NUMERICAL CALCULATION OF ELECTROMAGNETIC TRANSIENTS - INSULATION COORDINATION -

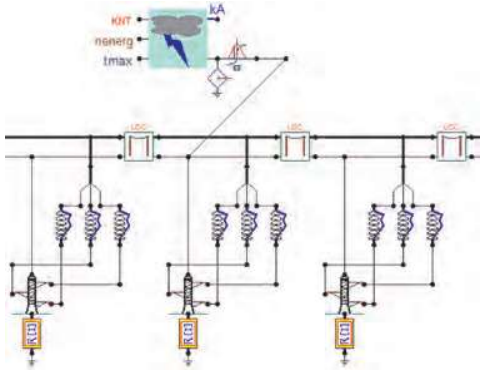
Electrical Engineering Institute Nikola Tesla a. d. Belgrade (Institute) has decades of experience in developing research methods, calculations and analysis of phenomena on medium and high voltage facilities and networks that are focused on transient processes of voltages and currents in the power grid, primarily to solve problems in the field of overvoltages and insulation coordination. Within the coordination of insulation, the problems of choosing the dielectric strengths of insulation for high voltage apparatus, ie their corresponding withstand voltages with regard to stresses caused by voltages and overvoltages that occur in networks during operation and with regard to the required reliability and the effect of applied protective measures. The objectives of numerical simulations and research are that the selection of insulation of equipment, facilities and lines, as well as the choice of protective measures and means to limit overvoltages, under operating conditions and expected voltages and overvoltages, is done so that continuity of work is achieved within economically and technically acceptable proportions.

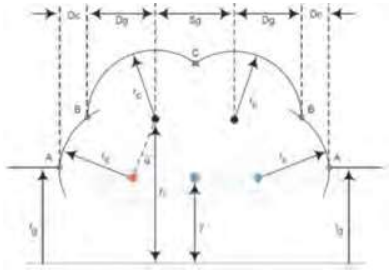
LIGHTNING OVERVOLTAGES

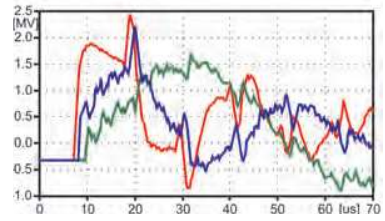
Lightning discharges are one of the most common causes of overvoltages in the power system, which have a great impact on the quality of delivered power, which is reflected in the increased number of interruptions, violation of network reliability parameters and failures of expensive equipment such as power transformers.

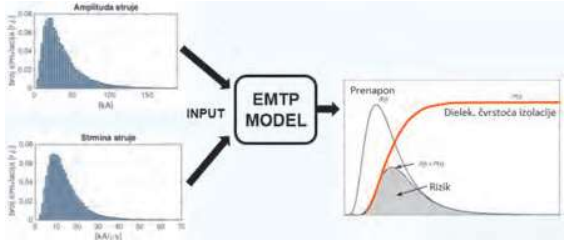
The application of software tools for the analysis of electromagnetic transients (EMTP) allows:

- Formation of an adequate simulation model, which takes into account frequency-dependent and nonlinear properties of components, suitable for calculation of overvoltages caused by lightning discharge in transmission line tower, shielding wire or phase conductor or lightning protection of facilities, substations, PV power plant or exposed parts of wind turbines.
- Statistical analysis (Monte-Carlo simulations) aimed at taking into account the stochastic nature of the occurrence and calculating the risk of destructive insulation discharges, mean number of years without equipment failure (MTBF), annual number of failures of overhead lines...
- Deterministic analysis whose goal is to calculate the maximum values of voltage or maximum values of energy of surge arresters, for given parameters of lightning discharge.









SWITCHING OVERVOLTAGES

Power electric equipment is exposed to overvoltages caused by switching manipulations on a daily basis. Depending on the power grid configurations, switching overvoltages can reach high levels and seriously endanger the insulation of the equipment, if there is no adequate overvoltage protection. Surges occur both when the circuit breaker is closing and when the circuit breaker is opening either in usual operations or during the faults.

Switching On

Statistical analysis (Monte Carlo simulations) provides the consideration of the random moment of the contacts closing and the time dispersion between the poles of the switch. As a result of the analysis, the distribution of overvoltage is obtained (probability of overvoltage occurrence).

