Design and Simulation of Triggering Circuit for Single-Phase Full-Wave Controlled Rectifier

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Abstract - ***This paper presents the design and simulation of a triggering circuit for single-phase full-wave controlled rectifier under variable supply voltage conditions. The triggering circuit is consisting of step-down transformer, uncontrolled rectifier, comparator, differentiator, monostable multivibrator, pulse amplifier and isolating transformer. The triggering pulses for the thyristors are generated by comparing the voltage sensor output with the reference dc voltage derived from the uncontrolled rectifier. The simulation results show that the delay angle can be controlled from zero to ninety degree by changing the reference voltage. From the simulation results, it is found that if the delay angle is kept to a specific value, it does not change with the variation of ac supply voltage and frequency. The triggering circuit will find good industrial applications for changing the dc output voltage of the controlled rectifier.***

Key Words: *Simulation, constant delay angle, controlled rectifier, line commutation, thyristor, variable voltage and frequency*

1. INTRODUCTION

Thyristors, or silicon controleld rectifiers (SCRs), are used in many areas of electronics where they find uses in a variety of different industrial applications, and in particular for power control [1-5]. These devices have even been called the workhorse of high power electronics. It is able to switch large levels of power with a wide variety of different applications. It is also used in low power electronics where they are used in many circuits from light dimmers to power supply over voltage protection. Because of its low cost and ability to work at high voltages, SCR is a better choice compared to Bipolar Junction Transistor (BJT) and Metal Oxide Semiconductor Field Effect Transistor ((MOSFET) [1-3].

Thyristor turning ON, also known as triggering, initiates it from Forward-Blocking state to Forward-Conduction state [1]. There are various control schemes used to generate gating pulse or firing pulse which are supplied between the gate and cathode of SCR. The output of thyristor rectifier provides a dc voltage with variable average value. The average voltage can be controlled and adjusted electronically by delaying the current pulse to the thyristor gate in proper synchronism with the ac input supply voltage. The same supply voltage is given to the bridge rectifier circuit and the triggering circuit through a step-down transformer.

There are many experimental research works that had addressed the improvements and innovations in generating triggering pulses [6-12]. There are plenty of ways to control the firing angle of the gating pulses, such as, using feedback control [8] and embedded system with double sided isolation [11]. In one scheme [9], a ramp signal is generated in synchronism with input ac supply voltage by using two comparators and an approximate ramp generator circuit using a transistor and capacitors. In other schemes [6,12], the supply voltage is first integrated to obtain a cosine wave and is compared with a reference dc voltage. The advantage of this method is that the output voltage is proportional to the control voltage i.e., the output voltage is independent of variation in input voltage. However, these circuits are not able to generate a triggering pulse of constant delay angle during supply voltage and frequency fluctuation due to the fact that the reference voltage is taken from a separate source.

In this paper, we have simulated the triggering circuit for single-phase full-wave controlled rectifier under variable supply voltage and frequency where the reference voltage is generated from the output of step-down transformer. The reference voltage is proportional to any supply voltage fluctuation and the firing angle remains constant irrespective of system voltage and frequency variations.

2. CIRCUIT AND SYSTEM DESCRIPTION

2.1 Block Diagram of Firing Control Scheme

Figure 1 shows the schematic block diagram of the control scheme. The main supply is given to the converter and the voltage sensor for generating triggering pulses for SCRs.

The scheme consists of step down transformer, uncontrolled rectifier, comparator, differentiator, monostable multivibrator, oscillator, AND gate, pulse amplifier and pulse transformer.

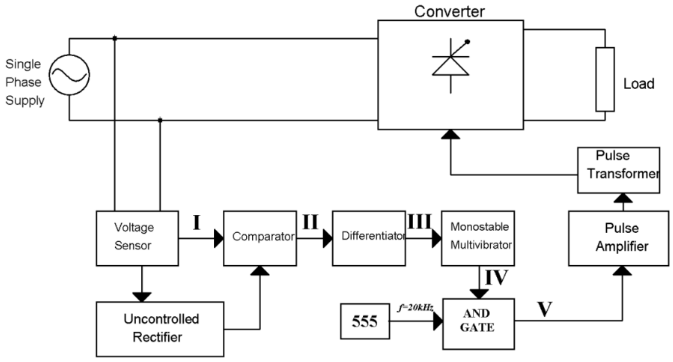

Fig-1: Schematic block diagram of firing circuit.

2.2 Circuit Diagram and Description

The complete circuit diagram of triggering circuit is shown in Fig. 2. A single-phase transformer with center tapped secondary windings has been used. The main purpose of this transformer is to step down 50Hz, 220 V to 6-0-6 V.

The secondary voltage of the transformer is compared with a dc reference signal using a 741C op-amp comparator to produce an alternating rectangular waveform of a variable pulse width. The output of the comparator ideally swings between +5 and -5 V at every crossing transformer output dc reference voltage. Using a variable resistor, the dc reference voltage can be altered and hence the rectangular waveform of variable pulse width is obtained at output terminal.

