An Introduction to the Simulation Program XTAP for the Analysis of Electromagnetic Transients in Power Systems
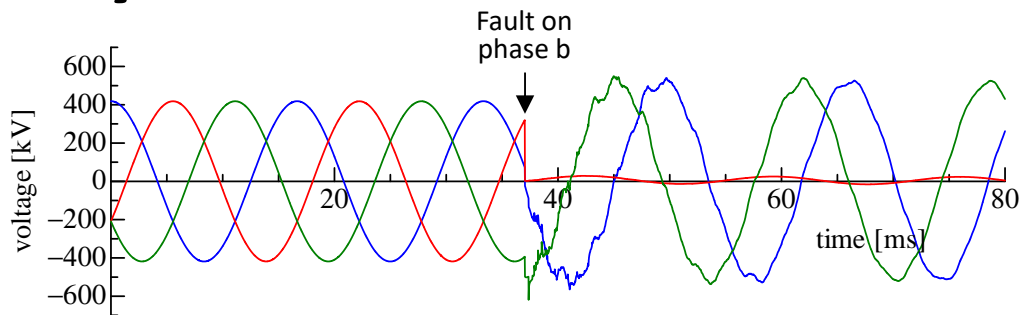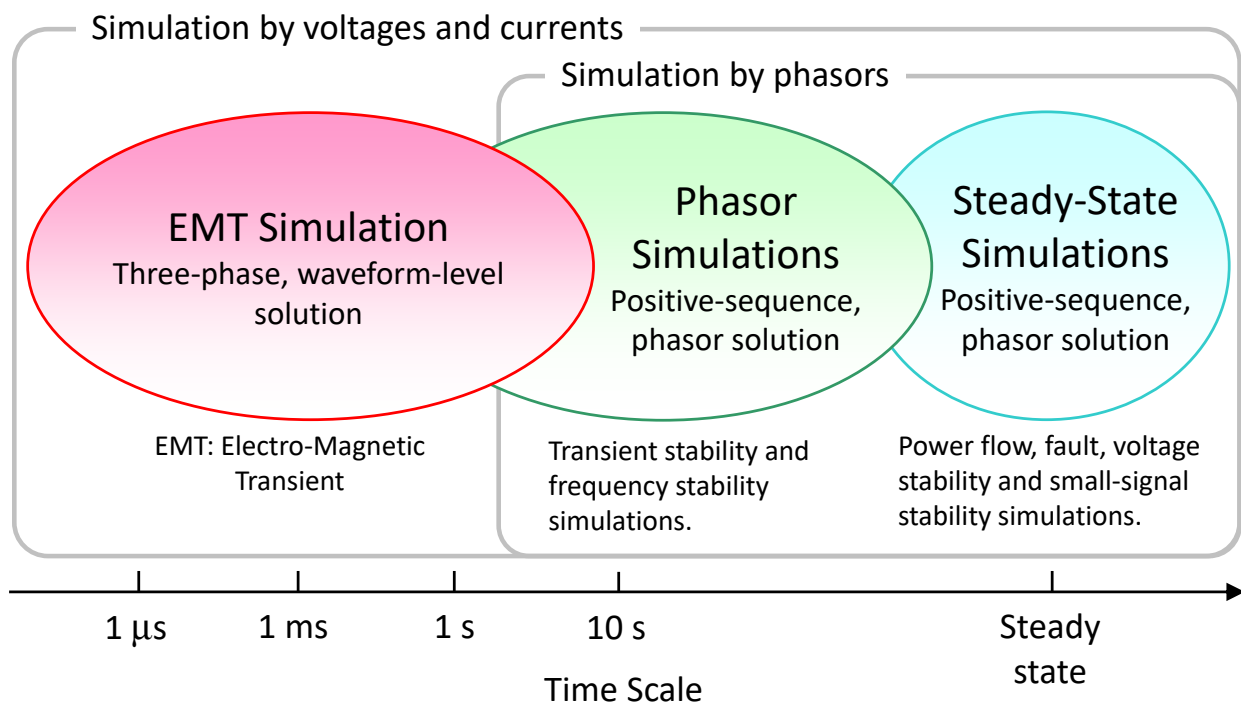
Fault on phase b

voltage [kV]

