SCR Power Controls Provide Reliable Industrial Electric Heating

Paul Evalds, Avatar Instruments, Broomall, Pa.

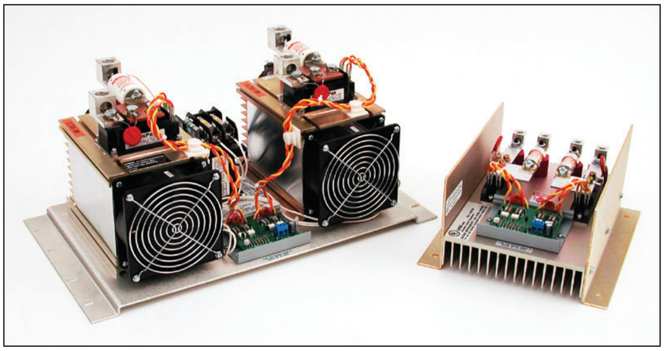
By following the few simple steps provided here, an SCR power control can give superior performance with minimal maintenance costs for many years.

Equipment manufacturers and maintenance engineers need a reliable, flexible approach to controlling electric-heating processes in today's competitive, cost-conscious industrial environment. SCR (silicon controlled rectifier) power control offers advantages including precise control of the heating process, extended heater life, improved product quality at faster production speeds and reduced maintenance costs. Proper selection of an SCR power control can result in many years of reliable service.

Comparing power controls

A silicon controlled rectifier is a solid state switching device that can provide fast, infinitely variable proportional control of electric power; an SCR can cycle as fast as 0.08 seconds on a 60-Hz power line. With proper selection and use, an SCR power control can cycle on and off 1,000,000,000 times without any problems.

Unlike a mechanical relay or contactor, an SCR power control has no mechanical parts to wear out. An SCR power control will not arc and is not affected by dirty contacts. By comparison, a mechanical relay must be replaced after a certain number of cycles. Due to the slow cycle time (30 seconds minimum) inherent in mechanical relays, control is poor, the heating process may be inaccurate and heater life could be shortened due to thermal shock.



SCR power controls have been used since the late 1950s. Today, SCR power controls are smaller, safer, versatile and very reliable.

A mercury displacement relay (MDR) cycles faster than a mechanical relay. However, overheating the relay due to excessively fast cycling or overloading will cause it to explode, a situation which creates a hazardous-materials problem. In addition, shipping and disposing of MDRs is becoming increasingly more difficult due to more stringent federal environmental regulations.

A solid-state relay (SSR) is a popular alternative to mechanical power control. However, solid-state relays are not supplied with lugs that make a solid electrical connection for higher power levels, and they are not always supplied with heat sinks, voltage protection or the fuses needed to protect and safely operate the device. A common characteristic of all solid-state devices (including SSRs) is that they generate heat that needs to removed. Solid-state relays generate more heat than SCRs.

Another consideration of solid-state relays is their rating, which could cause a problem. Almost all solid-state relays are rated for maximum output at a temperature of 25°C (77°F). However, in real world operating conditions where temperatures inside electrical enclosures exceed 40°C (104°F), a solid-state relay will fail if used at full output. Most manufacturers have a de-rating chart for their product to compensate for this discrepancy. Unfortunately, many plant personnel use the advertised maximum rating when selecting a solid-state relay. It is important to understand the manufacturer's data before determining which solid-state relay will work best for a specific process.

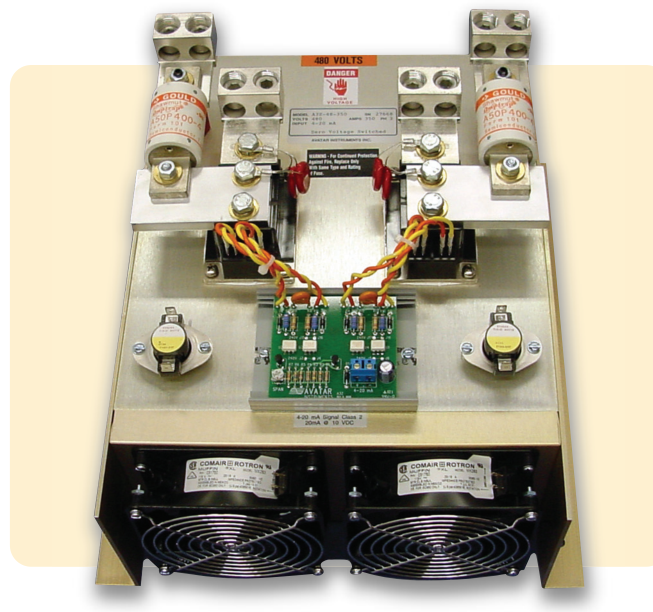
Most SCR power controls are rated for ambient operating temperatures of around 50°C (122°F) at full power ratings. Also, SCR power controls usually are supplied with fuses, heat sinks, voltage protection and power lugs.

