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Design And Simulation Of Firing Circuit Using Cosine Control Scheme

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***Abstract*: - Single phase fully controlled converter is used to convert the single phase AC into DC which is used for industrial applications such as DC motor loads. Controlled DC voltage with linear transfer characteristic is important in many industrial applications. The synchronization of the pulses is also very important. The main objective of this paper is to design an efficient, simple, robust and economical control circuit thereby triggering the fully controlled converter using four thyristors. It is a two quadrant converter where voltage polarity can reverse, but current direction cannot reverse because of unidirectional nature of thyristors. To achieve this, the Ramp control scheme is investigated and analyzed. Further, the Ramp and Cosine control schemes have been simulated in SaberRD student edition simulation software and analyzed.**

Keywords — Cosine control, firing pulses, Ramp control, SaberRD simulation tool

I. INTRODUCTION

Power electronic devices may be used as switches. Thyristors or Silicon Controlled Rectifiers (SCRs) are widely used as switching devices in the medium and large power levels starting from few kilowatts to several mega watts at voltage levels of few hundred to several kilo volt levels. To turn on a thyristor, various control schemes are used to generate gate pulses or firing pulses which are supplied between gate and cathode of the thyristor. The number of degrees from the beginning of the cycle when the thyristor is gated or switched on is referred to as the firing angle, α (alpha) and when the thyristor is turned off is known as extinction angle, β (beta).

II. OBJECTIVES AND SCOPE

The main objective of this project is to design an efficient, simple, robust and economical control circuit thereby triggering the fully controlled converter. The fully controlled converter uses four thyristors. It is a two quadrant converter where voltage polarity can reverse, but current direction cannot reverse because of unidirectional nature of thyristors.

III. CONCEPTUALIZATION

A single phase fully controlled bridge with four thyristors is shown in Fig.1[4]. Appropriate pulses between the gates and cathodes of the thyristors T1 to T2 are to be supplied with a provision to vary the firing angle α. With reference to the single phase converter circuit shown in Fig. 1, we note that when VAB > 0 or positive, two diagonally opposite thyristors T1 and T2 are forward biased and other two thyristors T3 and T4 are reversed biased.

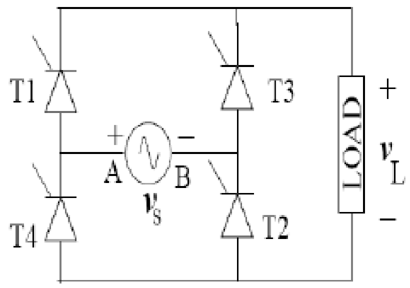

Fig. 1 Fully controlled converter

Assuming the rms value of the supply voltage to be Vs, the output voltage V_0 can be obtained [4].

$$V_0 = 1/\pi \int_{\alpha}^{\pi+\alpha} \sqrt{2}V_s \sin\omega t d(\omega t) \quad (1)$$

$$V_0 = \frac{2\sqrt{2}}{\pi} V_s \cos\alpha \quad (2)$$

$$V_0 = 0.9\, V_s \cos\alpha \quad (3)$$

Where V_o – output voltage of the converter
V_s – input voltage of the converter
α – firing angle in degrees

IV. RAMP CONTROL SCHEME

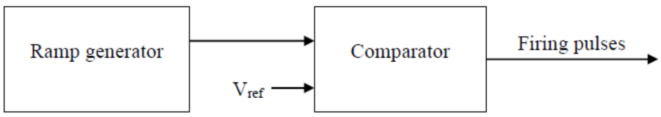

Fig. 2 Block diagram of Ramp control scheme

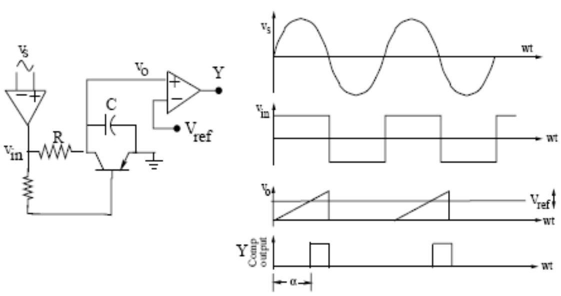

Fig.3 Circuit diagram and waveforms

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The first comparator translates the input sinusoidal voltage into a square wave voltage. When the square wave voltage is high, the transistor (P-N-P type) collector-base junction is forward biased; the transistor is in non-conducting stage (off) and the capacitor charges exponentially giving ramp rise of the voltage at the output. However, as soon as the square voltage is negative, transistor becomes on due to collector-base junction is reverse biased and the capacitor discharges sharply giving a saw tooth like waveform as shown in Fig. 3. This triangular voltage can now be compared by the second comparator with a variable reference d.c. voltage (Vref) to get the firing pulse signal at Y. The value of α can be varied in the range 0°≤ α ≤ 180° by changing the value of the reference voltage (Vref).

