INSTRUCTIONS

GEI-90839A
Supersedes GEI-90839

AIR-COOLED SILICON-CONTROLLED RECTIFIER (SCR) POWER TRAYS FOR SILCOMATIC POWER CONVERSION EQUIPMENT

SWITCHGEAR DEPARTMENT

GENERAL ELECTRIC

PHILADELPHIA, PA.

CONTENTS

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INTRODUCTION

Before installing or attempting to use this equipment, read these instructions carefully.

GENERAL DESCRIPTION

Each power tray is basically a power conversion unit using silicon-controlled rectifiers (SCR). These rectifiers provide a unidirectional current flow in which the time-of-start of the current is controlled.

The power trays are used in conjunction with transformers, excitation circuits, and other basic equipment to rectify (convert a-c power to d-c power), invert (convert d-c power to a-c power), or perform other applications involving unidirectional current flow with controlled conduction. The associated equipment in which power trays are used is generally referred to as "SILCOMATIC" power-conversion equipment.

TYPES OF POWER TRAYS

These instructions apply to the SCR Power Trays listed in the following table:

Catalog No.	SCR Cells per Tray	Type of Circuit	Special Features
0813D0351G1	12	3-Phase Bridge	None
	6	3-Phase Bridge	None
0813D0351G18	6	6-Phase Star or Double Wye	Tray bus positive
	6	6-Phase Star or Double Wye	Tray bus negative
0877D0361G1*	12	6-Phase Star or Double Wye	Tray bus positive
0925D0700G1	12	3-Phase Bridge	None
0925D0700G5	6	3-Phase Bridge	None
0925D0700G8	12	3-Phase Bridge	None
0925D0721G1	6	6-Phase Star	Tray bus positive
0925D0721G2	6	6-Phase Star	Tray bus positive

* Contains no fuses, lights or output transformers.

NOTE: All power tray ratings including voltage, current, frequency, maximum ambient temperatures and amount of cooling air are included in the instructions for the equipment in which these devices are supplied.

DEVICES

A typical SCR power tray is shown in Figure 1. This is a 12-cell tray, Cat. No. 0813D0351G1. Figure 2 shows the same tray installed in a SILCOMATIC rectifier. This particular tray contains most of the components commonly used in other trays.

As shown in Figure 1, the front panel of the tray containing the indicator lamps and tray handles is secured by two latches and drops downward to facilitate maintenance. The lamps (incandescent and neon) are connected in series with resistors and each lamp with its resistor connected across a SCR cell. All lamps are energized during normal operation.

Immediately behind the lamp panel (Figure 1) are six output transformers used to isolate and multiply the firing pulses. Coaxial cables from a plug connector at the left side of the tray (Figure 2) conduct the pulses to the H1-H2 connections of the output transformer. Similar coaxial cables from the "X" connections of the output transformers carry the pulses to the SCR cell control wires (gate and cathode).

Behind the output transformers (Figure 1) three cells mounted on heat sinks can be seen. Three more rows of cells are mounted behind the first row and two additional rows, not shown, are located near the back of the tray. At the center of the tray are the six power fuses and six reactors. The large resistors above the lower row of SCR cells provide for equal voltage division and resistor/capacitor circuits suppress transient surges.

The a-c cables (Figure 1) may be seen connected to the reactors near the center of the tray. Similarly, the d-c cables connect to the buses at the front and back of the tray.

A schematic diagram of the power devices used in the different types of power trays is shown in Figure 3.

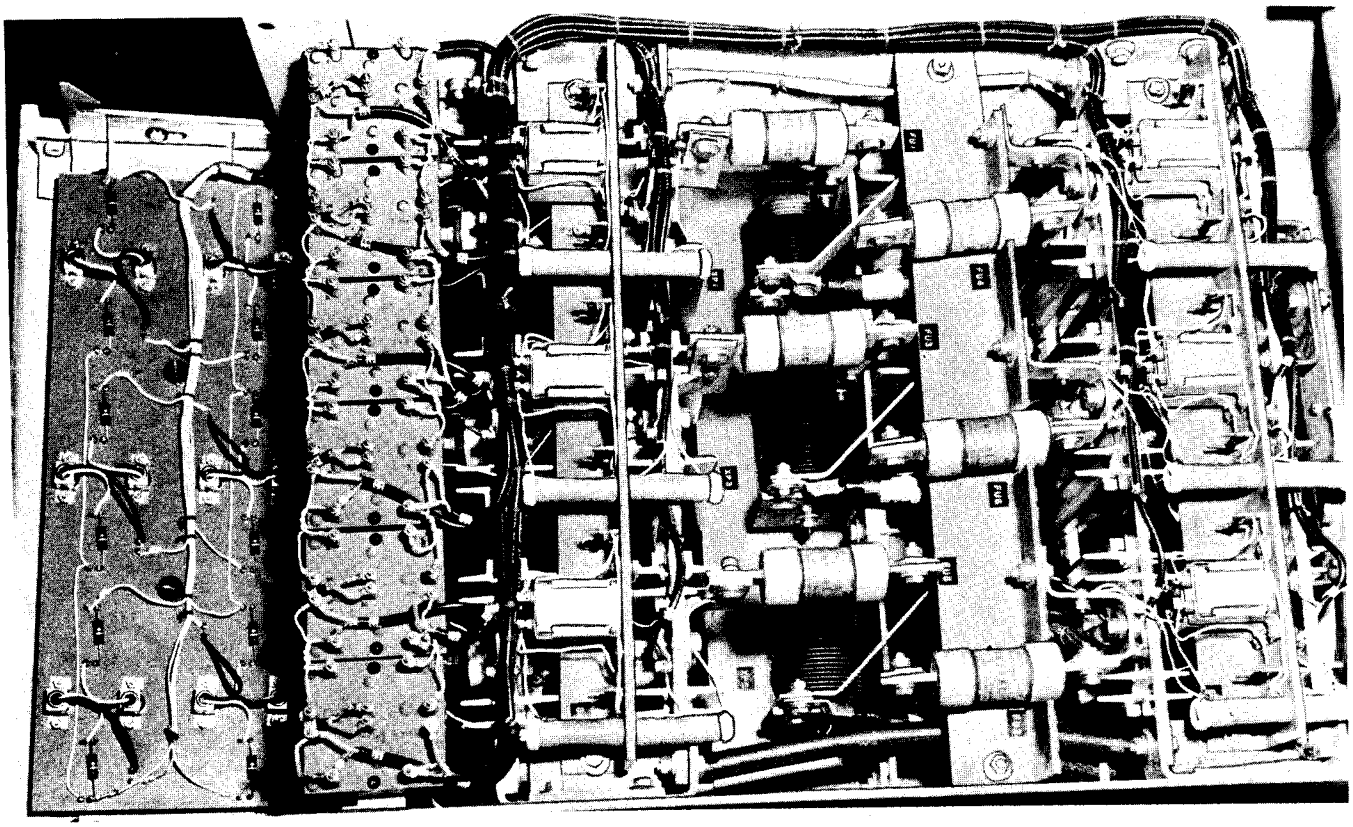


Fig. 1. Typical SCR Power Tray

RECEIVING, HANDLING AND STORAGE

Immediately upon receipt of the tray, examine it for any damage or loss sustained in transit. If injury or rough handling is evident, file a damage claim at once with the transportation company and notify the nearest General Electric Sales Office.

