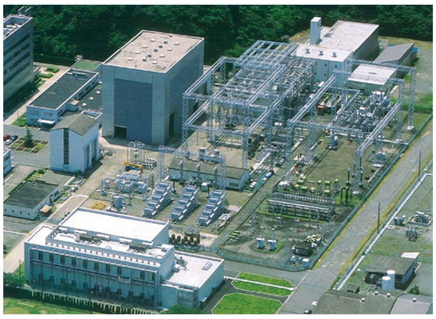
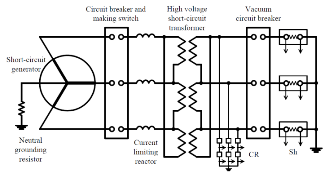
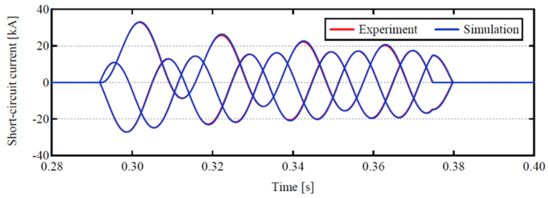
Practical Applications of the Electromagnetic Transient Simulation Program XTAP

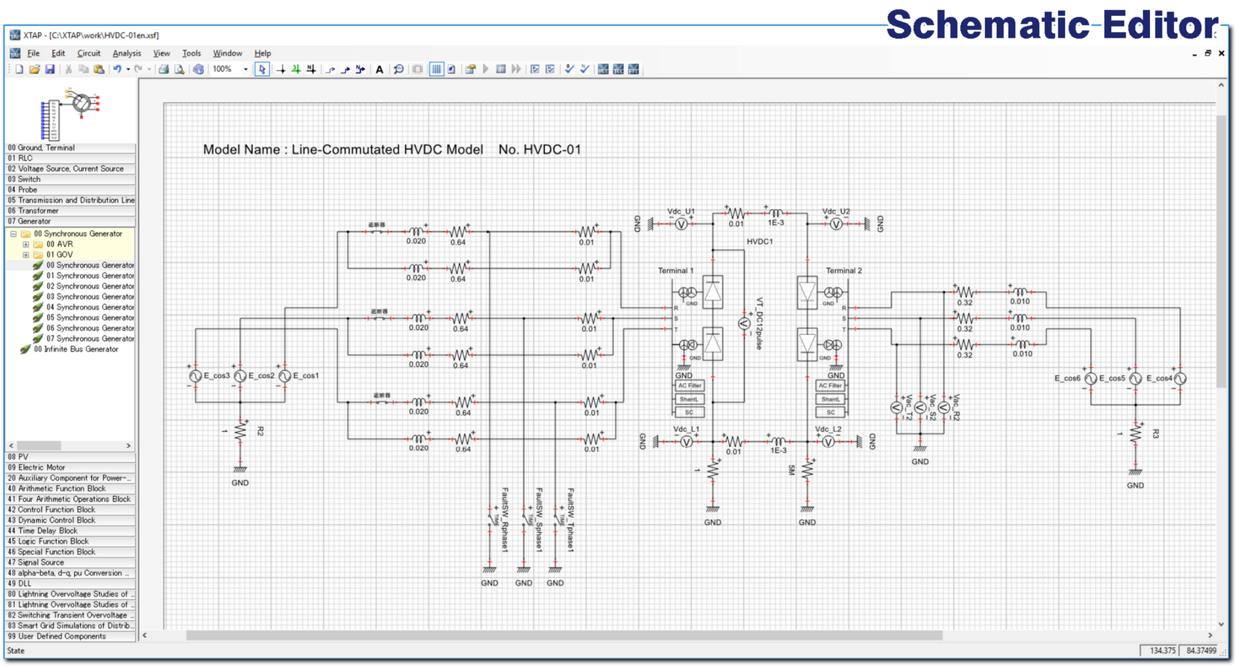






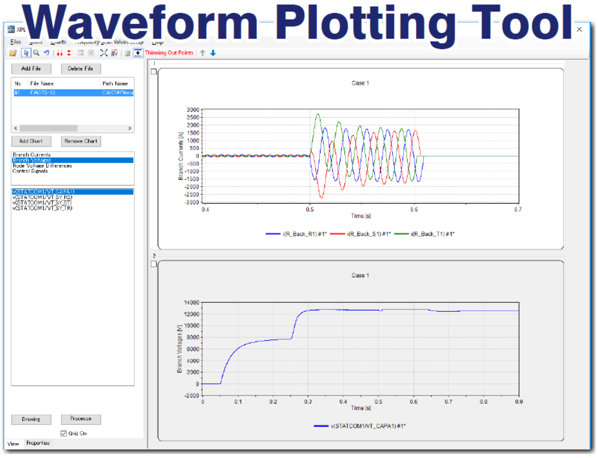
https://www.xtap.org/

XTAP (eXpandable Transient Analysis Program)

