Lecture three: AC voltage controller

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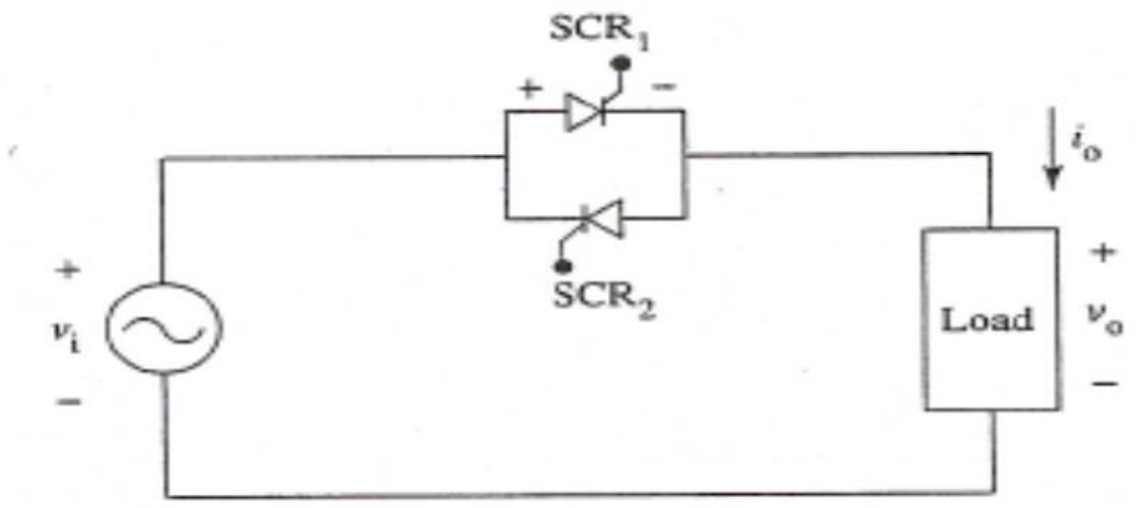
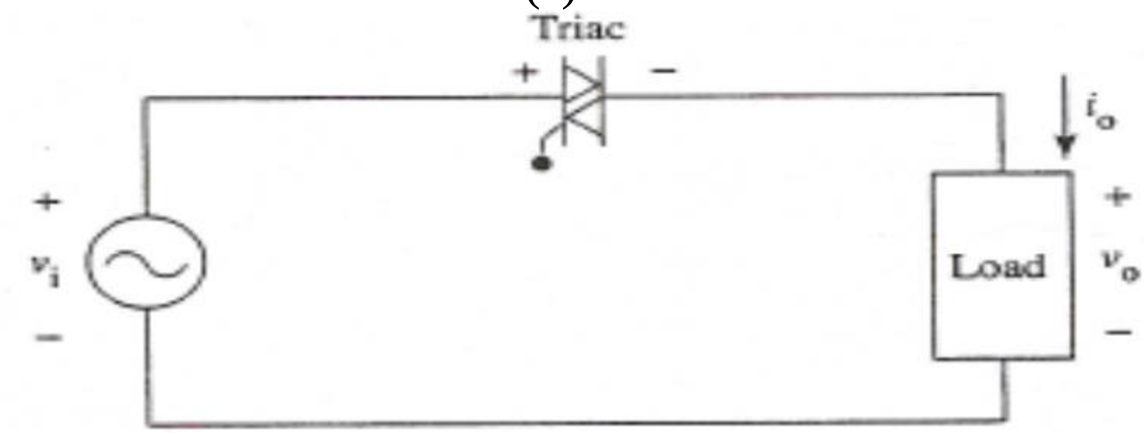
AC voltage controller

An alternating current voltage controller or regulator converts a fixed AC voltage source to a variable AC voltage source. The output frequency is always equal to the input frequency. The simplest way to control the AC voltage to a load is by using an AC switch. This switch can be bidirectional switch like a triac or a pair of SCRs connected in antiparallel as shown in Figure 3.1. Switching devices other than thyristors can also be used to implement bidirectional switches. For most purposes, the control result is independent of the switch used. The practical limitations of the presently available triac ratings often make it necessary to use SCRs in very high power applications for which triac might otherwise be used.



(a)



(b)

Figure 3.1: Basic AC Power Controller (a) an SCR Circuit, (b) a Triac Circuit

Applications of AC Voltage Controllers

(1) Light-dimmer circuits.
(2) Induction heating.
(3) Industrial & household heating.
(4) On load Transformer tap changing.
(5) Speed control of induction motors (single-phase and poly-phase).

Types of Thyrsitor control techniques

1- On-off (integral-cycle) control technique
2- Phase angle control technique

1. On-off (integral-cycle) control technique

   In the Ac voltage controller in Figure 3.1, the thyristors can be fires at α =00 to allow complete cycles of source voltage to be applied to the load. If there is no firing signal in any cycle, then no voltage appears across the load. This it is possible to allow complete cycles of source voltage to be applied to the load followed by complete cycles of extinction. If the load voltage is turned on and off in this matter (Figure 3.2), the average power to the load can be varied. The ratio of on time to total cycle time (the period in which the conduction pattern repeats) controls the average load power. In Figure 3.2 Ton is the number of cycles for which the load is energized and T is the number cycles in the full period of operation. During the Ton part of the cycle, the switch is on and the load power is maximum. During the remaining Toff (Toff = T -Ton) cycles, the switch is off and load power is zero.