Unpack the tray as soon as possible after being received. Use care in unpacking to avoid damage. Be sure no loose parts are missing or left in the packing material. Carefully remove with vacuum or dry air any dirt or particles of packing material that may have accumulated on or in the tray.

If the tray is not installed at once, store it in a clean, dry place. Covering the tray will prevent accumulation of dust. Do not use moisture-absorbing covering material.

INSTALLATION

All SCR power trays are removable from the enclosure by sliding on steel members or moving on slides with rollers. The power connections to the tray are made by cables, and control connections by means of coaxial cables. Connections terminate at a terminal board or to a special plug.

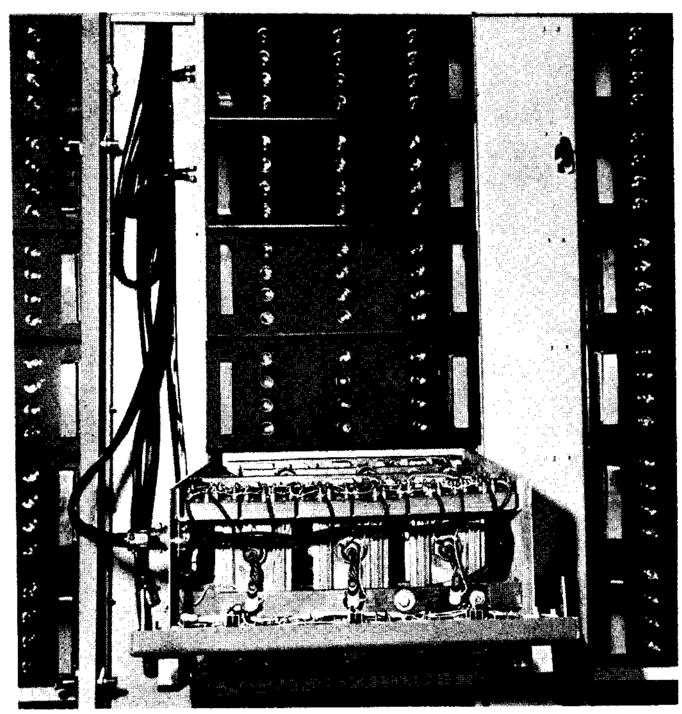


Fig. 2. Typical Power Tray Mounted in Silcomatic Rectifier

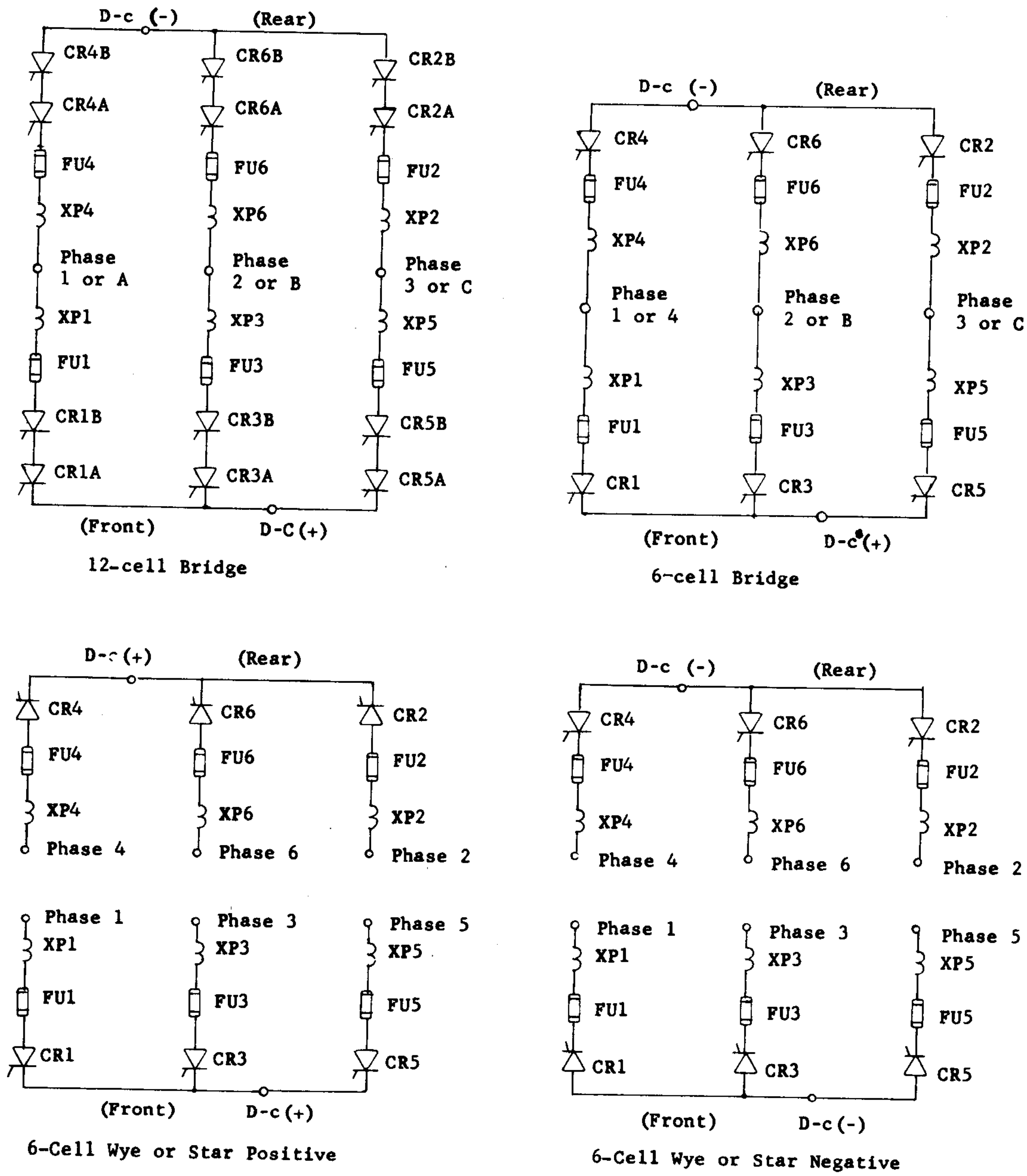


Fig. 3. Tray Power Circuits (Top View)

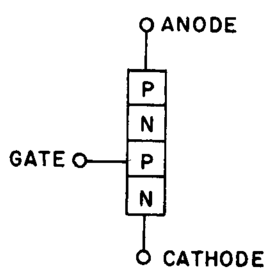


Fig. 4. Structure of Typical SCR Cell

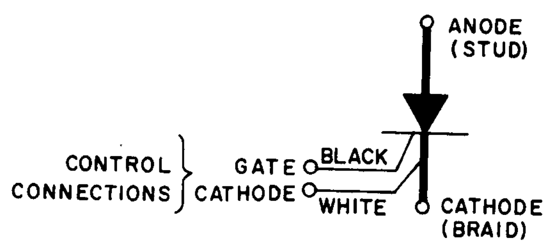


Fig. 5. Circuit Symbol of SCR Cell

The input and output power cables should terminate with lugs to bolt to the connecting points in the trays. The a-c connections are bolted to reactors in the middle of the tray, and the d-c connections fasten to bars at the front and rear of the tray. These bolted connections should be made with a good grade of electrical contact grease. To ensure current balance among parallel trays, all connections must be tight.