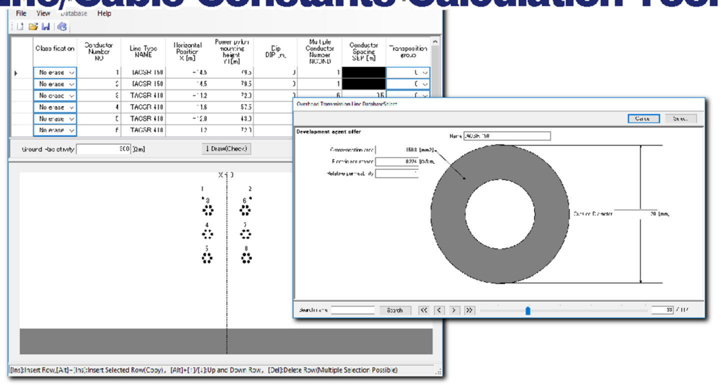


XTAP (eXpandable Transient Analysis Program)

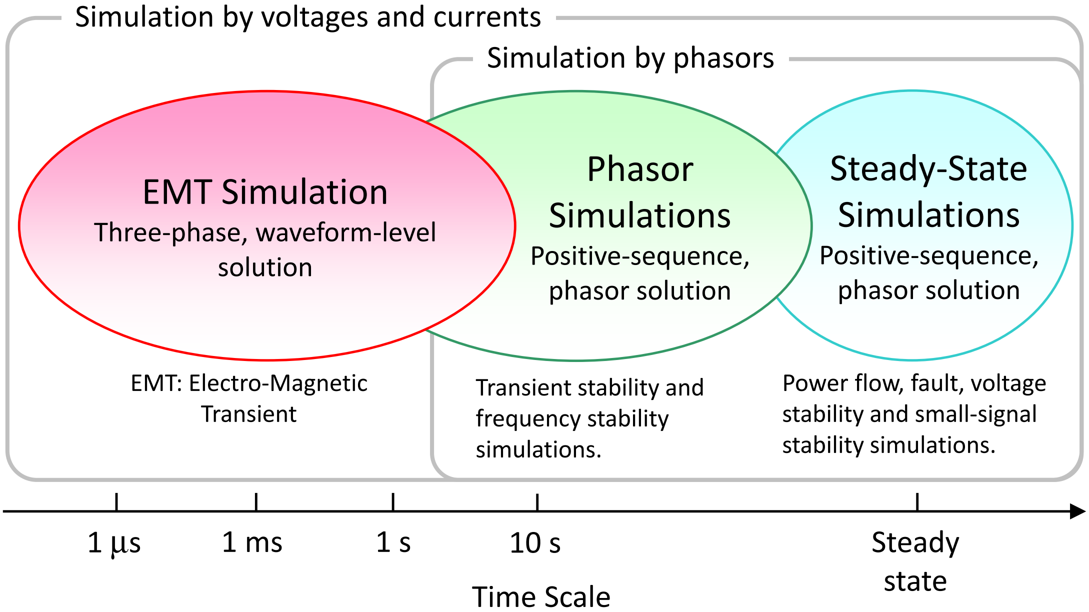
Waveform Plotting Tool



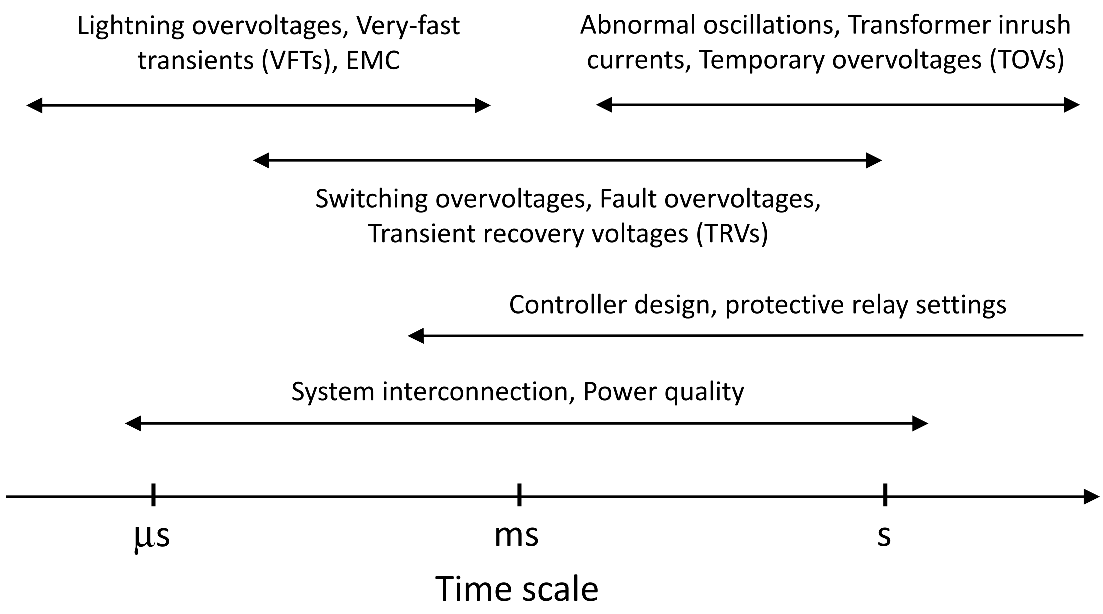
Line/Cable Constants Calculation Tool



Power System Simulation Methods



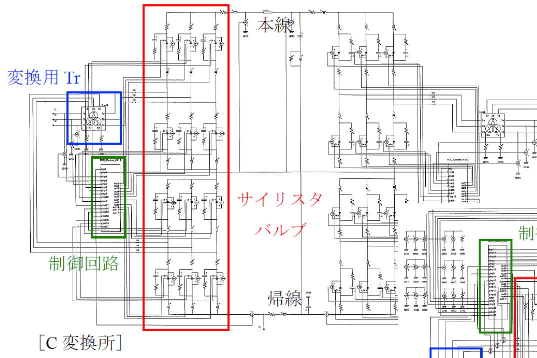
Types of EMT Simulations



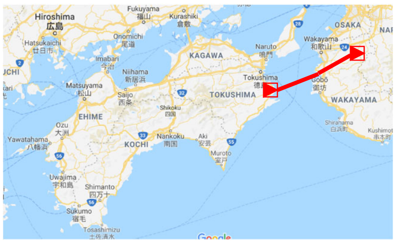
Applications

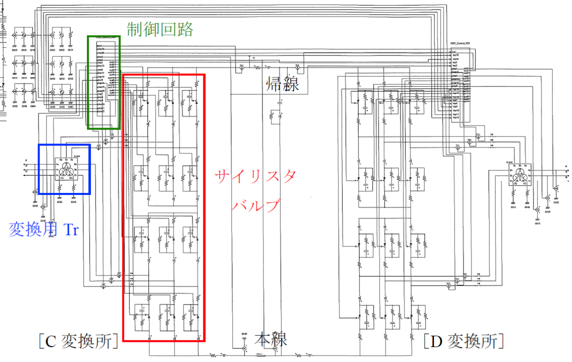
- ◆XTAP can be used not only for traditional EMT simulations but also for new simulation needs.
- ◆ Abnormal Overvoltages, Currents and Oscillations:
  - ✓ Lightning, switching and black-start overvoltages.
  - ✓ Transformer and induction motor/generator inrush currents.
  - ✓ Ferroresonance and subsynchronous 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.

Simulation Project # 1 – Large Power System Simulation Including an HVDC Transmission (Shikoku Electric Power)



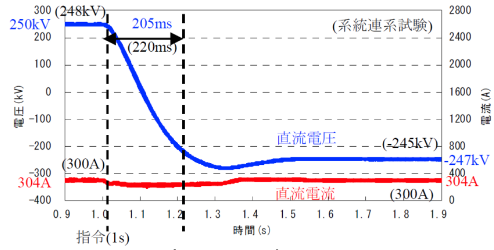
Entire Shikoku system with a 250-kV HVDC transmission system has been modeled in XTAP for various simulation purposes.



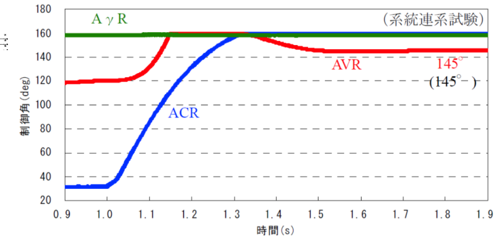


HVDC converter station models in XTAP.

