaches its set value for about 300 mS after the initial start-up. This value corresponds to the nominal current 40 mApassing through the LED of the transmitter $HFBR15XX$, denoted by $I4$ on fig.3. The output voltage V_{OUT} on fig.1 corresponds to $V2$ on fig.3. The last timing diagram on fig.3 displays the generator's current $I2$ and the output voltage $V2$. This shows that the synchronization is reached for about 70 mS.

IV. EXPERIMENTAL RESULTS

The synchronizing device has been used by the realization of a three-phase thyristorcontrolled rectifierwith output voltage 6000V at output current up to 40A. The maximum value of the input phase supply voltage is 3600V. The current transformers' data are as follows: magnet core - toroidal with dimensions 60 x 40 x 25 mm; number of primary coil windings - 3000; number of secondary coil windings - 180. Four resistors of 100 $k\Omega$ for each phase are included in series with the primary coil.

Fig.4 shows the synchronizing block. Besides the current transformers, the resistors included in their primary side are also visible.

Fig.5 shows the printed circuit board in the rectifier used for synchronization and measurement. The synchronizing channels are in its upper part and the secondary coils of the current transformers for R, S and T phases are connected to the respective terminals. On the same PCB there is also another circuit, used for measuring phase currents, which is shown in the bottom part.

Fig.6 shows the waveforms from the analysis of one channel in a set mode. The current passing through the secondary coil has been observed with a current probe100mV/A. The effective value of this current is 120mA at a nominal supply voltage of the rectifier. The synchronization remains stable within the range from 80mA to 160mA, i.e. approximately $\pm 30\%$, which exceeds the allowed variation range of the rectifier's supply voltage (according to the standard $\pm 10\%$).

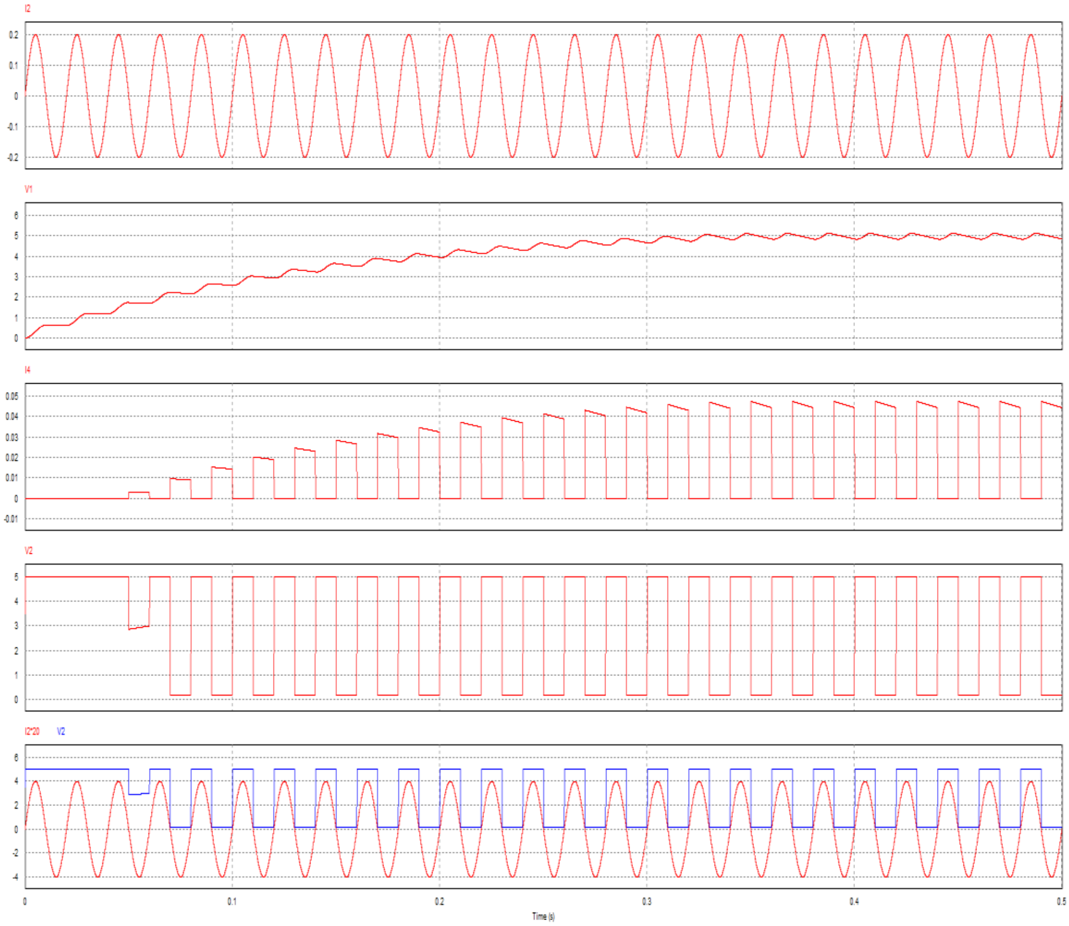

Fig.3. Computer simulation results - from top to bottom: I2 – current through the secondary coil, V1 – voltage on the capacitor C2, I4 – current through the LED, V2 – output voltage, I2*20,V2 – current through the secondary coil*20 and output voltage.

