Electromagnetic Transients in Power Systems – Insulation Coordination

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Electromagnetic transients

- Due to interaction between L-C elements in the network
  - Oscillations
  - Travelling waves
- Triggered by
  - Switching of lines, cables, transformers
  - Faults
  - Lightning
Course Outline

- Introduction and Basic concepts of electromagnetic transients
- Selected applications in power systems
Introduction and Basic concepts of electromagnetic transients

- Response of LRC circuits
- Representation of power system elements for a specific analysis
- Model Data
- Need for ‘sensitivity’ studies
Selected Applications in Power Systems

1. Transformer energizing
2. Transmission line and equipment switching
3. Capacitor bank switching
4. Circuit breaker Transient Recovery Voltage (TRV)
5. Overvoltages caused by lightning strikes
6. Motor starting
Transformer Energizing

- Core saturation
- Inrush current and harmonics
  - Voltage dips
- Network characteristics - frequency scans
  - Over voltages due to harmonic resonance conditions
Transmission line and Equipment Switching

- Overvoltage magnitudes and equipment insulation levels
  - Surge arresters

- Statistical distribution of overvoltage magnitude

- Transmission line ‘flash-over’ rates

- Investigation of overvoltage mitigation methods

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Capacitor Bank Switching

- Back to back switching
  - Inrush reactors

- Faults
  - Outrush reactors

- Cable energizing

- Resonance concerns

\[
\frac{di}{dt}_{allow} = \frac{\sqrt{2} \cdot 40k \cdot 2\pi \cdot 60}{10^6} = 21.326 \frac{A}{\mu s}
\]
TRV is the voltage developed across the breaker poles immediately after current interruption:

- Fast event
- Simulation circuit should consider details of station equipment
- Breaker TRV withstand capability limits
Lightning Overvoltages

- Lightning overvoltage studies are required to:
  - Determine the required insulation levels of equipment (BIL).
  - Surge arresters size and location
  - Determine transmission line ‘flashover’ rates
    - Very Fast event
    - Simulation circuit should consider details of station equipment

How do we represent system equipment
- Line segments
- Towers
- Insulators
- Tower footing resistance
- Flashover mechanism
Motor Starting

- Voltage dips and flicker caused by frequent starting of large motors at industrial plants is a power quality concern for utilities
  - Model data to match manufactures T-S and I-S curves
  - Impact of rotating inertia
  - Power System impedance characteristics near the interconnection point
  - Representation of load characteristics and the overall impact.
Thank you