Simulation: Power-flow inversion



DC voltage and current

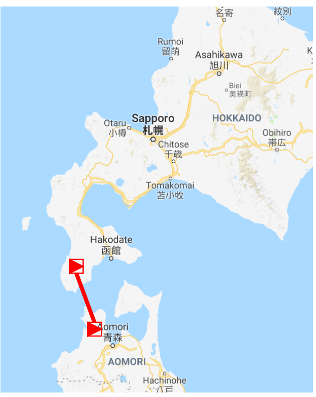


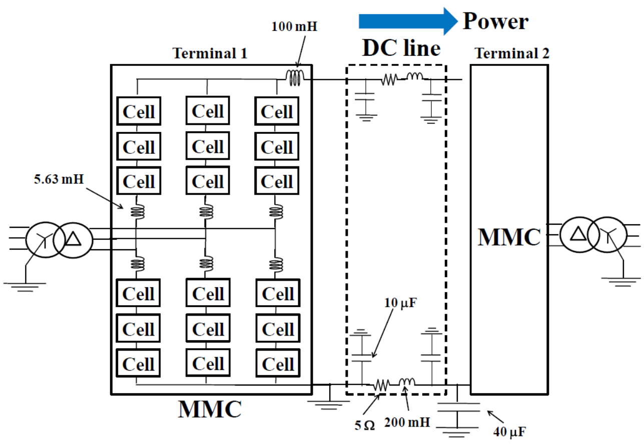
control signals

Source: Kawakami et al., IEEJ Power & Energy Society Meeting, 227, 2012.

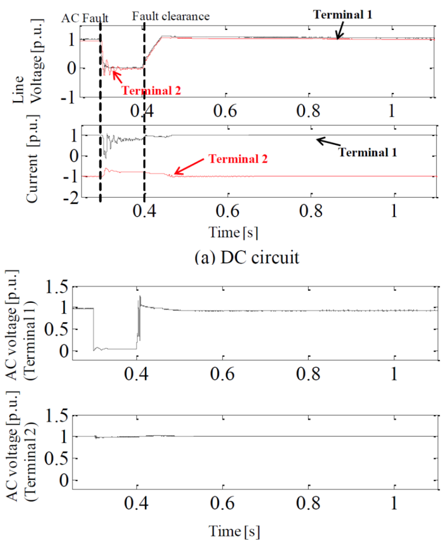
Simulation Project # 2 – Design of an MMC HVDC Transmission System (Hokkaido Electric Power)

A new HVDC interconnection between Hokkaido and Honshu (main island) is now under operation. It uses the Modular Multi-level Converter (MMC) technology for the first time in Japan. The entire HVDC transmission system has been modeled in XTAP for its design studies.





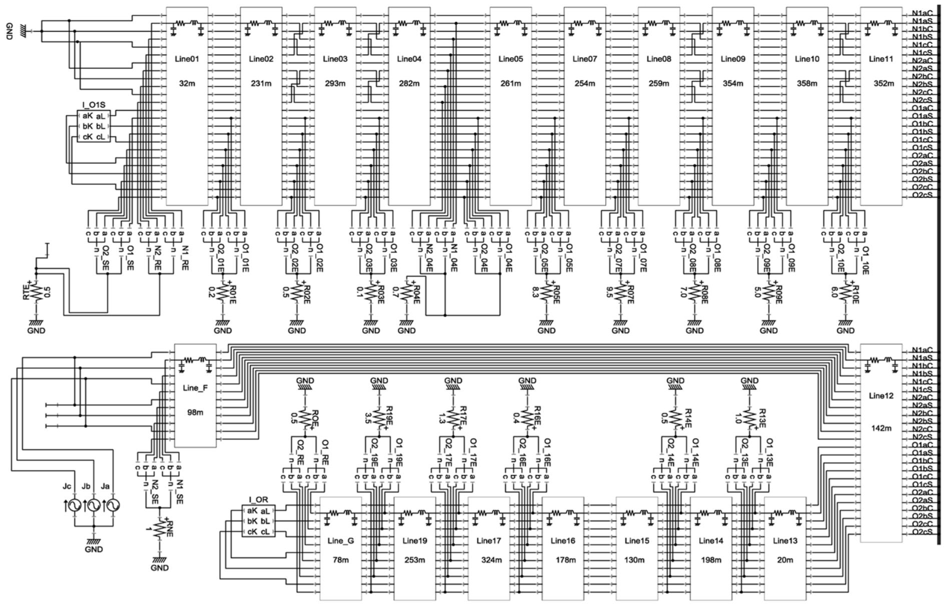
AC Fault Simulation



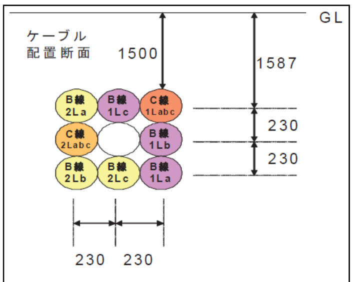
(b) AC voltage

Source: Kikuma et al., IEEJ Trans. on Power & Energy, Vol. 133, No. 5, pp. 449-456, 2013.