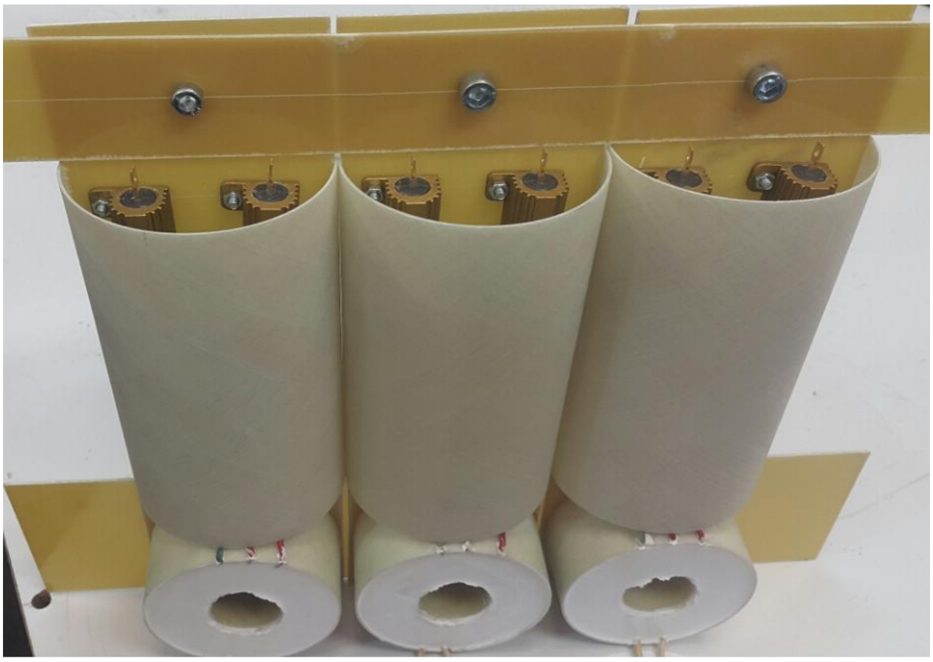

Fig.4. Synchronizing block.

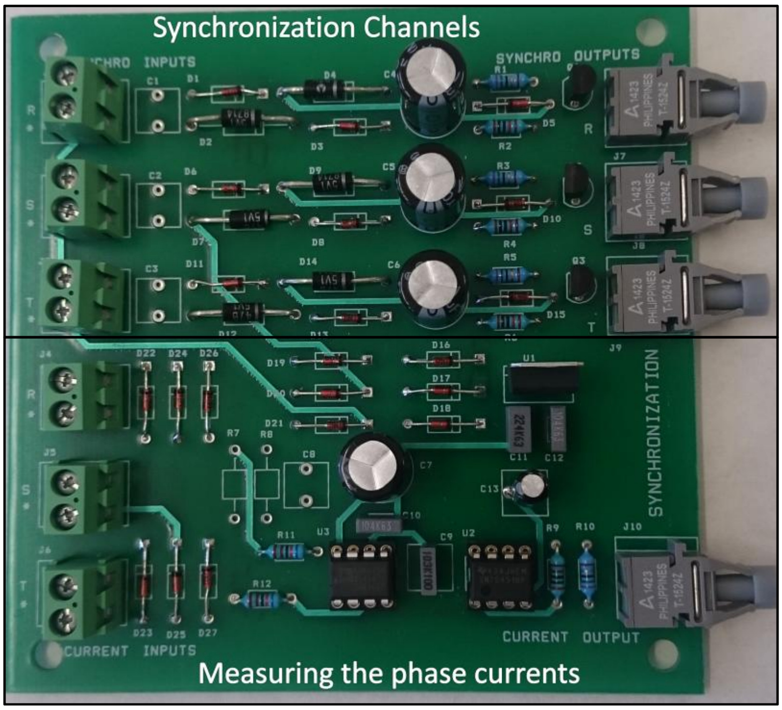

Fig.5. Synchronizing device implementation.

