Crydom's Solid State Relay 'P' Option for Overvoltage Protection

Introduction

AC output solid state relays operate in a wide variety of electrical environments. Some are benign with well-regulated and controlled AC supply lines, others are very hostile with switching transients from a wide variety of sources. These transient scan range from low voltage, low energy to high voltage, high energy. Providing that the amplitude of any line-borne voltage transients is below the rated transient voltage of the solid state relay, nothing will happen.

For Crydom relays, these transient voltage ratings are 600 volts for 240 Vrms rated relays and 1,200 volts for 480 Vrms rated relays. However, if arelay's transient voltage rating is exceeded, the relay may be damaged. In many cases the relay will break over into an uncontrolled conduction and recover at the next current zero with no damage. In other cases – depending on the frequency of break-over and the voltage capability of the various semiconductor elements that are exposed to the transient – the relay can be permanently damaged.

Circuit Description

Basically two control circuits are used in AC output solid state relays, shown in Figures 1 and 2. In the circuit shown in Figure 1, seven elements are exposed to line voltage: two output SCRs, four diodes in the bridge rectifier and the pilot SCR. Of these seven elements, if the lowest break down voltage is the reverse voltage of one of the output SCRs or one of the bridge diodes, any overvoltage transient will permanently damage this element. The result will be a solid state relay permanently on. If the lowest voltage breakdown voltage is the forward blocking voltage of any of the three SCRs, it will likely break over into conduction without damage.The relay will conduct until the next current zero, then turn off and work normally. In practice, the lowest voltage breakdown element is normally the pilot SCR (SCR3), which is only forward biased, so it breaks over into conduction and turns the output SCR (SCR1 or SCR2) through its gate, which is the normal turn-on sequence for the main SCRs.

The relay conducts until the next current zero and then regains control. In Figure 2, three elements are exposed to the AC line voltage: the output SCRs (SCR1 and SCR2) and the opto-triac Q1. If the lowest breakdown voltage is the reverse voltage of one of the output SCRs, then any over voltage transient will damage it and the relay will be permanently on. If the lowest breakdown voltage is the forward voltage of one of the output SCRs, it will likely break over into conduction without damage.

The relay will conduct until the next current zero, turn off and work normally. If the lowest breakdown element is the opto-triac, Q1, it will likely break over into conduction, turning on the output SCR (SCR1 orSCR2) through its gate, which is the normal turn-on sequence for the main SCRs. The break-over current through Q1 is limited by the series resistor. If, however, Q1 is repeatedly broken over into conduction, it will eventually fail, resulting in the relay being permanently on.

Fig. 1

Fig. 2
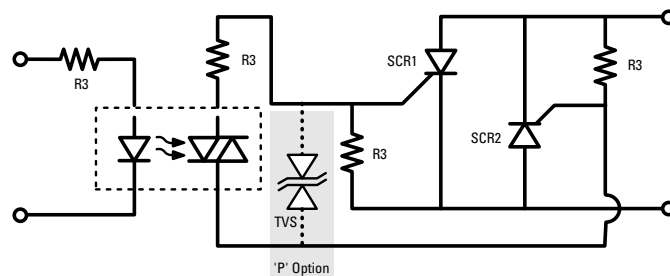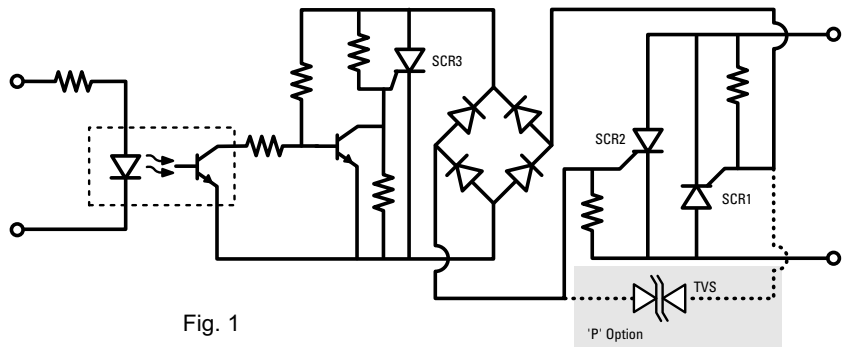
Standard Protection Methods

For many years Metal Oxide Varistors (MOVs) have been widely used to protect voltage-sensitive elements from overvoltage transients. MOVs have a voltage dependant resistance so that as the voltage increases, their impedance changes from a very high value to a lower value at some specified voltage. The slope resistance of the characteristic is fairly high, so that in the event of a relatively high current pulse, it can be difficult to coordinate the MOV clamping voltage, the protected device voltage rating and the system operating voltage. However, MOVs are available in a variety of energy absorbing sizes (joule rating) so that a suitable compromise can often be made.

A significant feature of MOVs is their wear-out mechanism: every time they absorb transient energy, their characteristics are changed, normally by the clamping voltage being reduced. Obviously if the MOV clamping voltage is degraded to the point where it overlaps the supply voltage, then the MOV will overheat and create a potentially hazardous over-temperature condition. For this reason MOVs are usually oversized and used with some reservation. MOV characteristics should be monitored to prevent catastrophic failures.

