ENERGIZATION & SWITCHING TRANSIENT STUDIES

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Overview

Electrical transients (or electromagnetic transients) occur when there is sudden change in the operating condition in a power system. These happens when a switching operation (closing or opening) of a circuit breaker or disconnect switch takes place.

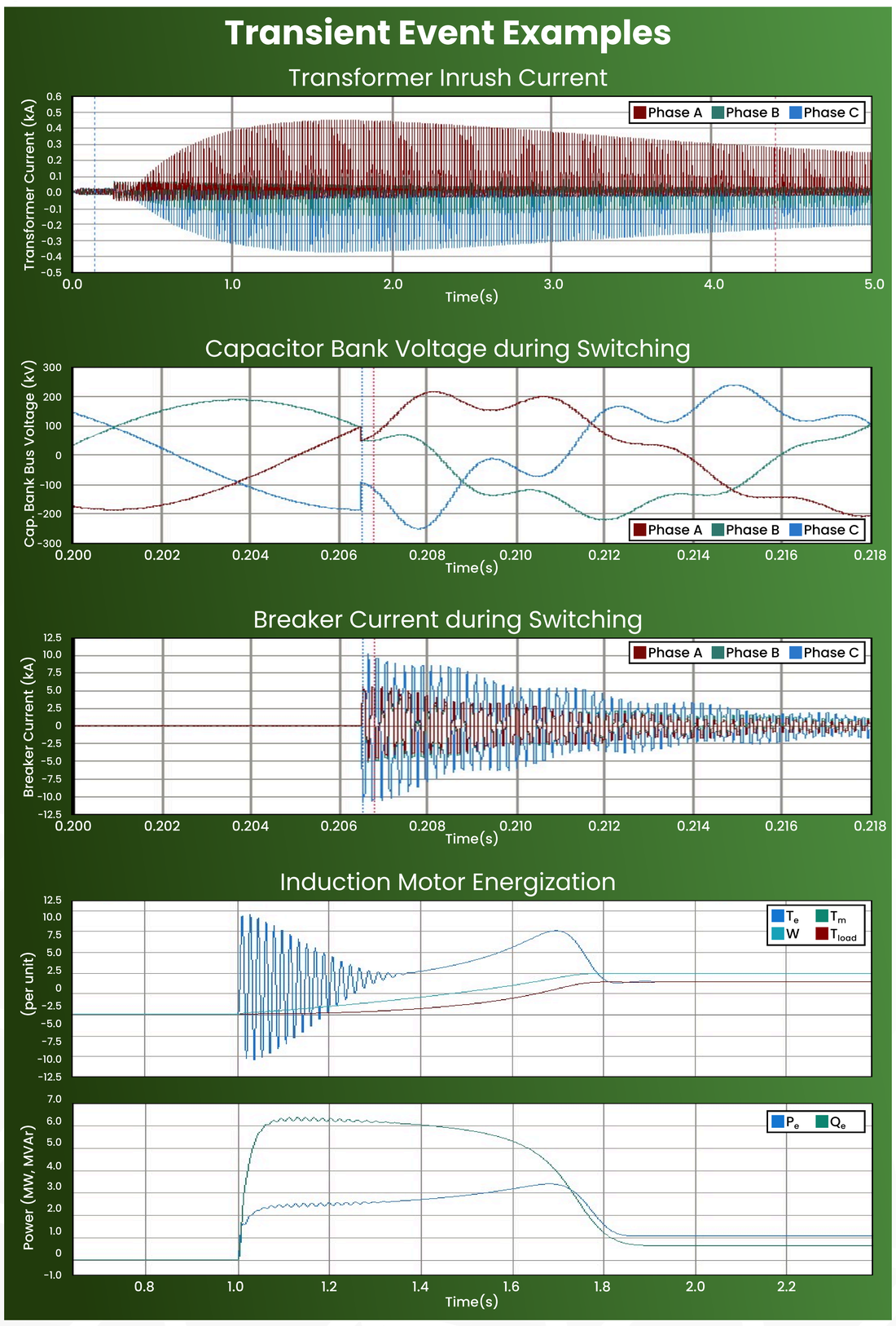
Power transformers, capacitor banks, reactors, transmission lines, underground cables, and motors introduce transients such as overvoltage, inrush currents, resonance, or travelling waves when operated.

Why study energization and switching transients?

In general, the greatest electrical stress an equipment will experience is during the transient period. It is important that insulation levels of equipment are properly coordinated or solutions are in place to prevent damage, if worst case happens.
The specific effects of electrical transients per equipment are:

- **Transformers**, when energized, produce inrush currents 6-10 times of the full load current. These inrush currents are rich in second order harmonics, which may affect the operation of protective relays.
- **Isolated and back-to-back Capacitor Switching** introduces high-frequency inrush currents and transient overvoltage. Proper circuit breaker applications for capacitor banks should be observed to handle the transients.
- **Transmission Lines** and **Underground Cables**, when first energized, produces transient overvoltage at the far end of the circuit. The overvoltage is more pronounced for long lines and cable circuits.
- **Opening of Circuit Breaker for Capacitor and Reactor Banks** may introduce severe transient recovery voltage across the former's contacts.
- **Large induction motor**, when energized (as part of commissioning or black start restoration process), draws excessive amounts of reactive power from the grid, causing poor voltage performance.

Transient Event Examples



Who needs and when are switching transient studies required?