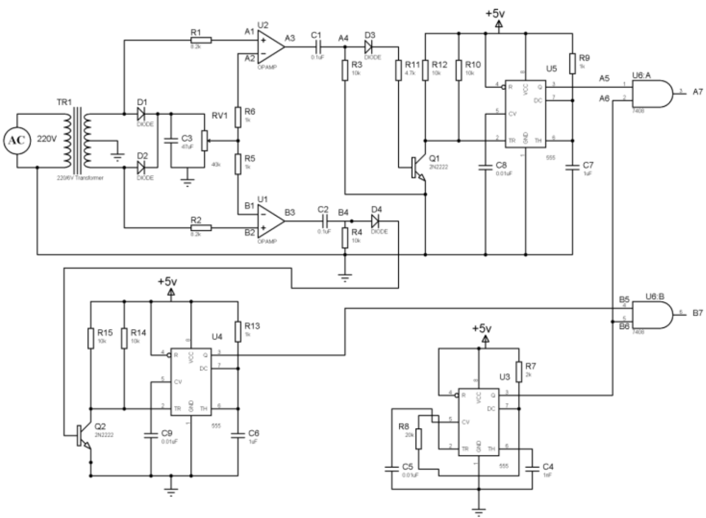

Fig-2: Circuit diagram of the triggering circuit.

A simple R-C differentiator is used to differentiate the rectangular voltage waveform. The elements R and C are selected as 10KΩ and 0.01μF, respectively.

Monostable multivibrator often called a one shot multivibrator, is a pulse generating circuit in which the duration of this pulse is determined by the RC network connected externally to the 555 timer. A 555 timer produces an output pulse using a positive going edge trigger to produce a delay angle between 0º and 90º for the conversion mode of operation. The negative spike of the differentiator is blocked by a connected diode. The number of comparators and monostable blocks are 2 blocks to produce firing pulses for conversion and inversion mode together. The values of R9 and C7 for the monostable are chosen so that the pulse width is approximately 0.5ms. Once triggered, the circuit's output will remain in the high state until the set time elapses. The output will not change its state even if an input trigger is applied again during this time interval. The output will remain in the low state until a trigger is again applied.

IC 555 timer is used as oscillator. The oscillator produces square wave output waveform of of 20kHz by connecting suitable resistor and capacitor. Pulse gating of thyristor is not suitable for RL loads, this difficulty can be overcome by using continuous gating. However, continuous gating may lead to increased thyristor losses and distortion of output pulse. So, a pulse train generated by modulating the gate pulse at high frequency is used to trigger the thyristor. This high frequency wave is known as carrier wave and is generated by using 555 timer.

The outputs of monostable multivibrator and oscillator are applied to the AND gate. IC 7408 two input AND gate is used for this purpose. A long duration pulse may saturate the pulse transformer and the firing pulse may be distorted so high frequency modulation is necessary. The duty cycle is kept less than 50 percent, so that the magnetic flux in the transformer can be reset. The modulation pulse also reduces the gate dissipation.

3. RESULTS AND DISCUSSIONS

The simulation results obtained using proteus Professional 8.1 software are shown in Figs. 3-6. The comparator inputs are taken from step down transformer TR1 and uncontrolled rectifier as shown in Fig. 3. The dc reference voltage can be altered by adjusting the variable resistor RV1 in Fig. 2 and hence the pulse width of the rectangular waveform obtained at A3 of comparator U2 can be varied. The differentiator output is obtained at A4 is also shown in Fig. 3. Figure 4 shows similar results obtained from the comparator U1 and differentiator B4.

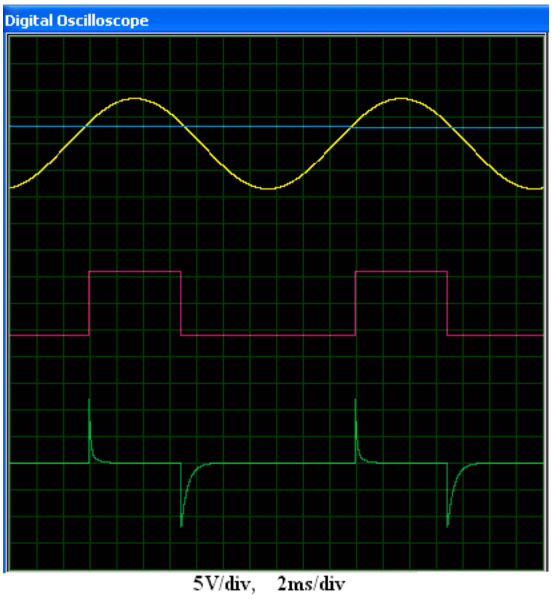

Fig- 3: Simulation results for comparator U2 input A1 and A2 in dual mode, comparator U2 output at A3 and differentiator output at A4 .

