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CYBEREX®

DYNAMIC INRUSH RESTRAINT (DIR)

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WHY IS IT NEEDED?

Today's data center designers often use static transfer switches (STS) in their power system designs. The STS allows for flexible maintenance, adds to system reliability, and overall uptime. The typical system design incorporates two separate Uninterruptible Power Supplies (UPS) feeding the primary and alternate sources of the STS. The most common and cost effective design is to do the switching at 480 volts. This only requires one downstream PDU transformer from the STS. The alternative design would be to switch at 208 volts. This design would require each source to have its own fully rated transformer.

Typically, UPS A and B are fed from the same utility grid. Both UPS inverters will synchronize to their utility inputs. During this normal condition, the phase angle between UPS A and B is minimal. However, during battery operation, each UPS goes on its own internal clock. Over time, the phase angle can drift apart. The problem can be made worse if each UPS has its own dedicated emergency generator. In either case, the phase angle between sources can be problematic to the critical power system.

When a 480 volt STS needs to conduct an emergency transfer during an out of phase condition, the open transfer time of the STS is less than a ¼ cycle. With this quick out of phase transfer, the transformer's magnetic field does not have enough time to collapse. This results in large inrush currents drawn from downstream PDU transformers.

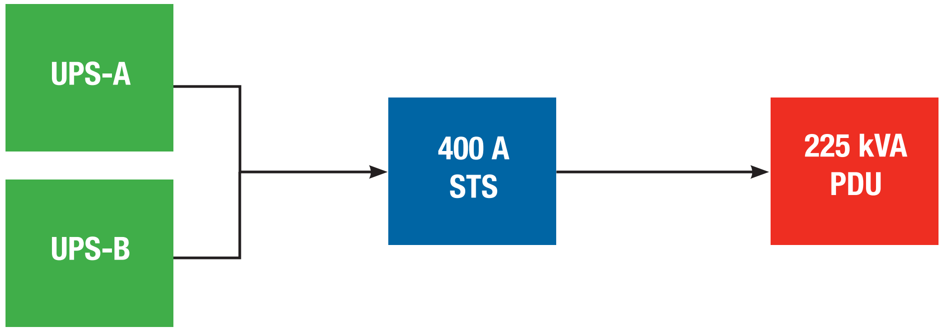

Figure 1

Let's look at a scenario (Figure 1) with a 480 volt STS, rated at 400 amps, feeding one 225 kVA PDU transformer. The 225 kVA transformer will draw 625 amps at full load. With a phase angle difference of 120 degrees, an inrush current could be up to 6100 amps during an emergency transfer as illustrated in Figure 2 below.

The bases of the peak value of the first cycle inrush current can be obtained using following equation:

$$I_{peak} = \frac{\sqrt{2}\,Vm}{\sqrt{(\omega^{*}L)2 + R2}} \left(\frac{2.Bn + Br - Bs}{Bn} \right)$$

Vm = Max applied voltage
L = Inductance of the transformer
R = Total resistance of the transformer
Bn = Normal flux density of the core
Br = Remanent flux density of the core
Bs = Saturation flux density of the core

The STS is designed to handle this short term overload situation. However, there are some significant problems elsewhere threatening data center reliability and availability.

- There are usually multiple PDU transformers all drawing high inrush currents.
- Breakers may open up depending on the magnitude of the inrush and circuit breaker set points.
- Inverters cannot handle the high currents and transfers to bypass.
- If the bypass source is an emergency generator, its voltage will dip with the large block load.
- These high currents stress all upstream infrastructure.

INITIAL SOLUTIONS?

At first there were two solutions to this problem. The first was a topology decision where an additional transformer was added to switch at 208 volts, instead of 480 volts. With this approach, each PDU transformer was always energized. Without the presence of downstream transformers, there would not be a resulting high inrush current during an out of phase transfer. This solution took up more space and was more costly with the additional transformer.

UPS manufacturers then worked on a solution involving the UPS inverter controls. Each of them called it something different, but they all roughly performed the same function. Regardless of the situation, the UPS inverters would maintain a minimal phase angle difference between multiple UPS sources. A centralized control circuit would force all inverters to the same phase reference, regardless of the current mode of UPS operation.