Both the phasing and polarities of the cables must be correct for proper operation. This is indicated on the diagrams of the over-all equipment and by component markings in the SCR power trays. Figure 3 shows the cable connections, power circuits, and power device identifications for the four basic circuits.

Control connections are terminated by means of a plug or terminal board. The control cables should be coaxial cable and must be connected in the correct sequential order.

OPERATION

The SCR power tray may be operated as a rectifier and/or an inverter, depending on the external power circuit and firing pulses applied to the SCR cells. Instructions for the primary equipment describe the type of operation. These instructions describe how the SCR cells provide controlled conduction periods both in rectifier and inverter circuits.

GENERAL DESCRIPTION OF SCR

The Silicon Controlled Rectifier, or SCR as it is more commonly called, is a three-terminal, semi-conductor device. It is much like an ordinary silicon rectifier, which has been modified to block in the forward direction until a small current signal is applied to the gate lead. After the gate signal is applied, the SCR will conduct in the forward direction with a forward characteristic very similar to that of an ordinary silicon rectifier. It will continue conduction even after the gate signal is removed. The SCR has characteristics similar to those of a gas thyratron, except that the forward drop is about 1/10th that of a thyratron (approximately 0.7 volt) and the turn-off time is much less than that of a thyratron (approximately 10-20 microseconds).

The SCR has a four layer structure with anode, cathode, and gate connections as shown in Figure 4. The SCR circuit symbol is shown in Figure 5.

ELECTRICAL CHARACTERISTICS

The forward and reverse characteristic of an SCR with no current applied to the gate is shown in Figure 6. In the reverse direction, the SCR has a characteristic very similar to a normal rectifier. That is, high impedance until the reverse voltage reaches a point where avalanche breakdown occurs.

The forward characteristic of the SCR is quite different from a normal rectifier. The SCR will block in the forward direction until the voltage reaches a value known as the "forward breakover voltage." At this point, the SCR breaks into a high-conduction state and exhibits a characteristic similar to a normal rectifier in the forward bias condition. The SCR will remain in this high-conduction state as long as the current is maintained above a certain minimum value known as the holding current. Should the current drop below this minimum value, the SCR will revert to the forward blocking state and remain there until the voltage is once again increased to the forward breakover value.

Changes in the forward characteristic as increasing values of gate current are applied are shown in Figure 7. The I_G=0 curve is the same as that shown in Figure 6, but enlarged to show detail. When a small value of gate current is applied (I_{G1}), the voltage where forward breakover occurs, becomes lower. Also, the holding current value becomes lower. As can be seen from the figure, as the gate current increases, the forward breakover voltage becomes lower, and the holding current is reduced in value. When the gate current reaches a high enough value, I_{G3}, the SCR exhibits a characteristic that is almost identical to the forward characteristic of a normal silicon rectifier.

In typical operation, an SCR is used that has a zero gate-current breakover voltage that is much higher than any voltage that will be encountered in the circuit. The SCR is then triggered by injecting current into the gate. The SCR is turned off by reducing the main current below the holding current value. This is the only way to turn off the SCR since the gate no longer has control once the SCR has fired.

FIRING PULSES

The firing-pulse current applied to the gate of an SCR cell is shown in Figure 8. This gate current flows into the black wire at the SCR cell, and returns through the white wire. Pulse specifications are listed below:

Pulse height and length: At least 150 milliamperes for 150 microseconds
Rise time (solid): From 15 to 135 milliampere in less than 20 microseconds
Rise time (dotted): From 15 to 135 milliampere in less than 40 microseconds. At the 135

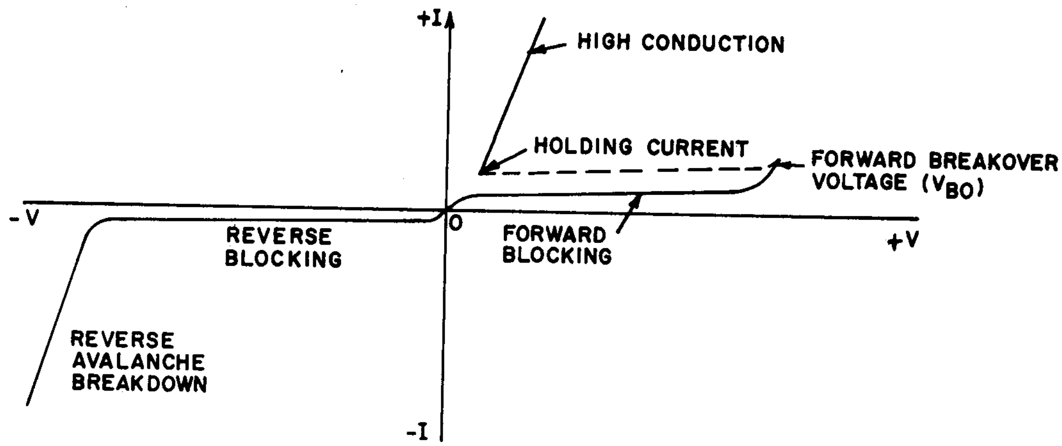


Fig. 6. Typical SCR Characteristics (No Gate Current)

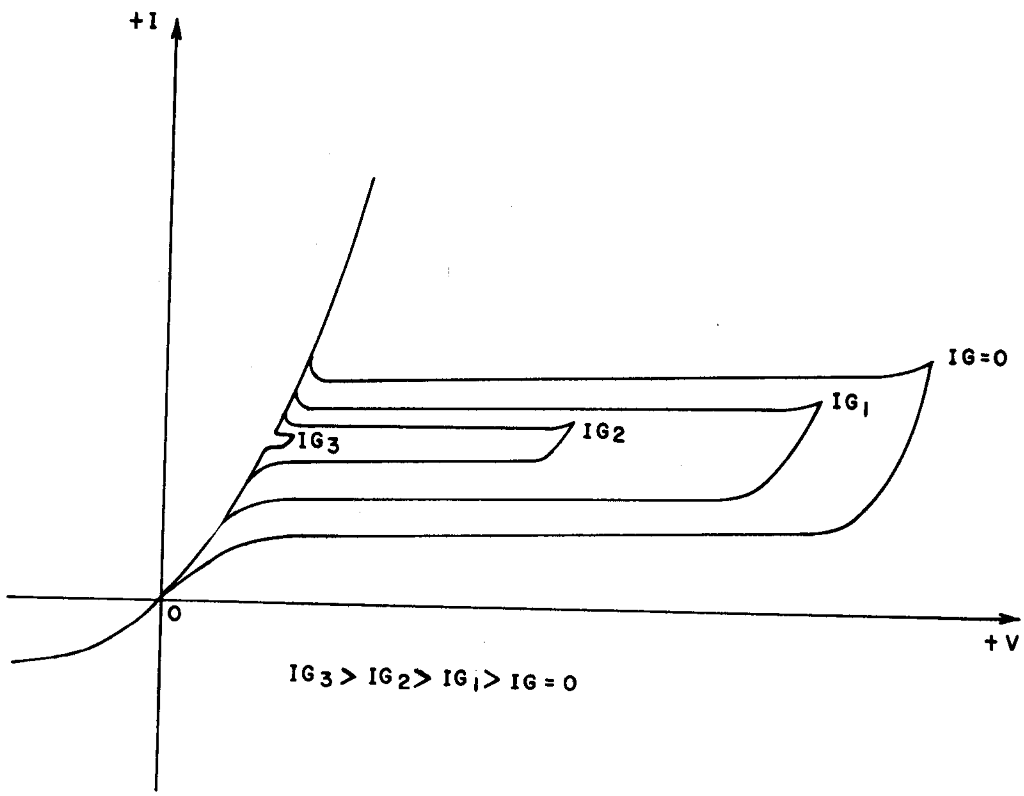
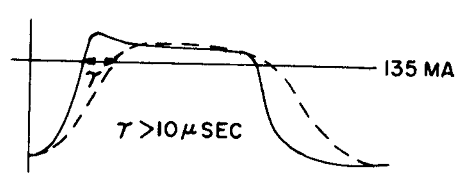


