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Fully controlled AC/DC converter

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***Abstract* — the paper describes operation of rectifier, advantages and disadvantages of its different types and selects the best type of rectifier for supplying the inverter for high frequency induction heating application.**

***Keywords* — rectifier, voltage, current, thyristor, converter**

I. Introduction

Rectifier is electrical equipment that transforms an alternating current and voltage into direct ones. In practical application, the rectifier according to requirements of connected power supply and purpose of its usage has to be used. From the aspect of power supply, rectifiers can be separated in to two main groups: single-phase rectifiers and three-phase rectifiers. The main advantage of single-phase rectifier is that consists of few parts only and it needs only single-phase of power grid, which is available in the households. Disadvantage of this topology lies in high voltage ripple. Drawback of three-phase rectifier is in necessity of three-phase electric grid, but in the other hand, it produces lesser voltage output ripple and provides higher RMS values of voltage and current.

In the following paper only single-phase rectifiers will be mentioned due to consideration of single-phase power supply.

Single-phase rectifiers can be divided to three groups. The simplest rectifier is half-wave rectifier (Fig.1), which only consists of one diode. Disadvantages are high voltage output ripple and low RMS

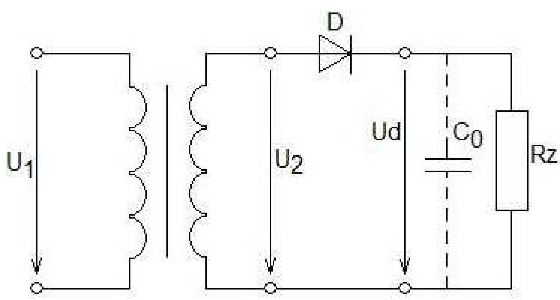

Fig. 1. Single phase half-wave rectifier

value of voltage and current, because this topology rectifiers only positive section of sine wave. RMS value of voltage can be calculated using following formula:

$$U_d = \frac{U_{2MAX}}{2 \cdot \sqrt{2}} = 0{,}353 \cdot U_{2MAX} \qquad (1)$$

The U_{1MAX} is maximum value of input voltage. U_{2MAX} is maximum value of voltage at the output of rectifier. This topology is depicted in Fig.1. In this case, a filter capacitor can be connected to the output terminals to minimize voltage ripple. But, on the other hand, he reduces the peak value of output voltage.

Another type of single-wave rectifier is a full-wave rectifier. The full wave rectifier converts the whole input sine waveform to one polarity signal at its output. This topology is shown in Fig. 2 and consists of two diodes and a center tapped transformer.

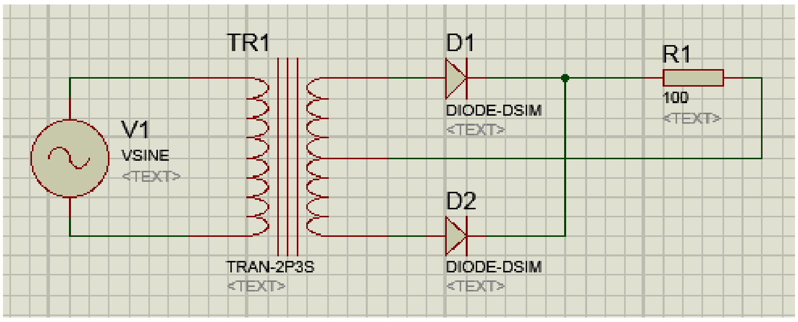

Fig. 2. Single phase full-wave rectifier with center tapped transformer

A center Tapped rectifier is a type of full wave rectifier that use two diodes connected to the secondary side of a center tapped transformer. The main drawback is necessity of using transformer with center tapped, which increases the costs. The RMS value of this connection is expressed by equation (2).

$$U_{R1} = \frac{U_{2MAX}}{\sqrt{2}} \tag{2}$$

The U_{1MAX} is input voltage of rectifier (output of transformer). If the transformation ratio is 1:1, then based on equation 2, the maximal RMS voltage is two times higher than in the case of half way rectifier.

