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A STEP-BY-STEP IMPROVEMENT OF THE GATE CONTROL OF AN SCR POWER CONTROL CIRCUIT

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Abstract: Silicon Controlled Rectifiers are widely used to control the power in a large number of industrial control applications. This paper presents the gradual change in the gate control circuit of an SCR. To get a controlled amount of electrical power, an SCR is triggered at different angles of the voltage cycle. The control of this triggering is examined by use of a number of control circuits – from rheostatic control to the UJT-triggered full-wave control circuit. The performances of all the circuits are studied and the most satisfactory circuit is recommended.

Keywords: SCR; Diac; Power control Circuit; UJT relaxation oscillator

Introduction

There are numerous applications like electric welding, electric heating, motor speed control and a variety of other industrial control applications which require the delivery of a variable and controlled amount power (Schuler *et al*., 1986). These could be performed by using a variable transformer to create a variable secondary output or by inserting a rheostat in series with the load (Maloney, 1979; Pascoe, 1976). But these methods are expensive, have less efficiency and need frequent maintenance. So solid state controls of power are recently getting more popularity. Thyristors especially SCRs are primarily used for such a power control circuit (Dowan and Straughen, 1975). But it is often a problem to have a suitable gate control of an SCR power control circuit (Kadir *et al*., 1992).

There may be different arrangement for the gate control (Millman and Halkias, 1971). In this paper, the gradual improvement of the gate control is presented with corresponding merits and demerits. The circuits were experimented with different loads and the data are presented to illustrate their performances.

Improvement of Gate Control Circuit

Some gate triggering arrangements are presented here.

Rheostatic control: This is the simplest type of gate control circuit shown in Fig. 1. Firing delay angle is determined by the setting of R_2 the variable resistance. The purpose of R_1 is to protect the gate from overcurrent in the event R_2 is zero. This type of circuit is very useful in alarm plications; but the firing angle is usually adjustable only from 0° to 90°. So we go to the capacitive gate ontrol.

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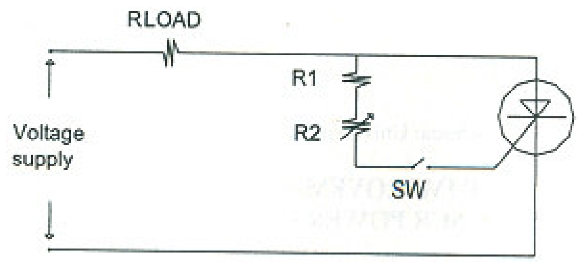

Fig.1. Rheostatic Control.

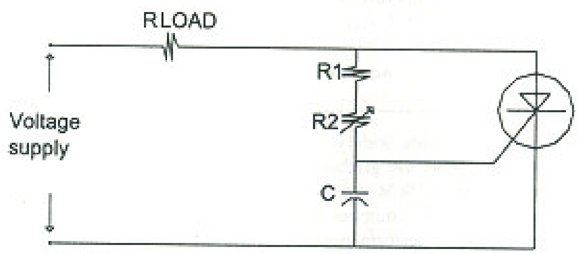

Fig.2.1. Capacitor used in Control Circuit

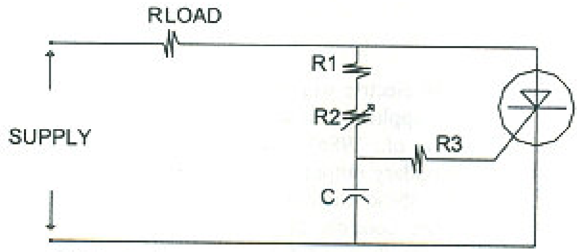

Fig.2.2. Resistor inserted in Capacitive delay

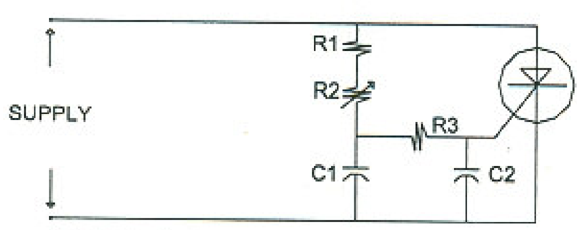

Fig. 2.3. A double RC gate control

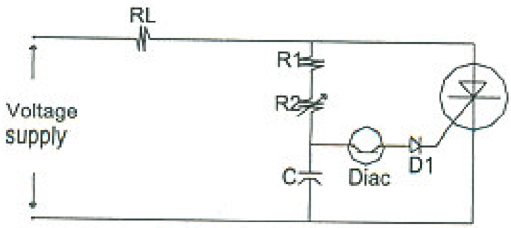

Fig. 3. Using diac in the gate load

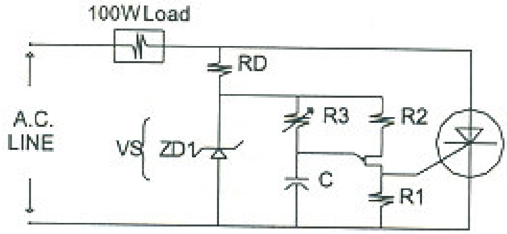

Fig. 4.1. UJT relaxation oscillator used in triggering SCR.

