Engineering White Paper

ELIMINATING TRANSFORMER SATURATION: THE LIEBERT STS2 OPTIMIZED TRANSFER

Introduction

Static transfer switches (STS) are used as either primary or secondary side switches in high availability dual-bus configurations. For primary side switching, the STS is connected to the primary or input of a down stream transformer. On secondary side switching, the STS is connected to the secondary or output of two transformers.

Primary side switches are less expensive to deploy, but have traditionally suffered from transformer inrush saturation current each time switching occurs. Liebert has developed a switching algorithm that eliminates this problem. This Optimized Transfer option, available on the Liebert STS2, is the subject of this paper.

Primary Side Switching

Primary side switching has cost advantages compared to secondary side switching because:

- Only one power distribution unit is needed,
- The STS is a lower current rating (- 480V versus 208V), and
- Installation and wiring costs are lower (3 wire versus 4 wire, smaller cable.)

The disadvantage of this configuration has been the tendency for the downstream transformer to cause large peak saturation current during automatic switching. The transformer saturation is caused by DC-flux build-up during transfer, especially when the sources are not in phase.

The Liebert Solution

Liebert has developed a new optimized transfer control algorithm that eliminates this problem.

Liebert's patent pending algorithm optimizes the transfer timing so that the volt-seconds applied to the downstream transformer primary is balanced, thus minimizing peak saturation current.

The volt-second balance is achieved by directly computing the volt-second applied to the transformer during transfer events and determining the optimum time to turn on the alternate source SCRs to balance the volt-second within the specified tolerance.

This results in a volt-second balancing algorithm that is independent of voltage wave shape, voltage failure decay rate and other anomolies, making it superior to other algorithms based only on voltage phase angle.

Figures 1 and 2 show results for the standard STS2 versus the optimized STS2 for the same condition (alternate source lags 120 degrees), respectively. Note how the optimized transfer control algorithm minimizes the transformer saturation current resulting from an out-of-phase transfer.

But Liebert's Optimized Transfer control does more than balance the flux.

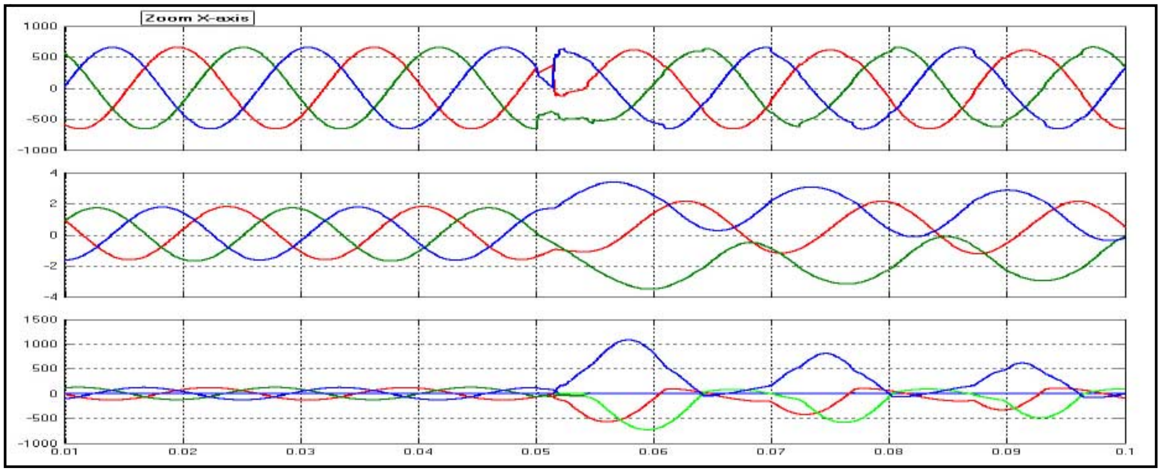

Figure 1. Standard STS Transfer (top to bottom): Load voltages, tranformer fluxes and primary currents.