A. Design and simulation of the Ramp control scheme

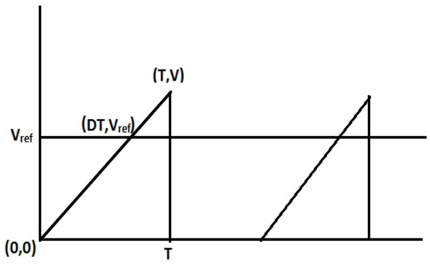

Fig. 4 Ramp signal

Referring the above figure, applying the two point formula,

$$\frac{V_{ref}-0}{DT-0} = \frac{V-V_{ref}}{T-DT} \quad (4)$$

$$\frac{V_{ref}}{DT} = \frac{V-V_{ref}}{T-DT} \quad (5)$$

$$\frac{V_{ref}}{DT} = \frac{V-V_{ref}}{(1-D)T} \quad (6)$$

$$V_{ref}(1-D) = D(V-V_{ref}) \quad (7)$$

$$V_{ref} = DV \quad (8)$$

$$D = \frac{V_{ref}}{V} \quad (9)$$

Where V_{ref} – reference dc voltage

V – voltage of ramp
D – duty ratio
T – time period

A. Simulation Results

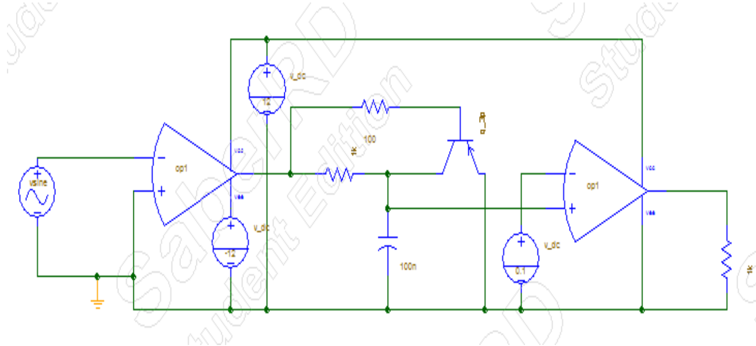
Fig. 5 Schematic of the Ramp control scheme

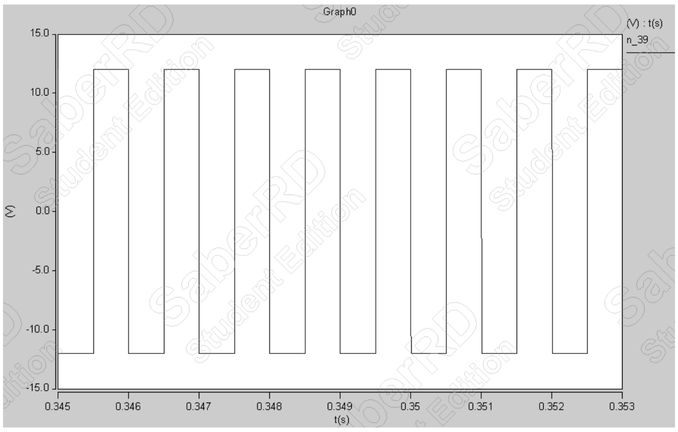

Fig. 6 Output of Ramp control scheme

(i) Half Wave Rectifier with Ramp control Scheme

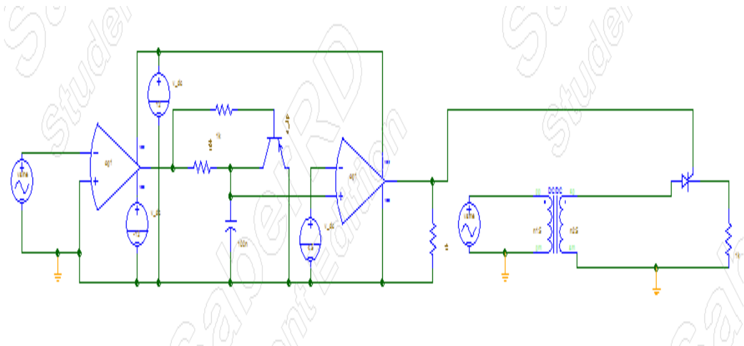
Fig. 7 Schematic of Half wave rectifier with Ramp control scheme circuit