The compromise solution between price and efficiency is given by bridge rectifier. This type consists of four diodes. Such number of power semiconductor parts also represents disadvantage of this connection. In the case of using of fully controlled parts, as for example thyristors, we must galvanically separate its control signals. Mentioned connection is illustrated on Fig. 3.

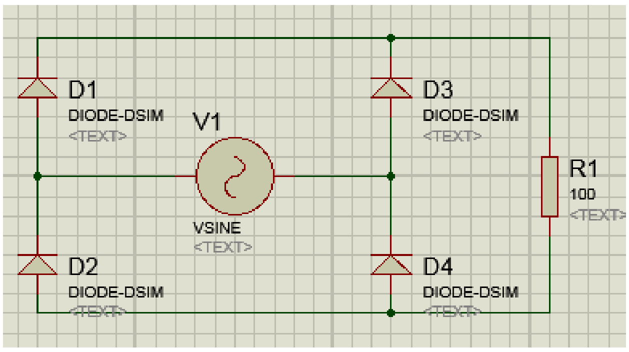

Fig. 3. Full-way bridge connection

II. INTEGRATED CIRCUIT TCA 785

For the control purpose of the rectifier we need to realize phase control. The best option is to use integrated circuit TCA 785. This circuit is designed for phase control of thyristors, triacs and transistors. The basic problem is to synchronize circuit with input voltage to obtain time when the controlled voltage is crossing through zero line voltage [4].

The basic recommended connection of TCA 785 for triac phase control is shown on Fig. 4.

