Beware of Transformer and Static Transfer Switch Location in Critical Environments

Keith Lane, P.E., RCDD/NTS, LC, LEED A.P.
Lane Coburn and Associates, LLC. 12900 NE 180th Street, Suite 201, Bothell, WA 98011

Consulting-Specifying Engineer

Editor's Note: *This is the author's follow-up to his June 2005 Pure Power article, Location, Location, Location. This sequel provides some further observations on the importance of being cautious and aware of proper transformer and static transfer switch location in critical environments.*

As stated in the first article on this subject, a means of transferring between sources of power within the confines of the CBEMA (Computer Business Manufactures Association) or ITI curve is essential in critical environments that require high levels of site availability. Automatic transferring between reliable sources of power is required to satisfy the requirements of a Tier 4 data center as defined by the Uptime Institute. The requirement for two active paths (See Tier 4 definition below) can be achieved with dual cord servers or with static transfer switches (STS).

Tier IV Data Center - Fault Tolerant
Tier IV provides site infrastructure capacity and capability to permit any planned activity without disruption to the critical load. Fault-tolerant functionality also provides the ability of the site infrastructure to sustain at least one worst-case unplanned failure or event with no critical load impact. This requires simultaneously active distribution paths, typically in a system + system configuration. Electrically, this means two separate UPS systems in which each system has N+1 redundancy. Because of fire and electrical safety codes, there will still be downtime exposure due to fire alarms or people initiating an Emergency Power Off (EPO). Tier IV requires all computer hardware to have dual power inputs as defined by the Institute's Fault-Tolerant Power Compliance Specification Version 2.0 (www.uptimeinstitute.org/spec.html).

Electrical distribution systems designed for critical environments that utilize PDU transformers downstream of STS can cause excessive inrush current to occur in the event of a transfer of sources. Depending on the static switch transfer time, the phase orientation of the sources and the location of the alternating current waveform at the time at which the voltage is reapplied after the original voltage is taken away (zero crossing is the worst case scenario), the transformer can saturate and cause excessive current inrush, as seen in Figure 1 below. Other factors that determine the total inrush current include the total combined size of transformer core, impedance of the source and the sine and value of the transformer residual flux.

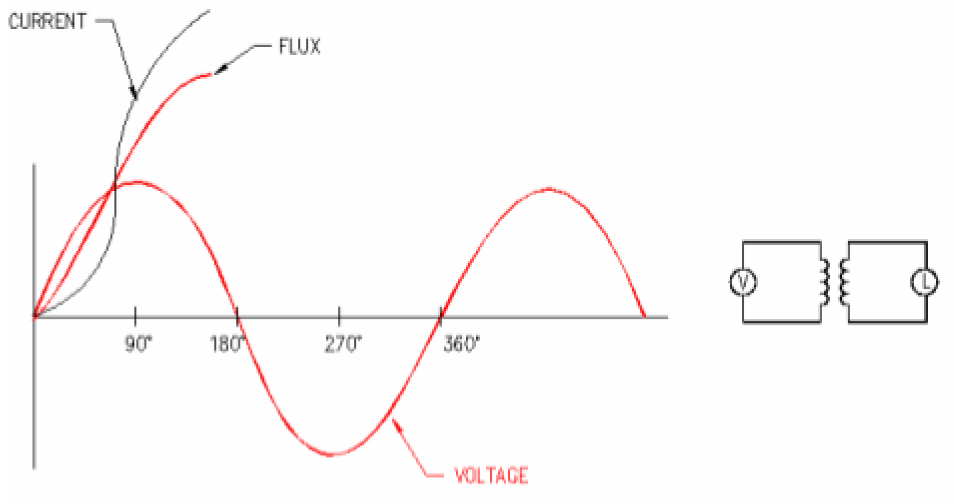


Figure 1 - Transformer Flux and Inrush Current at Zero Voltage Crossing

This chart represents the potential for transformer saturation and high inrush current. If the transformer is switched on when the voltage waveform is at the zero crossing, the required flux would be about double the steady-state amount. The winding current required to create this amount of flux in a "non-ideal" transformer can be significantly higher than twice the steady state current.

