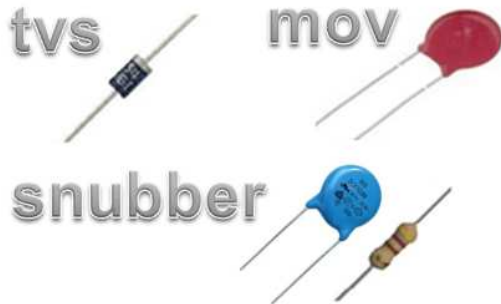


January 2012

## Protecting AC Output SSRs against voltage transient phenomena



SSRs are extremely reliable when operated within their specified parameters. For those cases where voltage or current transients may exist in the field that might otherwise exceed the SSR's ratings, there are several different means available to mitigate those situations. In this statement we'll deal with the voltage transients affecting AC output SSRs. First of all it is important to understand the origins of these transient phenomena:

- **an electrical origin** conducted by the power supply wires. As the I/O capacitive coupling is extremely low, these transients mainly affect the power output circuit and not coupled to the input circuit.
- **an electro-magnetic radiated origin** whose interference mainly affects the low-voltage structure of the SSR, such as the input circuit comprising the optocoupler.

However, whatever the phenomenon may be, it is often caused by lightning, switching on inductive loads (motors,

valves, etc.), distribution equipment placed on the electrical supply (micro power cut, etc.). These phenomena exist on all industrial electrical supplies, and their incidence can in many cases be reduced by simply being aware of them and taking elementary precautions.

A vital basic safeguard against all these phenomena is to select the correct size of SSR in relation to its application in order to take advantage of all the SSR characteristics with an adequate safety margin.

## Transient phenomena on input

The main problems encountered on an SSR input come from conducted voltage surges. If such a voltage surge exceeds the minimum turn-on voltage (1 to 3 volts) while the relay is in the offstate, the SSR output circuit may close for a period of time or until the output current next passes to zero. If the SSR is in the on state, the output may open if the transient polarity opposes the control voltage and exceeds the power supply rating. A voltage surge that is too high in either polarity could destroy the optocoupler if this is not adequately protected.

## Input protection method

The input of an SSR can be protected against possible voltage surges by adding a Zener diode, a TVS (bi-directional in case of AC input, mono-directional in case of DC input) or an RC supply mounted in parallel on the input. These components delay the relay

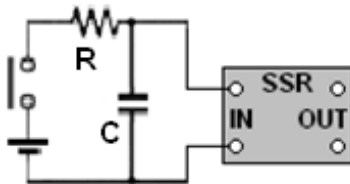
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switching for several micro-seconds (which will not have serious consequences, particularly with AC) and reduces the effects of a conducted or radiated stray impulse. Furthermore, a synchronous (or zero-crossing turn-on) relay is "naturally" protected against the effects of a stray impulse on the input as long as the stray impulse occurs outside the valid switching window.

The following is an example of a noise absorption circuit with capacitor C and resistor R connected to an SSR.



The value of R and C must be decided carefully. The value of R must not be too large or the supply voltage will not be able to satisfy the required input voltage value. The larger the value of C is, the longer the release time will be, due to the time required for C to discharge electricity.

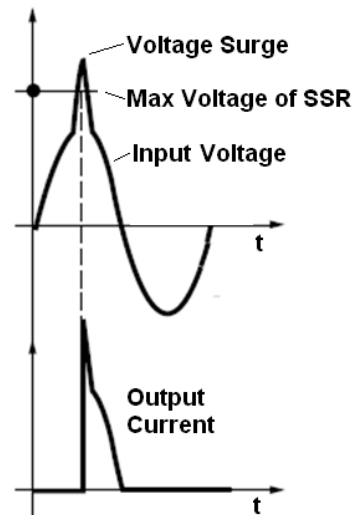
Typical values of RC network contain capacitors in the range of 0.010 to 0.1 microfarad and resistors in the range of 10 ohms to 1000 ohms.

Anyway, on the practical side, protection method should be more of concern for AC input SSR which are connected to the AC line. Usually, there are never problems associated to DC input SSR as they are fed by a power supply. So, the quality of the power supply being free of transients is important.

### Transient phenomena on output

If, following a voltage surge, the voltage at the output terminals of an AC SSR exceeds the maximum permissible direct voltage or breakdown voltage, the SCR or the TRIAC will switch on until the current next passes to zero.

Because of the high switching speeds of SCRs or TRIACs, switching can be triggered by a very short pulse of only a few  $\mu$ s.



### **Increase in dv/dt direct voltage**

This characteristic is linked to the physical structure of the output element and in particular to the coupling capacities between anode and cathode in an SCR or TRIAC. If the variation of the voltage at the relay terminals is too rapid, this can result in an uncontrolled turn-on. The severity of the consequences of such a stray trip will obviously depend on the application, but these can, in certain specific

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circumstances, lead indirectly to the solid state relay being destroyed.

There are 2 different type of dv/dt : static and commutating.

**Static dv/dt** is also known as turn on dv/dt because a static dv/dt failure is when the relay should remain off, but goes into conduction as a result of a sudden change in voltage (e.g.: initial application of line voltage). Static dv/dt is associated with all types of loads/applications.