Fig. 7. Effect of Gate Current, I_G, on SCR Characteristics



(Dotted pulse applies only to the "B" cells of the 12-cell bridge tray)

Fig. 8. Firing Pulse Current

milliampere level(end of pulse rise) the minimum time difference between dotted and solid pulse (see Fig. 8) will not be less than 10 microseconds.

OUTPUT TRANSFORMERS

Firing pulses may be applied directly from the pulse generator circuit, but most generally are applied through an output transformer for isolation, and sometimes pulse multiplication. The output transformer may be mounted on the power tray or in an external location.

Output transformers in the 12-cell bridge power tray also produce the delayed pulse (dotted in Figure 8) for the "B" SCR cells.

PULSE SEQUENCE

The firing pulses should be at 60-degree intervals and must be applied to the SCR cell gates in the sequence of the SCR cell numbering (CR1, CR2, CR3, etc.). On all bridge trays and some double-wye trays, each SCR cell gate is pulsed twice. It is first pulsed at the normal time and again 60 degrees later. This ensures that SCR cells connected to both the positive and negative d-c buses can conduct current at the same instant so that load current can flow.

MAINTENANCE

Once installed, the SCR power tray requires little attention. The rectifier should be cleaned of accumulated dust once or twice a year, or more often if required. Remove dust with a vacuum cleaner or carefully blow out with dry compressed air.

FUSES

Should rectifier power fuses require replacement, the same type and rating as supplied must be used. These are special fuses and substitutions can not be used.

SILICON CELL REPLACEMENTS

Should it become necessary to replace any silicon rectifier cells, a cell of the same model and grade must be used. A special Belleville spring washer is used under the nut and the new cell should be installed as described below.

The method of mounting and handling silicon rectifier cells is important for the following reasons:

1. The cell can be damaged internally by rough handling or abuse.
2. A low resistance electrical and thermal contact with the heat sink is necessary to prevent excessive heating of the cell.
3. The original operating conditions must be maintained over a long period of time even in a highly corrosive atmosphere.

GENERAL MOUNTING INSTRUCTIONS

1. Rough handling or abuse of the cell should be avoided. Any wrench applied to the front of the device should be designed to minimize the danger of damage to the ceramic. This is especially true when front mounting. The wrench should be designed such that it can not bear against any part of the device other than the hex base during torquing.
2. The mounting surface of the silicon rectifier cell must be smooth and free of any nicks or irregularities. Examine the cell for this type of damage incurred during shipping or handling.
3. The surface to which the cell is to be mounted must be clean and free of any grease, paint or other accumulation. It must be flat within 0.001 inch for a diameter of 1-7/8 inches. The surface should be finished to at least 32 micro finish smoothness.
4. Grease must be applied to the mounting surfaces and cell threads. For plated aluminum or copper heat sinks Dow Corning 4 compound or equivalent should be applied. For unplated aluminum or copper heat sinks Burndy "Penetrox" or equivalent should be used. On aluminum sinks the contact surfaces should be wire brushed through the grease for the best penetration of the oxide film. These greases should be applied as directed on the containers. Correct application of these compounds will remove the oxide film and maintain a low resistance contact. This grease will also protect the threads and insure the proper force when the recommended torque is applied.
5. When mounting with a nut, rotate the cell in the hole so that the flexible cable can be connected without strain on the cell.
6. Do not exceed the recommended torque.
7. Wipe excess grease from around base of cell to prevent excessive accumulation of dust.

8. When connecting the flexible cable to its terminal do not strain or use the bolt to bring it into position.

ASSEMBLY WITH BELLEVILLE WASHER

1/2 - 20 Thread - Belleville washer, drawing 3200A5483 P003, is approximately 400 pounds when flat. The Belleville washer is compressed to 85 percent of flat by running nut up finger tight and then rotating nut 300 degrees (5/6 of a turn). In no case should 150 lbs. in. be exceeded.

3/4 - 16 Thread - Belleville washer, drawing 3200A5483 P004, is approximately 1000 pounds when flat. The Belleville washer can be compressed to 85 percent of flat by running nut up finger tight and then rotating nut 150 degrees (5/12 of a turn) or by applying 250 lbs. in. of torque (greased threads). A minimum of 8 1/2 threads should be engaged because 30 lbs. in. per thread begins to damage the threads.

FRONT MOUNTING

Only the 3/4 - 16 thread should be front mounted. Data to date indicates that 325 to 400 lbs. in. of torque should be applied (greased threads) to prevent loosening and insure good thermal contact. A minimum of 11 threads should be engaged because 30 lbs. in. per thread begins to damage the threads.

TROUBLE SHOOTING

(*See waveforms in next section)

