Overview of Transients in Power Systems

Introduction

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Based on white paper: "An Overview of Transients in Power Systems", Jon Bickel, P.E.

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Agenda

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Advance power quality monitoring: Unique benefits

Cyber Security

1

Accuracy

2

Meaningful PQ analysis

3

Flexible and Adaptable

ION9000T: Unique benefits

Cyber security

- Achilles L1
- Secure protocols (SFTP, SSH)
- Secured webserver HTTPs
- Strong password
- Security event logging
- Encrypted and digitally signed firmware

HTTPS SFTP SSH syslog

SNMP IPv6

Most accurate power meter in the world

Precision metering:

- Class 0.1S accuracy (IEC & ANSI)
- Cycle by cycle RMS measurements updated every ½ cycle

Power Quality accuracy :

- PQI-A,
- IEC 61000-4-30 ed 3,
- IEC 62586-1&2

Taking accuracy further

- Transient event capture accuracy enhanced with 200K s/c @50Hz and up to 10,000 V!

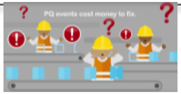
Meaningful PQ analysis

PQ compliance reports accessible via onboard webpage: EN50160, IEEE519

Impulsive transient statistics

Power event analysis on PME

- Correlate groups' network wide alarms and events into incidents (EcoStruxure Power Monitoring Expert 9.0)
- High speed transients & Extended waveform capture along other PQ parameters help in identifying the root cause of almost every PQ related problem
- Patented disturbance direction detection helps in identifying the location of PQ event



Flexible & Adaptable

Patented ION technology enables customization to meet the needs of different users, industries and geographies

New High speed transient capture ION Module

Modular Architecture:

- Panel meter with integrated display
- DIN rail meter with remote display
- Large touch screen display
- Various IO options
- Multiple communication options: Modbus, ION, DNP3, IEC 61850, RS-485 serial port, dual-port ethernet ports, ethernet to serial gateway

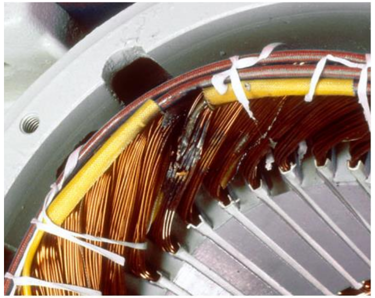
Introduction

Transient overvoltage events stress equipment insulation leading to gradual breakdown and abrupt failure of the dielectric.

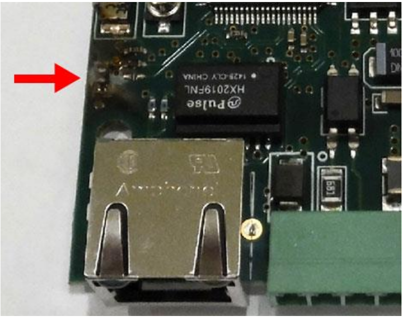
Industrial facilities commonly experience multiple voltage transients every hour that may exceed nominal values by 5 to 10x.

Understanding and reducing the magnitude and duration of these events will extend the life of equipment insulation.

Globally, billions of dollars in electronic equipment losses occur each year due to transient overvoltage.



Winding damage due to voltage transients



Damage caused by Overvoltage Transients

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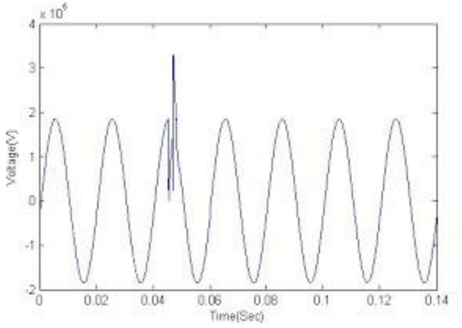
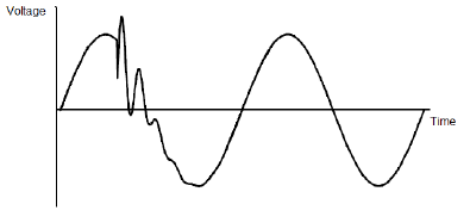
Types of transients

IEEE 1159-2019 defines two types of transients:

Impulsive Transients are described as a sudden, non-power frequency change in the voltage, current, or both that is unidirectional in polarity.[2] An example of an impulsive transient would be a lightning stroke, arcing, step load change, insulation breakdown or electrostatic discharge.