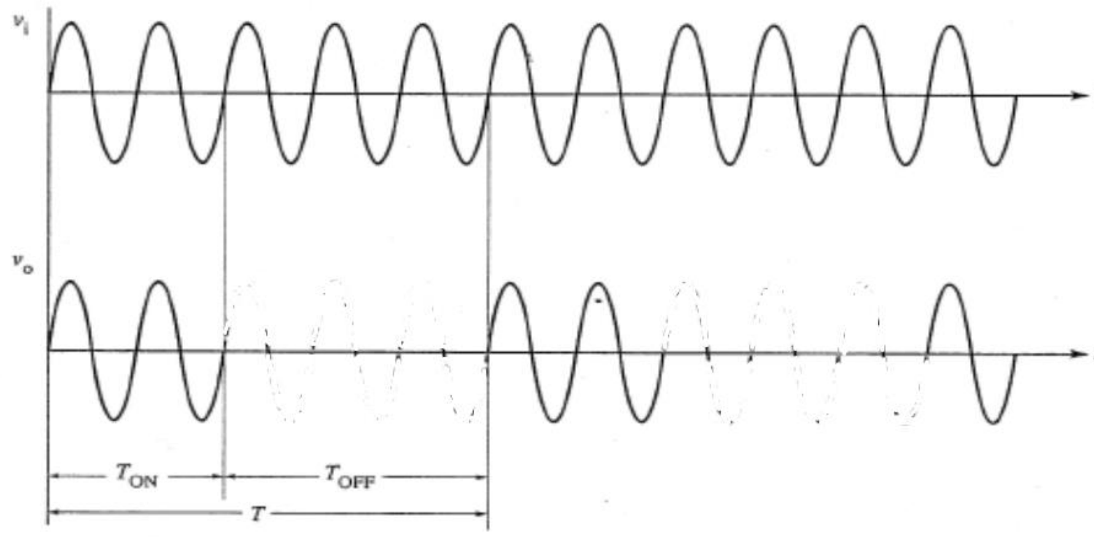


Figure 3.2 Integral Cycle Control

the on time interval is determined by

$t_{on} = n \times T$

the on and off time interval is determined by

$t_{off} = m \times T$

The Duty cycle (d) is determined by

$$Duty\ cycle\ (d) = \frac{n}{n+m}$$

The rms output voltage

$V_{o,rms} = V_s\sqrt{d}$

The input power factor

$PF = \sqrt{d}$

Example:

A single-phase full-wave AC voltage controller, is operating using ON/OFF control technique, has a supply voltage of 230V (rms), 50Hz, and a load resistance of 50Ω. The controller is on for 30 cycles and off for 40 cycles Calculate (1) the on and off time intervals, (2) Duty cycle, (3) the rms output voltage, (4) the input PF.

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Vs=230, f=50Hz, R=50Ω, n=30, m=40

$$V_m = \sqrt{2}\, V_s = 230\sqrt{2} = 325.269V$$

$$T = \frac{1}{f} = \frac{1}{50} = 0.02sec$$

1. $t_{on} = n \times T = 30 \times 0.02 = 0.6sec$

   $t_{off} = m \times T = 40 \times 0.02 = 0.8sec$
2. $Duty\ cycle\ (d) = \frac{n}{n+m} = \frac{30}{30+40} = 0.4285$
3. The rms output voltage

   $V_{o,rms} = V_s\sqrt{d} = 230\sqrt{0.4285}$=150.58V
4. The input power factor

   $PF = \sqrt{d} = \sqrt{0.4285} = 0.655$

2. Phase angle control

The basic circuit in Figure 3.1 can be used to control the power to a resistive load. As is done with a controlled rectifier, output voltage is varied by delaying conduction during each half cycle by and angle α. The delay angle α is measured from the source voltage zero. SCR1 which is forward biased during the positive half cycle, is turned on at an angle α. It conducts from α to π. Supplying power to the load. SCR2 is turned on half cycle later at π+α. It conducts up to 2π, supplying power to the load. The waveform in Figure 3.3 are identical to those of the full wave rectifier with a resistive load. The difference here is that each second half cycle has a negative current rather than a positive one. There is however no effect on the power, because power is a squared function.