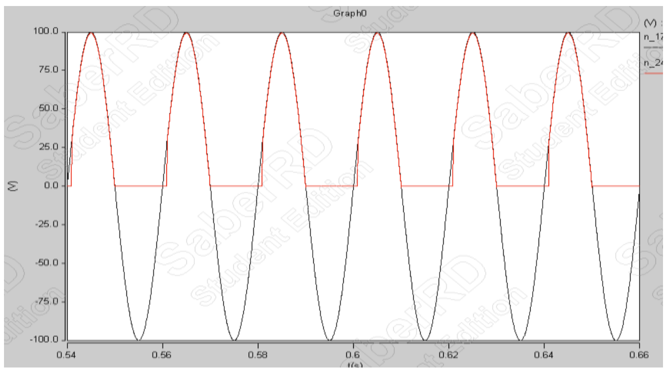

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Fig. 8 Output waveform of Half wave rectifier with Ramp control scheme circuit

(ii) Full Wave Rectifier with Ramp control Scheme

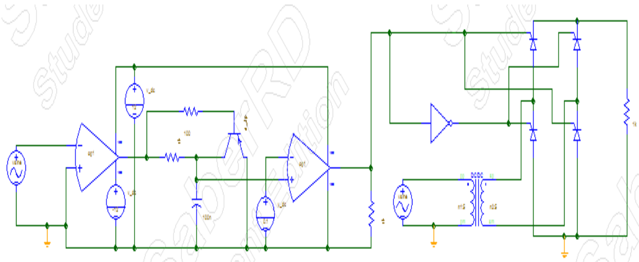

Fig. 9 Schematic of the Circuit

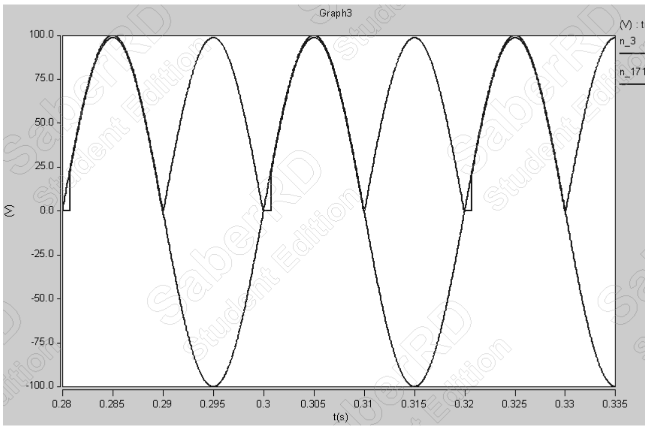

Fig. 10 Output waveform of Full wave rectifier with Ramp control scheme circuit

A. Limitations of the scheme

- Firing angle does not vary linearly with the dc control voltage
- It provides limited range of firing angle variation
- Any changes in the input supply, causes changes in the output.

I. Cosine Control Scheme

In this scheme, the supply voltage Vs is first integrated to obtain a cosine wave as shown in Fig. 11. The cosine wave so obtained is compared with a reference d.c. voltage (Vref). Therefore square pulses will be generated at the output terminal Y of the comparator. The signal at Y is synchronized with the pulse and is delayed from the supply zero crossing by an angle α. The value of α can be varied a range of 0°≤ α ≤ 180°.

