LayerZero Technical Opinion: On the Inability to Truly Detect Open SCRs on the Inactive Side of Static Transfer Switches

Background

An open SCR condition on the inactive side of a static transfer switch cannot be detected. When a switch is in an off position it is impossible to predict that the switch will conduct current through it when it is turned on. At best, it may be possible to ascertain whether the controller that turns the switch on will operate when it is required to do so.

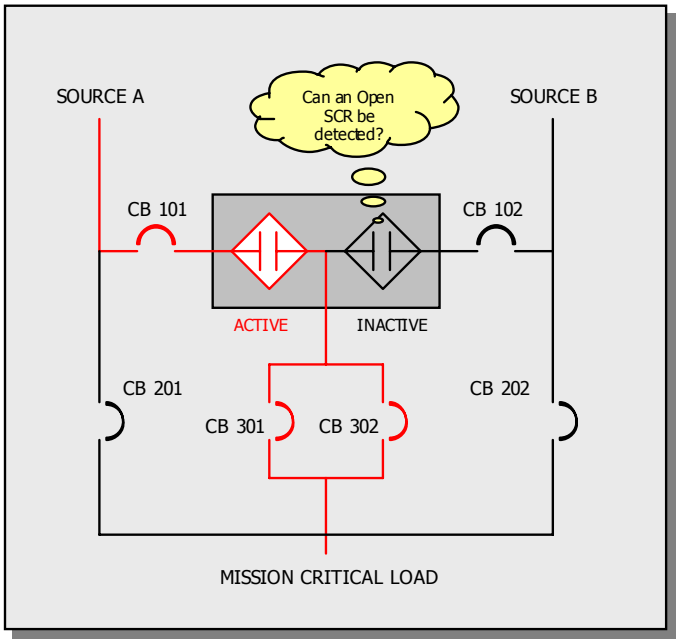

Figure 1: STS electrical one-line shows flow of power when Source A powers the critical load

An Open SCR on the active side of the STS turns off one half-cycle of one phase of the active source. Unless appropriate evasive action is taken by the STS, the mission critical load is suffers from a half-wave condition on one phase. In general, STS devices do take evasive action in the presence of open SCR conditions on the active side. Some designs transfer to the alternate source and shunt-trip the previously active side. LayerZero's design philosophy precludes the use of shunt-trips for this purpose. *(See LayerZero Technical Opinio: A Case for the Omission of Shunt-Trips in STS; LayerZero Document Number: 94-DA-400629).* A more reliable method is to transfer to the alternate source and inhibit re-transfer to the source with the open SCR condition.

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SCR Operation for Beginners

SCRs are three-terminal power electronic switches. In the ON position, current flows from the Anode to the Cathode. In the OFF position, no current flows from the Anode to the Cathode. The Gate terminal provides the ability to turn the SCR ON. If sufficient Gate-to-Cathode current is injected in the SCR while the voltage drop across the Anode-to-Cathode junction is higher than a prescribed threshold, then current starts to flow from across the Anode-Cathode junction. An SCR conducts current only in the Anode-to-Cathode direction. Current cannot flow in the Cathode-to-Anode direction.

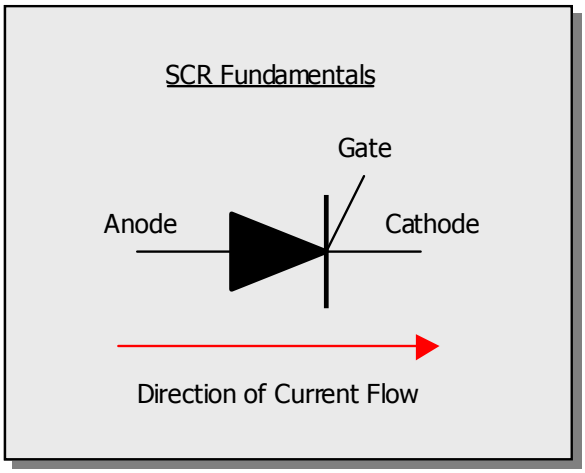


Figure 2: SCR Symbol and Flow of Current

In a Static Transfer Switch, each phase conductor has a pair of SCRs connected in an anti-parallel arrangement. One side of the anti-parallel set of SCRs is connected to a Source and the other to the Load. In the Inactive state, neither of the anti-parallel pair of SCRs is turned ON. In this state no amount of external perturbation or experiment can guarantee that Anode-to-Cathode current will flow when called upon at some future time. It is entirely possible that the Anode-to-Cathode junction in one or both pairs of SCRs has become defective and that when a Gate current is injected to turn the device ON, there will be no current flow across the Anode-to-Cathode junction.

