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Preventing Transformer Saturation and Inrush Current

November 18

Introduction - 1

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Static Transfer Switches – STS - are an important part of most redundant power systems. Using static transfer switches helps to achieve constant power to downstream equipment regardless of faults on the primary side (Raw, UPS, Generator) power.

When PDU transformers are placed on the output of Static Transfer Switches with both power supplies in synchronism, the transfers between sources are transparent to the transformer and there is no inrush current.

Inrush current occurs in transformers when there is a break in the supply or the when the supplies are asynchronous. The inrush current phenomenon is fundamental to transformers only. The degree of inrush is a function of many factors, however it is mostly a function of the phase difference between the sources at the instant of transfer.

The ideal solution to prevent transformer saturation and inrush problems would involve relocating PDU transformers to the upstream side of static transfer switches, however this may not always be possible or convenient, hence PDU transformers are often placed on the output of the STSs.

Introduction - 2

iSTS Static Transfer Switches have functionality called Intelligent Transfer Delay that eliminates the requirement for supply synchronisation and reduces the inrush current value to minimal value, which prevents transformer saturation. This report covers the application of this functionality based on primary supply phase differences to prevent transformer saturation and dangerous inrush currents.

The test results contained in this report were undertaken using an iSTS Model B2 - iSTS32B2s3P4, Static Transfer Switch rated at 32 Amperes, feeding a 30 kVA (42A/phase) - three-phase Delta-Star transformer. The transformer has a typical inrush current of 12 – 15 times the nominal value.

The results are fully scalable, and the Intelligent Transfer Delay functionality is user settable in all single-phase and three-phase iSTS products.

The case with a 1:1 ratio between the STS and the transformer - being the same rating - is considered a worst-case scenario. These are the results and outcomes that are contained within the report.

iSTS Transfer Modes and Methods

All iSTS devices have two selectable modes for inserting a break during transfers, each uses a different method. The user or integrator should understand them both to determine which mode best suits their application.

The method for the **Phase Delay vs Angle Mode** imposes a fixed delay period once the phase difference between the two sources exceeds a pre-set value (say 3 degrees) and the break time is generally fixed and constant. On iSTS devices this period can be set to any value between 0 and 50ms, in 10ms steps. The phase angle difference that initiates this break time is also settable between 0° and +/-180°, with the default being 30°. Therefore, the STS can be set for no-inserted break independent of what the angle is and any setting ratio between angle and break time that the user wishes.

The method for the **Intelligent Transfer Delay Mode** (also referred to as the "Vt balance intelligent algorithm") works by calculating the area under the voltage curve, just prior to the instant of transfer and determining the point that the alternate source should be turned on at. The tests results contained within this report show that there are no saturation effects on the transformer at any angle. The break times are always less than the CBMEA/ ITIC standard requirement for maximum break times as required by IT and communications equipment manufacturers, so there is no danger that the transfer would cause interruption of power to the critical loads.

The Intelligent Transfer Delay Mode is the default setting on all iSTS devices and the Phase Delay vs Angle Mode is a settable option.

Transformer Saturation - 1

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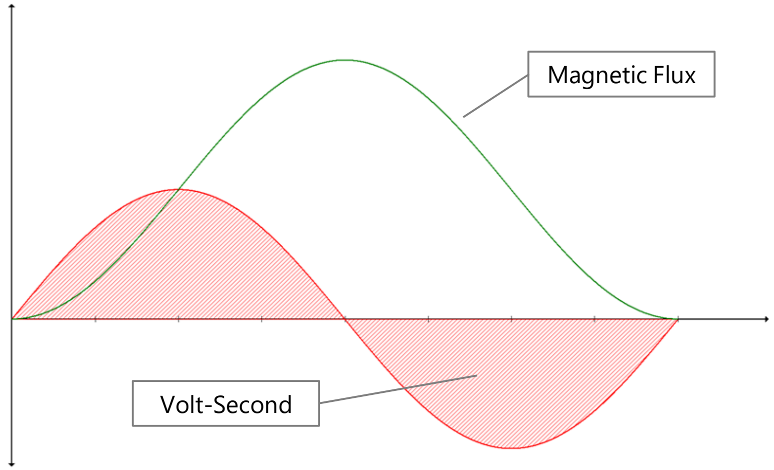
The relationship between voltage and magnetic flux in a transformer can be described as follows:

- Area under curve of Voltage (volt-seconds) = Magnetic Flux
- Rate of change of Magnetic Flux = -Voltage (counter-voltage)

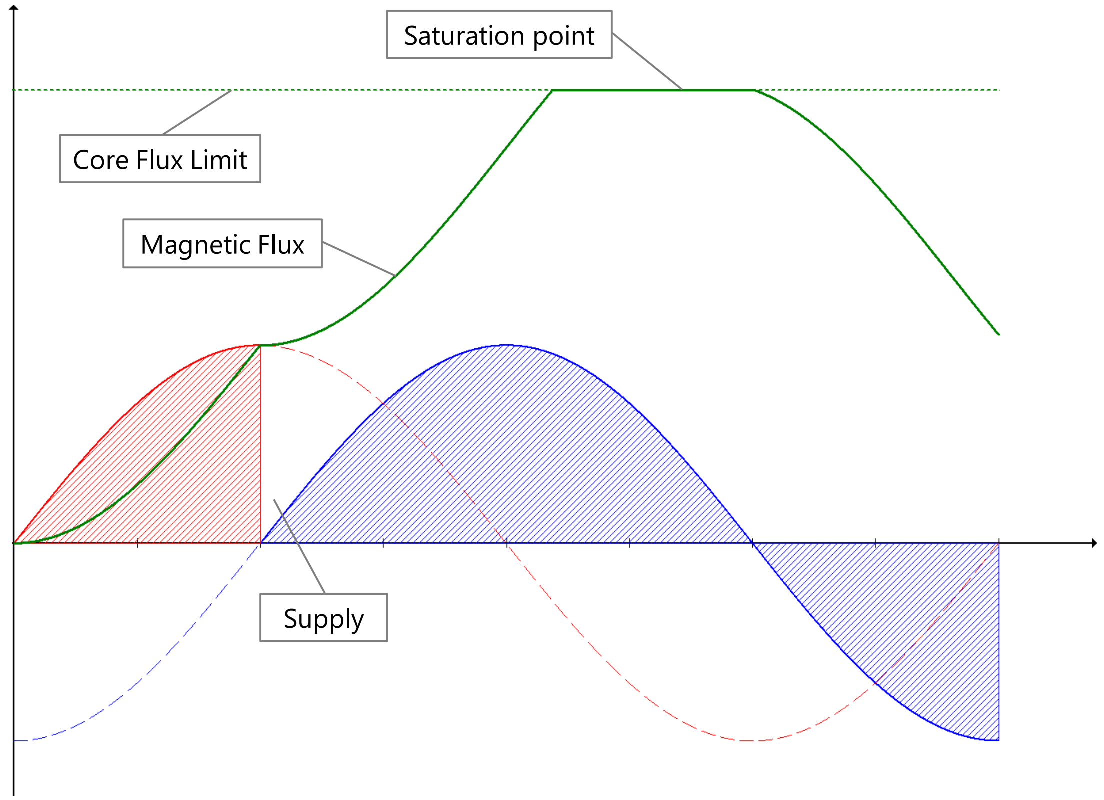
Transformers have a limit of how much magnetic flux can exist in the core. Exceeding this limit will saturate the transformer, where no additional flux can be created. When the core becomes saturated the rate of change of flux approaches zero, and so the current limiting counter-voltage also approaches zero. This causes very low primary coil impedance creating what is called inrush current.

This infers that the volt-seconds (positive and negative) applied to the transformer should be maintained within this limit and their net value should be close to zero to prevent core saturation and high inrush current.



Transformer Saturation - 2

During a direct transfer to a phase shifted supply, the volt-seconds will both exceed the transformer limit and the net value will stray from zero. This will saturate the core and create high inrush currents.