Pterra have conducted numerous electromagnetic transient studies for utilities (substations or transmission lines), electric cooperatives, and project developers (conventional plants, solar, BESS, and wind).

Studies are performed to confirm and/or aid the design of the electrical facility prior to the procurement of major power equipment. The studies are also carried out to comply with standard engineering guidelines set forth by the utility. In some cases, electrical transient studies were performed to investigate equipment failure.

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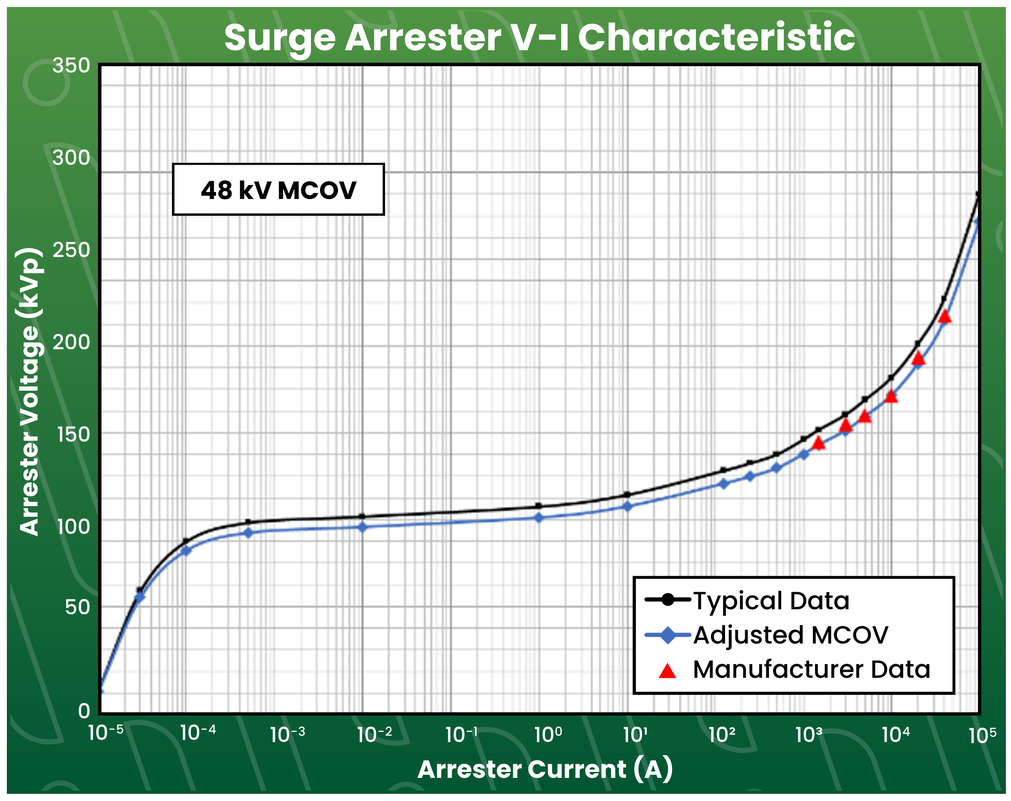
Modelling Considerations

To capture the phenomenon under study, power system components should be modelled properly. At Pterra, the typical modeling details include:

- Power system components such as source/utility representation, transformers, lines and underground cables, capacitors, and station buses.
- Component parameters such as transformer core characteristics, tower geometry or cable layout, frequency dependent line models, and grounding resistance.
- Surge arrester manufacturer's data and plotted V-I characteristics.
- Manufacturer's data of circuit breaker and disconnect switches.



Study Scope and Scenarios

Correct Scenarios and contingency conditions are essential to simulate the electrical transients under study.
Pterra brings in real world and practical experience in high-voltage equipment to aid the analysis of transients. Scenarios may include consideration of point on wave switching, transformer remanence, trapped charges, status of switching devices, and operating sequences.

Common Mitigation Techniques

When simulations indicate potential violations, mitigation measures are explored starting from the least cost to the most expensive one.
Mitigation solutions available are:

- Controlled point-on-wave switching.
- Pre-insertion resistors.
- Current-limiting reactors.
- Higher/lower surge arrester MCOV rating.
- Higher circuit breaker rating.
- Transformer with higher knee point voltage.

Tools

The time range of electrical transient phenomena ranges from several milliseconds to few microseconds.
The study timeframe requires the use of electromagnetic transient program (EMTP).
Pterra uses PSCAD/EMTDC to study transients and uses E-Tran for network reduction and equivalencing large power system networks.

Deliverables & Key Results

Equipment insulations are typically rated at line-to-ground basis. Therefore, it makes sense to monitor the peak line-to-ground overvoltage voltage and peak inrush current values when studying electrical transients. Instantaneous and root-mean square (RMS) values are plotted.
Surge arrester absorbed energy is compared against the manufacturer's data. Stress is also compared against switching devices' duties. The monitored parameters are analyzed both in qualitative and quantitative terms to give actionable action items and meaningful conclusions.

Benefits to Your Project

Energization and switching transient studies are not just for compliance or part of a typical design work – it is a necessary step to de-risk the project from failures, additional equipment installation, and longer downtimes.

Learn More

Pterra's experience in performing an engineering study like electrical transients provide actionable insight into fast switching phenomena—helping engineers design safer and more reliable power systems.

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