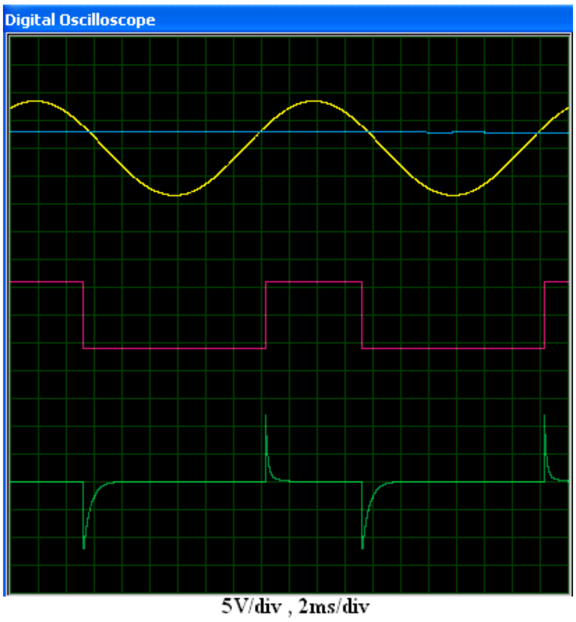

Fig- 4: Simulation results for comparator U1 input B1 and B2 in dual mode, comparator U1 output at B3 and differentiator output at B4 .

The output of differentiator A4 triggers the monostable multivibrator U5 to generator a pulse of fixed pulse width at the output A5 as shown in Fig. 5. This is ANDed with the oscillator U3 output at A6. The output of the AND gate at A7 generates a train of pulse with a frequency of 20kHz. Figure 6 is a zoomed picture of the simulation results for monostable U5 output, oscillator U3 output and AND gate U6:A output.

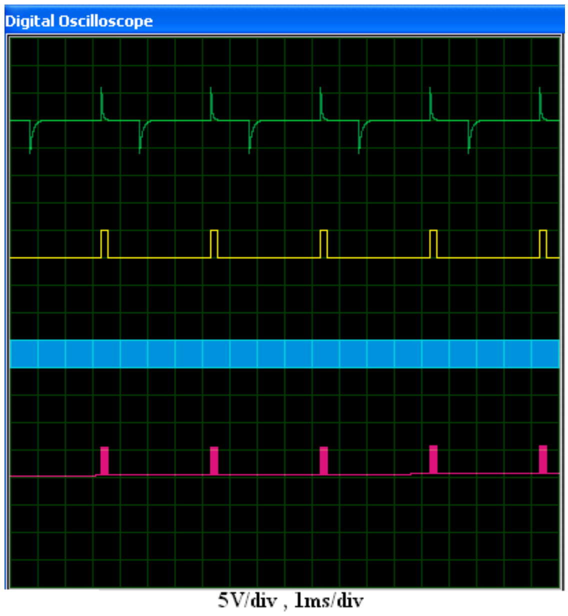

Fig-5: Simulation results for differentiator output at A4, monostable vibrator U5 output, oscillator U3 output, AND gate output.

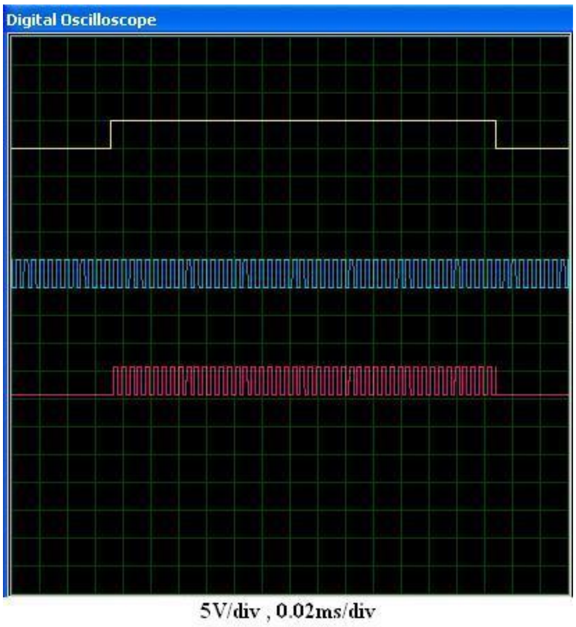

Fig. 6. Simulation results for monostable vibrator U5 output, oscillator U3 output, AND gate U6:A output.

3. CONCLUSIONS

In this paper a triggering circuit for a single-phase full-wave controlled rectifier has been simulated using Proteus Professional software. The simulation results shows that the present control scheme provides gating pulse where the firing angle is proportional to the dc control voltage and does not change with any variation in system voltage and frequency. The circuit may be implemented in the laboratory and the experimental results may be compared with the simulation results in future. The present control scheme can be successfully utilized to get the controlled dc voltage for industrial applications.

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