600
400
200
0
−200
−400
−600

20   40   60   80

time [ms]

https://www.xtap.org/

1

Power System Simulation Methods

Simulation by voltages and currents

Simulation by phasors

EMT Simulation
Three-phase, waveform-level solution

Phasor Simulations
Positive-sequence, phasor solution

Steady-State Simulations
Positive-sequence, phasor solution

EMT: Electro-Magnetic Transient

Transient stability and frequency stability simulations.

Power flow, fault, voltage stability and small-signal stability simulations.

1 μs   1 ms   1 s   10 s   Steady state

Time Scale

2

# EMT versus Phasor

■ EMT simulation … calculates voltage and current waveforms actually occurring in a power system.
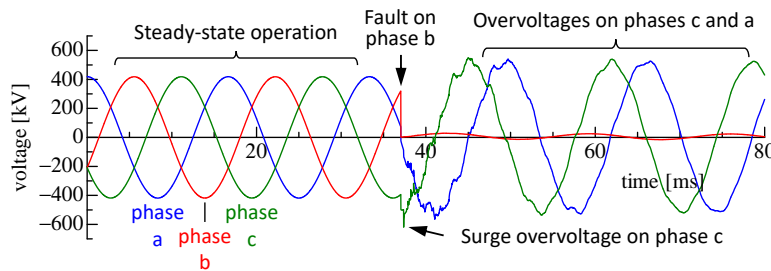
Since the EMT simulation gives detailed waveforms of all phases, momentary overvoltage and current values are obtained. It is suitable for detailed simulations of a particular part of a power system.

■ Phasor simulation … calculates 50- or 60-Hz voltage and current phasors in a power system.
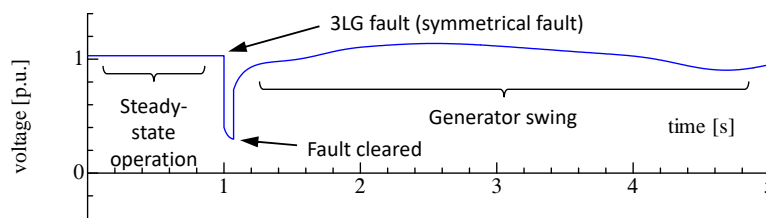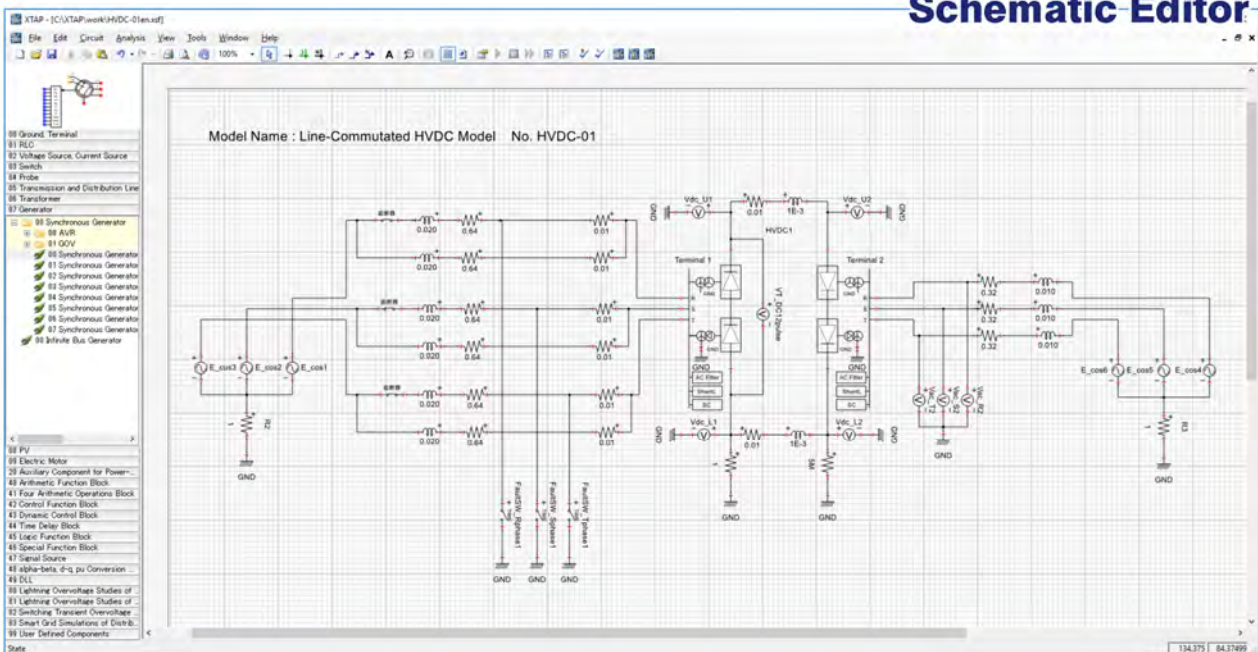