Intelligent Transfer Delay Mode - 1

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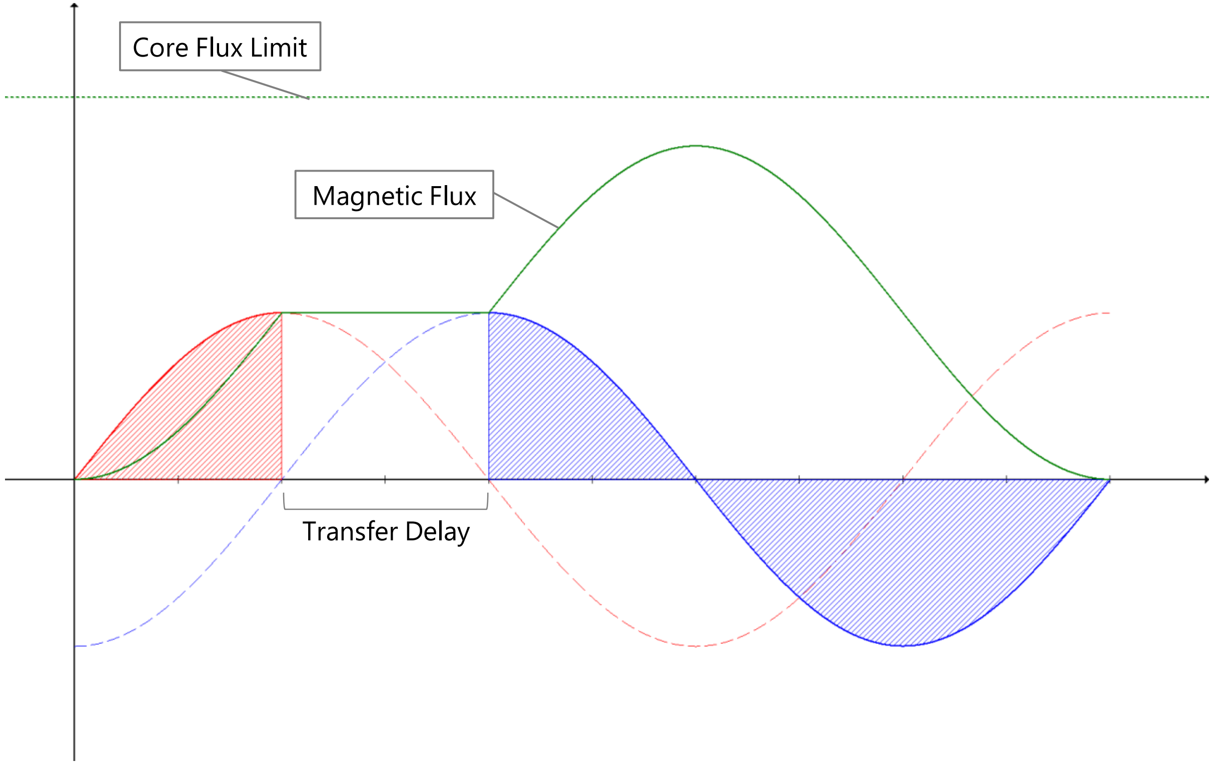
By using the Intelligent Transfer Delay Mode, the iSTS device can eliminate the saturation of the transformer core. During a primary supply fault, instead of turning on the alternate supply immediately, a small delay is inserted. This delay is calculated using the phase offset of the alternate supply. In a three-phase system this delay is calculated per-phase which allows for independent transfer delays. Figure 3 shows an alternate supply leading by 90° and how the inserted delay eliminates the core saturation by balancing the volt-seconds applied.