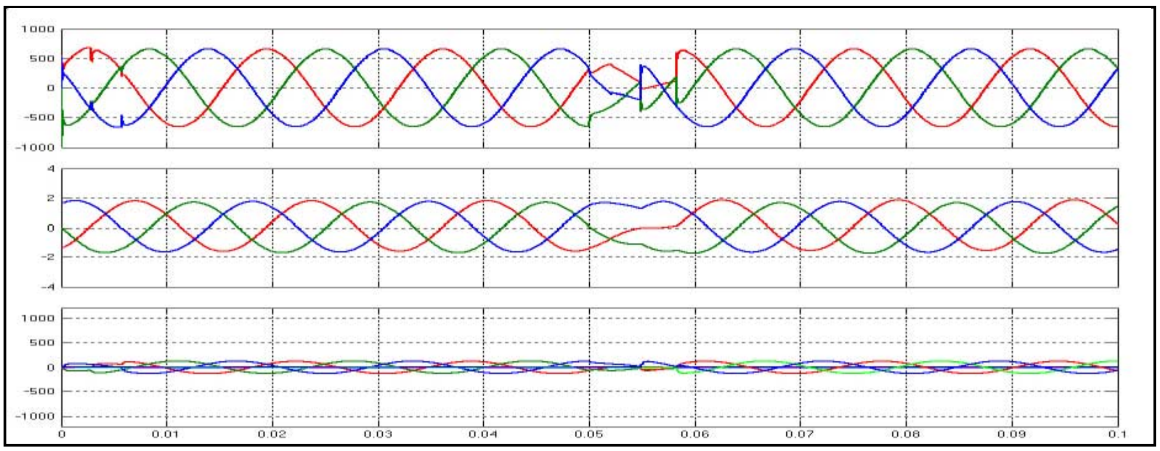

Figure 2. Optimized STS Transfer (from top to bottom): Load voltages, transformer fluxes and primary currents.

Whenever possible, Liebert's method minimizes the voltage disturbances while still maintaining transformer flux balance by taking both voltage disturbance and volt-second balance into consideration. In terms of classical optimization formulation, this algorithm solves the problem of minimizing the output voltage disturbance with the constraint of balancing the flux (volt-sec).

The Liebert flux balance algorithm doesn't just "sit and wait" for the balance point to occur. Rather, it will "pulse fire" the SCRs as soon as possible (whenever it is "advantageous" to do so) to minimize the load discontinuity and hence the voltage disruption. This is shown in Figure 3. As a comparison, a transfer technique that "only" balances volt-seconds without regard to the voltage waveform would result in a voltage disturbance as shown in Figure 4.

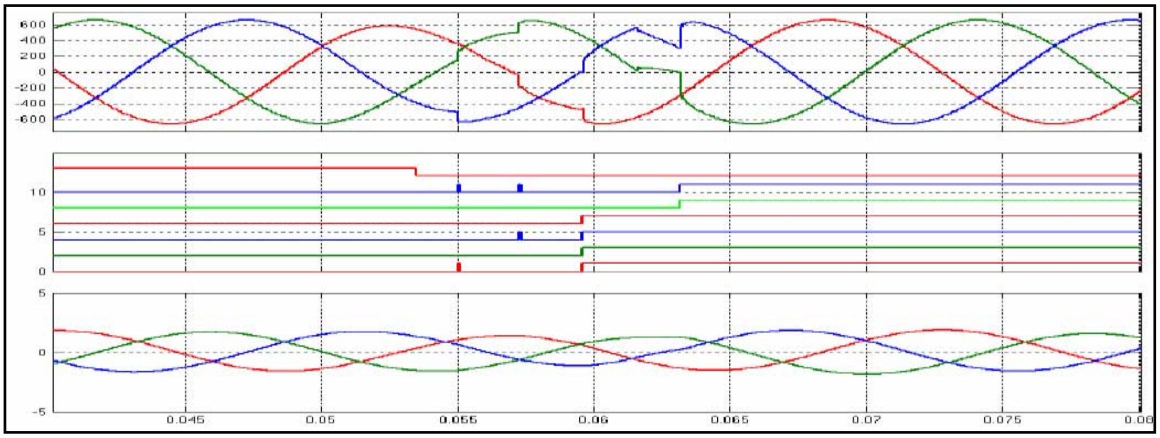

Figure 3. Liebert's optimized transfer with SCR pulsing balances the volt-second and optimizes the voltage waveforms for minimum distortion. From top to bottom: Load voltages, SCR firing signals and transformer fluxes.