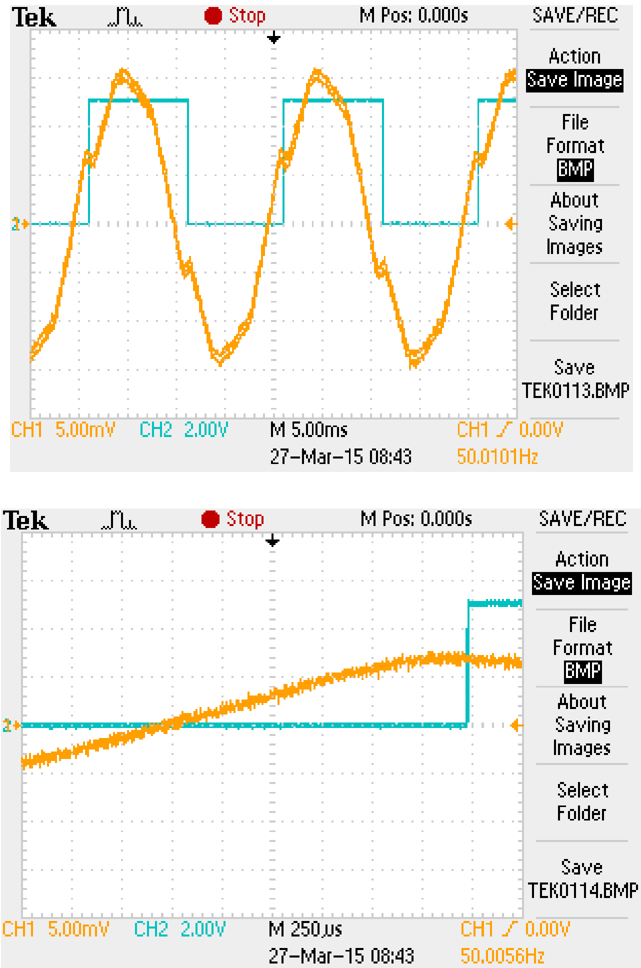

Fig.6. Waveforms in set mode: CH1 - current through the secondary coil;
CH2 – output signal of the optical receiver HFBR2524.

The delay time to the front edge of the output signal is about 1.5 mS. Additionally 0.17 mS more are added in the rectifier control system, thus the moment of the thyristors natural commutation is determined at 50 Hz mains voltage frequency. Hence, the delay corresponding to the rectifier adjustment angle is determined.

Fig.7 shows the transitional process at initial connection (start-up) and minimum current 80 mA.

Fig.8 shows the transitional process at initial connection and nominal current 120 mA.

Fig.9 shows the transitional process at initial connection and maximum current 160 mA.

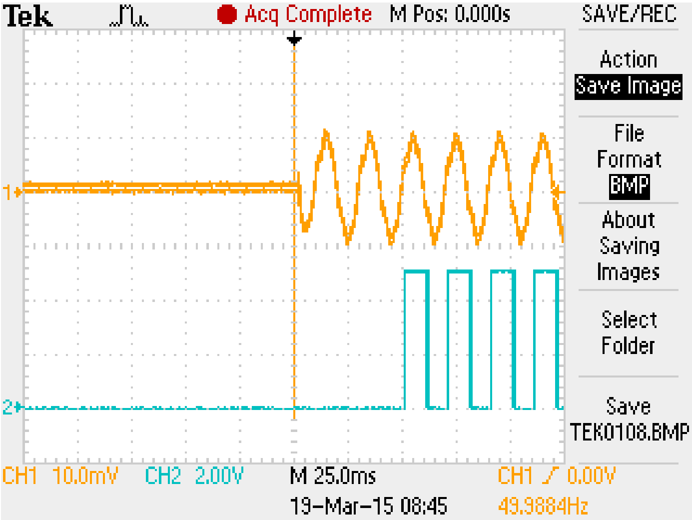

Fig.7. Transitional process at start-up and current 80mA :
above – current through the secondary coil;
below – output signal of the optical receiver HFBR2524.