Intelligent Transfer Delay Mode - 2

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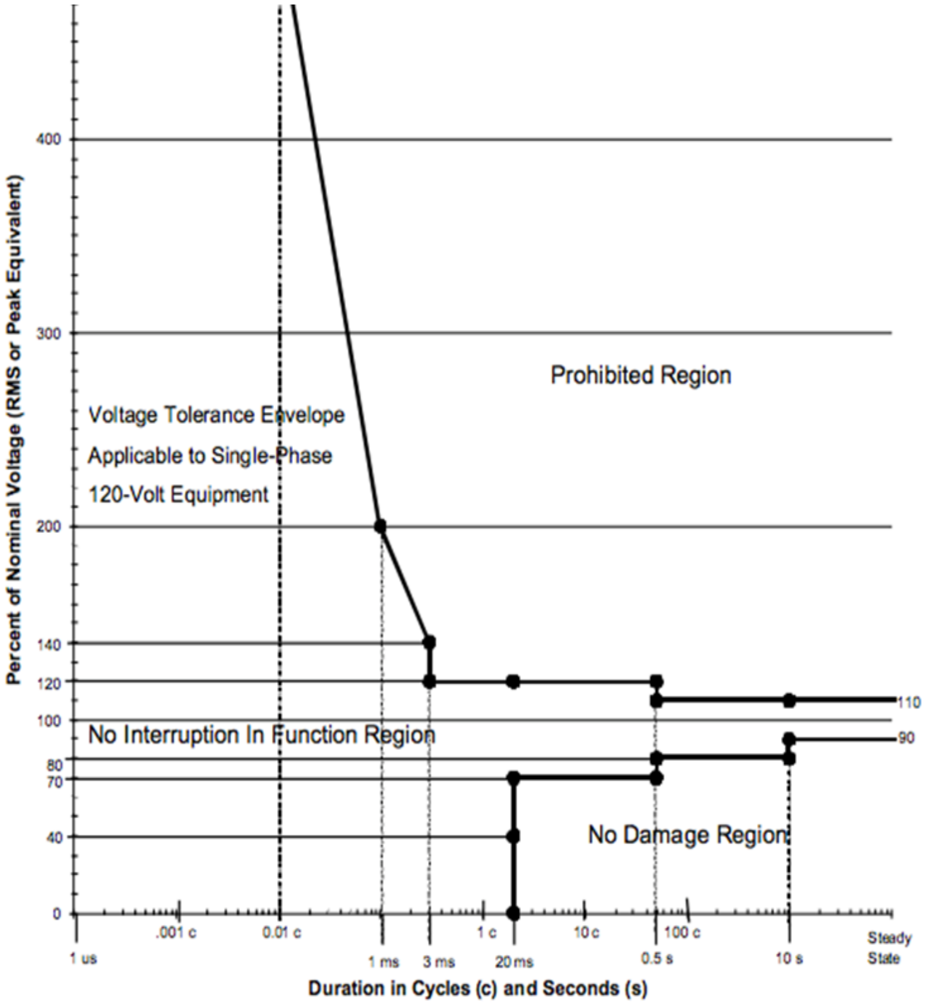
This transfer delay will always be less than 1 power cycle conforming to the ITI (CBEMA) Curve



Intelligent Transfer Delay Examples – 5ms delay

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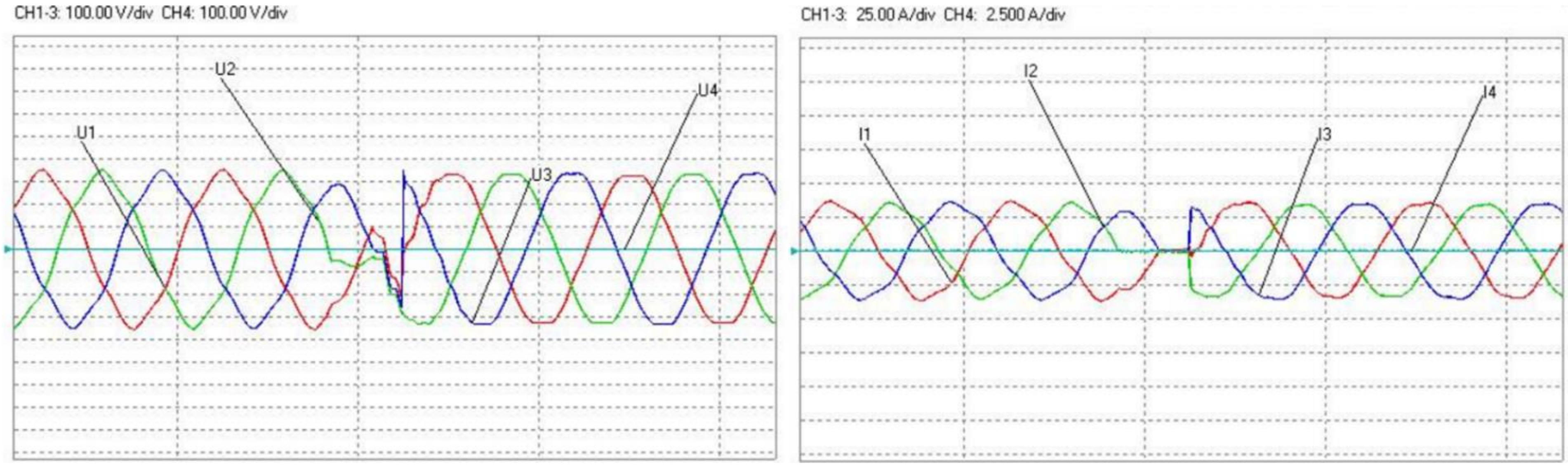
The following graphs were captured using the HIOKI 3196 power quality analyser.