The phasor simulation traces the variations of the magnitudes and the phase angles of voltages and currents and ignores their momentary variations. It is suitable for simulations of a large power system.

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XTAP (eXpandable Transient Analysis Program)

is an industrial-grade EMT or waveform-level simulation program.

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XTAP (e**X**pandable **T**ransient **A**nalysis **P**rogram)

is equipped with a waveform plotting tool with useful functions, a line/cable constants calculation tool, an automated consecutive simulation function, a statistical simulation function, a PV panel modeling tool, and so on.
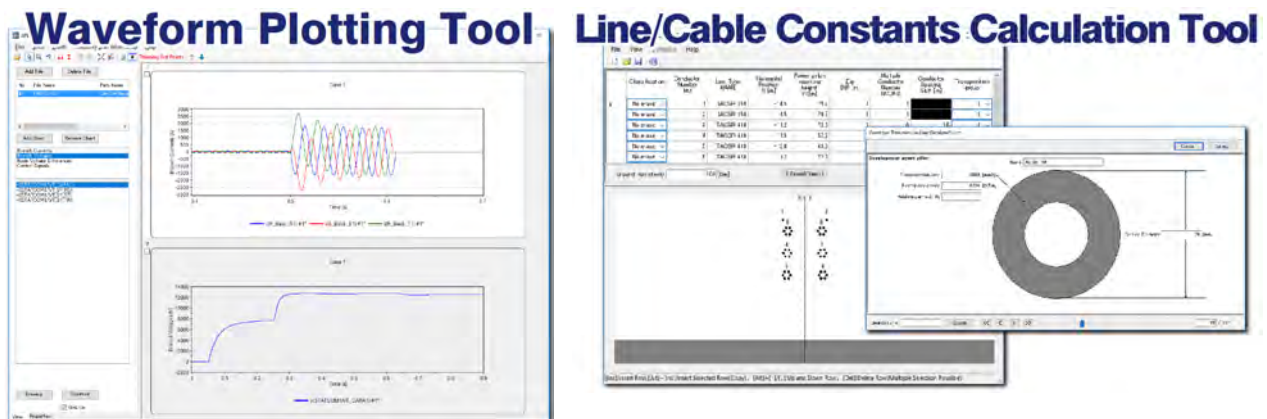
Components and Models

◆ Comprehensive electrical and control components.
◆ Synchronous generator model with saturation and torsional dynamics.
◆ Line models (π equivalent, constant-parameter and frequency-dependent).
◆ Transformer models (2, 3-winding and autotransformers).
◆ HVDC and FACTS converter models (line-commutated, PWM and MMC AC/DC converters; SVC and STATCOM).
◆ PV power generation systems.
◆ User-defined models: You can create your own models – You can even draw your own icons for them!
◆ DLL-defined blocks.