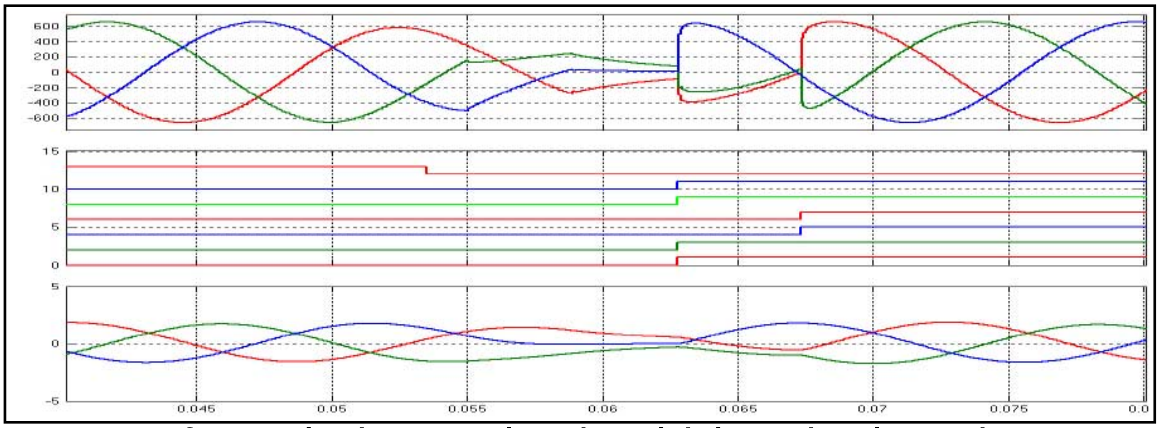

Figure 4. Transfer control without SCR pulsing that only balances the volt-second. From top to bottom: Load voltages, SCR firing signals and transformer fluxes.

Both transfers in Figure 3 and Figure 4 are performed under the same source failure, phase difference and load conditions. Note that both methods balance the volt-seconds, preventing transformer saturation. However, Liebert's optimized method shown in Figure 3 results in far superior voltage waveforms applied to the load.

Because of Liebert's unique approach, transfer time should not be the only performance measure for this new optimized STS2. This is illustrated in Figure 5. Even though the "transfer time" is longer than the standard 4 ms, it can be seen that the voltage waveforms are hardly disturbed.

Here we have used the classical definition of transfer time (IEEE Benchmark Systems for Static Transfer Switch 2001), i.e. the time elapsed between the source failure detection to the transfer completion (all alternate switches are on).

In light of this, we add the following performance measures, in addition to the "transfer time:"

a) Minimum RMS voltage applied to the load during transfer as illustrated in Figure 6.

b) Maximum load current interruption (period of time the load current is zero) as illustrated in Figure 7.

Using these three performance measures (minimum RMS voltage, transfer time, and load current interruption),

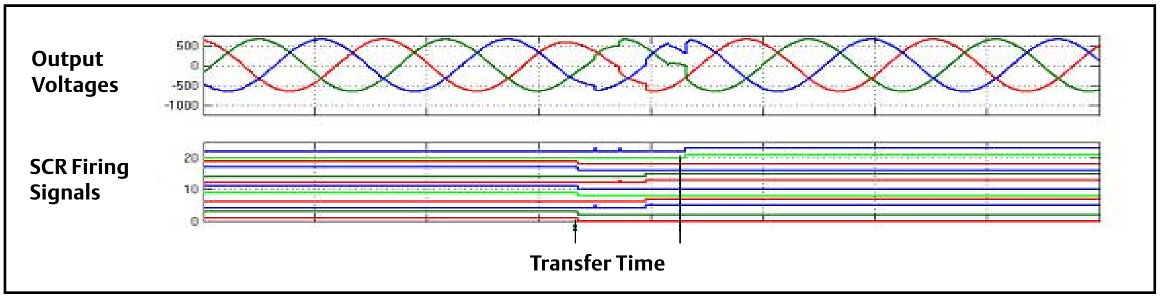

Figure 5. Optimized transfer with SCR pulsing: Load voltages (top) and SCR firing signals (bottom).

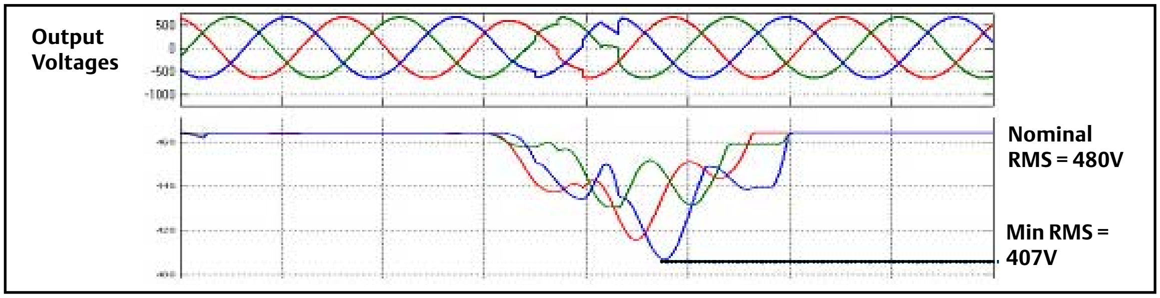

Figure 6. Optimized transfer output voltage: output voltages (top) and moving window one cycle RMS (bottom).