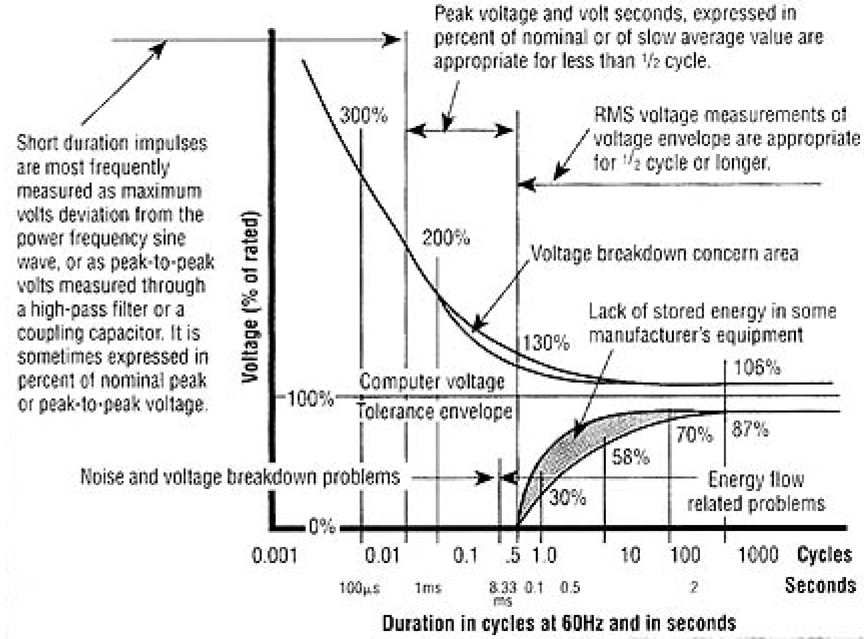
The conclusion to my previous article stated the following: “Mechanically, the most ideal solution would include relocating the 208/120-volt 3-phase PDU transformers to the upstream side of the static transfer switches. This solution can represent voltage drop issues for the system and larger ampacity requirements for the STS based on the transformation from 480/277-volt 3-phase to 208/120-volt 3-phase upstream of the STS, but would eliminate the transformer saturation and inrush problems. Proper critical facility design and maintenance and operation procedures are of paramount importance to ensure high levels of site availability.”

Recently, new technology has become available that now brings additional light to this subject and may provide an additional alternative to ensuring maximum system uptime while minimizing total system electrical distribution cost. There are newly developed systems that have optimized the transfer control algorithms that can eliminate the transformer inrush problem. According to the system literature, these algorithms can eliminate this potential inrush problem even if the two input systems are not synchronized, and are in an electrical distribution system where the transformer is downstream of the STS.

These newly developed systems utilize algorithms that optimize the transfer time so that the volt-seconds applied to the downstream transformer are balanced. This will minimize the potentially large saturation current associated with transformers downstream of STS. The actual minimizing of the saturation current is achieved by systematically determining the best time to fire the silicon-controlled rectifiers (SCRs) in the STS to balance the volt-seconds to within a predetermined tolerance. These systems indicate that they are independent of the voltage waveform shape and other voltage attributes. These manufacturers indicate that the systems are better than the systems that rely solely on the voltage phase angle to determine the firing of the SCRs.

These systems also indicate that they minimize the voltage disturbance while maintaining the transformer flux by taking considering the voltage-second and voltage disturbance into the systems algorithm. These types of systems can deliver a better waveform to the critical systems. Because of these systems’ additional “thinking” and “intelligent firing of the SCRs, the actual transfer time may be greater than the classic 4 ms of the traditional STS. These systems indicate that the increased time required for the operation of these advanced systems is offset by the minimization of the disturbance of the output waveform that the intelligent firing of the SCRs can produce.

When selecting an appropriate solution for your critical environment project, the electrical engineer or data center architect must ensure that under all circumstances the voltage waveform to the critical load will stay within the CBEMA/ITI curve, shown in Figure 2, below.