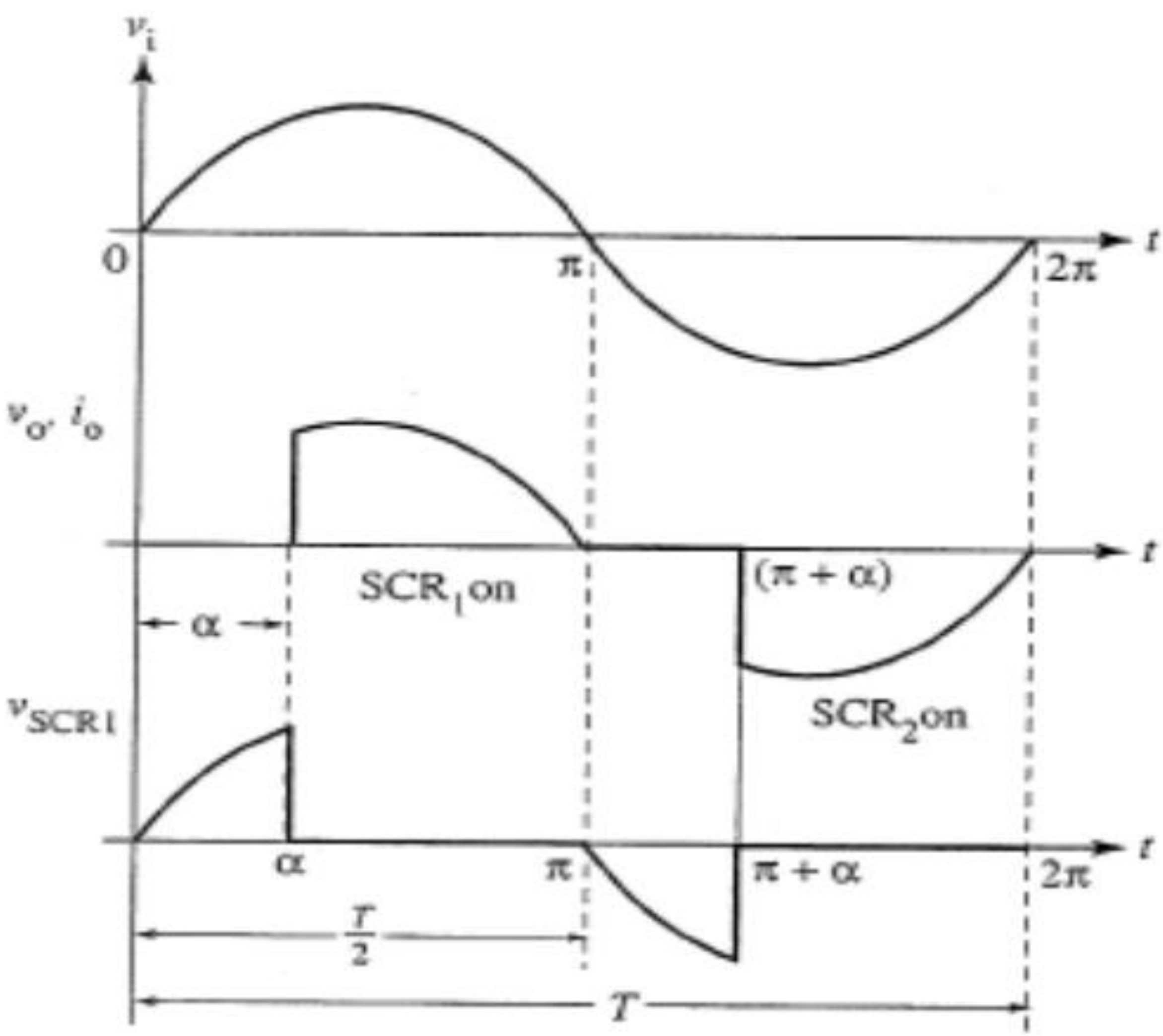

Figure 3.3: AC Phase Angle Control Waveforms with Resistive Load

The equation for the RMS value of the output voltage ($V_{o,rms}$) is:

$$V_{o,rms} = V_s\sqrt{1 - \frac{\alpha}{\pi} + \frac{sin2\alpha}{2\pi}} \qquad (1)$$

The equation for the RMS value of the output current ($I_{o,rms}$) with a resistive load is:

$$I_{o,rms} = \frac{V_s}{R}\sqrt{1 - \frac{\alpha}{\pi} + \frac{sin2\alpha}{2\pi}} \qquad (2)$$

Output power is given by:

$$P_{o(avg)} = {I_{o,rms}}^2 R \qquad (3)$$

The RMS current rating of the triac is given by

$I_{T(RMS)} = I_{o(RMS)}$

Example

A 120V source control power to a 5 Ω resistive load using a phase control switch. If the load power required is 1 kW, find

a) the maximum load current

b) the RMS value of load current

c) the RMS value of switch current if the switch is triac

a)
$$V_m = \sqrt{2}(120) = 170 \text{ V}$$
$$I_m = \frac{V_m}{R} = \frac{170}{5} = 34 \text{ A}$$

b) $P_{o(avg)} = 1000W$

$P_{o(avg)} = {I_{o,rms}}^2 R$

$1000 = {I_{o,rms}}^2\ 5$

$I_{o(RMS)} = 14.14 \text{ A}$

c) $I_{T(RMS)}$ is the same as the RMS load current, 14.14 A