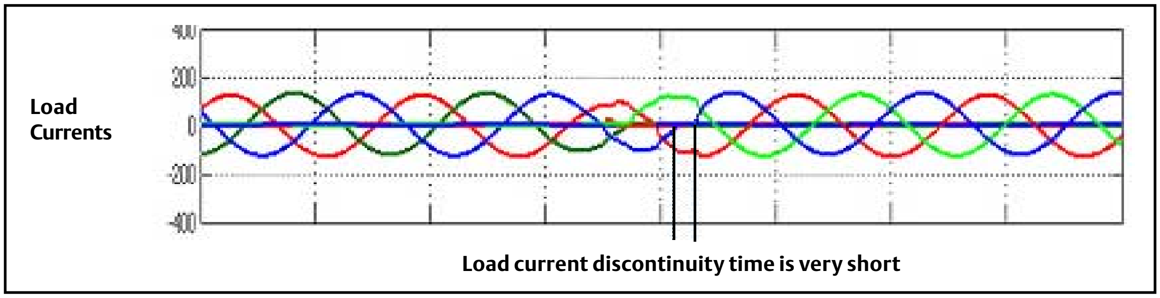

Figure 7. Optimized transfer load current interruption: Load currents.

Figures 8- 12 show the performance of the optimized STS2 for five major faults conditions including loss of source (three-phase breaker open); loss of a phase (single-phase breaker open); voltage droop; phase-to-neutral short; and, phase-to-phase short.

Liebert's unique control allows completion of all transfers in under a cycle with the worst-case load current interruption of 5 ms.

Liebert's Optimized STS2 safely meets both the CBEMA standard (prior to 1996) and the latest ITIC standard (1996) for critical loads. Figure 13 shows the performance of Liebert's Optimized STS2 in relation to the two standards.