SCR selection and care

Three factors that will destroy all solid-state power controls are over-temperature, short circuits and transient voltage spikes. Protection against over-temperature, voltage spikes and short circuits should be taken into account at the outset of a system design.

All solid-state power devices (that is, thyristors such as SCRs TRIACs and SSRs) generate heat. Voltage drops, which can be anywhere from

Properly designed SCR power control built with fan cooled heat sink, MOV voltage spike protection and I^2T fusing.



To prevent premature power control failure, the SCR power control contains thermostats to provide an alarm if ambient temperature is too high, fans have failed, or air supply is interrupted.

1 to 2 volts depending on the device across a power device, generate heat. The more current (amps) put through the device, the higher the wattage the device will generate in the form of heat, which must be removed or the device will fail. Almost all semiconductors are destroyed at an internal junction temperature of 125°C (260°F).

The higher the amperage output, the greater the heat that is generated. The simplest, most common way to remove heat is to use a heat sink. Many manufacturers use fans to remove excess heat from their high-output SCR power controls. On some superhigh-output SCR power controls (over 1000 A), water-cooled heat sinks are used. If a properly sized heat sink is used, an SCR can operate at its full rating at an ambient temperature of 50°C (122°F).

One problem with some SCRs and solid-state relay controls is packaging. In an effort to reduce the size of the heat sink, the fin area is not adequate to remove excess heat. DIN rail-mounted heat sinks can save panel space and installation time. However, with many controls mounted close together on a DIN rail, the power density (W/area) inside the enclosure is increased. At the same time, airflow to the heat sinks is decreased or blocked. If such an arrangement is used, it is important that the manufacturer has not asked that the DIN rail heat sink be fan cooled or mounted with the heat sink fins outside the cabinet. It also is important to check the de-rating curve for the device at the power level at which it will be used.

Even at low power (such as 25 A), each controlled leg of an SSR will generate close to 50 W of heat. Therefore, if 20 DIN rail mount SSR power controls are used in a small enclosure, it is necessary to remove 1000 W of heat.

To determine the proper spacing for power controls, a rule of thumb is to use twice the footprint of the device when mounting. For example, if the SCR power control has a 12 in. × 12 in. (305 × 305 mm) footprint, use a 24 in. × 24 in. (610 × 610 mm) area for mounting.

Proper ventilation of the electrical enclosure is critical to keep an SCR power control functioning. Even a power control having an adequate heat sink will fail if the heat cannot escape from the enclosure. When venting an enclosure, the basic formula is to use 10 in.^{2} (64.5 cm^2) of inlet and outlet area for every 50 A per controlled leg. Vent holes should be at the top and bottom of the enclosure.

Wattage and airflow

The heat (as watts generated) generated by each controlled leg (C) of an SCR controller is equal to 1.5 times the amperage load (I). Fan cooling is an efficient way to keep the enclosure at safe operating temperatures. The size of the fan required can be determined by multiplying the watts generated by 3.16 and dividing by the temperature rise (10°F) above ambient. The resulting value is simply taken as the fan volume size in ft^3/min (cfm).

For example: To limit the heat rise in an enclosure to 10°F above ambient temperature, with 1000 W of generated heat, you have:

$$\frac{1000\,(3.16)}{10} = \frac{3160}{10} = 316\text{-cfm fan}$$

Plastic enclosures function as thermal insulators. An SCR power control most likely will be destroyed if installed inside a plastic enclosure. The only reliable way to use a plastic enclosure is to have a "through-hole mount" heat sink, with the heat-sink fins on the outside of the enclosure.

Short-circuit protection and fusing

Semiconductors are destroyed by a short circuit. One of the simplest ways to protect an SCR power control is proper fusing. While an SCR is a robust, reliable device, semiconductor, subcycle, and I^2T current-limiting fusing must be used to ensure maximum performance and service life. Nearly all SCR power-control manufacturers incorporate these fuses on their controls. I^2T fuses will clear within 2 milliseconds and limit the current as they clear. They are reliable and easy to replace.

Not using a semiconductor fuse is penny wise and dollar foolish. If there is no fuse protection, an SCR can be damaged when it need not be damaged. A fuse is the easiest component to replace if there is a heater short. It is important to clear the shorted heater or wiring before installing a new fuse.

Note that 99.9% of fuse failures are due to shorted heaters, loose connections, incorrect (too large) load matching and miswiring of the SCR power control. With high inrush loads (such as with tungsten heaters, transformer primary drivers, molybdenum heaters and shortwave heaters), use of anything other than a soft start, phase-angle fired SCR control will blow fuses. Never switch on a cold inrush heater bank after the soft start has been activated. Changing taps on a transformer while in use also may blow fuses.

