LayerZero Technical Opinion: A Case for the Omission of Shunt-Trips in STS

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STS in Mission-Critical Applications

Static transfer switch (STS) devices occupy a unique architectural location in mission critical infrastructure systems, in that their tolerance for failure is virtually zero. Generally located at the intersection of redundant power distribution networks, STS are charged with providing critical load with power whenever at least one source is available and simultaneously isolating the multiplicity of redundant power distribution networks from each other. This demanding requirement forces STS equipment to be designed with particular attention to reduction of single points of failure modes and minimization of risk in components that can not be made redundant. Input and output circuit breakers are among the few STS components that cannot be reasonably made redundant against all failure modes. LZPS has taken the design approach where the potential single points of catastrophic system failure due to failure of circuit breaker shunt trip mechanisms and their associated driving circuitry is completely eliminated from the reliability equation by elimination of the shunt trip mechanisms from all circuit breakers.

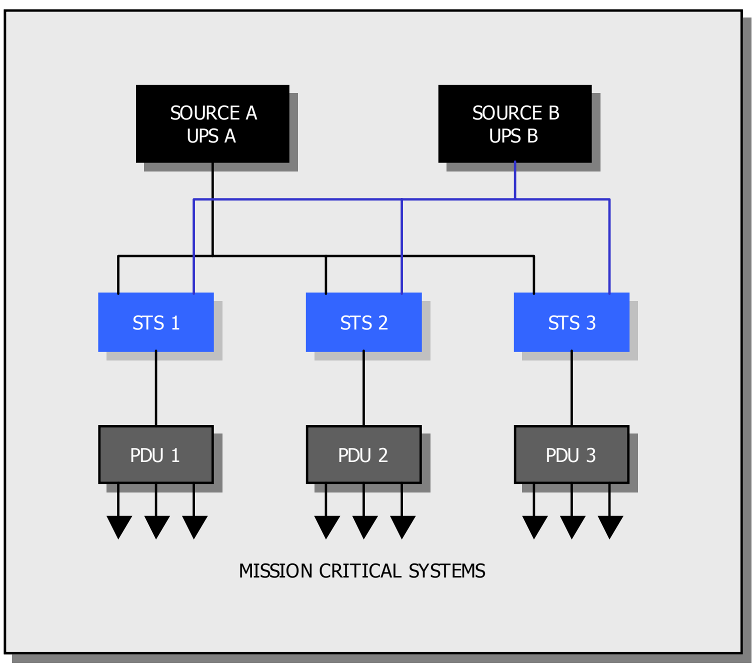

Figure 1: STS at the Intersection of Redundant Power Distribution Networks

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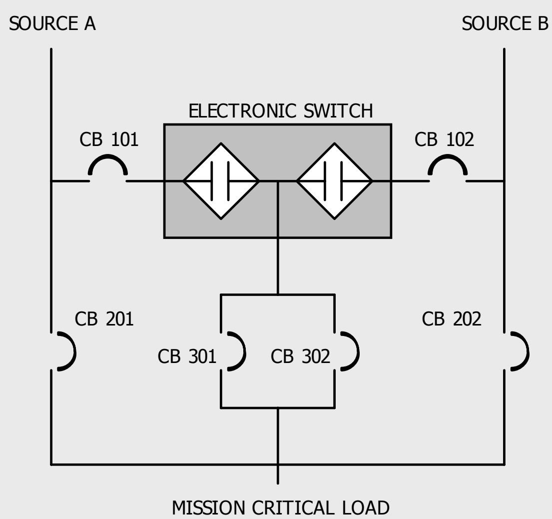
Shunt-Trip Mechanism

Circuit breaker shunt trip mechanisms are mechanical in nature and prone to misoperation for a variety of reasons. In a mission critical power system, the objective of a circuit breaker is to remain closed at all times, except when required to open for electrical reasons. In order to insure that the circuit breaker will be able to successfully open under the high mechanical forces present in a fault situation, the circuit breaker stores significant mechanical energy. The shunt trip mechanism is capable of releasing the stored energy, opening the circuit breaker, based on small electromechanical inputs. The tolerances of these parts, wear, variations in lubrication and external vibration all stack in the direction of encouraging the shunt trip mechanism toward instability, open the breaker without sufficient cause. The system gain from inputs (vibration, wear, tolerance) to output (circuit breaker releasing stored energy and opening the circuit) is very large, with no feedback to stabilize the system against mechanical or electrical noise. For this reason, the basic shunt trip mechanism in the circuit breaker is viewed by LZPS as insufficiently reliable for use in mission critical situations.

The software and electronic circuits driving circuit breaker shunt trip mechanisms can be designed to be extremely reliable, but ultimately result in the introduction of a single point of failure due to the existence of a single shunt trip mechanism per circuit breaker. LZPS STS equipment pioneered the use of Triple Modular Redundancy for mission critical power systems, and use redundancy to eliminate statistically significant failure points. However, the fact that a single magnetic component is used in the shunt trip mechanism requires that a single signal and driver be used

STS: Typical Electrical One-Line



CB 101	SOURCE A Isolation Switch (Normally Closed)
CB 102	SOURCE B Isolation Switch (Normally Closed)
CB 201	SOURCE A Bypass Switch (Normally Open)
CB 202	SOURCE B Bypass Switch (Normally Open)
CB 301	LOAD Isolation Switch #1 (Normally Closed)
CB 302	LOAD Isolation Switch #2 (Normally Closed)

STS equipped with Shunt-Trips, typically, have the ability to trip the two Source isolation and the two Bypass isolation switches. An erroneous Trip command can instantly shut-down power to the Mission Critical Load.