Oscillatory Transient is described as a sudden non-power frequency change in the voltage, current, or both that is bidirectional in polarity. An example cause could be capacitor bank energizing or cable switching.



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Nature of Transients

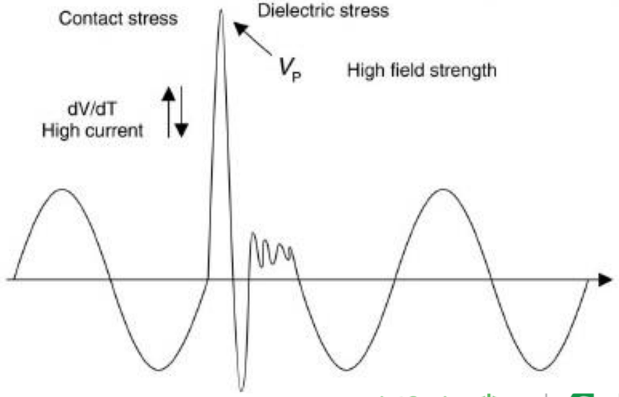
Transient voltage durations are typically from 1µ second (or less) to several milliseconds.

They are classified into two modes:

- Normal-mode: transient between any two power or signal conductors
- Common-mode: transient equal and in phase on each power or signal conductor to ground

Transients damage equipment through:

- Dielectric breakdown
- Electrical flashover
- Fracture
- Thermal stress
- Instantaneous peak power overload
- Surpassing dV/dt or dI/dt limits



Effects of transients

The influence of voltage transients generally falls into four categories:

1. Intermittent interruption: regular and recurring events resulting in loss or corruption of data, device lock-up, tripping or improper operation
2. Chronic degradation: over time – generally days, weeks or months – cumulative effect results in eventual inoperability of vulnerable components
3. Latent failure: similar to Chronic above, but caused by a significant transient event damaging components, but not to the point of immediate failure – impact days, weeks or months later
4. Catastrophic failure: obvious event resulting in immediate inoperability typically with visible impact

Effects of transients on components, equipment and data

IEEE 1100-2005, “Recommended Practice for Powering and Grounding Electronic Equipment” describes the effects of transients on equipment failure modes:

Type of Equipment	Surge Parameters					
	Source Impedance	Peak Magnitude	Maximum Rate of Rise	Tail Duration	Repetition Rate	I^2t in Device*
Insulation						
• Bulk		•		•		
• Windings		•	•			
• Edges		•	•			
Clamping SPDs						
• Bulk	•	•			•	•
• Boundary Layer		•				
Crowbar SPDs	•			•	•	•
Semiconductors						
• Thyristors		•	•			•
• Triacs	•	•	•			•
• IGBTs		•	•			•
Power Conversion						
• DC Level	•	•		•	•	
• Other			•	•		
Data Processing Malfunction		•	•		•	

*The I^2t in the device is the combined result of surge parameters and the device response to the surge. Like other power and energy-related equipment stress, I^2t is not an independent parameter of the surge.

Transient sources

Within the facility

Energizing and de-energizing components that are inductive by nature, like transformers and motors, can generate transient voltages in electrical systems.

- **Reason:** Any disruption in the flow of current to these devices concurrently with the collapse of the device's magnetic field results in voltage impulses or transients.
- **Effects:** The effect of these transient voltages is determined by several factors, such as location on the electrical system, size of the source and its resulting transient, periodicity of events, susceptibility of adjacent equipment, and configuration of the electrical system.

Several sources of transient voltages within a facility are presented in the following list:

- Capacitor Switching
- Current interruption (motors, etc.)
- Power electronics operation (SCRs, etc.)
- Electrostatic discharge
- Electric furnace
- Ovens
- Induction heaters
- (Arc) welding
- Copy machines
- Faulty wiring
- Contact and relay closure
- Load startup or disconnect

Transient sources

Outside the facility (Utility Grid)

Lightning is the usual suspect for transient voltages from the outside, however, voltage transients due to capacitor switching are more common, especially in the summer.