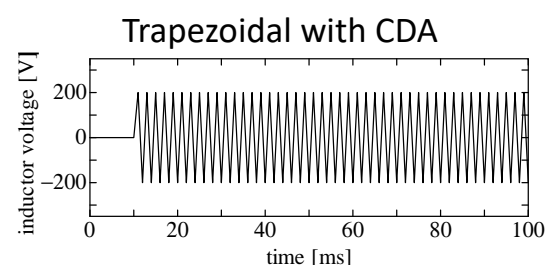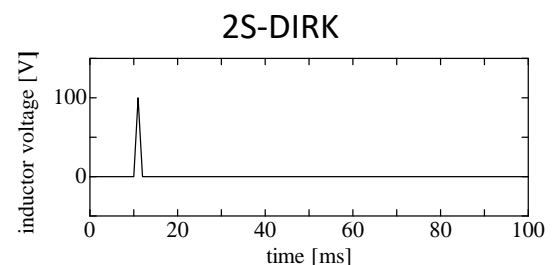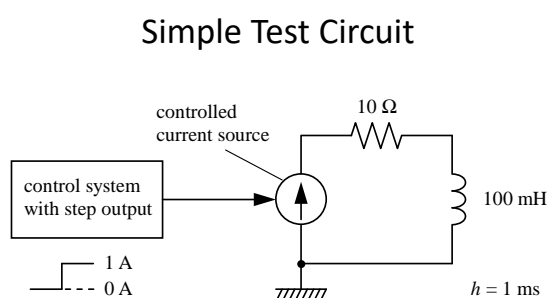# Applications

◆ XTAP can be used not only for traditional EMT simulations but also for new simulation needs.

◆ Abnormal Overvoltages, Currents and Oscillations:
  ✓ Lightning, switching and black-start overvoltages.
  ✓ Transformer and induction motor/generator inrush currents.
  ✓ Ferroresonance and subsynchronous resonance.

◆ Power Quality Assessments:
  ✓ Harmonics, flicker and voltage interruptions/drops/swells.

◆ Performance Studies of Power Electronics Converters:
  ✓ HVDC systems, FACTS devices, power electronics converters used in renewable energy (PV and wind) generation systems and battery storage (EV) systems.

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2S-DIRK versus Trapezoidal

◆ XTAP uses the 2S-DIRK method for the numerical integration. It is mathematically guaranteed that the 2S-DIRK method never produces fictitious numerical oscillation due to sudden changes of inductor currents and capacitor voltages unlike the trapezoidal method used in other programs.

Simple Test Circuit

10 Ω, 100 mH, controlled current source, control system with step output, 1 A / 0 A, $h = 1$ ms

2S-DIRK

Trapezoidal with CDA

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Strong Research Base

◆ XTAP has been developed with incorporating recent research results obtained at CRIEPI:

  ✓ The 2S-DIRK (two-stage diagonally implicit Runge-Kutta) method is used for the numerical integration of differential equations. It is especially suitable for power-electronics (switching-circuit) simulations.

  ✓ A practical three-phase (unbalanced) steady-state initialization method is implemented.

  ✓ A robust and efficient solution method, in which the Newton-Raphson (NR), the biaxial NR and the Katzenelson algorithm are combined, has been developed and is used to solve nonlinear circuit equations.

  ✓ An efficient sparse-matrix manipulation algorithm accelerates the solution process.

  ✓ The last two are patented but free to use in XTAP.

User Community and Development

◆ User Community

  ✓ In Japan, all T & D companies use XTAP as their standard, and major manufacturers, engineering companies, universities and research institutes form a user community. The total number of users is more than 3,300 as of Sep. 2021.
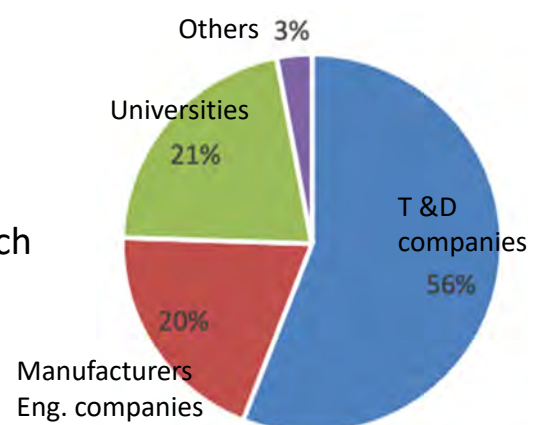

