

## Electromagnetic Transient Analysis

### DAY 1

#### MODULE 1: Power System Transients

**Presentation: Introduction to electromagnetic transients** **1 h**

Transient phenomena in power systems. Classification of overvoltages acc. to IEC60071: temporary, slow-front, fast-front and very fast-front transient overvoltages. RMS versus EMT simulations. Handling: definition of simulation events and result variables. Visualisation of simulation results. Fast Fourier Transform analysis.

#### MODULE 2: Transformer Energisation

**Presentation: Transformer energisation** **1 h**

Fundamentals. Transformer inrush currents. Saturation characteristics. Residual flux. Harmonic content of inrush currents. Resonance and overvoltages excited by inrush currents.

#### Coffee break

**Exercise: Transformer energisation** **1 h**

Energisation of a transformer in a weak network. Determination of maximum inrush currents. Decaying DC component. Voltage dip during energisation. Assessment of typical grid code compliance. Mitigation of inrush currents. Conversion of RMS to peak values.

#### Q&A session

#### Lunch break

#### MODULE 3: Capacitor Switching

**Presentation: Capacitor switching** **1 1/2 h**

Fundamentals. Inrush currents and switching overvoltages during energisation of capacitor banks. Back to back connections. Mitigation of inrush currents.

#### Coffee break

**Exercise: Filter bank energisation** **1 1/2 h**

Natural oscillation frequencies. Simulation of inrush currents and maximum transient overvoltages in a filter bank. Back-to-back energisation of a second filter bank.

#### Q&A session

## DAY 2

### MODULE 4: Transient Recovery Voltage (TRV) Analysis

**Presentation: Transient recovery voltage (TRV) analysis** 1 1/2 h

Fundamentals. Overview of abnormal switching transients, trapped energy and current chopping. Dielectric strength of circuit breaker after contact opening. Suppression (or chopping) and recovery overvoltages. Voltage escalation following abnormal switching.

#### Coffee break

**Exercise: TRV analysis for shunt reactor drop out** 1 1/2 h

Assessment of switching overvoltages due to reactor drop out. Circuit breaker capability curves. Current chopping. Mitigation using R-C surge suppressors.

#### Q&A session

#### Lunch break

### MODULE 5: Overhead Line and Cable Models for EMT Simulations

**Presentation: Overhead line and cable models** 1 1/2 h

Geometric models for overhead lines and cable systems. Conductor types and frequency dependency. Single core cable types and bonding options. Lumped and distributed parameter models. Travelling wave effects.

#### Coffee break

**Exercise: Modelling of overhead lines and cable systems** 1 1/2 h

Definition of double circuit overhead line and double circuit single core cable system. Analysis of coupling effects using EMT simulations. Line energisation with distributed parameter model. Travelling wave effects.

#### Q&A session

## DAY 3

### MODULE 6: Line Switching

#### **Presentation: Line switching**

1 1/2 h

Fundamentals. Line re-energisation. Distributed frequency dependent line models. Stochastic switching assessment. Mitigation measures.

#### **Coffee break**

#### **Exercise: Switching overvoltages in a mixed OHL/cable system**

1 1/2 h

Overhead line energisation and re-energisation. Cable energisation with missing zero-crossings. Maximum transient overvoltages based on deterministic and stochastic approaches. Modelling of surge arresters and pre-insertion resistors. Stochastic switching.

#### **Q&A session**

#### **Lunch break**

### MODULE 7: Lightning Transients

#### **Presentation: Lightning transients**

1 h

Fundamentals of transient phenomena and its interaction with the power system. Modelling of relevant power system components for lightning transient analysis: impulse sources, line/cable surge impedances, tower footing resistance, dielectric strength of isolators. Surge arresters.

#### **Exercise: Model enhancement for lightning analysis**

1 h

Definition of the overhead line model for lightning analysis. Phase conductors and earth wires. Line couplings. Model of the footing resistance. Voltage controlled switches to represent the flashover. Impulse current sources.

#### **Coffee break**

#### **Exercise: Assessment and mitigation of lightning overvoltages**

1 h

Determination of the lightning performance of a transmission line. Simulation of direct and earth wire strikes. Back flashover. Overvoltage mitigation: selection of surge arresters. Lightning protection characteristic. Energy duty. Lightning overvoltages under consideration of surge arresters.

#### **Q&A session**

## Time Schedule (Central European Time)

	Time
<b>First 90 minutes block</b>	9:00
<b>Coffee break</b>	10:30
<b>Second 90 minutes block</b>	10:45
<b>Q&amp;A session</b>	12:15
<b>Lunch break</b>	12:30
<b>Third 90 minutes block</b>	13:30
<b>Coffee break</b>	15:00
<b>Fourth 90 minutes block</b>	15:15
<b>Q&amp;A session</b>	16:45
<b>End of the training day</b>	17:00



DIGSILENT GmbH  
Heinrich-Hertz-Str. 9  
72810 Gomaringen  
Germany

T +49 7072 9186-0  
F +49 7072 9168-88  
mail@digsilent.de

[www.digsilent.de](http://www.digsilent.de)