- **Reason:** When a capacitor bank is energized, a large inrush current charges the capacitors, resulting in an initial notch into the voltage waveform. The system voltage recovers quickly and overshoots its value just before switching and continues to oscillate or ring. The ringing of the system voltage is due to the addition of capacitance to a system that is inductive by nature.
- **Effect:** Some variable speed drives (VSDs) are sensitive to this ringing and may trip offline as a result.

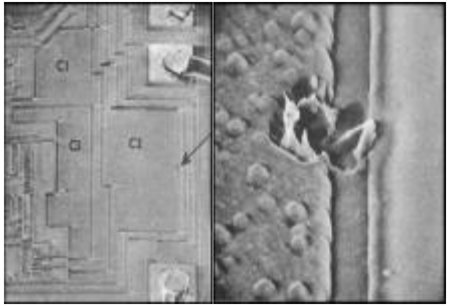
Several sources of transient voltages external to a facility are:

- Lightning
- Capacitor switching
- Line/cable switching
- Transformer switching
- Current limiting fuse operation

Although voltage transients originating on the utility's electrical system can impact a facility's operation, transient voltage sources within the facility are more common. The normal daily operation of loads within the facility—such as **electric furnaces, ovens, induction heaters, welders, or motors**—can produce voltage transients that affect adjacent equipment.

Impact of Transients

Component damage from a lightening strike



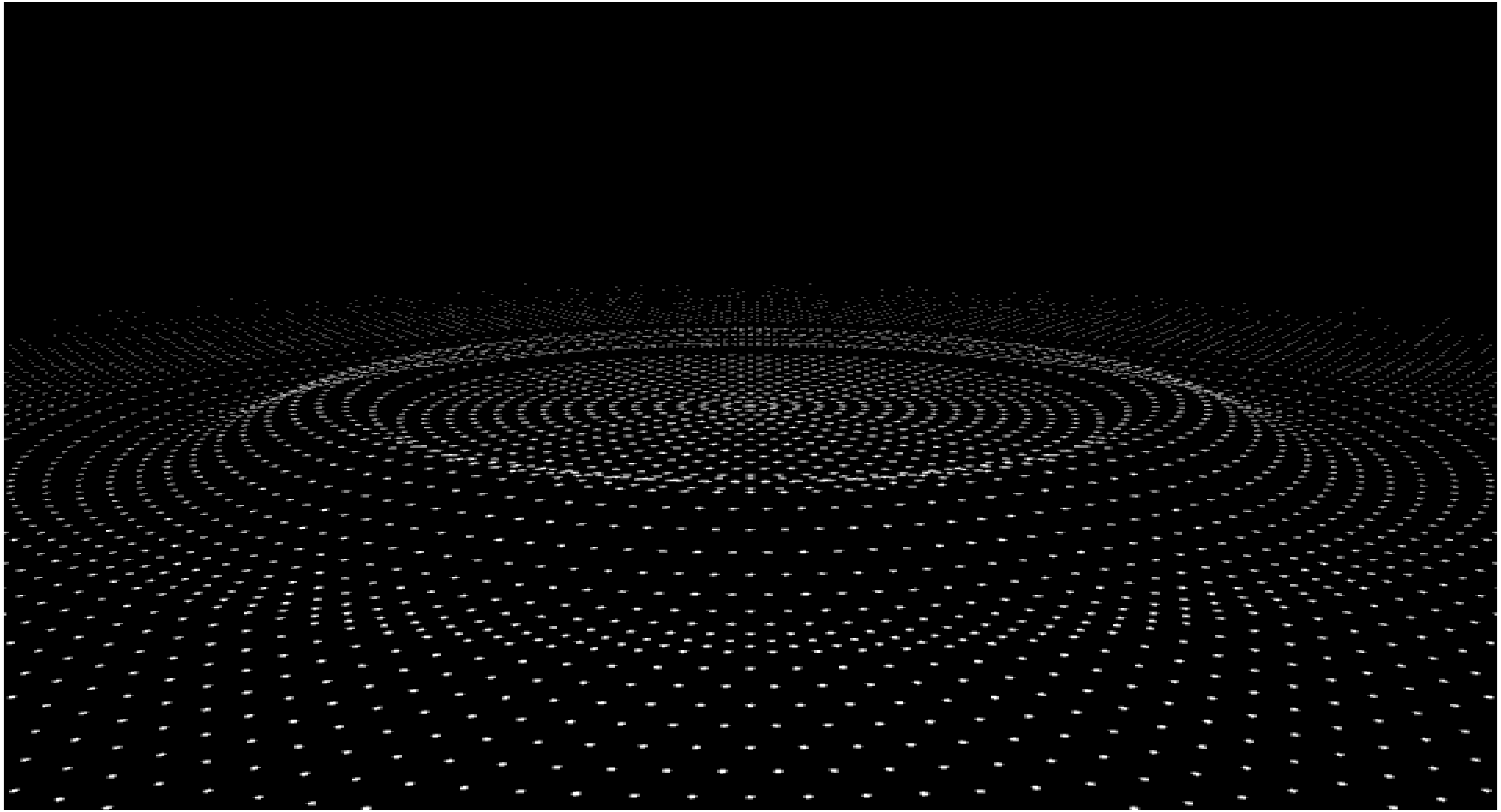
Electrostatic discharge (ESD) damage to C2 MOS capacitor