BEST PRACTICE–DYNAMIC INRUSH RESTRAINT

The 208 volt solution remains an effective approach, but does cost more. The UPS inverter synch design also costs more and adds another complex system to maintain. Therefore, UPS manufacturers were asked to look at solutions in the STS.

The investigation into a new solution started with the ITIC curve (Figure 2). This characteristic curve states that IT equipment power supplies can ride through 20 ms without voltage. Without the ¼ cycle (4.17 ms) constraint, STS designers were free to explore other alternatives. Here is where *'Dynamic Inrush Restraint'* was born.

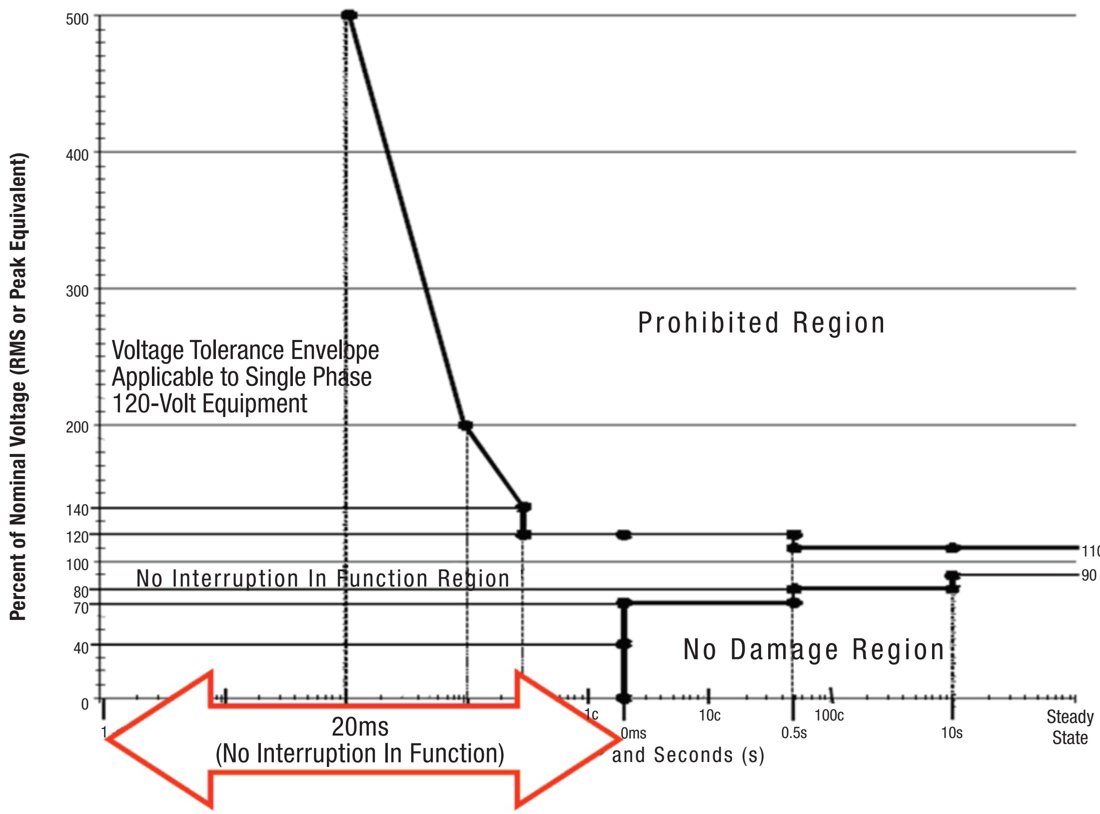

Figure 2

HOW DOES IT WORK?

The STS constantly looks at the power quality of both input sources. The Digital Signal Processor (DSP) of each source is sensing voltage, current, frequency, and phase angle differential. The user selects their power quality tolerance settings for the STS. These settings are usually dictated by the facility's design engineer and validated during commissioning of the critical power system. Most customers use the recommended setting of "DIR Sometimes." This means the STS will auto select when, and if, the DIR function is needed.