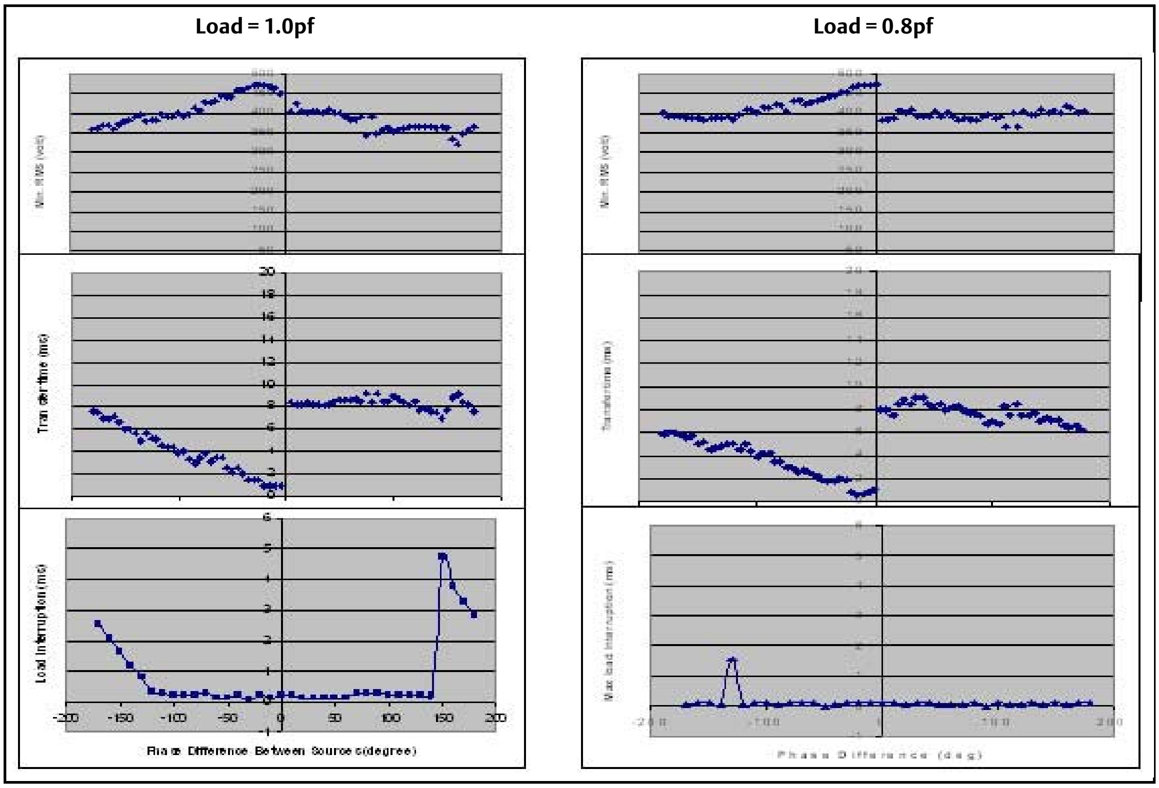

Figure 8. Optimized STS2 Performance: Loss of source (three-phase breaker open).

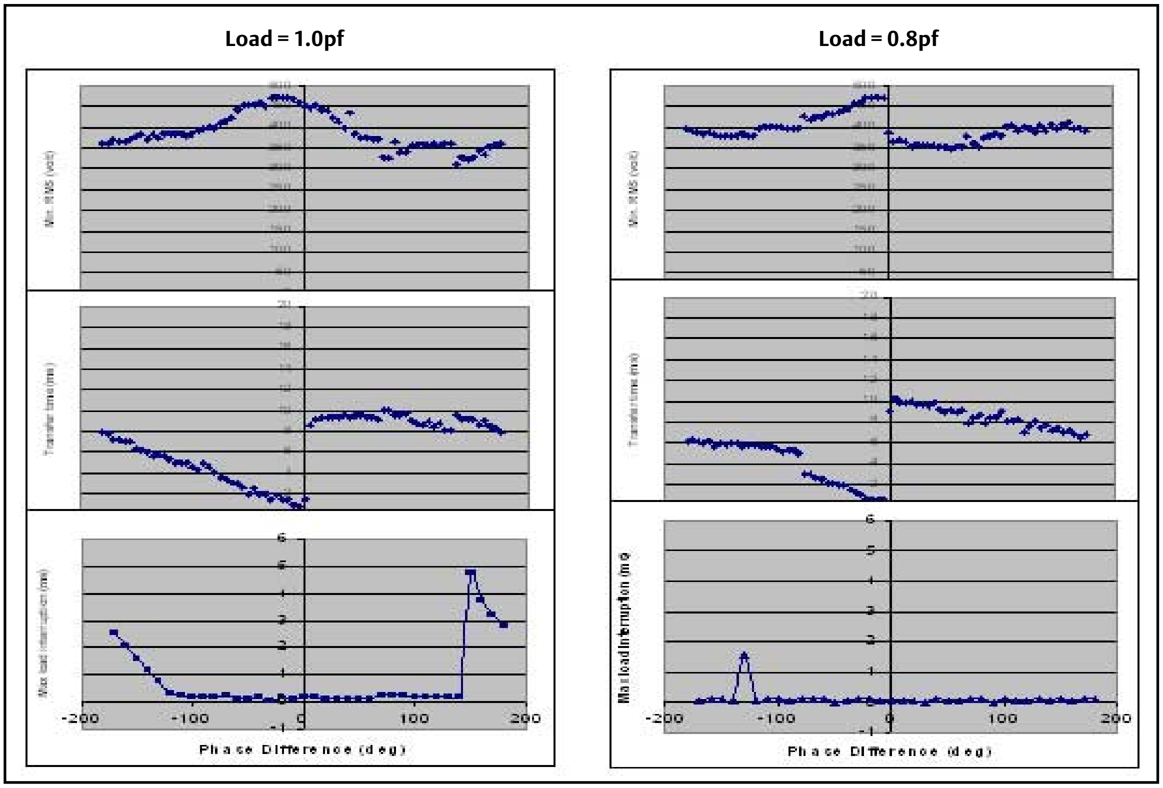

Figure 9. Optimized STS2 Performance: Loss of source (single-phase breaker open).