Transient overvoltage impact on motor stator winding

Images taken from: https://chiefdelphi.com /t/a-little-off-topic-lightning-and-electrical-components/122537/2, https://nepp.nasa.gov/index.cfm/6095,, https://www.easa.com/resources/booklet/typical-failures-three-phase-stator-windings,

Identifying and Characterizing transients

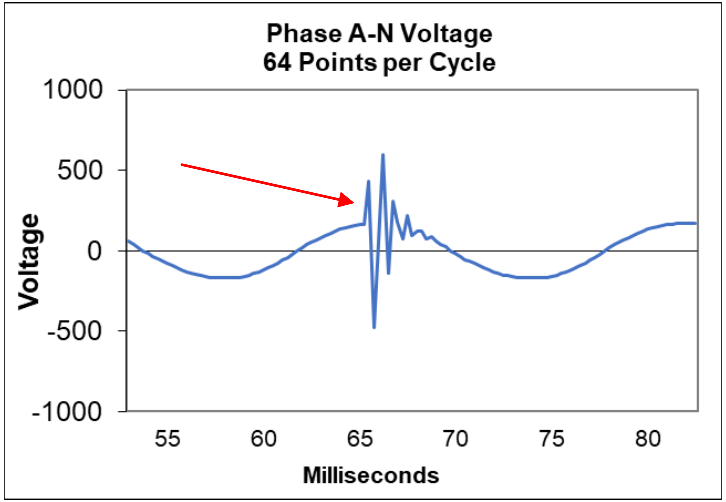
- Appropriate metering equipment is required to determine the source and effects of transients
- High-speed sampling / resolution and wide range magnitude are both required to detect and record a transient’s amplitude, duration, initial polarity and time of event
- A transient’s amplitude is important in understanding the impact on equipment
- The leading edge polarity of the waveform may indicate the source of the transient
- Multiple high-speed monitoring devices across a network will help with locating the source

