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Design and Analysis of Single Phase Thyristor Converter for Different Loads

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Abstract—*A rectifier is a circuit that converts ac power into dc power. The thyristor converters are commonly known as phase controlled converters. Diode rectifiers provide a fixed dc output voltage while thyristor converters provide variable dc output voltage. Thus thyristor converters are preferred over diode based rectifiers as these converters output can be controlled using the firing angle while it is not possible using diode rectifiers. The output voltage of the converter is a function of the firing angle α. The type of load in a rectifier circuit has an important effect on the behavior of the circuit. The Matlab model and simulation of a single phase half wave controlled converter using thyristors is presented in this paper. The behavior of the converter feeding different types of loads is also analyzed .The output waveforms for voltage and current is studied.*

Keywords: *Thyristor, converter, output voltage, load.*

1. INTRODUCTION

Rectification refers to the process of changing alternating current to direct current. It is extensively used in charging batteries, supplying dc motors, power supply sections of industrial equipments. An ideal rectifying element is the one which allows the current to flow in only one direction without offering any resistance but blocks the current from flowing in opposite direction [2]. The block diagram of a phase controlled converter is shown in fig. 1 below.

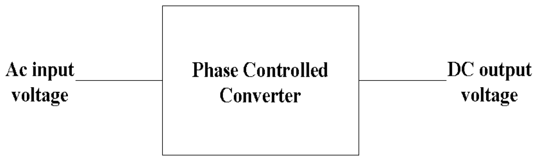

Fig. 1: Block diagram of Phase controlled Converter

The phase controlled thyristor converters make use of natural reversal of ac source voltage for commutating the conducting thyristors. These converters are simple and inexpensive and extensively used in industries [1]. The type of load in a rectifier circuit has an important effect on the behavior of the circuit. The rectifiers are classified on the basis of the semiconductor device used in the circuit as -

(i) Uncontrolled rectifiers –Diodes
(ii) Controlled Rectifiers or converters – Thyristors

If diodes and thyristors are together used in rectifier circuit then it is called as a half controlled converter or semi-converter. The phase controlled converters find applications in dc motor control, electrochemical processes, battery charging and dc traction drives.

2. CONTROLLED THYRISTOR CONVERTERS

The rectifiers are classified according to the supply as single phase and three phase rectifiers. Also according to the output corresponding to one cycle of supply voltage they are classified as half wave and full wave rectifiers. Rectifiers are also categorized depending upon their pulse number. Pulse number of a rectifier refers to the number of output voltage or current pulses in a single time period of the input ac supply voltage. The pulse number of a rectifier is always an integral multiple of the number of input supply phases. A single phase half wave controlled converter consists of only one semiconductor device. It has a single phase ac input voltage supply and load. Since the supply is ac therefore natural commutation of thyristors takes place. Natural commutation refers to the turning off of thyristors at the end of positive half cycle due to reversal of supply voltage. As thyristors are unidirectional devices i,e. they allow the flow of current in one direction only, thyristor conducts only during positive half cycle of supply voltage and in negative half cycle it is reverse biased. Thus we get output in one half cycle of supply so, this circuit is termed as a half wave converter. The thyristor is a controlled device means that its conduction can be controlled with the help of gate signal.. Firing angle of a thyristor refers to the time interval from the instant a thyristor is forward biased to the instant when a gate pulse is actually applied to it. Similarly extinction angle β refers to the time interval from the instant when the current through an outgoing thyristor becomes zero (and a negative voltage applied across it) to the instant when a positive voltage is reapplied.

A single phase half wave controlled converter consists of a single phase ac source, a thyristor and a load connected in series. In the positive half cycle of supply voltage the thyristor is forward biased since its anode is positive with respect to its cathode. When the thyristor is triggered at a firing angle α, it starts conducting and power is delivered to the load. However in negative half cycle, thyristor is reverse biased and blocks the line voltage so no current flows to the load. When the load is resistive , the current waveform is identical to the applied voltage wave after thyristor is fired at α.

Average output voltage for a half wave controlled converter with restive load is given as –

$$V_o = \frac{V_m}{2\pi}(1 + \cos\alpha)$$

If the load is inductive, the increase in current is gradual. When thyristor is conducting energy is stored in inductor. At $\omega t = \pi$ when supply voltage reduces to zero and then reverses, the thyristor is still in conduction because the current through the inductance cannot be reduced to zero .During the negative half cycle of supply , the current continues to flow till the energy stored in inductance is dissipated in the load resistor and a part of the energy is fed back to the source. Thus due to the energy stored in the inductance, current continues to flow up to $\omega t = \beta$.

Average output voltage for a half wave controlled converter with restive-inductive load is given as –

$$V_o = \frac{V_m}{2\pi}(\cos\alpha - \cos\beta)$$

In order to prevent the reversal of voltage due to inductance, a diode is connected across the load. This diode helps in transferring the load current away from the main rectifier. So, it is called as freewheeling diode. With the diode connected the thyristor is unable to conduct beyond $\omega t = \pi$. During the negative half cycle the freewheeling diode is forward biased and carries the load current. So, no power is returned to the source and voltage is not reversed. Thus, the output voltage is waveform is similar to that in resistive load.