Where transient energy levels are known and are of limited magnitude, another option is to use TVS clamping diodes or breakover diodes. Both are silicon semiconductor devices with no wear-out mechanism but in sensible sizes and costs; they cannot absorb the same amount of energy as a large MOV. The clamping TVS diode exhibits very high impedance until its clamping voltage is reached and then essentially goes into a controlled avalanche mode with a very low slope resistance. The breakover (or crowbar) diode
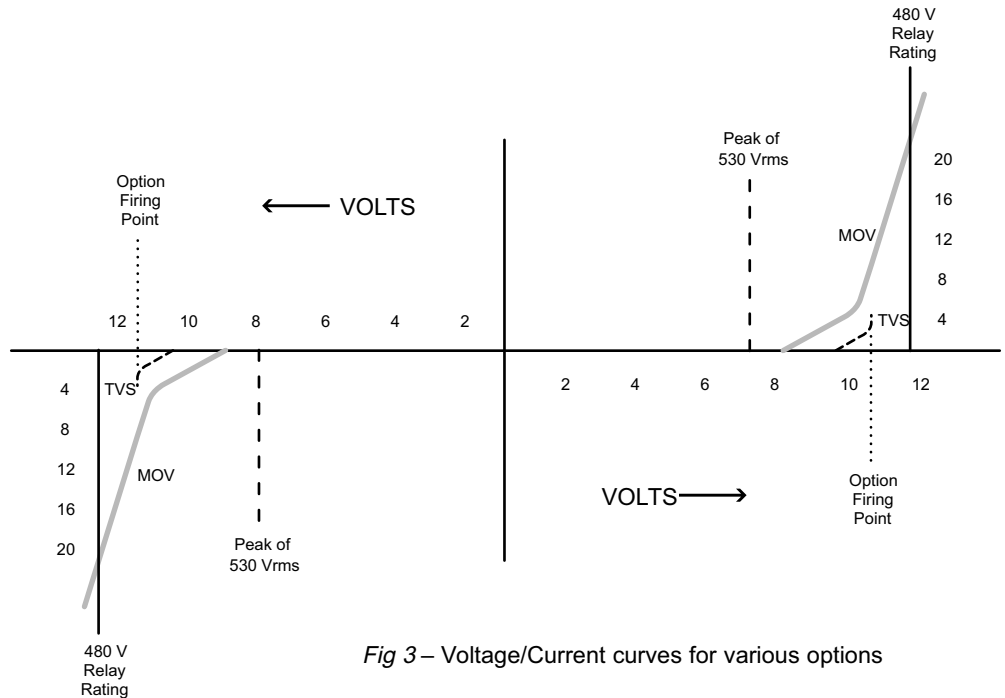

Fig 3 – Voltage/Current curves for various options

exhibits a very high impedance until its breakover voltage is reached and then breaks down to a low impedance, thus protecting against high voltage transients.

Figure 3 shows the various voltage levels involved in the protection of a 480 volt solid state relay, which has a maximum rms voltage rating of 530 Vrms, resulting in a peak voltage of approximately 750 volts, as shown in Fig 3. Every Crydom solid state relay rated at 480 Vrms is tested at least three times at 1,200 volts peak, as shown as "480 V relay rating" in Fig 3. A typical MOV clamping curve is shown, starting to clamp at about 900 volts but with a relatively high resistive component taking the clamping voltage above the relay rating if the voltage transient can supply about 21 Amps peak.

Also shown in Fig 3 is the typical breakdown voltage of the type of TVS that is used to protect a Crydom

Poption relay. The current in the internal TVS will never reach the 4 Ampsshown, indicating the much lower slope resistance of TVS protectors. In mostcases the internal TVs diode will trigger the relay when the TVS currentreaches 0 to 100 mA. Although this energy level may seem high, it is spread over a number of series TVS elements, which possess excellent thermal management and dissipation paths.

Solid State Relay Internal Protection Methods

Because of the problems associated with MOVs, particularly the possibility of over heating, Crydom will not supply solid state relays with internal MOVs. Certain applications may employ TVS diodes (as shown by the dotted line connections in Figs 1 and 2), connected to the gates of the output SCRs, which will conduct at voltages above maximum line voltage and below the voltage rating of the solid state

relay. If a transient voltage occurs, the TVS diodes conduct and normal gate flows into the gates of the output SCRs, the forward biased SCR turns on. This is a standard turn-on sequence for the solid state relay output SCRs; they are turned on by the normal injection of gate current and no compo nentis overstressed.

This internal overvoltage protection is available on selected models of Crydom solid state relays. To specify this internal protection the letter P is added to the standard part number.
However, it is most important to discuss the application with Crydom engineering personnel before specifying this option, as it is not suitable for all applications. Generally for resistive loads the P option is suitable, providing the load can tolerate the transfer of the transient to the load. For capacitive loads it is inadvisable to use the P option as this could lead to very high inrush (surge) currents and possibly latent or catastrophic di/dt failures.

In some motor start and stop applications the P option might be suitable depending on the motor load, the effects of a sudden, undesired small movement of the motor, etc. Where this form of protection can not be used under any circumstances is in motor reversing. This poses is a significant danger of two relays being turned on by a transient, resulting in aline-to-line short that damages the relays and other circuit elements.