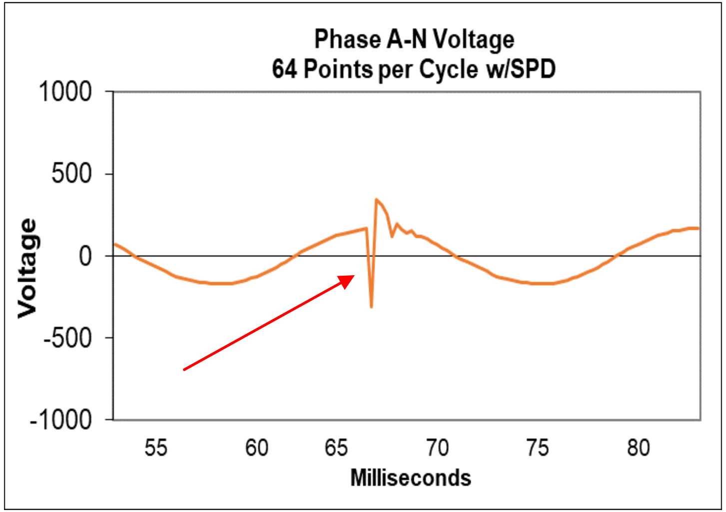


Importance of sample rate

Example 1: Transient events captured at 64 samples per cycle

- Waveform 1 shows initial polarity of the event to be out of the voltage signal, while Waveform 2 shows the initial polarity to be into the signal.
- Initial polarity of an event out of the voltage signal indicates energy is being added to the system. (here a transient generator)
- Initial polarity of an event into the voltage signal indicates energy is being taken out of the system.
- Misinterpreting this information can be misleading and costly, should the wrong solution be employed to correct the issue.
- Longer durations between samples, associated with slower sample rates, can miss the initial polarity of an event.
- The waveform confirms the SPD attenuated the transient event, which lowered the amplitude of the event and shortened the ringing period.
- However, with the lower sampling rate, it is a mistake to assume the true magnitude and polarity of the transient event is reflected in the waveform.

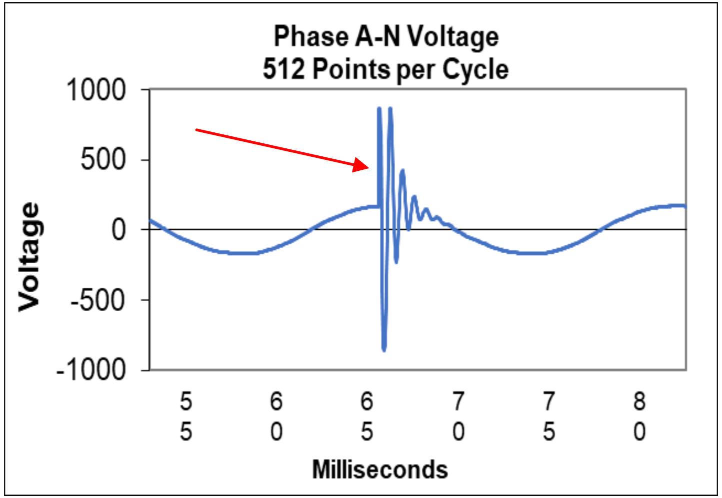


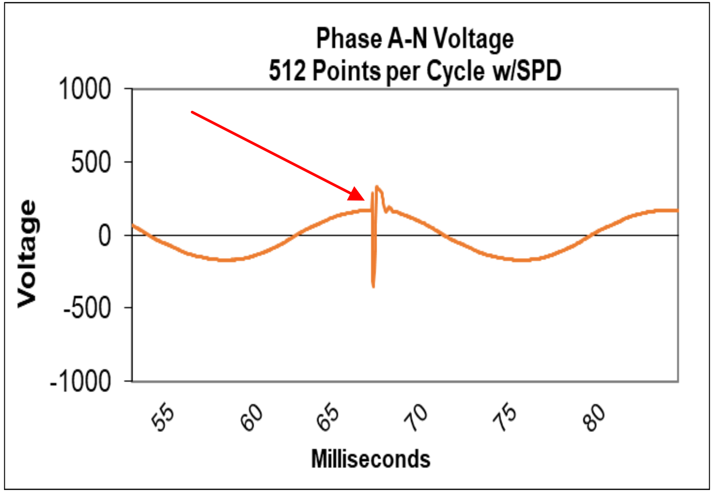


Importance of sample rate

Example 2: Transient events captured at 512 samples per cycle

- Polarity of the transient event is out of the waveform as expected, but lack of data points causes the second waveform to barely indicate the correct polarity.
- Even at 512 samples per cycle, the troubleshooter should not assume the polarity of the event has been accurately recorded.
- 512 samples per cycle is one sample every 32.5 µsec., but still may not detect a short duration event, which may disrupt equipment and processes. (i.e. bouncing mechanical contacts, removing inductive loads, and electrostatic discharge (ESD) impulses)
- The SPD attenuated the transient event; however, once again the slower sampling rate does not necessarily allow reliable conclusions to be made regarding the actual magnitude of attenuation.