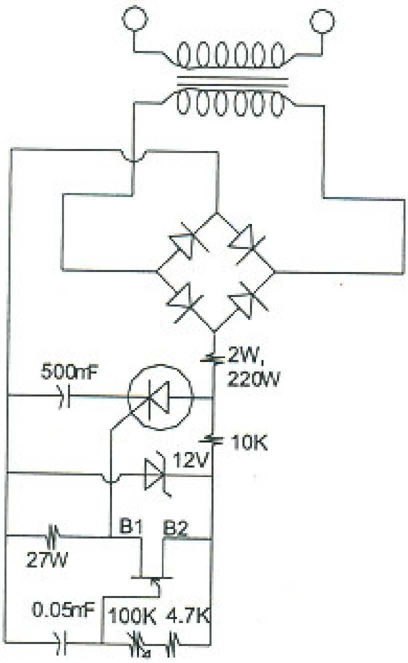

Fig. 4.2. UJT-Triggered full-wave power control circuit

Capacitor Used to Delay Firing: Figures Fig. 2.1, Fig. 2.2 and Fig. 2.3 illustrate three different arrangement of capacitors to delay firing. During the negative half-cycle of the supply in Fig. 2.1, the capacitor C is charged with negative on the top plate and positive on the bottom plate. When the supply enters its positive half-cycle, the forward voltage across the SCR tends to charge C in the opposite direction. However, voltage build-up in the new direction is delayed for removal of charges in the capacitor plates. This delay can be extended past the 90° point.

In the circuit of Fig. 2.2, a resistor has been inserted into the gate lead, requiring the capacitor to charge higher than the circuit in Fig. 2.1 to trigger the SCR. Hence delay is extended more in this arrangement. Fig. 2.3 shows a double RC network for gate control. In this scheme, the delayed voltage across C_1 is used to charge C_2, regulating in even further delay in build-up of gate voltage.

Using Breakover Devices in the Gate Lead

All the circuits discussed so far share two disadvantages. These are:

Temperature dependence: An SCR tends to fire at lower gate current when its temperature is higher. So a change in temperature causes a change in firing angle and a consequent change in load current.

Inconsistent firing behaviour between SCRs of same type: The aforesaid circuits cannot tolerate the variation in electrical characteristics of different types of SCRs, especially the variation in I_{GT}.

These disadvantages can be eliminated by using breakover device like a diac in the gate lead. If the voltage across the capacitor is below the breakover voltage of diac, the diac acts as an open switch. But as soon as the capacitor voltage crosses the breakover point, the diac acts as a closed switch causing burst of current into the gate. Diac has the advantage that it is relatively independent of temperature and that the breakover voltage can be held constant from one unit to another. In the circuit of Fig. 3, diode D_1 is inserted into the gate circuit to prevent the reversal of gate current.

Delayed Firing of SCR by UJT

This scheme of gate control, as shown in Fig. 4.1, uses UJT relaxation oscillator to trigger the SCR. In this circuit, Z_{D1} clips the V_s waveform at the zener voltage during the positive half-cycle of the ac line. Zener diode serves as a dc biasing source for the relaxation oscillator. This circuit provides automatic synchronization between the firing pulse of the UJT and the SCR polarity. That is, when the UJT delivers a pulse, the SCR is guaranteed to have the correct anode to cathode voltage polarity for turning ON. To have the full-wave UJT-triggered power control by SCR, the circuit can be arranged as in Fig. 4.2.

Experimental Results

Experiments have been conducted with different types of gate control circuit for resistive lamps, inductive choke coil and a dc series motor. The result is a variation in the range of firing angle through which the static or dynamic loads can be varied. The results can be summarized as follows.

1. Diac circuit with resistive load was successful in controlling power angles from 45° to 140°.
2. Diac circuit with a choke coil having $R = 18.8\Omega$ and $L = 0.80H$ was tested and faithfully controlled power from 60° to 130°.
3. UJT full-wave control circuit with resistive load supported power variation from 5° to 180°.

4. UJT full-wave control circuit with dynamic load (dc motor) gave a little poor performance, still its performance was better than other circuits. It gave a power variation from 30° to 160°.

Conclusion

The results of our experiments reveal that UJT full wave circuit as in Fig. 4.2 is the most suitable gate control circuit. The advantages of using UJT in SCR trigger circuits are threefold. Firstly, UJT produces a pulse type output, which is excellent for accomplishing sure turn-ON of an SCR without straining the SCR's gate power dissipation capability. Second, UJT firing is inherently stable over a wide temperature range. Finally, UJT control circuits are easily adaptable to feedback control. Taking all these considerations in view, the circuit in Fig. 4.2 is recommended for full wave power control.

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