Simulation Project # 3 – Calculation of Zero-Sequence Circulating Currents in Cables (Kansai Electric Power)



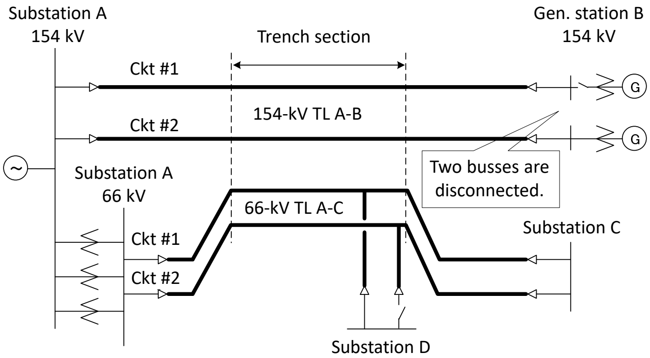
Multiple-voltage, multiple-circuit underground cable systems have been modeled in XTAP in detail so as to accurately calculate zero-sequence circulating currents. The study has solved a problem of a protective-relay malfunction.



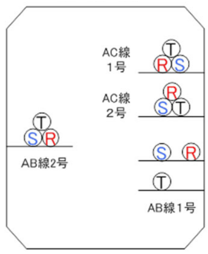
Duct Arrangement

Source: Koine, R&D News Kansai, Vol. 468, pp. 2-3, May 2012.

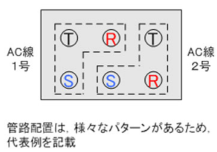
Simulation Project # 4 – Calculation of Zero-Sequence Circulating Currents in Cables (Tohoku Electric Power)



Cable arrangement in the trench section



Cable arrangement in the duct section



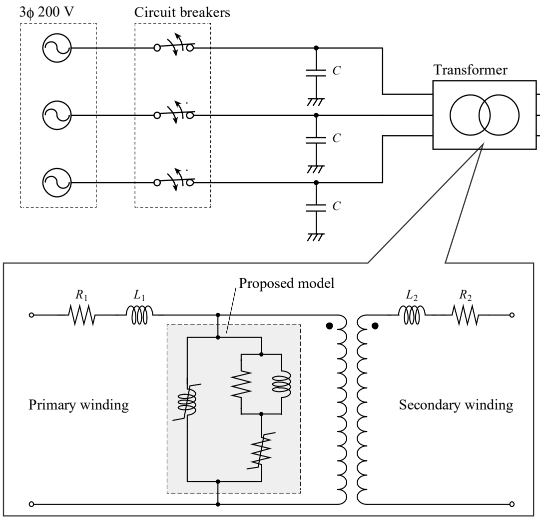
Two underground cable lines, one is 154 kV and the other is 66 kV, share the same route in a trench. For relay settings related to zero-sequence currents, circulating zero-sequence currents I_{0th} due to electromagnetic couplings and impedance imbalance must be assessed precisely. For this purpose, XTAP is used, and the simulation results agree well with corresponding field-tests results.

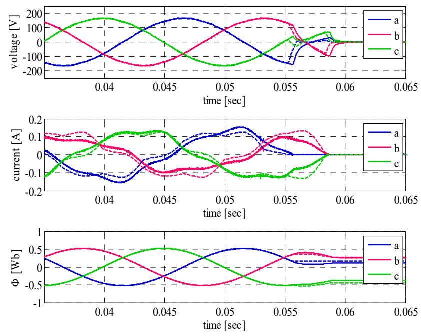
Comparison between field tests and simulations

Case	Magnitude of I_{0th}		Phase angle of I_{0th}	
	field test	simulation	field test	simulation
1	3.8%	3.9%	317 °	317 °
2	3.7%	3.7%	300 °	300 °
3	4.1%	4.2%	331 °	332 °
4	3.9%	4.1%	331 °	332 °
5	3.9%	3.8%	326 °	327 °

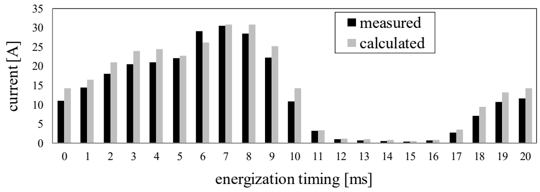
Source: Misawa et al., Tohoku Branch Meeting of Electric-Related Academic Societies, 2A13, 2017.

Simulation Project # 5　Transformer Inrush Currents (Kyushu, Tohoku and Shikoku Electric Power)





Ring-down transient example



Inrush current simulation results

The three electric power companies and CRIEPI developed a magnetizing circuit model for transformer inrush current simulations. This model is able to reproduce not only inrush transients but also ring-down ones, and the model parameters can easily by obtained by utility engineers.

Source: Yonezawa et al., IEEJ Trans. on Power & Energy, Vol. 134, No. 9, pp. 749-758, 2014.