◆ Development

  ✓ Hokkaido Electric Power, Tohoku Electric Power, TEPCO Holdings (Tokyo Electric Power), Hokuriku Electric Power, Chubu Electric Power, Kansai Electric Power, Chugoku Electric Power, Shikoku Electric Power, Kyushu Electric Power, Okinawa Electric Power and Electric Power Development Company financially support the development, and CRIEPI performs the development project.
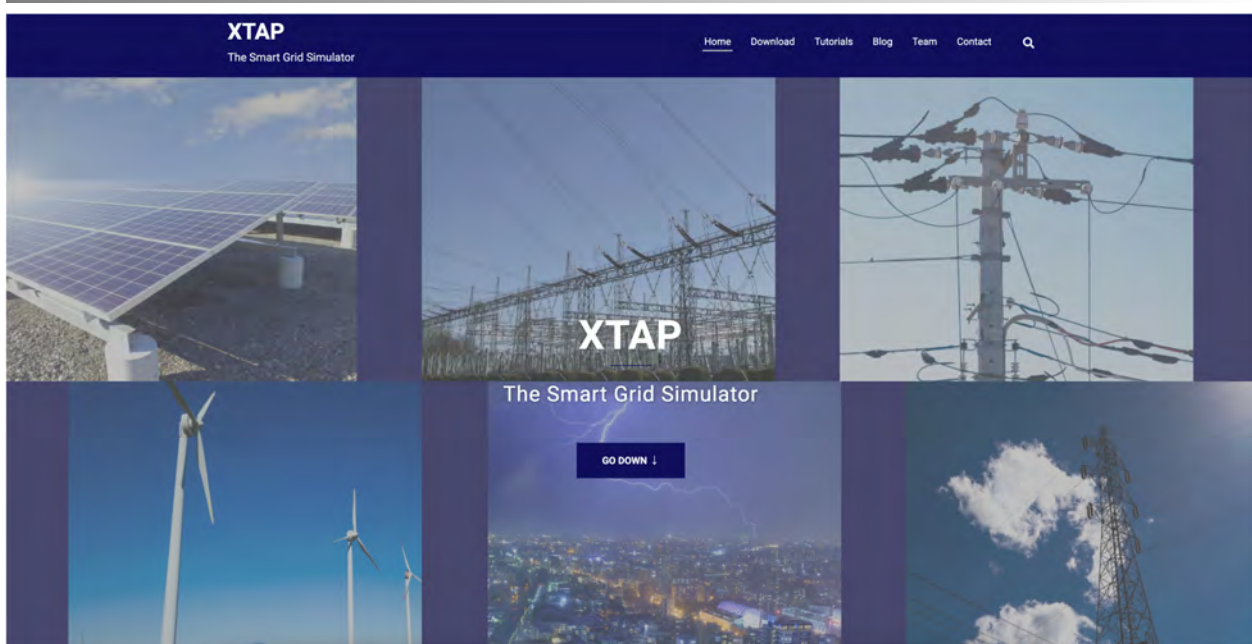
Education Opportunities

◆ XTAP comes with a 178-page manual and 42 introductory and practical test cases for self-learning.

◆ A summary of XTAP is given in the IET Book below.

◆ Courses by EMT specialists are offered in Japan (English on-line courses can be arranged).
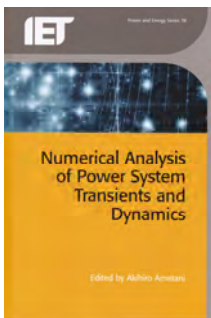
Web Site - www.xtap.org

XTAP is available to everyone for free of charge and can be downloaded from this site.

XTAP
https://www.xtap.org/