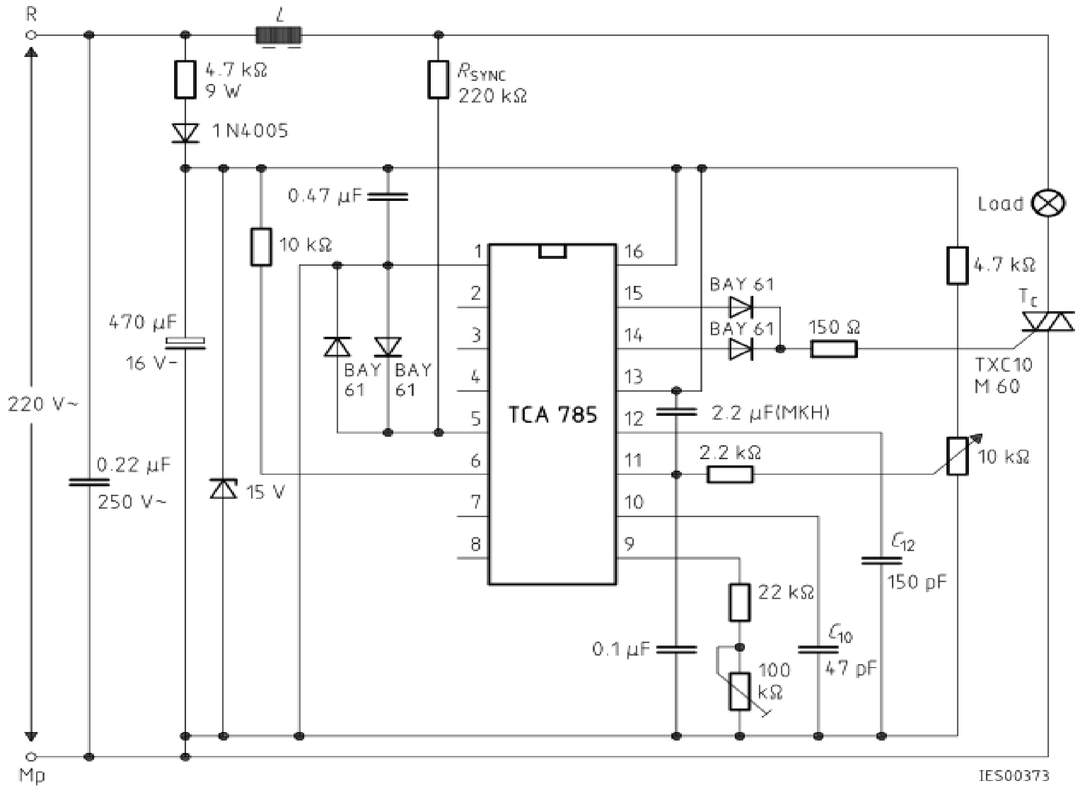

Fig. 4. Recommended connection of TCA 785

In described case, the outputs 14 and 15 are connected to diodes BAY 61, and its outputs are united, because we need control of both half periods. For our purpose these diodes can be removed and both output signals should be isolated by separate optical elements, so that it can be used for control of individual thyristors connected in bridge rectifier.

III. CONNECTION OF CONVERTER

For simplification of control circuit connection, we can use two way one phase rectifier that consists from four diodes. Thyristor is connected as control element. In such case we can connect TCA as shown on Fig. 4. The final effect is similar as in case of usage of rectifier with four thyristors, but control circuit don't require galvanic separation. Simplified connection of convertor is shown on Fig. 5.

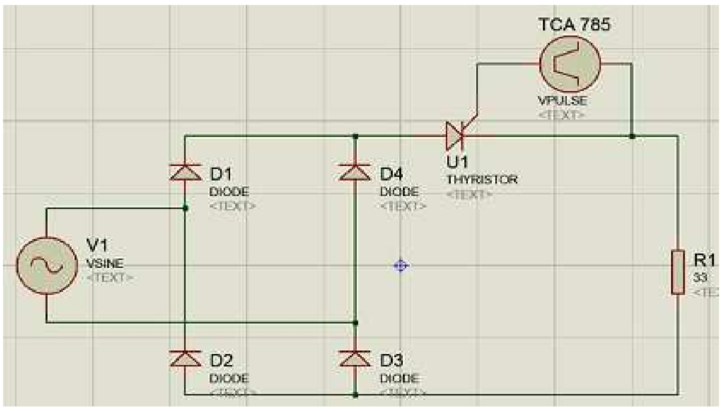

Fig. 5. Connection of simplified converter

IV. MEASURED OSCILLOSCOPE WAVEFORMS

Next voltage waveforms were obtained via measurement by oscilloscope. Measurement will be performed only with resistance load.

The output voltage waveforms with control phase angle 0° and without filtration capacitor we can see in Fig. 6.

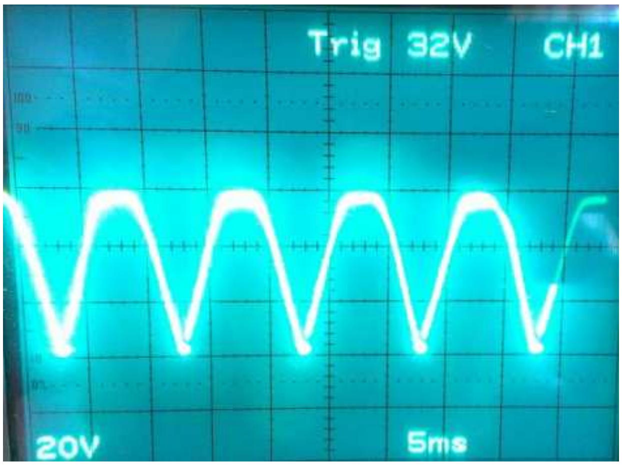

Fig. 6. Output voltage in the case when the control phase angle is 0° and without filtration capacitor

The output voltage waveforms across the load, with phase angle 0° and with connected filtration capacitor we can see in Fig. 7.