Simulation Project # 6　Multiphase Flashover of Transmission Lines (Hokuriku, Chugoku, Kyushu and Okinawa Electric Power)

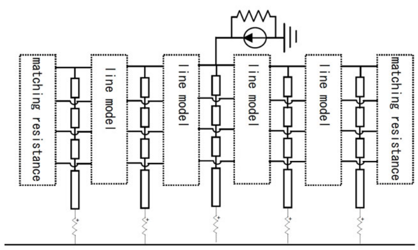


Fig.1 Transmission line model

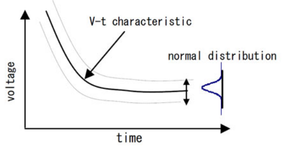
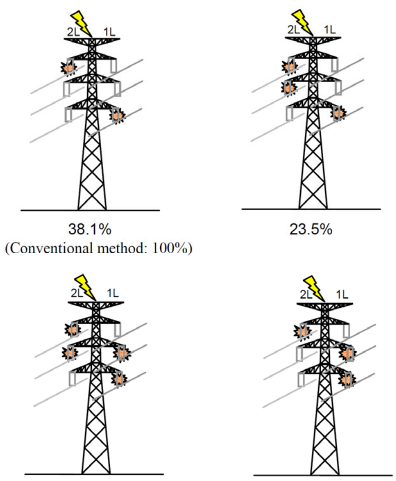


Fig.2 Flashover characteristic



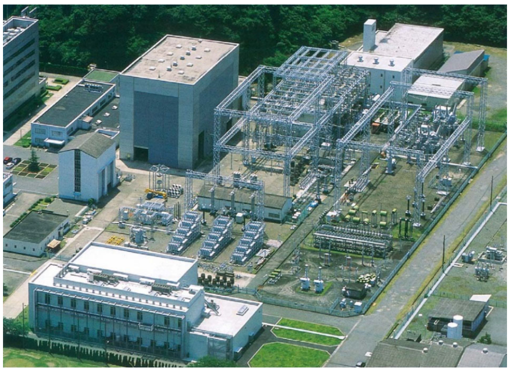
No	DATA		1st circuit U	1st circuit M	1st circuit L	2nd circuit U	2nd circuit M	2nd circuit L	Peak current (kA)
1	2014/12/13	a		●	●	●			−322
		b			△	△			
		c	−289	−154	443	443	−154	−289	

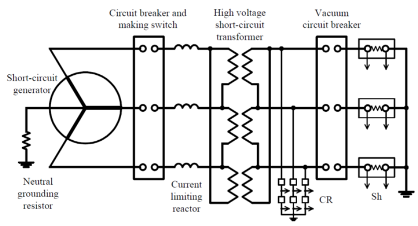
a: flashover phases obtained by field recording
b: flashover phases predicted by the conventional method.
c: ac voltages at the instance of the flashover.

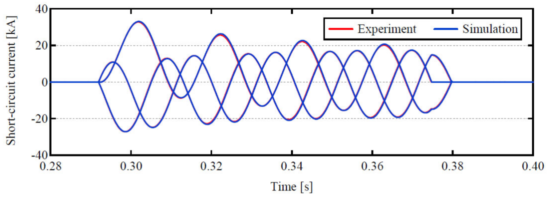
The four electric power companies and CRIEPI developed a method to predict multiple flashover phases of a transmission line using the statistical simulation function of XTAP. It takes into account the statistical characteristics of flashover. The developed method, in a statistical sense, predicts multiple flashover phases which cannot be predicted by the conventional deterministic method.

Source: Itamoto et al., IEEJ Annual Meeting, 7-060, 2018.

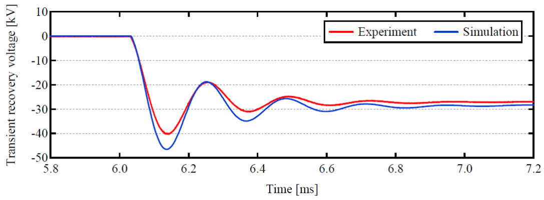
Simulation Project # 7 Studies for the High-Power Testing Laboratory (CRIEPI)







Comparison of short-circuit currents.

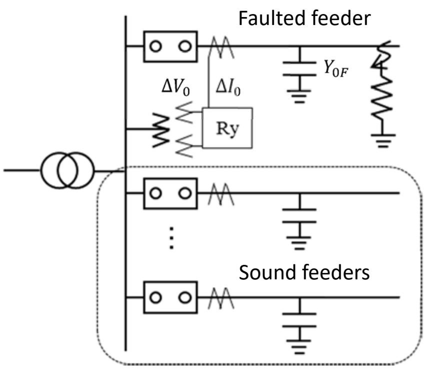


Comparison of a transient recovery voltage (TRV).

