Power Switching Principles

What Is An SCR Power Controller?

An SCR, or thyristor, is a semiconductor device which switches AC power ON and OFF. It is used to control the electrical power delivered to heating elements.

Eurotherm SCR units incorporate the SCR devices together with the driver electronics and heatsink which dissipates the heat generated by the SCR devices. Some Eurotherm SCR units include internal fuses to protect the thyristor while others require <None>external fusing. One benefit SCR units offer is a reliable long term alternative to electromechanical devices, reducing the necessity for maintenance.

SCR units are particularly cost effective for fast systems, for complex loads involving transformers and/or heaters whose resistance changes with temperature or time. They are the best means of controlling electrical heating power.

SCR units generally offer improved controllability, which gives economy, easy serviceability and reduces down time and maintenance costs.

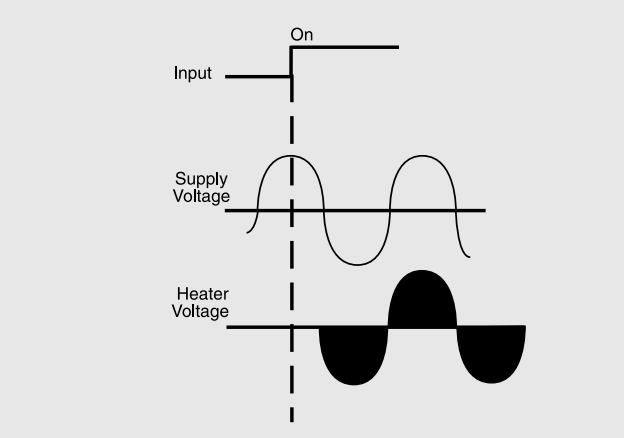
Almost silent in operation, SCR units can eliminate the switch on surge by operating in synchronization with the supply, improving the electrical environment.

Solid state relays (SSR) or solid state contactors (SSC) are SCR units that replace mechanical relays or contactors. These units turn power on when commanded by an input signal and turn power off when the signal is removed.

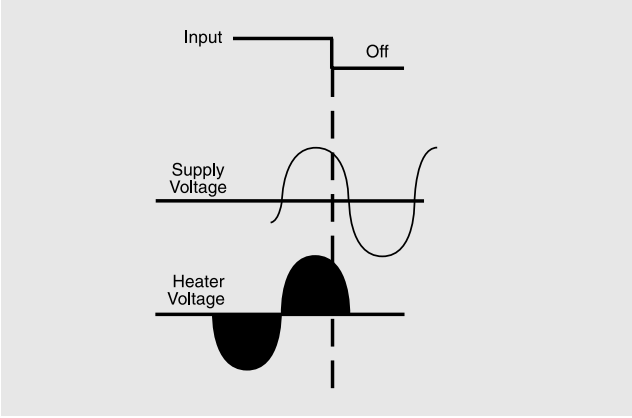
Firing Modes—SSR, SSC Or SCR Unit With Logic Firing Mode

The control input for this type of SCR unit is a 'Logic' output from a Eurotherm temperature controller. The SCR operates like a relay or contactor, i.e. when the logic signal is low the SCR unit is OFF and when it is high the SCR unit is ON.

To minimize interference, the SCR unit switches on at the first zero crossing of the line voltage, after the logic input goes high.

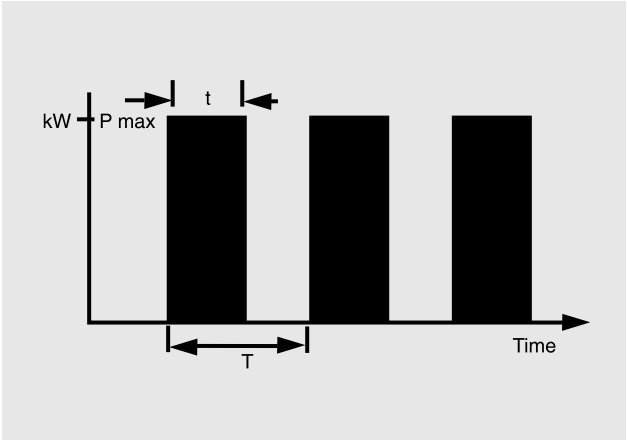


When the logic input goes low, the unit switches off at the first zero crossing point of the heater current



Cycle Proportioning, Zero Crossing Or Burst Firing (Fast Cycle, Slow Cycle, Single Cycle)

This is a means of controlling power by time proportioning the available power. The 'burst repetition' rates come under the headings of Fast Cycle, Slow Cycle and Single Cycle and are intended to serve the requirements of different applications. The table below gives further details. Typical analog control inputs for this type of SCR unit are 0-5V or 4-20mA.