Target specifications for DIR are illustrated below in Figure 3:

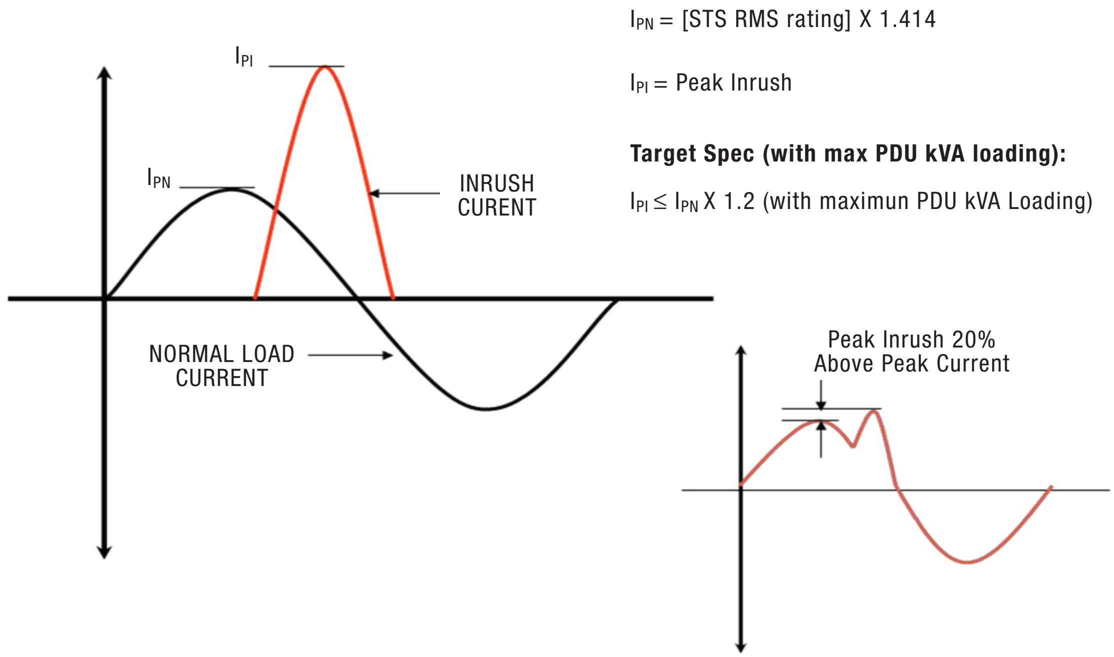

Figure 3

There are various methods of performing this delayed style transfer. Some manufacturers merely add a time constant delay on top of the original ¼ cycle transfer. This type of transfer will produce various inrush current results, depending on the phase angle and the point on the waveform that the transfer is initiated. Another manufacturer pulses the SCR's to create a quick low inrush transfer. This approach uses complex circuitry and creates a chopped up voltage waveform.

The optimal solution is to intelligently select the transfer time based on real-time power-quality sensing and perform a non-pulsed clean transfer with less than 2x.

Let's return to the same scenario with the 480 volt, 400 amp STS feeding our 225 kVA PDU transformer. This time, the STS is set up with a plus/minus 15 degree phase window tolerance. The DIR function is set to "DIR Sometimes." An emergency out of phase transfer of 120 degrees is performed, resulting in a reduced 1,125 amps (1.8x) inrush current. The transfer time was 10 ms, or half of the allotted time according to the ITIC curve. The DSP selects the best time to initiate its transfer. This algorithm results in a typical transfer time of 8 to14 ms with an inrush below 2x. The actual test result is illustrated in Figure 4:

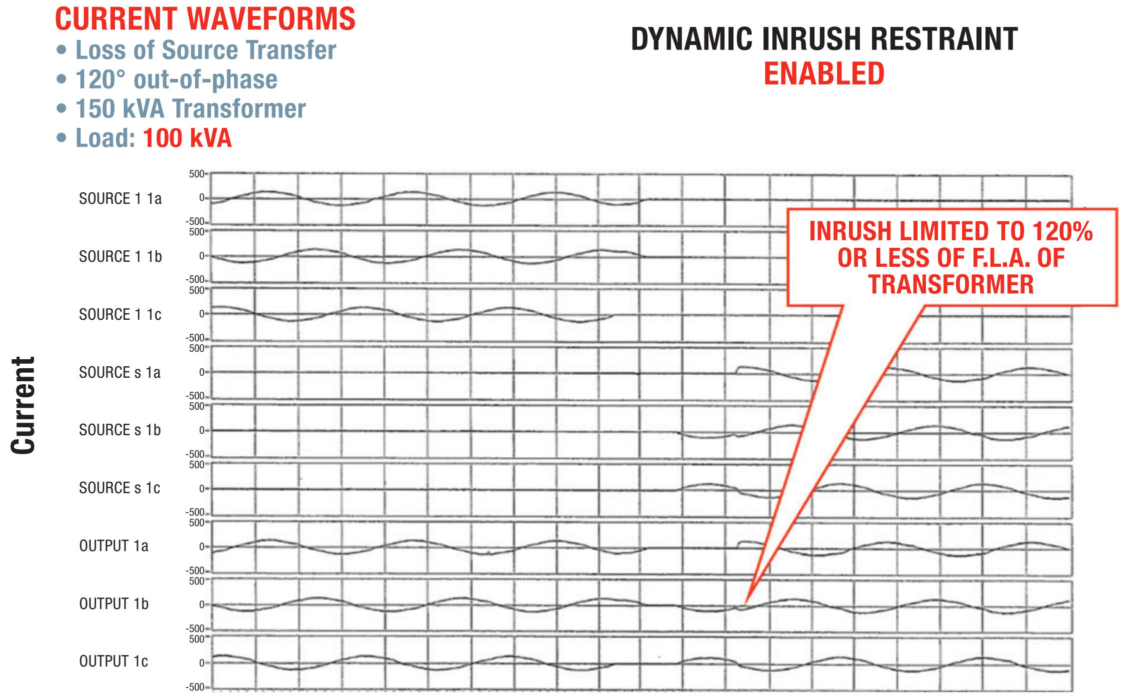

Figure 4

DYNAMIC INRUSH RESTRAINT

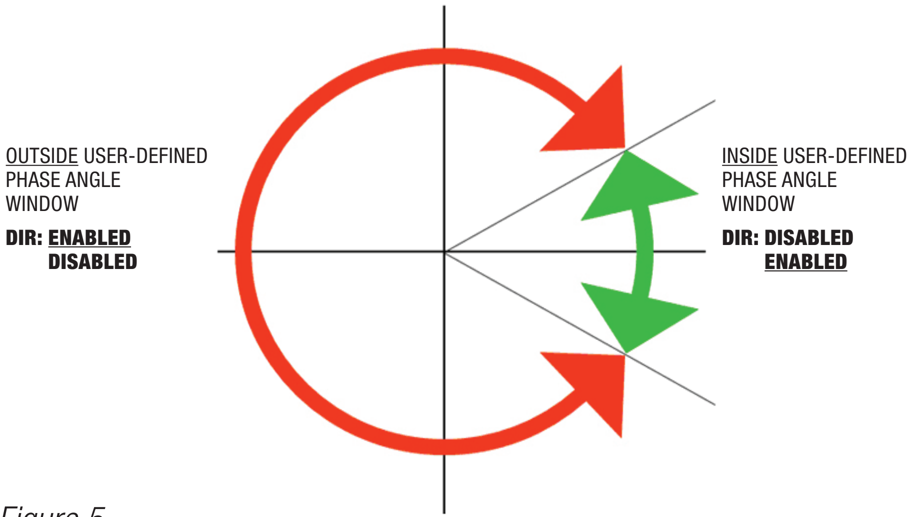

Figure 5

The DSP technology is used to dynamically compute switching delay based on volt seconds at transformer input, phase difference between sources and phase angle of source oncoming, if the phase angle differential is recognized ***inside*** the users preset window. The DSP will intelligently pick the optimum time to initiate the transfer, if the phase angle falls ***outside*** the preset window. The DSP takes into consideration the volt-second integration of both input sources. Then, based on known magnetic flux properties of downstream transformers, the DSP selects the best time to initiate the transfer.

Cyberex's patented simultaneous transfer (Figure 5) is not an answer to the traditional sequential transfer in the static transfer switch. The simultaneous algorithm produces a faster, smoother transfer -- especially under ideal, in phase transfer conditions.