Central Research Institute of Electric Power Industry (CRIEPI) performs various tests at the High-Power Testing Laboratory in Yokosuka. XTAP is used for its studies.

Source: Ohtaka et al., IEEJ Power & Energy Society Meeting, 361, 2012.

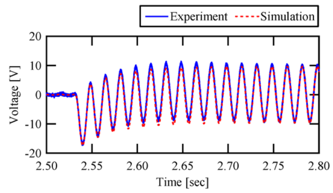
Simulation Project # 8 Protection Relay Settings at Distribution Substations (Hokuriku Electric Power)



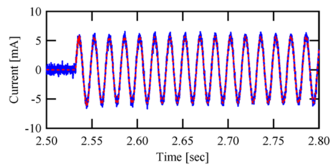
Formula for Sensitivity Prediction

$$R_F' = \frac{Y_0'}{Y_0} R_F$$

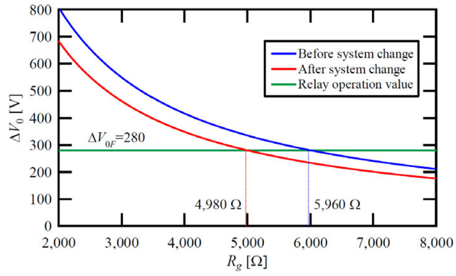
For details, see the paper below.



Zero-seq. voltage



Zero-seq. current



Example of Sensitivity Prediction

Hokuriku Electric Power carried out studies of protective relay settings at distribution substations using XTAP and the Smart Grid Simulator of CRIEPI in Yokosuka. As a result, a formula to predict the sensitivity of the line-to-ground fault relay used was derived and rationalized the necessary procedures.

Source: Aoki et al., IEEJ Annual Meeting, 6-309, 2018.

Simulation Project 9 – Lightning Protection of Distribution Lines (Chubu Electric Power)

Experimental Setup

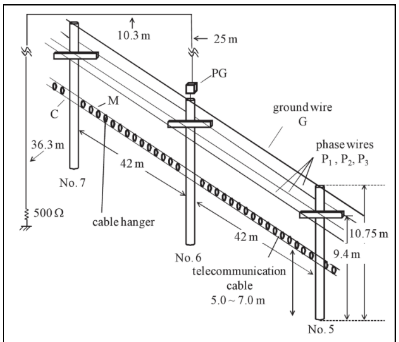


Fig. 7. Experimental setup.

Simulation Model

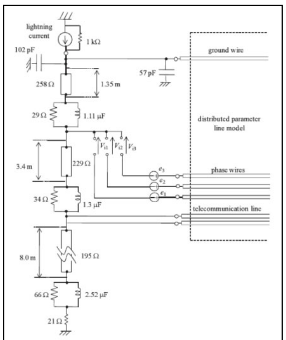
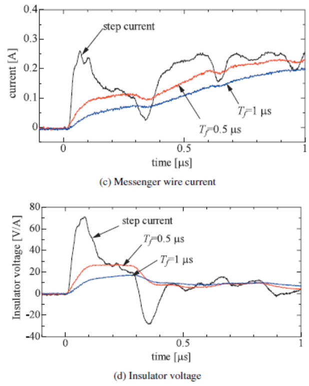
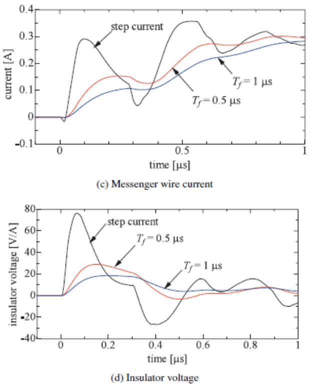


Fig. 12. Simulation model of pole No. 6.

Field Test



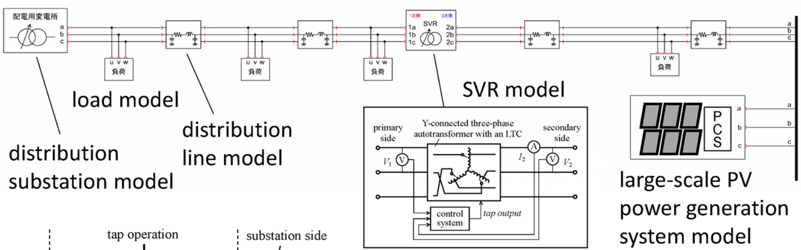
Simulation

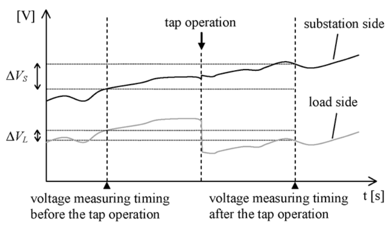


Traditionally, communication wires installed below phase wires are not considered in lightning-protection design of distribution lines. Since the communication wires are equipped with a metallic messenger wire, it also carries part of a lightning current and thus reduces lightning overvoltages. This study first made clear the role of communication wires in the lightning-protection design.