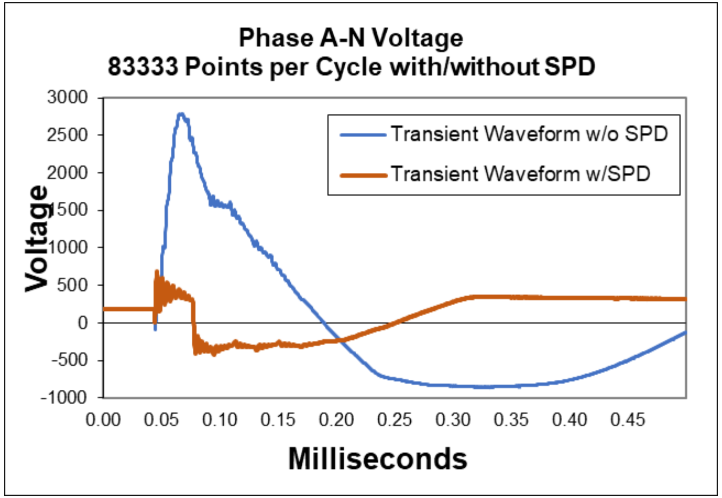




Importance of sample rate

Example 3: Transient events captured at 83,333 samples per cycle (5 MHz)

- Increasing the sample rate to 83,333 samples per cycle reveals much more information.
- In this case, the polarity of the transient event is clearly shown to be out of the waveform; that is, something is putting energy into the system.
- Waveform here shows much more energy is present in the voltage transient than was indicated by the slower sampling rates
- Table illustrates measured magnitudes of the transient appear different at different sampling rates, both with and without SPDs installed.
- The conclusion to be drawn is that faster sample rates give truer pictures of the magnitude of transients, and subsequently, the potential damage to equipment.



	64 samples / cycle	512 samples / cycle	83,333 samples / cycle
Without TVSS	≈ 865 volts	≈ 866 volts	≈ 2,800 volts
With TVSS	≈ 341 volts	≈ 349 volts	≈ 680 volts

High-Speed Transients

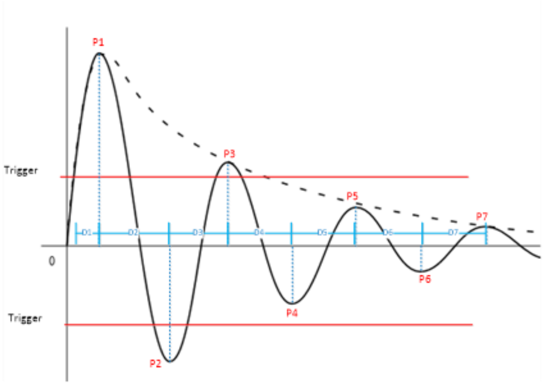
Summary

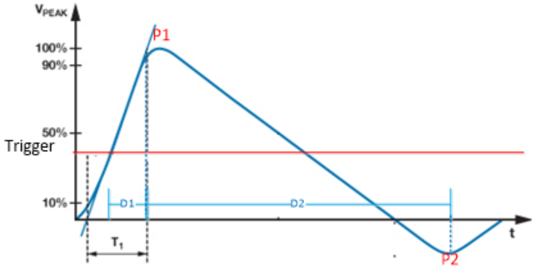
- Due to metering limitations and the rapid duration and randomness of many transients, facility personnel may be unaware of the existence and impact of voltage transients on their electrical system.
- Over time, transients may be responsible for unexplained equipment mis-operation and/or component damage.
- Transient voltage sources can affect equipment operation, and transient voltages may originate either inside the facility or outside on the utility's electrical system.
- When troubleshooting and solving voltage transient problems, it is important to have metering equipment that adequately measures and represents the true likeness of the original transient signal.
- Using standard sampling rates, the true impact of voltage transients, even if captured, would likely be understated and mitigation strategies misapplied.
- By sampling the waveform at higher rates, a troubleshooter can conclusively determine the magnitude, duration, and initial polarity, and energy associated with a high-speed voltage event.

High-Speed Transient capture & detection by ION9000T

PowerLogic ION9000T will provide:

- Impulsive and Oscillatory transient detection and capture
- 10 MHz sampling (>100ns duration, 10kV) on 4 phase voltages
- Ability to upload and view transient waveform
- Statistics for each high-speed transient event include:
  - date/time of event
  - peak voltage magnitude
  - duration of the event
  - energy of the event (volts-seconds) including total energy of each peak
  - accumulator for events by phase
  - counters for number of events per phase by magnitude and duration
  - event type
- Ability to provide a simplified event view based on analytics of the event
- High-Speed Transient (HSTC) web page summary





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