The total transfer time (4ms or ¼ cycle) = sense time (1–1.5ms) + transfer time (2–2.5ms)

(Load type and condition of transfer may result in different total transfer time not to exceed 16ms).

Let us review the anatomy of the A9 simultaneous transfer:

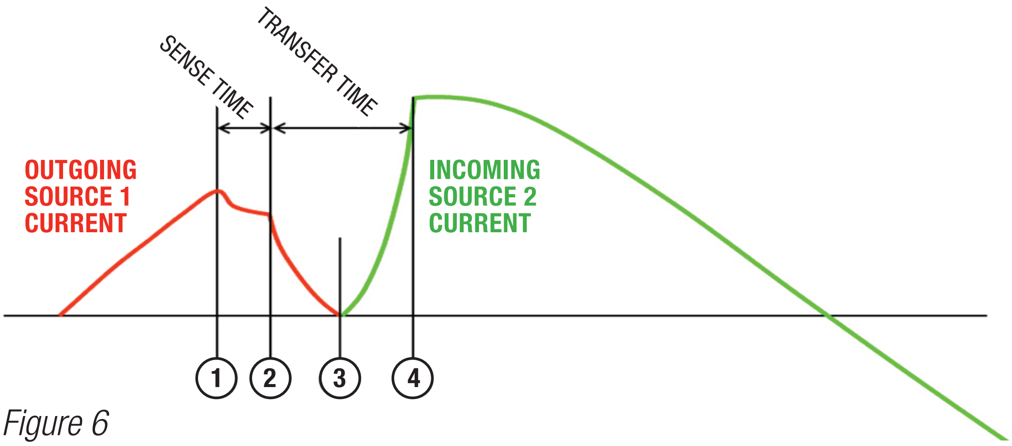

Figure 6

1. Sensing
2. Source 1 gated off – wait for source 1 current to decay
3. Source 2 gated on
4. Transfer complete

DIR IS THE BEST CHOICE FOR MULTIPLE REASONS:

- Initiated on demand.
- Allows for smaller equipment footprint (one PDU transformer).
- Eliminates the need for complex inverter control schemes.
- Maintains true independence between UPS systems (higher reliability).
- Keeps inrush currents below 2x.
- Completes emergency transfer safely within 20 ms ITIC curve.
- Reduces cost of installation (smaller STS, one transformer).
- Better PUE, no load losses eliminated from 2nd PDU transformer.
- Protects expensive critical electrical infrastructure (UPS, breakers, stand by generators, and cables).

SUMMARY

Dynamic Inrush Restraint (DIR) has been installed in thousands of installations and has proven to be the most cost effective and reliable solution to the inrush current problem. This approach conducts out of phase transfers only when needed. These transfers are in compliance with ITIC guidelines. The magnitude of the inrush currents are minimized to safe operating levels.

ABOUT CYBEREX

From the clean environment of a data center to the harsh conditions of an offshore oil platform, Cyberex products meet the challenge of providing clean, dependable electric power to industry, government, and the service sector.

Loss of data can mean losing millions of dollars every minute. In this critical industry, the need for stable power is paramount. The loss of a single data record can mean the permanent loss of business, and Cyberex products provide power quality solutions for you.

Cyberex products provide peace of mind–the peace of mind that comes from knowing your equipment is safe and secure from the consequences of unpredictable power. By designing the world-class standard in power equipment, Cyberex products have become a leader in custom-designed digital static transfer switches, power distribution and uninterruptible power systems.

COMPANY PROFILE

Thomas & Betts Corporation, incorporated in 1917, is a leading designer and manufacturer of electrical components used in industrial, commercial, communications, and utility markets.

For more than a quarter century, the people of Power Solutions have been providing innovative, imaginative solutions in response to customer needs. Power Solutions is dedicated to providing mission critical, power quality products and services manufactured and marketed under the following leading brands – Cyberex®, Current Technology®, Joslyn®, United Power® and JT Packard. Products like the Cyberex Digital Static Transfer Switch and Cyberwave UPS lead the industry in quality, technology and functionality. Standalone power distribution systems, premium hardwired surge protection solutions and 24x7 global field services are also offered.

CYBEREX

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