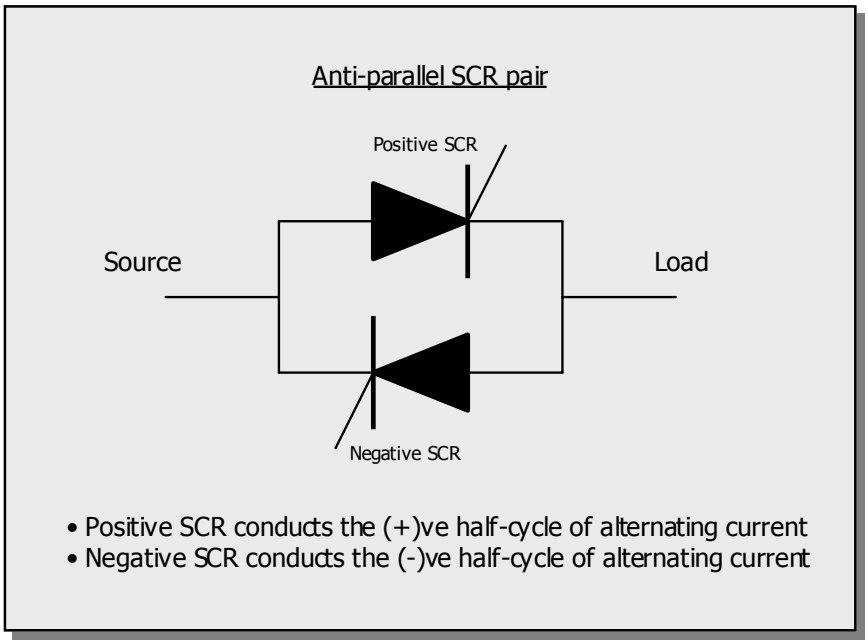
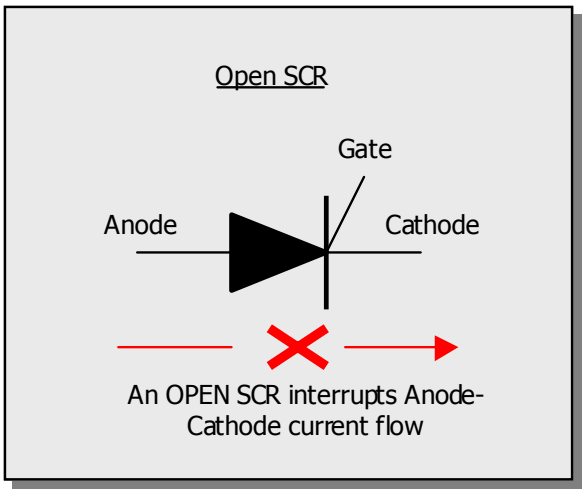


Figure 3: Anti-parallel SCR pair for AC waveform

The fundamental assertion in this Technical Opinion is that it is



not possible to predict that a switch will close and conduct current (or will not close and will not conduct current when required) by observing the switch in its open state. In order to declare a switch defective, an attempt has to be made to allow it to carry current.