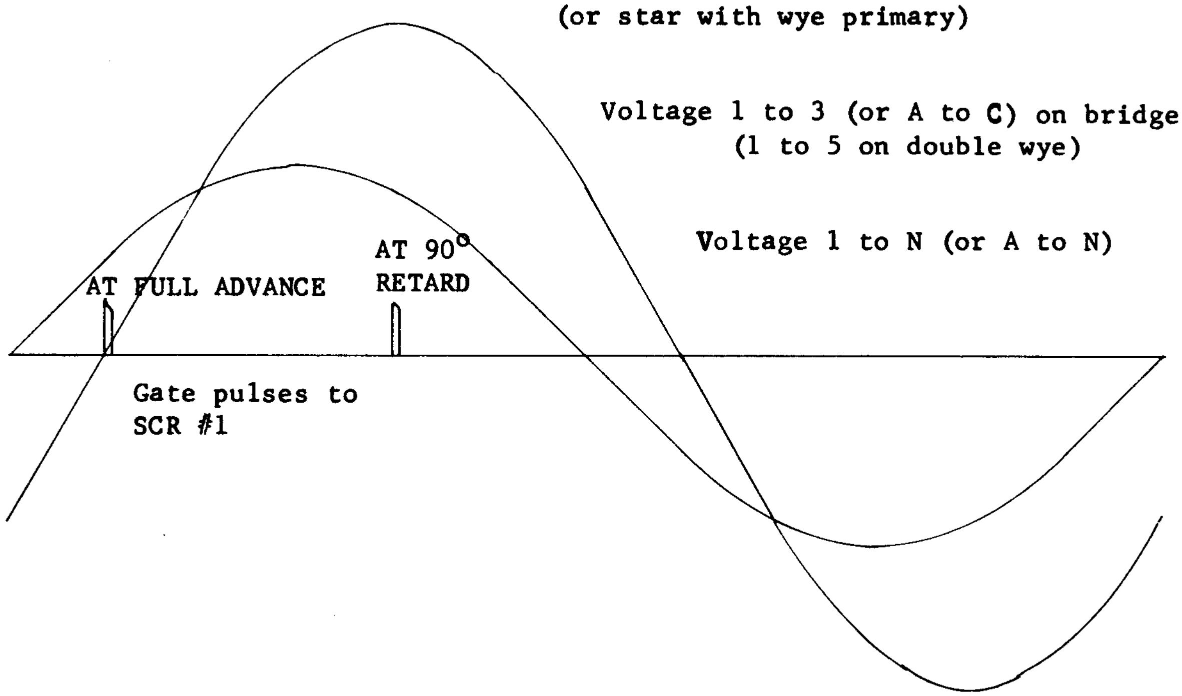
1. Light out - Check for
   1. Burned-out bulb
   2. Open lamp resistor
   3. Open fuse
   4. Shorted cell*
2. Low d-c voltage - Check for
   1. Low a-c voltage
   2. Power cable phasing wrong
   3. Firing pulses missing at SCR cell gates
   4. Firing pulses in wrong phase sequence
   5. Firing pulses in wrong relationship to a-c voltage*
3. Dips in d-c voltage - Check for
   1. Intermittent missing firing pulses at SCR gates
4. Missing firing pulses -
   1. Connect 20-ohm, 10 w resistor from black to white lead at SCR cell. If pulse appears, then gate is open and the cell must be replaced.
   2. If pulse is still missing, connect 20-ohm, 10 w resistor across primary of output transformer. If pulse appears (across resistor), then a winding is open and the output transformer must be replaced.
   3. If pulse is still missing, connect a 200-ohm, 10 w resistor at the plug or terminal board where the pulse should enter the tray. If the pulse appears, then the wiring at this point is open or improperly connected.
   4. If pulse is still missing, check the gate-pulse generator circuits. This should include wiring between the gate-pulse generator and the SCR power tray.

WAVEFORMS

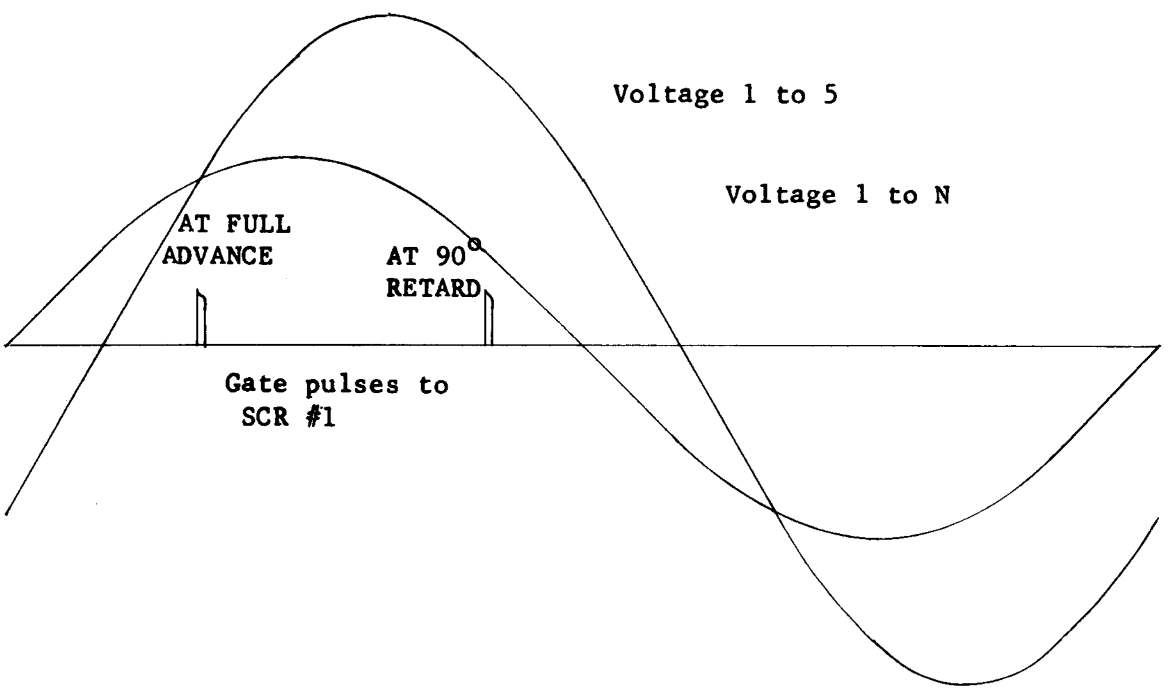
(one cycle of fundamental frequency shown unless noted)