Below figure demonstrate a phase shifted failure transfer using where an Intelligent Transfer Delay was inserted, and the resulting steady currents.



Phase delta: 90° - 5ms delay

Intelligent Transfer Delay Examples – 10ms delay

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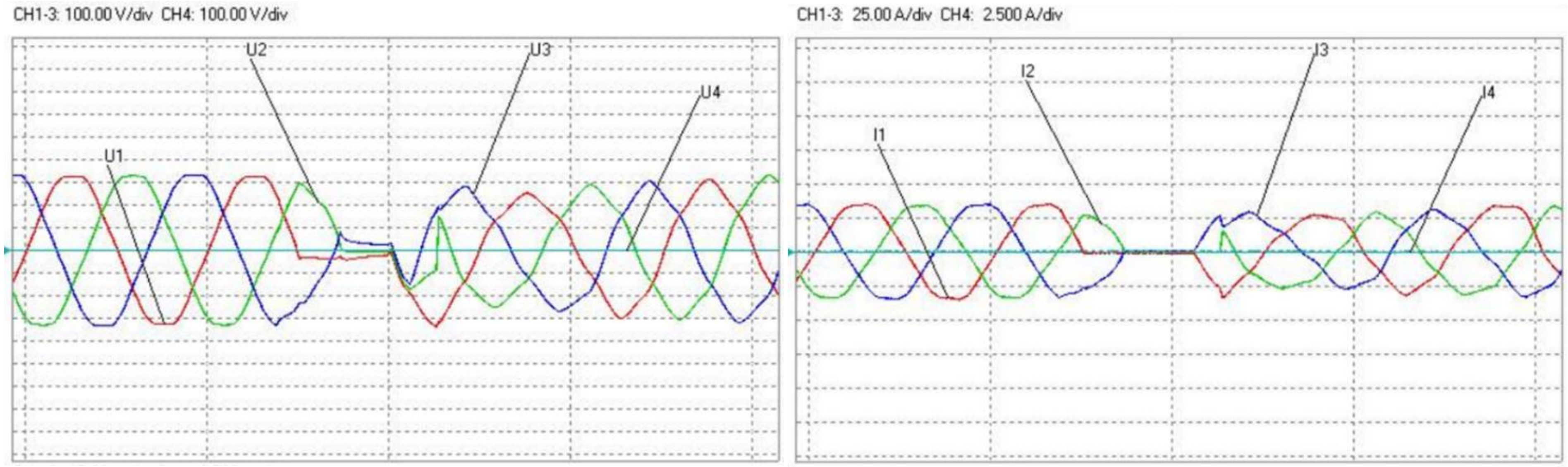

Phase delta: 180° - 10ms delay

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Saturation examples - 180° with no delay