Figure 4: An Open SCR interrupts current

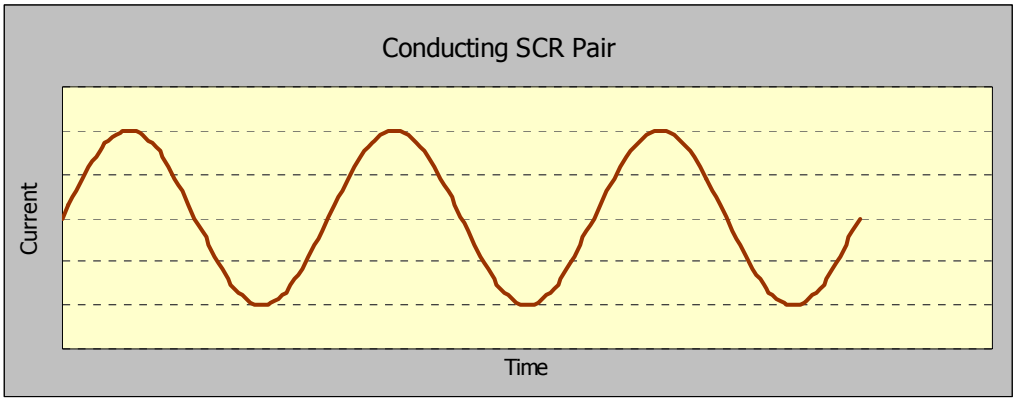


Figure 5: AC waveform through an anti-parallel SCR pair

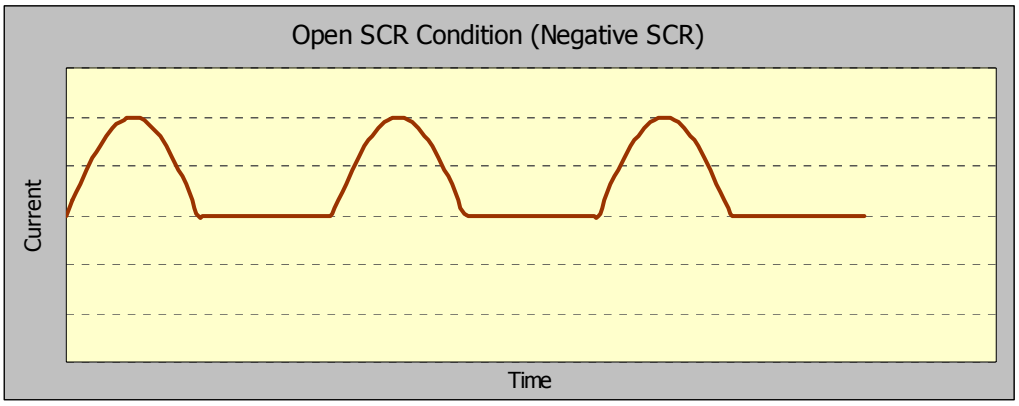
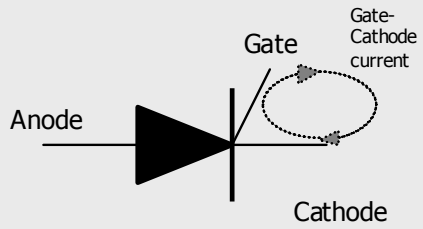


Figure 6: AC waveform through anti-parallel SCR pair with an Open SCR condition of the Negative SCR

Open SCR detectors on Inactive Source

Designers that claim knowledge about an open SCR condition on the inactive side are, in reality, checking the continuity of the Cathode-Gate junction. A true check of the open SCR condition would involve checking the continuity of the Anode-Cathode junction. It is entirely possible to have a healthy Cathode-Gate junction but an unhealthy Anode-Cathode junction in an SCR. In such a case, the open SCR detectors on the alternate side of the switch would report a healthy SCR, whereas in reality, if the switch were to transfer to the alternate source, the SCR would turn out to be in an Open condition.

SCR Gate-Cathode Junction Check



Gate-Cathode continuity is erroneously flagged as an healthy SCR on the inactive side

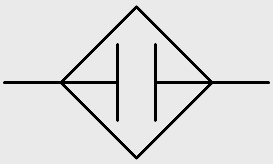
Location of SCR Monitors

SCRs are controlled by driver circuits called Gate Drives. Open and shorted SCR detectors often conveniently reside on the Gate Drive circuit boards. However, if the gate drive circuit board fails, the system loses the ability to detect the state of the SCRs associated with that gate drive board. If the gate drive board associated with an Active (i.e. conducting) pair of SCRs fails it results in the loss of a phase to the load. In mission critical applications, this is an unacceptable consequence.

LayerZero's STS design provides an SCR monitor that is decoupled from the Gate Drive circuit boards. If the Gate Drive circuit board of an active SCR fails catastrophically (thereby failing to keep the SCRs turned ON), the system detects this condition as an "open SCR" and transfers the load to the alternate source. This design feature is embedded in both Triple Modular Redundant and Single Module Redundant variants of the OPTS product.

Legend:

NEMA Symbol for an Anti-parallel SCR pair



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