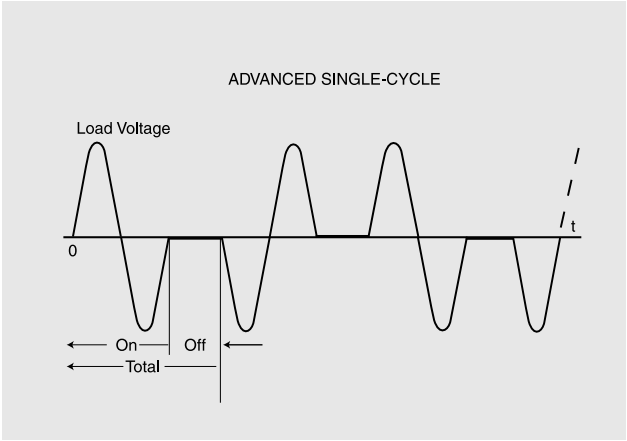


Control mode	50% Power
Fast Cycle (F.C.)	200ms ON and 200ms OFF typically
Slow Cycle (S.C.)	20s ON and20s OFF typically
Single Cycle (F.C.1.)	One cycle ON and one cycle OFF

To minimize interference, the SCR unit always switches on when the voltage across the heater is zero and switches off when the current through the heater is zero. Each 'burst' is therefore a complete number of cycles of the supply.

Advanced Single Cycle Firing

Advanced Single Cycle is a zero cross fired mode for use with various resitive loads and especially with Short Wave Infrared (SWIR) loads. Output power is controlled by regulating the number of complete cycles and half cycles going to the load. The typical output waveform for a power controller set for a 66% output is shown below.



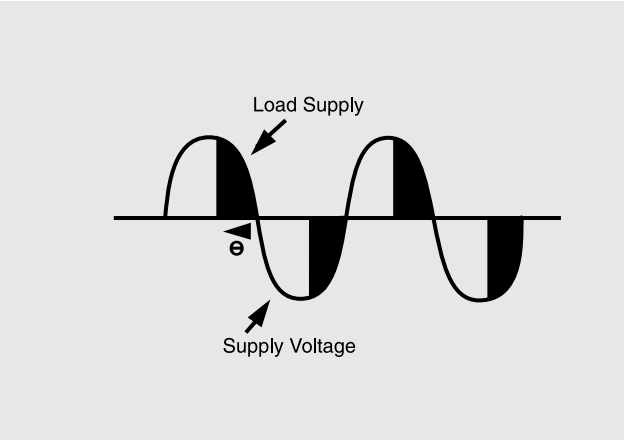
When comparing traditional Phase Angle firing to Advanced Single Cycle firing, the Advanced Single Cycle firing does not lead to Power Factor degradation, which reduces power utility penalties and does not generate RFI interference, which can interfere with other equipment.

Intelligent Half Cycle Firing

Similar to Advanced Single Cycle firing, Intelligent Half Cycle firing is only available when using the Remote I/O (REMIO®) Digital Inerface and the TE10S/425S solid state contactors (SSC). Power to the load is regulated by the number of half cycles on and off to the load. Intelligent Half Cycle firing is ideal for Short Wave Infrared loads (i.e. tungsten lamps). Intelligent Half Cycle firing offers the same benefitsas the Advanced Single Cycle firing (i.e., high power factor, reduced RFI switching interference)

Phase Angle (P.A.)

In this mode, power is controlled by allowing the SCR to conduct for part of the ac supply cycle only, (see diagram below). The more power required the more the conduction angle is advanced until virtually the whole cycle is conducting for 100% power.