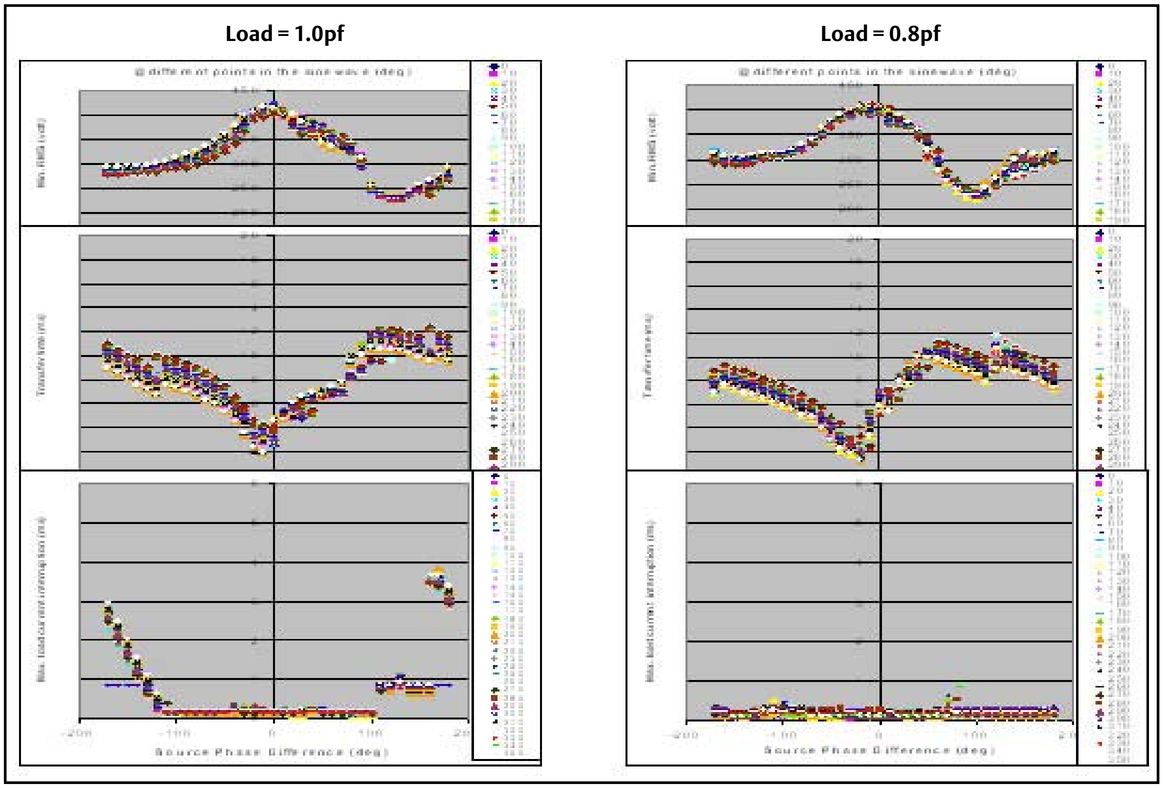

Figure 10. Optimized STS2 Performance: Voltage drop.