**Commutating dv/dt** or turn off dv/dt occurs when the SSR is expected to stop conducting load current but continues to carry load current as a result of a high rate of rise of voltage at the moment of turn off due to a large voltage/current phase shift associated with reactive loads. Commutating dv/dt failures are exclusively associated with turn off of inductive loads where there is a significant phase shift due to the power factor of the load. While conducting, the SSR has a voltage across the semiconductor equal to the forward voltage drop, typically 1.2 volts, and then must rise to value of the line voltage when turning off. If there is a significant phase shift, the voltage may be as high as peak line voltage.

## Output protection method

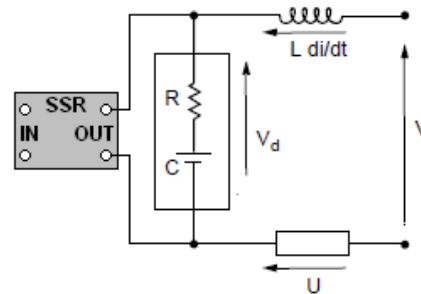
### 1 - RC network - "Snubber"

Mounting an RC element in parallel on the output of the SSR both reduces the dv/dt gradient generated by a stray impulse and reduces the amplitude of

this impulse by filtering, as long as the impulses do not recur.

Any variation in the voltage at the terminals of an RC element results in a current in the C capacitor, causing a voltage drop in the load such that:

$$V_d = V + (L * di/dt) - U$$



This voltage drop could protect the output SCR. The main disadvantage of this type of filter is the significant increase in the SSR off state leakage current. The leakage current of a snubber may be x10 or x100 the value of leakage current of the SSR itself (SSR is typically <0.1 mA while a snubber alone can be >5 mA). Some SSRs have "snubber" filters, which improve their performance. However, some SSRs use special SCRs which accept significant dv/dt variations. These relays are known as "Snubberless". The value of R is selected to protect the capacitor from too much inrush current and the capacitor has to be rated at something more than AC line voltage.

RC snubber networks address both static and commutating dv/dt. Snubbers address rate of change of voltage, while TVS and MOVs (see next chapters) address amplitude. Obviously by changing the rate of rise of voltage,

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snubbers may also effect amplitude depending upon the source impedance of the supply.

Typical value of a "Snubber":  
Resistance :  $33\text{ohm} < R < 100\text{ohm}$   
Capacity :  $0.022\ \mu\text{F} < C < 0.047\ \mu\text{F}$

*Some of Crydom Panel Mount SSRs have the snubber already included in the relay or they have it as an option (S option).*

## 2 - Bi-directional Transzorb (TVS)

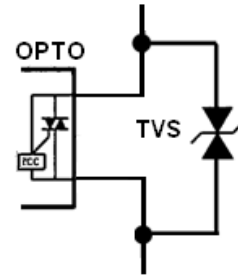
A "Snubber" filter alone is not usually sufficient to protect an SSR effectively, particularly against high-energy stray pulses. Using a TVS (also called "Transzorb" or "Transil") improves this protection reliably. Surge-suppression diodes are intended to protect electrical equipment which is sensitive to fast transients of low or medium energy levels. They are designed to have very good performance where the needs of this type of equipment are concerned, i.e. for overloads lasting close to one millisecond or less. This type of component can also provide good protection against electrostatic discharges (ESD).

With an alternating current a bi-directional version, or two "Transils" mounted head to tail, should be used.

*Most of the Crydom Panel Mount and Din Rail Mount SSRs have this option available (P option).*

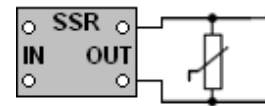
When the SSR is ordered with this option included a TVS is internally mounted across the Opto-isolator, the

component most susceptible to failure due to the transient.



## 3 - Varistors (MOV)

To protect the SSR against high energy stray pulses, it is also possible to use a Metal Oxide Varistor (MOV).



The drawback with these is that they lose their characteristics over time as a result of the stray pulses received. They must be replaced after each incident. The characteristic of a varistor is that with a voltage at its terminals less than its nominal value, the impedance of the MOV is very great (several Mohms). However, once that value is exceeded the impedance very quickly drops to less than 1 Ohm, with the response time for the MOV being approximately 20 to 50 ns.

Although the bi-directional TVS diodes provide very good performance for fast transients, the use of the MOV is a must in the case of a Solid state reversing contactor. Relays with internal TVS must not be used in motor reversing applications. An internal TVS may switch on the output of the SSR when

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subjected to an electrical transient, effectively creating a phase-to-phase short. A MOV may be placed across the output of each SSR to provide protection from transients.

*All the Crydom Solid State Reversing Contactors such as the DRA3R or 53RV series already include the MOV.*

#### 4 - SSRs with higher blocking voltage

In some installations, where electrical transients are very common and violent, using a standard high voltage SSRs (480-660Vrsm) is possibly be not enough. The standard blocking voltage for these SSRs is typically 1200V.

A good way to approach these types of applications is to use SSRs with higher blocking voltages. Going in this direction Crydom has, in 2012, presented the new **Crydom H16** model.



Complementing the successful Crydom Series H1 1200 Volt Blocking models, the new models now offer even higher levels of breakdown voltage and noise immunity (**>1600 volts**) for applications in installations where electrical

transients are common and might otherwise damage less robust SSRs.

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