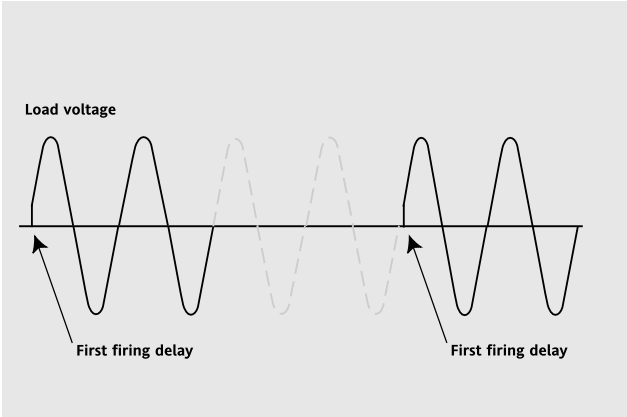
A disadvantage with Phase Angle firing is the possible emmisions interference generated by the rapid switching action at non zero voltage.

Phase Angle Start Fast Cycle (P.A. Start F.C.)

This is a variant of the cycle proportioning mode in which each on period consists of a run up over several supply cycles to full conduction in Phase Angle mode. Once this state is achieved the remainder of the on period will be at full conduction in Fast Cycle mode.

Preset Delayed Triggering

Preset delayed triggering is used in conjunction with cycle proportioning where a mixed inductive/resistive load such as a transformer supplied heater is used. A preset angle can be adjusted corresponding to the 'lag' angle which will prevent inrush surge currents when using zero voltage switching of inductive loads. Highly inductive loads will require Phase Angle firing, soft start and current limit.



Power Feedback

Supply voltage changes will obviously result in power to the load changing. To overcome the effect of supply voltage changes, the Eurotherm controllers which drive the SCR unit have power feedback to automatically compensate for this.

In brief, a 100KW load rated for 500Vac would experiencea 19% drop in power if the supply voltage decreases by 10%. Upon sensing a decrease in voltage, the instrument would immediately increase the output level to maintain the desired power going to the load, reducing the likeihood of a process variation.

Partial Load Failure (PLF)

This is an option that continuously monitors the load resistance and detects an increase arising from the failure of one leg of a parallel connected load. When a partial load failure is detected, an output to an external alarm is given. The PLF setting is adjusted with the SCR unit working normally and delivering current to the load. A decrease in load resistance is not acted upon.

Partial Load Unbalance (PLU)

Similar to PLF, the PLU monitors and detects changes in 3∅ current greater than 25%. If an unbalance is detected, a latching or non-latching alarm relay contact opens or closes (specify N/C or N/O when ordering).

Overload Circuit

This option is only available with PLF on certain equipment and is designed to detect overload currents in the region of twice the partial load failure setting or greater. When it operates, the SCRs are prevented from firing, a front panel lamp lights, and a relay or logic alarm output is activated.

Current Limit

With low cold resistance loads, if used with cycling modes, the first complete cycle could cause a current surge and blow a fuse. Phase Angle operation starts from zero and the Phase Angle is advanced slowly until a current limit threshold is reached to keep the current within the safe limits of the element and the wiring, independent of load resistance.

Inhibit Or Enable

A voltage applied to the input of the circuit will stop (or alternatively enable) the output at the next zero crossing. The external circuit is usually arranged so that the SCR is quenched at switch on, to enable the circuit conditions to stabilize.

Power Control

This is not usually required in applications using a Eurotherm temperature controller with relay or logic output. Power control requires I and V to be measured and is sometimes needed when loads cannot sensibly use Power Feedback, i.e. those with a low cold resistance.

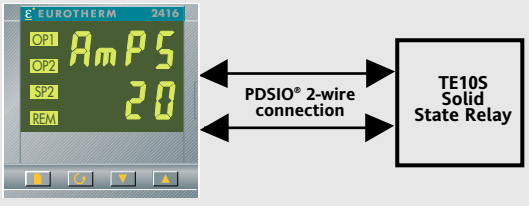
Power control may be an advantage in open loop non-temperature controlled applications where it is the energy input which is to be controlled.

Pulse Gating

Gating of the SCR firing pulses may be necessary on Phase Angle SCR units, particularly for applications with a leading power factor or cross coupling between phases. The triggering of the SCR is inhibited until the voltage has risen through zero. Once the SCR has fired, the trigger pulses are removed to ensure that the SCR turns off as the forward direction current reduces to zero (again some degrees before the voltage waveform).