FIRING PULSES IN RELATION TO A-C VOLTAGE AT TRAY

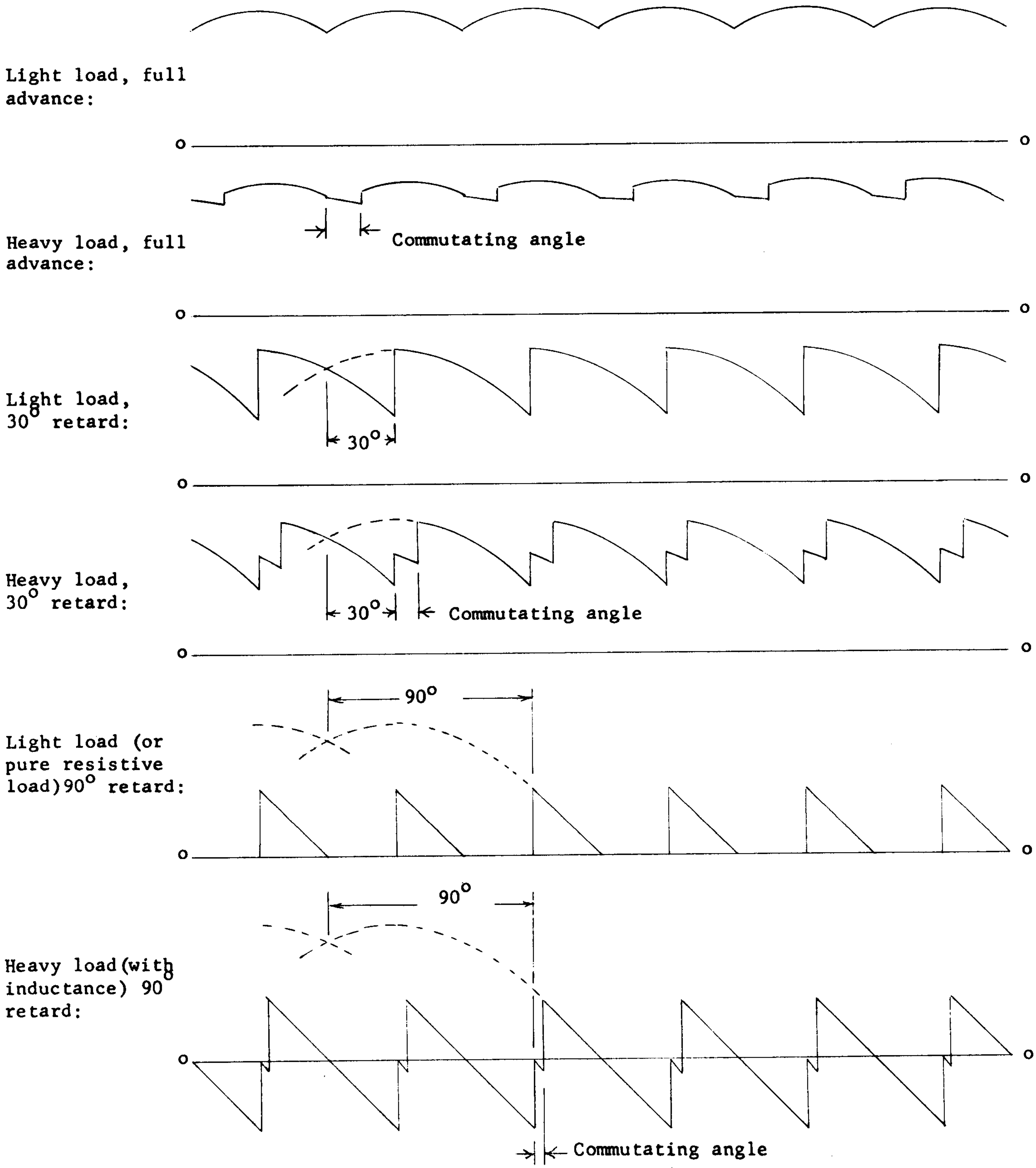
Three-phase bridge or double-wye rectifier:
(or star with wye primary)



Star Rectifier:



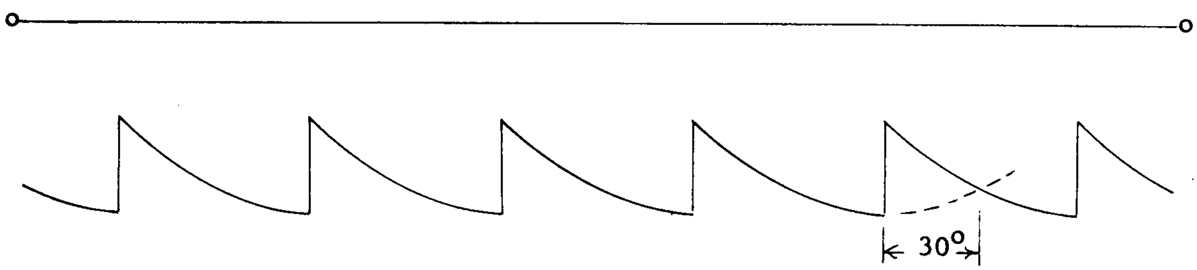
RECTIFIER D-C BUS VOLTAGES



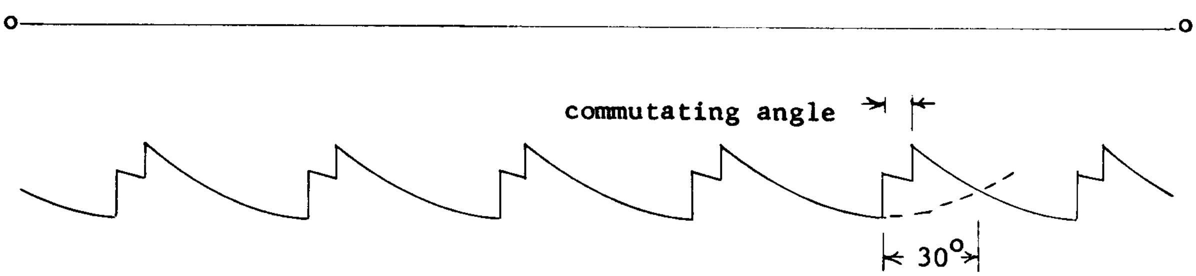
INVERTER D-C BUS VOLTAGES

Light load, 30° advance

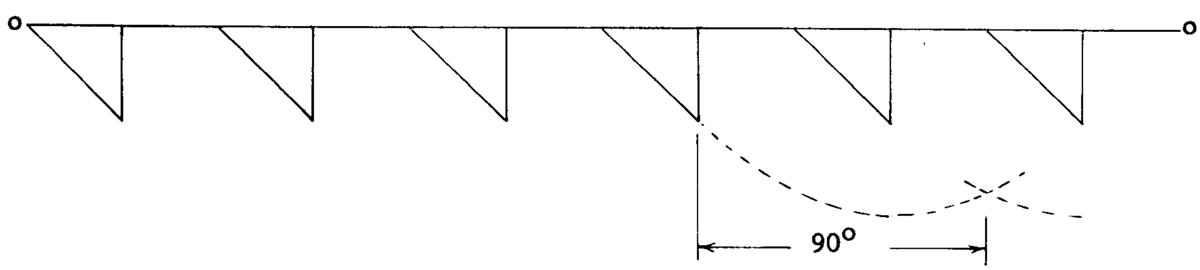
(Note-inverter cannot operate at 0° advance, and normally should not be operated at less than 20° advance)



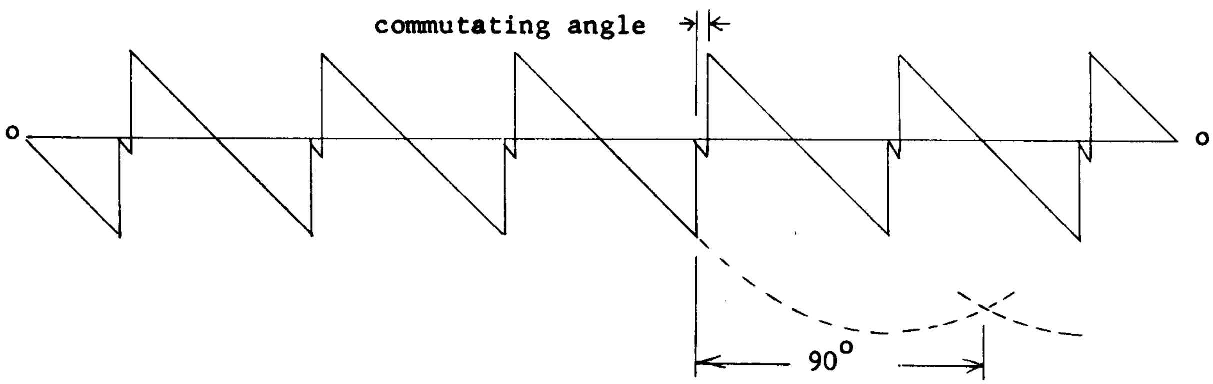
Heavy load, 30° advance:



Light load, 90° advance:

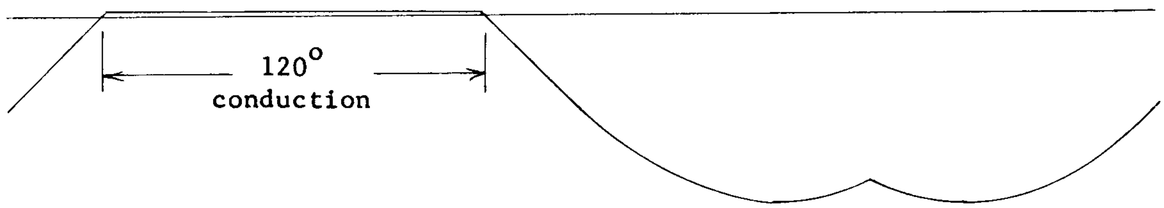


Heavy load (with inductance), 90° advance:

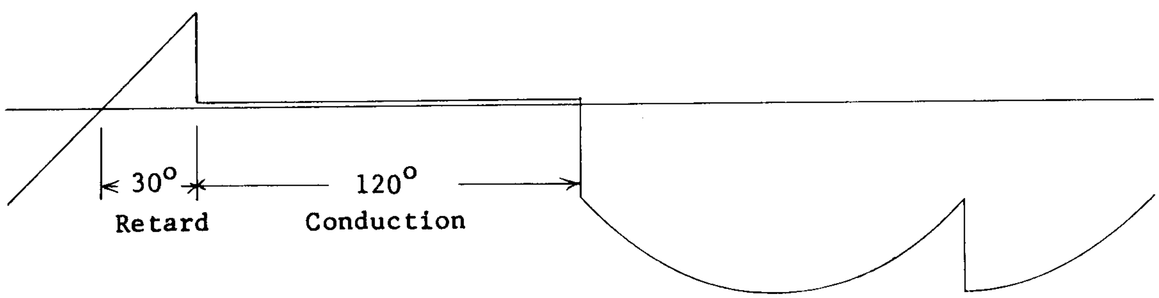


SCR CELL VOLTAGES, ANODE TO CATHODE
(Bridge or Double-Wye Circuit)

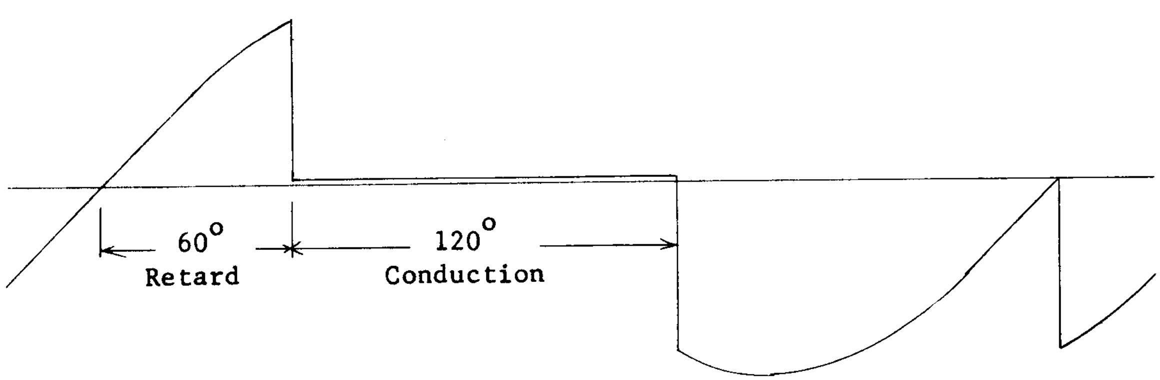
Full Advance (Rectifying):



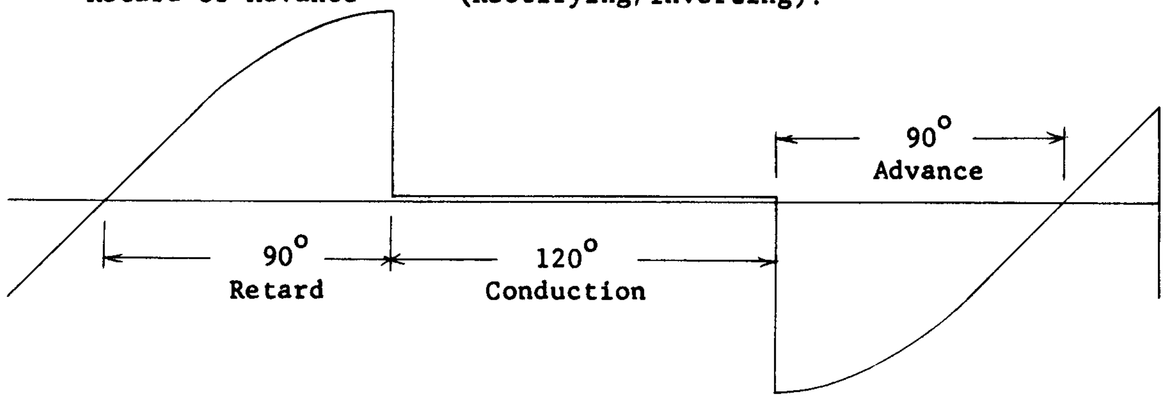
30° Retard (Rectifying):



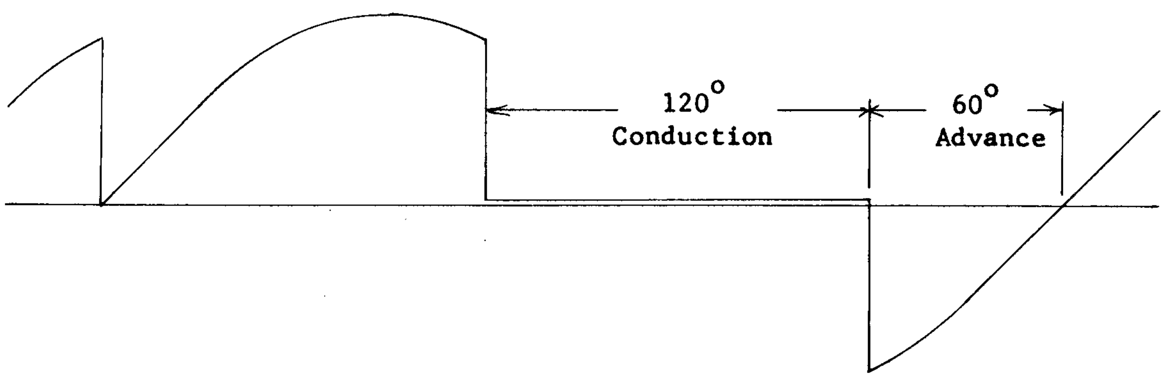
60° Retard (Rectifying):