It is necessary to size an SCR power control to the heater load. Because heaters and power lines have some fluctuation, an SCR power control with a rating of at least 110% of the maximum heater load potential should be used to be safe.

Transient voltages

Over-voltage spikes affect almost all electronic devices. Transient-voltage spikes can cause an SCR to misfire or can even permanently damage an SCR.

The simplest protective device for over-voltage is a metal-oxide varistor (MOV), which is wired in across the SCR. By using an MOV having a voltage rating higher than the line voltage, but lower than the SCR peak voltage rating, the MOV becomes an effective guard against voltage spikes. If a transient voltage spike goes over the rating of the MOV, the MOV will block the spike. If the spike is powerful enough, the MOV will explode, protecting the SCR.

SCR power control safety design features. The SCRs have I^2T fusing and MOV voltage protection, and heat sinks are spaced at a safe distance from each other for efficient cooling. Door mounted fan and vents in top of enclosure provide sufficient cooling for all components. Courtesy of Radiant Energy Systems.

The use of a DV/DT suppression board is the next step in power-line noise and voltage-spike protection. With a network of power resistors, high-voltage capacitors and MOVs, the SCR has greater protection from line noise and voltage spikes. The network helps eliminate damage to the SCR, as well as SCR misfiring.

Because continuous overvoltage will destroy an SCR, it is necessary that the SCRs used on the power control are rated with a voltage high enough to withstand industrial voltage peaks. The higher the peak voltage rating of the SCR, the safer it will be. The minimum SCR voltage ratings for the power line on which it will be used are shown in Table 1.

Selecting an SCR power control

Three ways an SCR power control can deliver electrical power to heaters are: phase-angle fired, zero-voltage switched and on/off control.

Phase angle-fired controls proportionally turn on a percentage of each power line half cycle, which gives smooth, infinitely variable application of power to the heaters. It is the most precise method of control. Phase-

Table 1 SCR voltage rating vs. line voltage

Line voltage	Minimum SCR repetitive peak reverse voltage rating
120	200
240	400
380	600
480	800
600	1,000

Table 2 Power control selection chart

Heater/load type	Heater/load characteristics	Control type	Typical applications
Constant resistant elements Immersion heaters	Slow response	On/off, zero-voltage switched	Large-tank heating and mechanical-relay replacement
Medium-wave infrared, ceramic, cartridge, duct, strip and band heaters Platens	Faster response; constant-resistance heaters only	Zero-voltage switched	Thermoforming, textiles, industrial furnaces and ovens, chemical-process heating and fast water heat
Open-coil/wire heaters Medium-wave infrared quartz Infrared panels	Fastest, most precise response	Phase-angle fired	Paper and pulp drying, packaging machines, pharmaceutical processes, infrared ovens and dryers
Silicon-carbide heaters Graphite heaters	Load changes in resistance with age; high-temperature elements	Phase-angle fired with current-limit option	High-temperature ovens and furnaces, glass, ceramics & high-temperature alloys
Tungsten (T-3) lamps and heaters Short-wave infrared elements Molybdenum heaters	High inrush currents High hot/cold resistance ratio Tungsten 14:1 Molybdenum 20:1	Phase-angle fired with soft-start option	High-speed paper & ink dryers, high-temperature infrared heating and high-temperature materials processing
Transformer-couples loads. Primary driving Inductive heater loads	Inductive loads	Phase-angle fired with soft-start option	Used with transformer-coupled loads to drive low-voltage elements

angle firing can increase heater life up to seven times depending on heater type, and also allows options such as soft start, voltage limit and current limit. These options are not available using any other methods of control.

Zero voltage-switching controls proportionally turn on and off each power line full cycle. The SCR provides power to the heaters by varying the number of ac power line cycles. With a variable time base, the optimum number of cycles turned on/off is achieved. This method produces less RFI line noise than phase angle-fired SCRs.

On/Off controls function in the same way as a mechanical or mercury relay, but with the advantage of much faster cycle times.

Table 2 shows SCR power control matching for typical applications. The use of an SCR power control offers the most precise means of controlling electric heaters. Heater life is extended, production is increased and product quality is improved. SCR power controls are an environmentally friendly alternative to mercury relays. The flexibility of SCR power controls provides solutions to power-handling needs unavailable using any other device. IH

For more information:
Paul Evalds is Vice President Sales, Avatar Instruments, 577 Abbott Dr., Broomall, PA 19008; tel: 610-543-5155; fax: 610-543-5255; e-mail: pev@avatarinstruments.com; Internet; www.avatarinstruments.com