Pulse Density Signaling I/O (PDSIO®)

PDSIO® is a patented bi-directional communication method for model TE10S solid state contactors and Series 2000™ controllers. PDSIO® passes additional control loop status data transparently on the same wires that carry the primary analog or logic control signals. It is not just another digital communications protocol that requires external smart I/O interfaces or special software drivers.



PDSIO® can detect problems like open heater burn out, blown heater fuse, open SCR device, no line voltage, and broken controller signal wire. By detecting these problems early, contingency plans can be implemented quicker thus saving money and maximizing valuable production time. PDSIO® can also be used to monitor load currents valves.

Digital Communications

Eurotherm offers SCR power controllers with digital communications utilizing standard protocols. This allows the heater load to be monitored with a computer. Additionally the load can be controlled directly from the digital communications. This minimizes wiring, the need for signal transducers and provides vital process information.

Agency Ratings

Some models of Eurotherm's power controllers have approval ratings for CE. Some models are approved for UL, cUL and VDE.

Installation

The SCRs must be installed in accordance with recommendations expressed in the installation guide supplied with each unit, and also in accordance with local wiring regulations. It is important to be aware that each controlled phase in a SCR generates a heat loss calculated at approximately 1.3 watts per amp (per phase)load current. Adequate ventilation or forced cooling must be provided to maintain the ambient conditions inside the control panel enclosure within the operating specification.

Fuse Protection

Eurotherm Controls SCR regulators are generally supplied with high speed fuses, designed to protect the SCR device against short circuit currents resulting from load or wiring faults. The high speed fuse does not provide protection to the load or to the branch circuit against sustained medium scale overloads, and it is therefore necessary to fit a standard circuit protection fuse (HRC fuse or circuit breaker) in the supply lines to the regulator.

Mounting And Enclosures

Most SCR units are designed to work in ambient temperatures up to 45°C. It should be noted that SCR units generate a significant amount of heat internally through the SCR itself, the fuse and the cabling. A general rule is to reckon that a SCR unit, and its fuse, will generate 1.3 watts of heat per amp per phase.e.g. 100 amp three phase SCR unit type TC3000 will generate 390 watts. With a TC3000 in a standard cubicle 2.1m x 600mm x 600mm with no ventilation the internal temperature will rise 20-30°C. Adequate ventilation is therefore essential, preferably forced by fan. Mushroom tops and louvers are not particularly effective in removing this heat.

Neutral Currents On Three Phase Installations

Under certain circumstances, such as four wire Phase Angle installations, open circuit heaters or unbalanced loading, substantial neutral currents can flow. Neutral cable sizing should therefore be chosen with care. With balanced load resistances neutral cable current rating should be twice the line current for safety under all possible circumstances.

Power Factor

In large installations poor power factor may increase the cost of the electrical power supplied. Phase Angle firing gives a sharp rise in current when turned on and may cause a distorted supply waveform. The apparent power factor can therefore be adversely affected. Fast Cycle, Slow Cycle, Single Cycle, Advanced Single Cycle and Intelligent Half Cycle are all zero cross firing modes with no current waveform distortion and therefore do not affect power factor.

Plant Safety

The SCR regulator is a control device, and should not be used as the safe means of removing power from the load. When plant or personnel safety is at risk, a circuit breaker or contactor should be fitted in the supply lines to the regulator, and arranged to automatically trip in the event for example of a plant emergency stop, or over temperature switch operating.

Personnel Safety

The SCR regulator does not provide an effective means of isolation in its turned "OFF" or "DISABLED" state due to leakage currents through the various protection components around the SCR itself. In particular, when using a two phase SCR to control a three phase load, the complete load and associated wiring will be at the potential of the uncontrolled phase in the OFF state. It is therefore imperative that an effective means of isolation is provided. Working practices set up to ensure that the regulator and associated circuitry are made safe before any maintenance work takes place.

If In Doubt, Ask

If you are in any doubt about the application of these or any other Eurotherm Controls products, please ask for guidance.

Special Applications

There are many possible circuit connections other than those described in this guide. Eurotherm Controls Applications Department has a wide range of experience in special applications which need particular attention for successful operation.