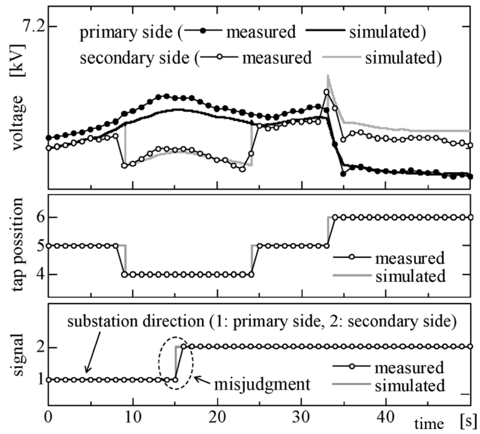
Source: Ishimoto et al., IEEJ Trans. on Power & Energy, Vol. 131, No. 7, pp. 591-601, 2011.

Simulation Project 10 – Interference of an SVR and a PV System (Tohoku Electric Power)





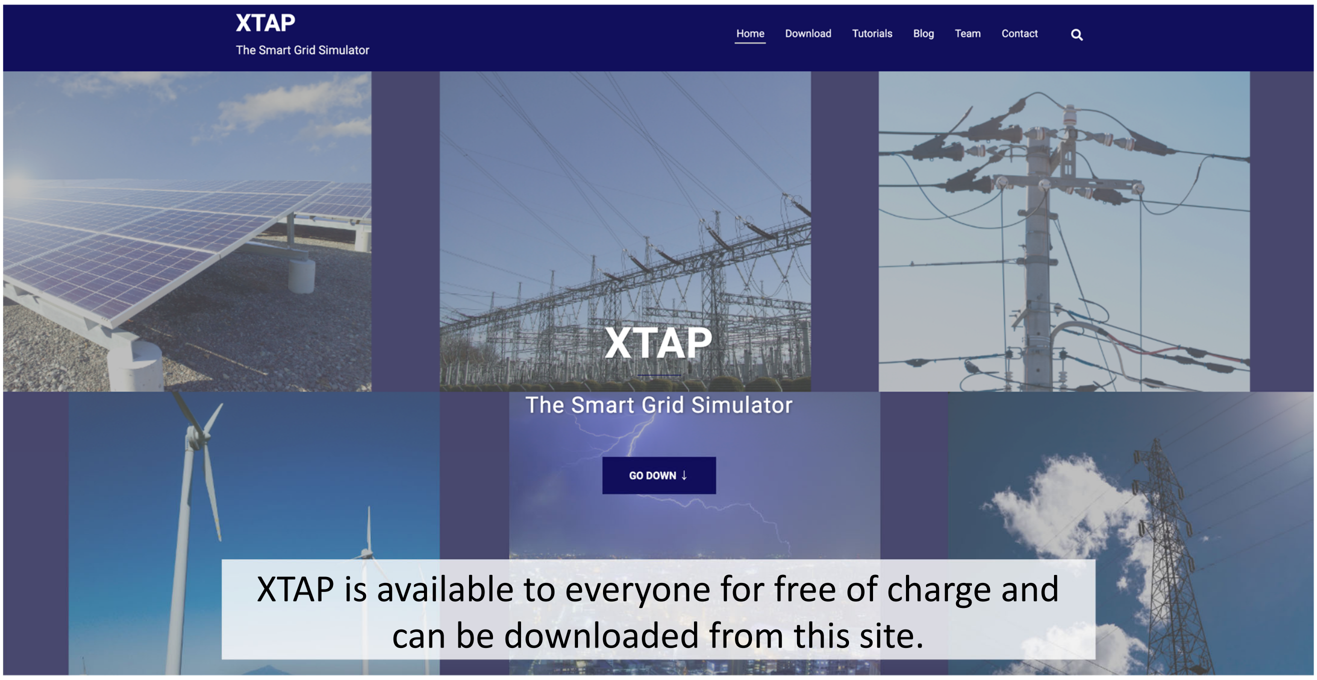
$Z_S = \frac{\Delta V_S}{\Delta I_S}$, $Z_L = \frac{\Delta V_L}{\Delta I_L}$



It was reported that an SVR (step voltage regulator) which is operable under reverse power flow interfered with a large PV generation system and failed to detect the substation direction. The cause has been identified by XTAP, and an improved control system of the SVR has been validated using XTAP before installation.

Source: Nagashima et al., IEEJ Trans. on Power & Energy, Vol. 137, No. 2, pp. 154-155, 2017.

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/