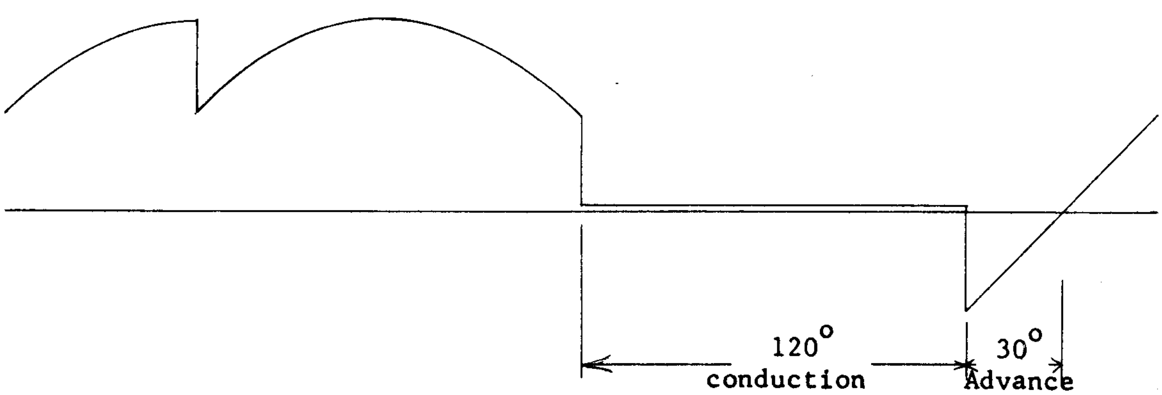
90° Retard or Advance (Rectifying/Inverting):



60° Advance (Inverting):

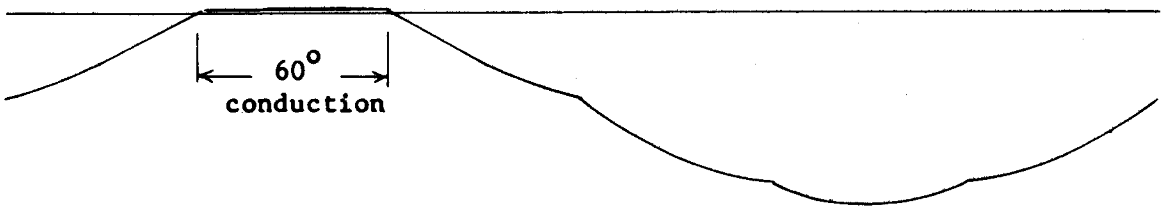


30° Advance (Inverting):

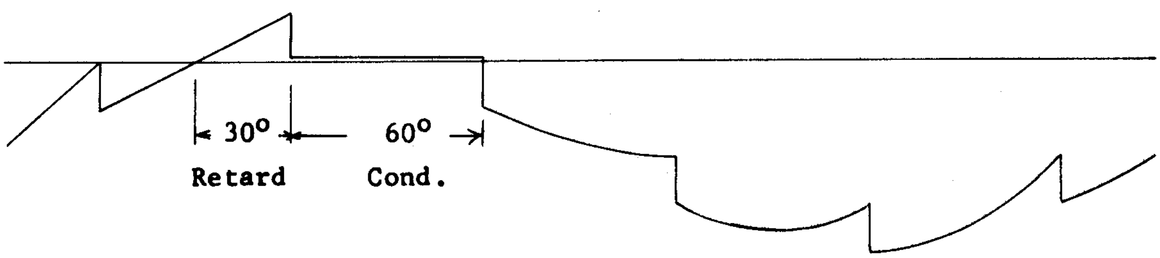


SCR CELL VOLTAGES, ANODE TO CATHODE
(Star Circuit)

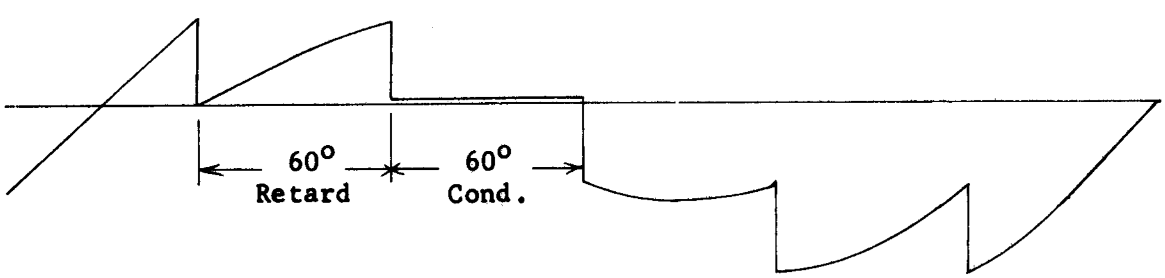
Full Advance (Rectifying):



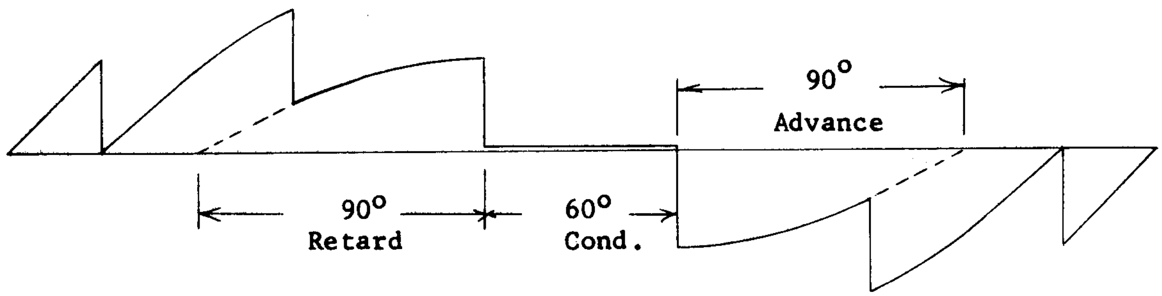
30° Retard (Rectifying):



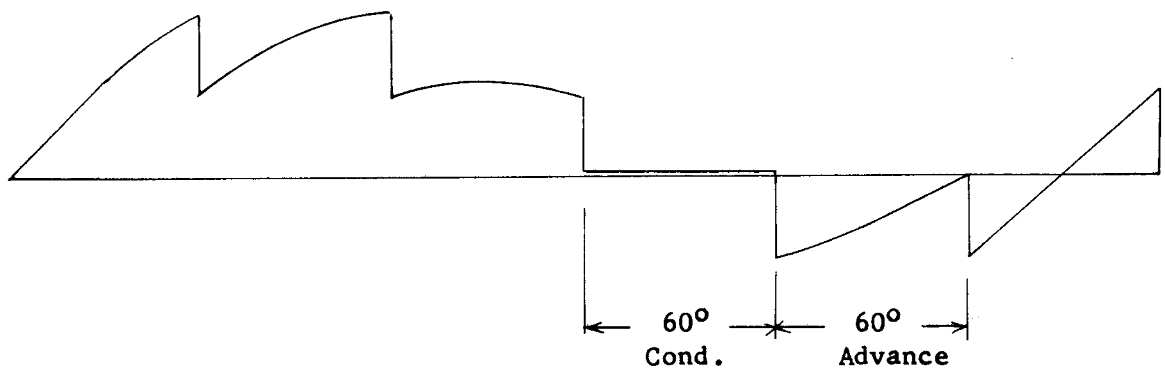
60° Retard (Rectifying):



90^o Retard or Advance (Rectifying/Inverting):



60^o Advance (Inverting):



30^o Advance (Inverting):