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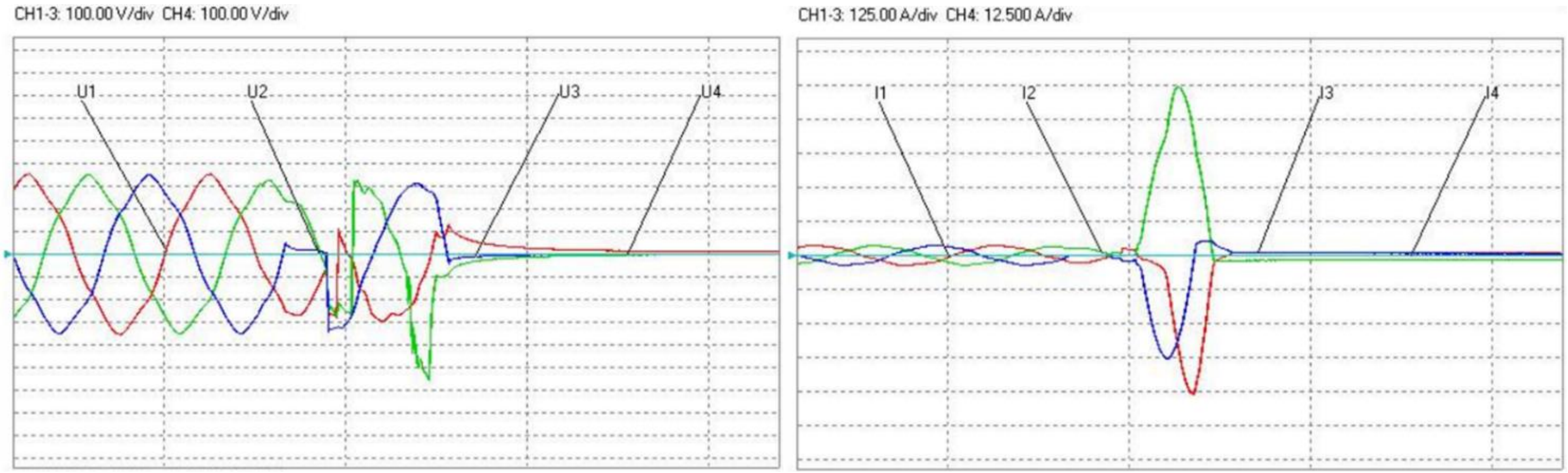
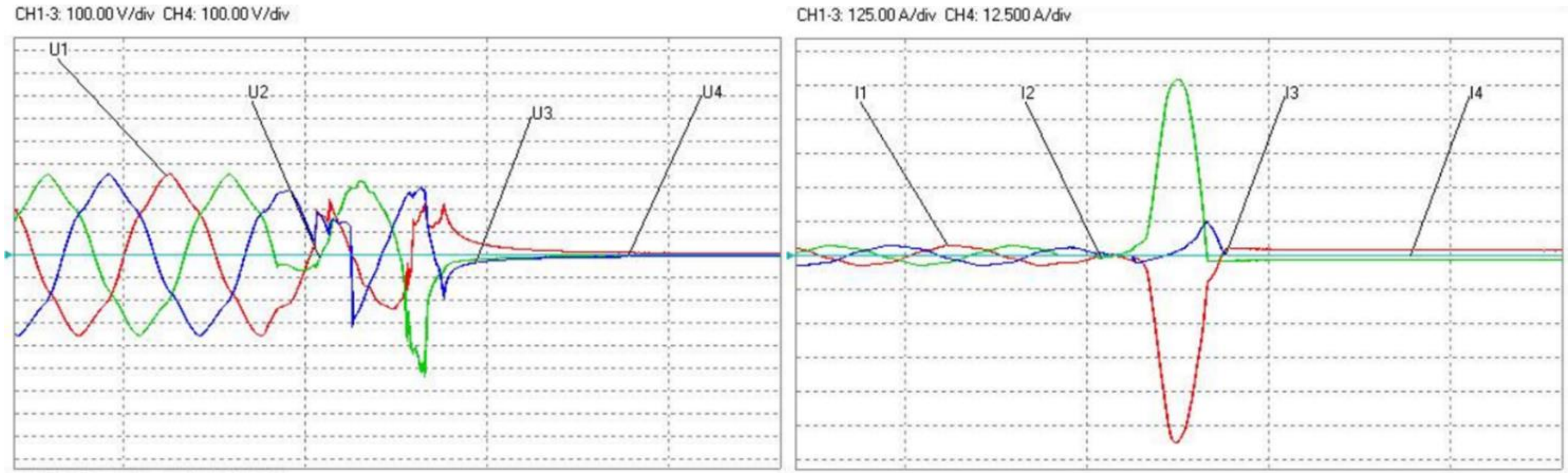
Below figures demonstrate a transfer without the Intelligent Transfer Delay insertion, the resulting inrush currents, and eventual loss of power from breakers opening.



Phase delta: 180° - No delay

Saturation examples - 270° with no delay



Phase delta: 270° - No delay

Conclusion

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To eliminate any issues due to asynchronous transfers, where possible it is always better to position transformers on each source prior to the STS, although this is not always possible or convenient.

Using an iSTS Static Transfer Switch with the Intelligent Transfer Delay functionality to transfer a load side transformer between two asynchronous sources will eliminate the chance of saturation in the transformer caused by inrush currents.

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