3. SIMULATION AND RESULTS

A single phase half wave thyristor converter with resistive, inductive and inductive with freewheeling diode is designed in Matlab model file and simulated using Simulink. From the voltage and current waveforms it is observed that the converter circuit output changes according to the connected load. The output can be further varied by changing the firing angle α. For the paper the various parameters for load connected were taken as –

3.1 Single phase half wave converter with R load

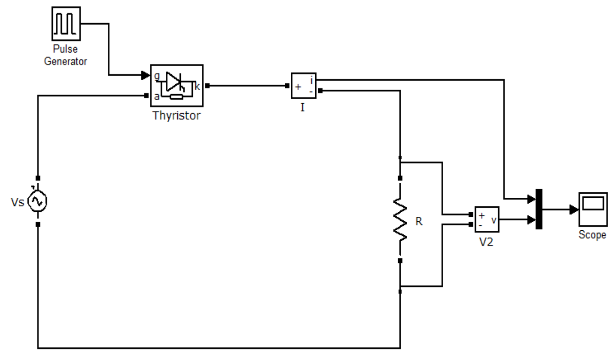

Fig. (a): Simulink model of half wave thyristor converter with resistive load

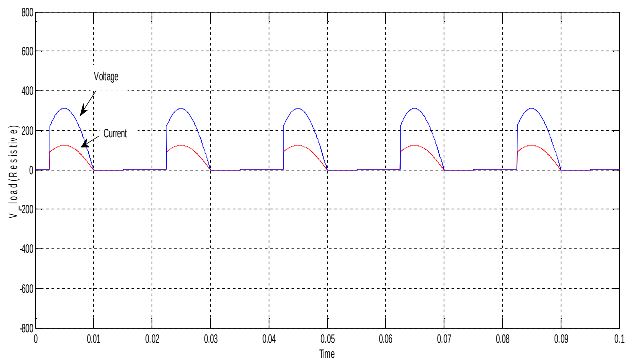

Fig. (b): Output voltage and current for resistive load and α = 45^0

3.2 Single phase half wave converter with R-L load

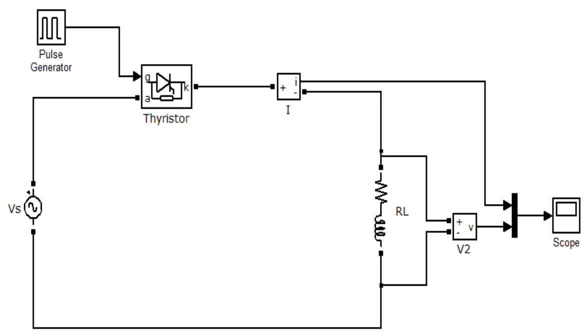

Fig. (c): Simulink model of half wave thyristor converter with inductive load

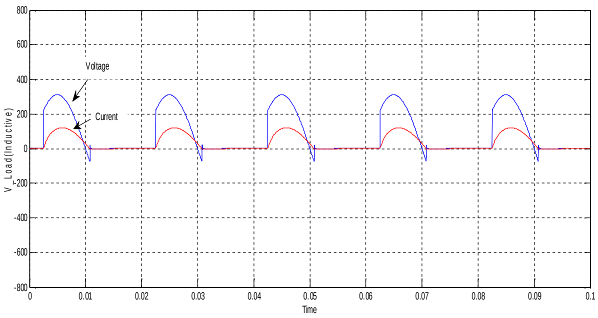

Fig. (d): Output voltage and current for inductive load a α = 45^0

3.3 Single phase half wave converter with R-L load and freewheeling diode

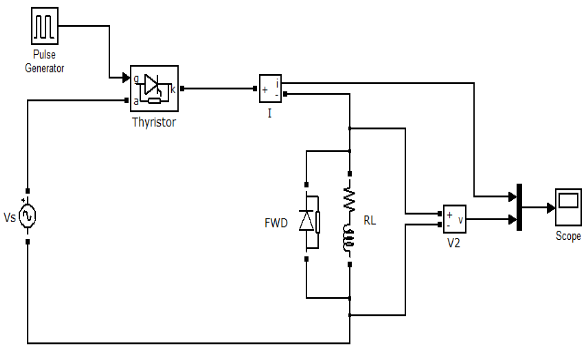

Fig. (c): Simulink model of half wave thyristor converter with freewheeling diode (FWD)

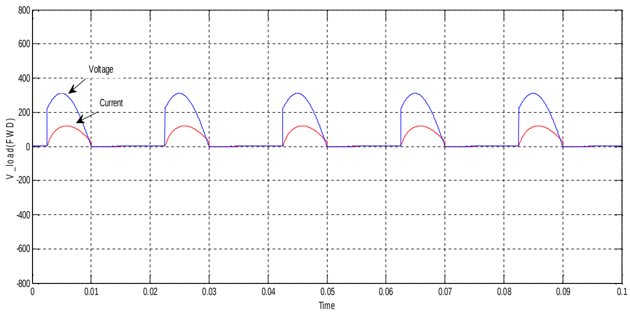

Fig. (f): Output voltage and current for inductive load and freewheeling diode and α = 45^0

4. CONCLUSION

Thus it has been observed that depending upon the load connected output of the converter changes. The firing angle of all the circuits have been taken as 45^0.It can be changed as per the requirement of the load for a particular application. The freewheeling diode is required only in case of inductive load since inductance stored energy is to be dissipated in resistance through the diode.

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