This chart represents the potential for transformer saturation and high inrush current. If the transformer is switched on when the voltage waveform is at the zero crossing, the required flux would be about double the steady-state amount. The winding current required to create this amount of flux in a "non-ideal" transformer can be significantly higher than twice the steady state current.

The conclusion to my previous article stated the following: "Mechanically, the most ideal solution would include relocating the 208/120-volt 3-phase PDU transformers to the upstream side of the static transfer switches. This solution can represent voltage drop issues for the system and larger ampacity requirements for the STS based on the transformation from 480/277-volt 3-phase to 208/120-volt 3-phase upstream of the STS, but would eliminate the transformer saturation and inrush problems. Proper critical facility design and maintenance and operation procedures are of paramount importance to ensure high levels of site availability."

Recently, new technology has become available that now brings additional light to this subject and may provide an additional alternative to ensuring maximum system uptime while minimizing total system electrical distribution cost. There are newly developed systems that have optimized the transfer control algorithms that can eliminate the transformer inrush problem. According to the system literature, these algorithms can eliminate this potential inrush problem even if the two input systems are not synchronized, and are in an electrical distribution system where the transformer is downstream of the STS.

These newly developed systems utilize algorithms that optimize the transfer time so that the volt-seconds applied to the downstream transformer are balanced. This will minimize the potentially large saturation current associated with transformers downstream of STS. The actual minimizing of the saturation current is achieved by systematically determining the best time to fire the silicon-controlled rectifiers (SCRs) in the STS to balance the volt-seconds to within a predetermined tolerance. These systems indicate that they are independent of the voltage waveform shape and other voltage attributes. These manufacturers indicate that the systems are better than the systems that rely solely on the voltage phase angle to determine the firing of the SCRs.

These systems also indicate that they minimize the voltage disturbance while maintaining the transformer flux by taking considering the voltage-second and voltage disturbance into the systems algorithm. These types of systems can deliver a better waveform to the critical systems. Because of these systems' additional "thinking" and "intelligent firing of the SCRs, the actual transfer time may be greater than the classic 4 ms of the traditional STS. These systems indicate that the increased time required for the operation of these advanced systems is offset by the minimization of the disturbance of the output waveform that the intelligent firing of the SCRs can produce.

When selecting an appropriate solution for your critical environment project, the electrical engineer or data center architect must ensure that under all circumstances the voltage waveform to the critical load will stay within the CBEMA/ITI curve, shown in Figure 2, below.