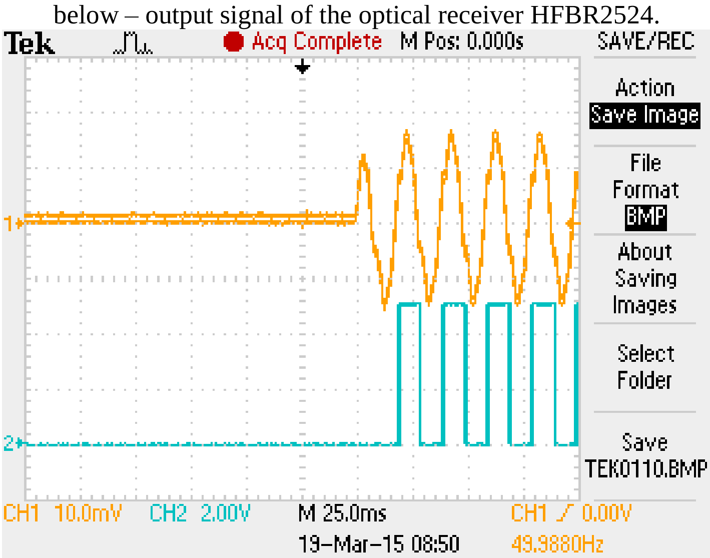

Fig.8. Transitional process at start-up and current 120 mA :
above – current through the secondary coil;
below – output signal of the optical receiver HFBR2524.

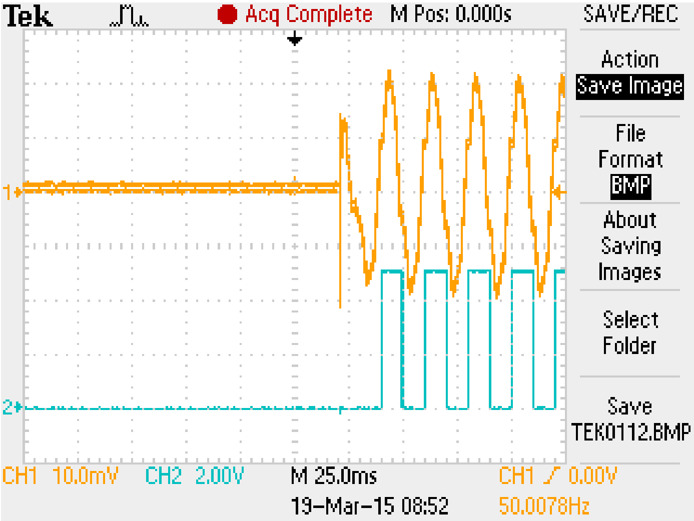

Fig.9. Transitional process at start-up and current 160 mA :
above – current through the secondary coil;
below – output signal of the optical receiver HFBR2524.

The waveforms show, that the time for the initial synchronization decreases with the increase of the current through the secondary coil of the current transformer. Synchronization at nominal current 120 mA is practically reached after about 30mS. This time is less than the time obtained in the computer simulation and the difference is due to the fact that an optoelectronic couple from the program PSIM library has been used for the simulation, while for the practical realization - a transmitter HFBR1524 and receiver HFBR2524.

V. CONCLUSION

The synchronizing device for power electronic converterswith AC input voltage,illustratedin the present paper, is characterized by the following advantages: the voltage transformer is avoided, which is of crucial importance at high input voltages; a double galvanic isolation from the input voltage has been achieved. The results from the computer simulation and the experimental studies show, that synchronization is achieved in less than 100 mS after applying the input voltage and the circuit operation is not affected by voltage frequency changes within the practical values around 50 – 60 Hz.

References:

[1] Sen T., P.K. Bhattacharjee, M. Bhattacharja, Design and Implementation of Firing Circuit for Single-Phase Converter, *International Journal of Computer and Electrical Engineering, 3(3)*,2011, 368-374.

[2] Lahade S.V., S.R. Hirekhan, Microcontroller based Firing Trigger Circuit for Converter, *Proc. of Int. Conference in Power Electronics and Instrumentation Engineering*, 2014,277-283.

[3] Wall R.W., Simple Methods for Detecting Zero Crossing, *Proceedings of The 29th Annual Conference of the IEEE Industrial Electronics Society*,1-5.

[4] Weidenbrug R., F.P.Dawson, New Sinchronization Method for Thyristor Power Converters to Weak AC-Systems, *IEEE Transactions on Industrial Electronics*, *40(5)*, 1993, 505-511.

[5] Phillippow, E. Herausgeber, *TaschenbuchElektrotechnik*, (B. 2 VEB VT Berlin, 1965).

[6] Applied Power Systems Inc., APP 6617 HV SCR Pulse Switch, www.appliedps.com.

[7] Applied Power Systems Inc., BAP 1289 HV SCR Gate Driver Board System, www.appliedps.com.

[8] Wahl F.P., Firing Series SCRs at Medium Voltage: Understanding the Topologies Ensures the Optimum Gate Drive Selection, *Power System Word Conference*, Chicago, USA, 2002.

[9] Agilent Technologies, HFBR-0501 Series Versatile Link The Versatile Fiber Optic Connection Technical Data, www.semiconductor.agilent.com.

[10] Powersim Inc., PSIM Simulation Software, www.powersimtech.com.