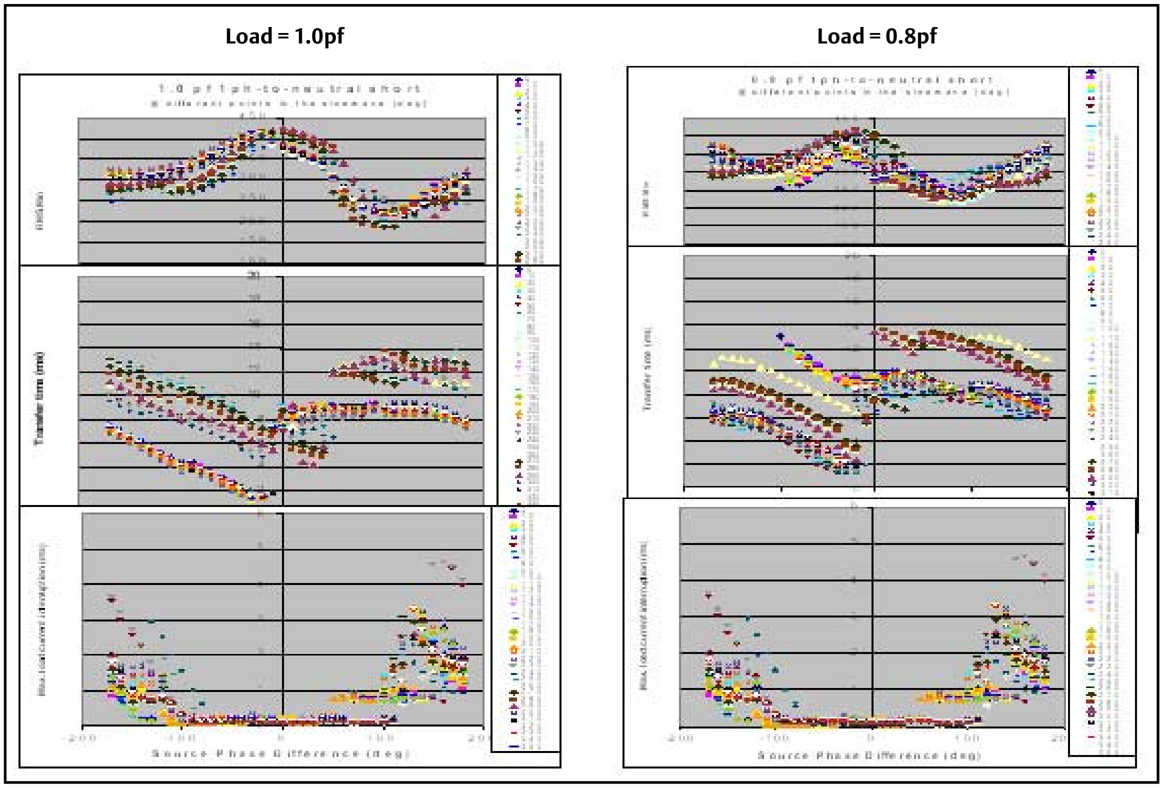

Figure 11. Optimized STS2 Performance: Phase-to-neutral short.

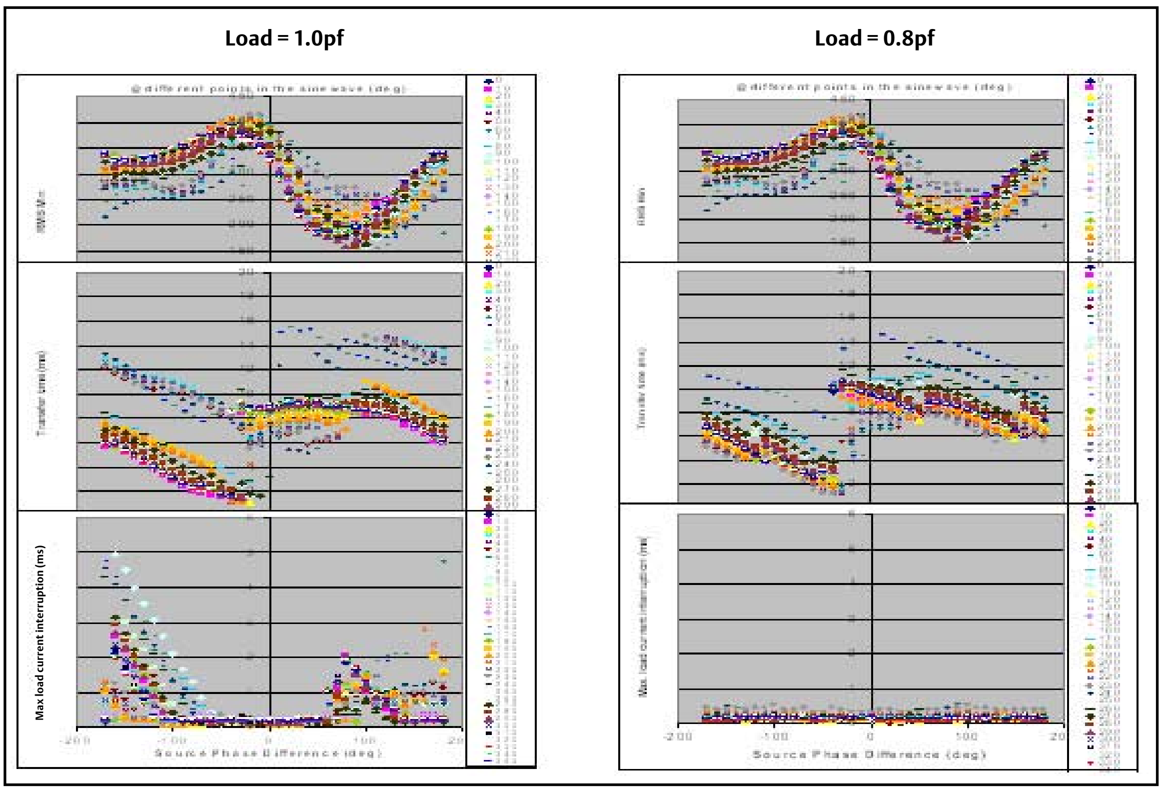

Figure 12. Optimized STS2 Performance: Phase-to-phase short.