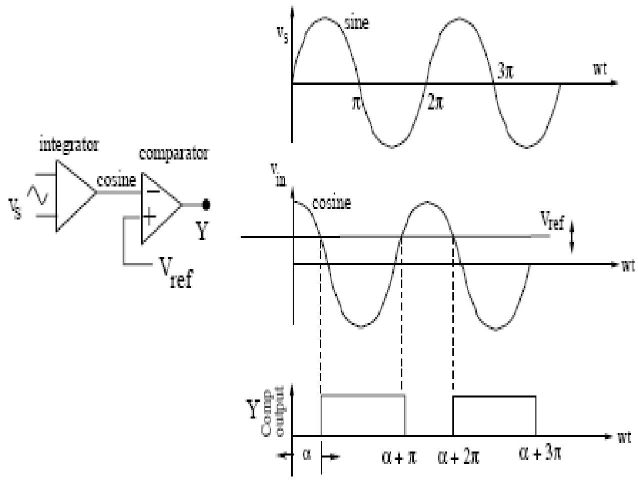

Fig.11 Cosine control scheme conceptualization

A. Block diagram of the scheme

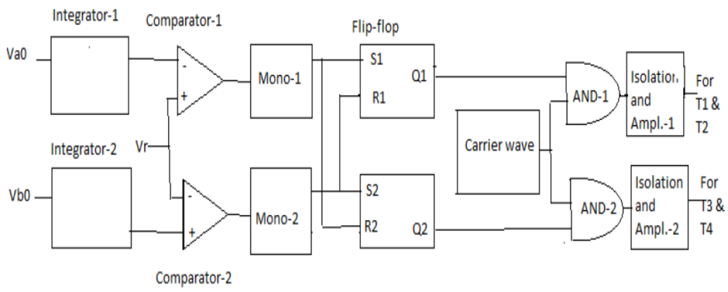

Fig. 12 Block diagram of the cosine control scheme

Assume V_{ab} as the supply voltage feeding the converter for which the control pulses are to be generated. With the help of a step down center tapped transformer, V_{ab} is transformed into two power level voltage V_{a0} and V_{b0}, these are 180° out of phase. T1 and T2 are fired when V_{a0} is positive and T3 and T4 are fired when V_{b0} is positive. The range of variation of firing angle is 0 to 180° from the instant when V_{a0} is crossing zero and increasing in positive direction. The signal V_{a0} is integrated with integrator-1 and generate cosine wave and then it is compared with the comparator with the reference voltage V_r for generating the square wave, monoshot blocks are used for generating the pulses of small width which are displaced by 360°. Same is done with V_{b0} by using integrator, comparator and monoshot block-2 and the pulses generated by monoshot-1 and monoshot-2 are shifted by 180°. The output of monoshot-1 and monoshot-2 can be used in conjunction with two SR flip-flop so as to generate two square waves each having a fixed width of 180°.

B. Advantages of the scheme

- The advantage of this scheme is that the output voltage is proportional to the control voltage.

- The output voltage is independent of variation in input voltage
- This scheme also provides automatic negative feedback to the changes in input ac supply
- Single phase fully controlled converter is used to convert the single phase AC into DC which is used for industrial applications such as DC motor loads. As per the industrial need, controlled DC voltage with linear transfer characteristic is important in its applications. Hence, cosine control scheme is adopted.

II. Simulation Results

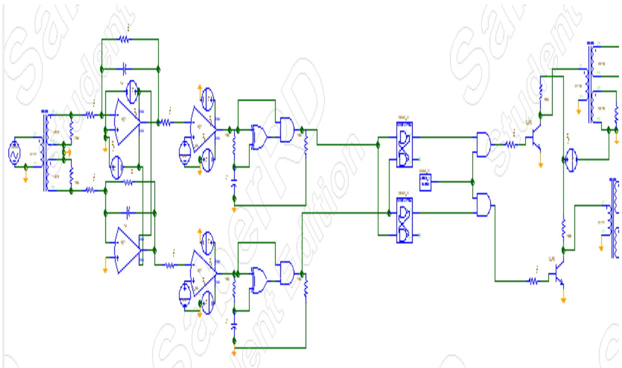

Fig. 13 Schematic of cosine control scheme

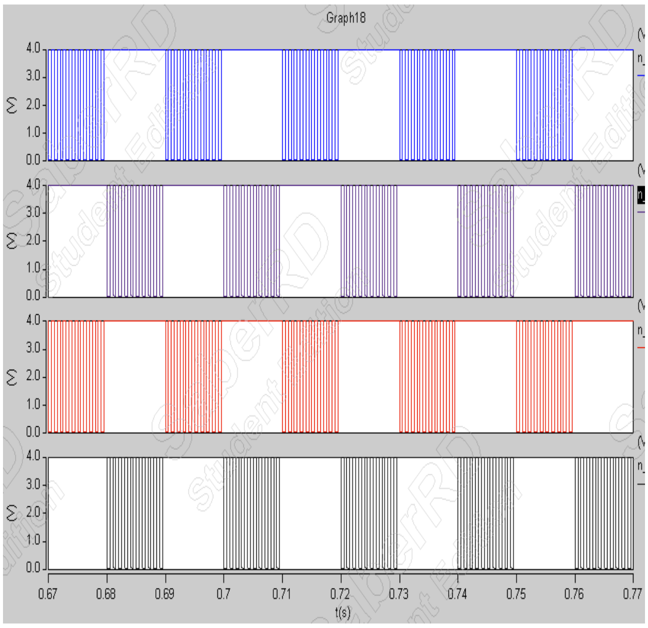

Fig. 14 Firing pulses

Conclusion

Gate pulses obtained by the Ramp control scheme have been effectively utilized to control the output voltage of single phase half wave and full wave controlled rectifiers on resistive load. Through the simulation, the disadvantages of the Ramp control scheme could be studied and analyzed. We observe that the cosine control firing scheme has an advantage that the output voltage is proportional to the control voltage. This scheme also provides automatic negative feedback to the changes in input ac supply.

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