Figure 2: Typical STS electrical one-line. Shunt-trips can, inadvertently, shut-down power to the critical load

to ultimately cause current to flow in the electromagnet used in the shunt trip mechanism. This circuit cannot be reasonably made free of statistically significant single points of failure. Thus even if the mechanical aspects of the shunt trip mechanism could be made completely reliable, the driving electronics remain an unavoidable single point of failure.

Misplaced Automation Reduces Reliability

In the case of circuit breakers used in STS equipment, the impetus to open circuit breakers under automatic control is the desire to (1) remove shorted SCRs from source to source cross current paths and (2) guide or correct errors in the system bypass procedure. Both of these goals are highly desirable, but are best served by design methods that do not involve shunt tripping circuit breakers. When shorted SCRs are detected on inactive sources, current may begin to flow between sources. Shunt trip mechanism are very slow compared to the potential rate of rise of current between sources, thus the use of shunt trips to stop cross current flow will generally be too late to completely accomplish the goal. A far better strategy is to simply transfer the STS to the source with the shorted SCR, lock the STS on that source, and post appropriate alarms. In the case of helping with bypass procedures, the typical scenario is to connect the shunt trip in series with the auxiliary contact on another circuit breaker. This situation is particularly egregious in that auxiliary contacts are notoriously unreliable. Connecting two mechanical devices in series demands that both devices operate perfectly for mission success. The numerical product of the relatively low reliabilities associated with these components results in a probability of mission success completely unacceptable

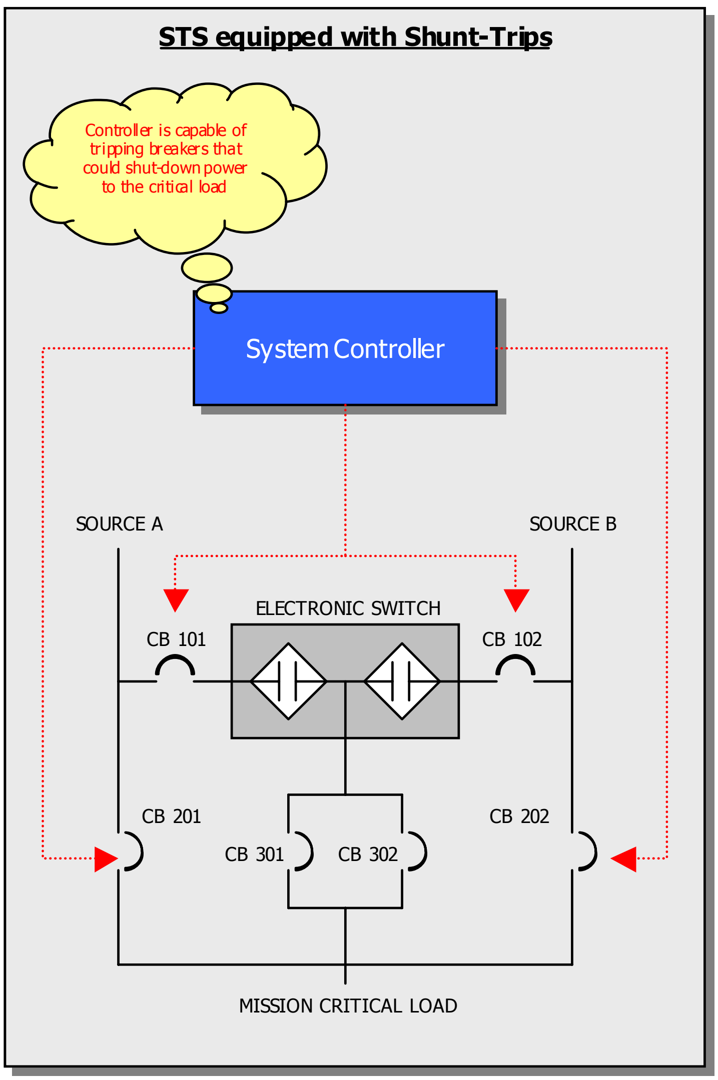


Figure 3: The presence of Shunt-trips in STS vastly reduce the probability of mission success

in mission critical applications. Simple mechanical stops and gates on circuit breaker handles provide excellent protection from operator induced bypass procedure error with no negative impact on overall probability of mission success for the system.

The Ultimate Goal: Reliability

LZPS STS products are designed to provide, and have demonstrated, superior reliability through careful elimination of numerically hazardous components. Circuit breaker shunt trip mechanisms represent extremely high hazard rate components, located in system positions where it is unreasonable to effectively mask their lack of reliability through redundancy. By taking the approach of not incorporating circuit breaker shunt trips in any STS device, LZPS provides significant, measurable, demonstrated reliability improvement over equipment relying on shunt trips for operation.

Shunt Trips; Auxiliary Contacts and UL-1008 Requirements

In response to a shorted SCR condition on the inactive source; UL requires that the STS take appropriate action to prevent the inadvertent cross-connection of sources. The standard notes that one method of preventing the inadvertent cross-connection of sources may be the use of shunt-trip devices on appropriate input isolation breakers. Separately, UL makes provisions for the listing of "Bypass Isolation Switches", as applied to electromechanical transfer switches to have a two-step mechanism to complete Bypass & Isolation steps. This standard is not applicable to STS unless the manufacturer wishes to list the device as a Bypass & Isolation system. When applied to STS, one method of realizing a two-step procedure requires the series coupling of CB Auxiliary Contacts with CB Shunt-Trips.
LayerZero does not recommend this technique in STS devices.