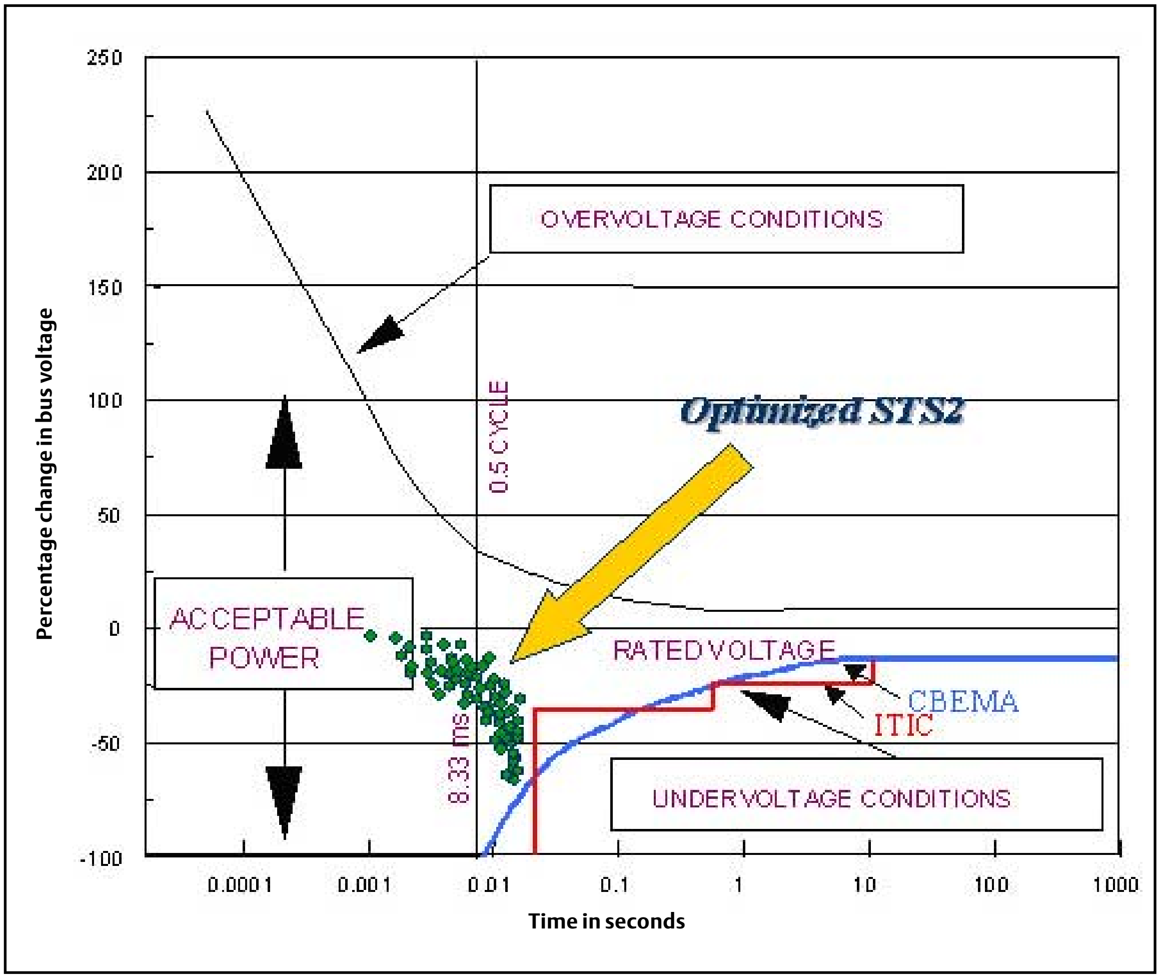

Figure 13. Liebert's Optimized STS2 performance in relation to CBEMA and ITIC standards. Points in the graph represent typical and worst case performances during transfers under five major fault conditions.

Conclusions

- Liebert's Optimized STS2 eliminates the risk of transformer saturation problems during automatic transfers.
- Liebert's control (patent-pending) ensures minimum voltage disturbance during transfers while still balancing the flux.
- Liebert's Optimized STS2 safely meets the maximum voltage outage specified by the CBEMA and ITIC standards.
- Standard design – 4ms transfer
  - Secondary side, 208V, switching
- Optional Optimized Transfer
  - Primary side, 480V / 600V, switching
  - Out-of-phase transfers

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