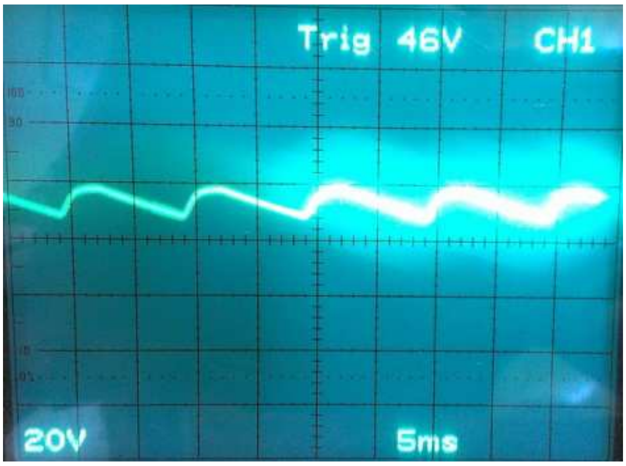

Fig. 7. Output voltage in the case when the control phase angle is 0° and with filtration capacitor

The voltage waveforms across the load, with phase angle 120° and without filtering capacitor we can see in Fig. 8. It is evident that RMS value of the output voltage is meaning lower due to fact that control phase angle is higher. The dependence of output voltage on control phase angle is non linear.

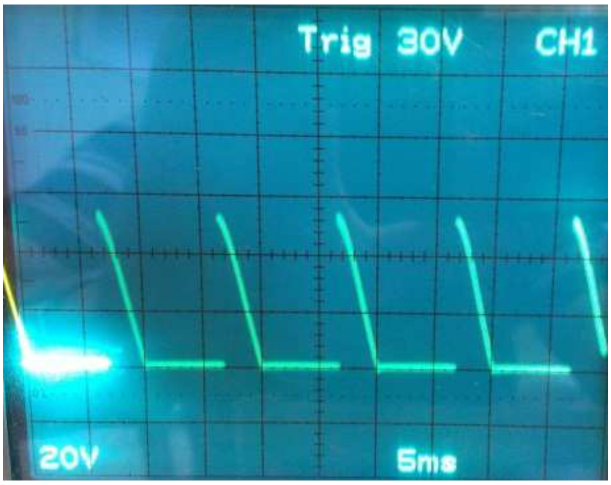

Fig. 8. Output voltage in the case when the control phase angle is 120° and without filtration capacitor

The load voltage waveforms with phase angle 120° and filtering capacitor we can see in Fig. 9. One can see that by connecting of capacitor the voltage undulation is reduced.

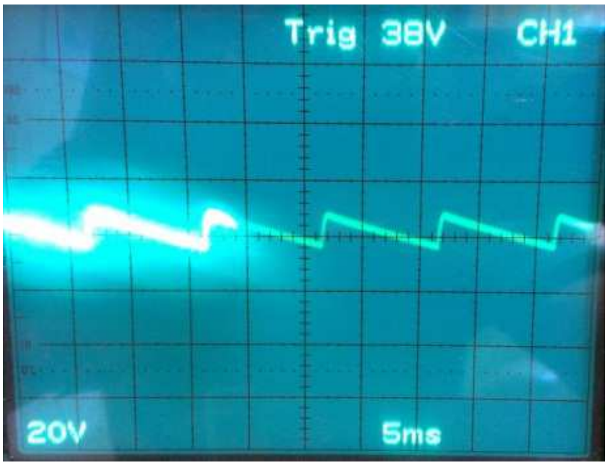

Fig. 9. Output voltage in the case when the control phase angle is 120° and with filtration capacitor

V. CONCLUSION

To complete the measurement, it is necessary to perform measurement with resistive and inductive load. Automation of the control algorithm is possible to do by interconnecting of control input voltage, with range of 0 till 10V, to the control input terminal number 11 of integrated circuit TCA785. Such analog signal can be generated for example by PLC 312 C produced by SIEMENS company, which contains four analog inputs and two analog outputs.

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