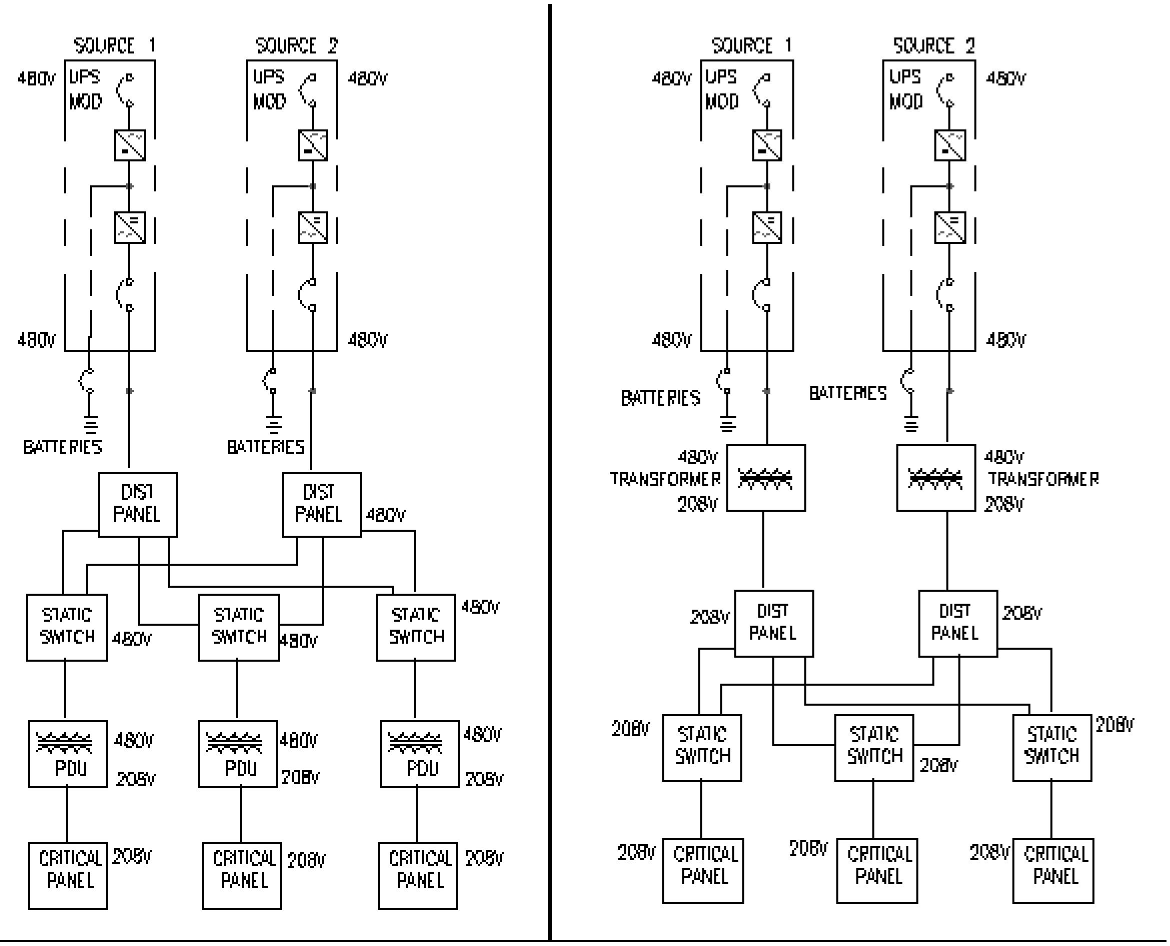


Figure 3 - Electrical Distribution System

The figure on the left (above) represents the 480-volt STS upstream of the 208/120-volt 3-phase transformer PDUs. The diagram on the right represents the 208/120-volt 3-phase transformers on the UPS output, upstream of the 208-volt STS. The system on the right would eliminate the transformer inrush issues associates with a transfer of the STS, but could represent higher construction cost associated with larger ampacity of the STS and electrical distribution based on transforming to 208 volt further upstream.

The static transfer switch is a critical component within a data center or other critical environment. These systems can also be the Achilles heel of the electrical distribution system if not operating properly and can represent a single point of failure in the system. If critical loads (servers) are all dual cord, the STS is not even required to bring two sources of power to the critical loads (servers). As these advanced static transfer switch systems with the new algorithms and firing abilities of the silicon controlled rectifiers (SCRs) are still relatively new, I have yet to utilize them in a data center or other critical environment application. The potential cost savings in the electrical distribution system from the use of these STS are tangible. The additional savings from these systems could be a direct savings to the facility owner, or could be utilized to enhance other components within the electrical distribution system to ensure optimum uptime.

This new technology is a further step in the advancement for cost effectively providing the highest system reliability. I do however have some hesitation with the use of these new improved STS systems. This hesitation could stem from the fact that I have not yet actual utilized these advanced STS in a data center of other critical installation. Sometimes a step towards new technology or design methods can include questions concerning reliability. In my opinion, there is potentially more of a possibility of something not operating properly as these systems become more technical and advanced to program, operate and maintain. If for some reason the systems do not properly fire the SCRs or the algorithm is not operating in a manner to ensure a transfer of sources of reliable power within the time frame of the CBEMA/ITI curve, critical loads could be dropped off line. After a track record of successful projects, this technology and the placement of the static transfer switches upstream of the transformer may become the preferred method and the standard design practice for data centers and other critical environments.

When the STS are located on the secondary of the transformer, the electrical distribution systems do not have to rely on this new technology to ensure saturation current is not a problem. On the other hand, this electrical distribution topology can be cost prohibitive. The electrical design engineer or data center architect must weigh the potential tangible cost savings when utilizing these new static transfer switch systems with the potential increased level of complexity these systems may bring to the table prior to moving forward with the use of these advanced static transfer switch systems.