Commonly simulated are switching-on of the:

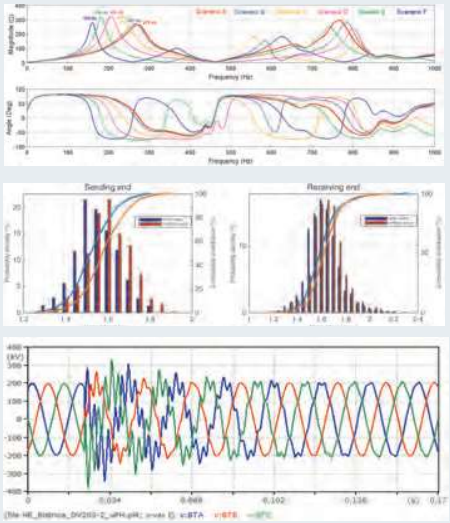
- Powel lines (overhead, cable mixed);
- Transformers (taking into account the residual flux in the magnetic circuit);
- Reactors and capacitor banks…

Possible types of switching-on operations:

- “Classic” switching-on;
- Auto-Reclosing (AR) on OHL;
- Out-of-phase switching;
- Sympathetic switching of transformers;
- Back-to-back switching of capacitor banks;
- Point-of-Wave switching;

Frequency scan

Frequency scan simulations provides identification of resonant points and potentially dangerous configurations.



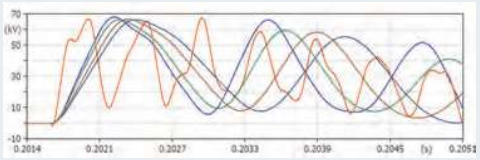
TRV (RRRV) analysis

When the switch is opened, a transient recovery voltage (TRV) is established between its contacts).

The switch has successfully cleared the fault if the TRV is less than the dielectric strength in the inter-contact gap.

Numerical tools are allowing the simulations of the:

- Terminal, long line and short line failures;
- Different types of faults (LG, LLLG, LLL);
- Out-of-phase switching;
- Presence of the electric arc between contacts (Cassie and Mayr Arc)

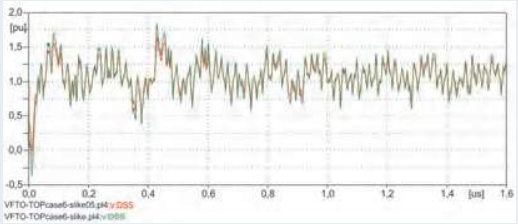


VERY FAST OVERVOLTAGES

VFFT in GIS

Switching manipulations with earthing switch, disconnector and circuit breaker in gas-insulated plants can cause very fast front overvoltages that can cause problems in primary and secondary circuits.

With detailed GIS data, credible models can be considered.

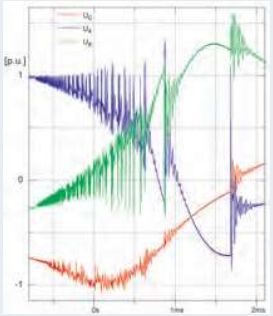


Vacuum Circuit Breaker

Switching operations of vacuum switches, due to the occurrence of multiple arc reignition and restrikes, can be the source of very fast overvoltages, endangering the inter-winding insulation of the equipment in the facility.

Numerical simulations make possible to:

- Check the efficiency of overvoltage protection
- Select the optimal RC snubber values.

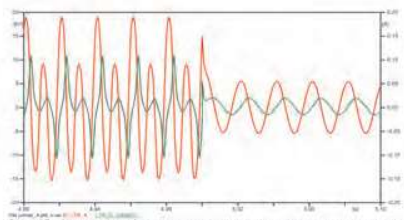


TEMPORARY OVERVOLTAGES

Temporary overvoltages are undamped or weakly attenuated surges of oscillatory shape and relatively long duration, from several periods of industrial frequency to several hours. They usually do not endanger the insulation of the equipment, but can cause problems in the operation of certain devices, such as surge arresters, voltage transformers, etc.

Oscillatory transients can occur during :

- Resonance
- Ferrroresonance
- SLG fault
- Load rejection
- Phase missing



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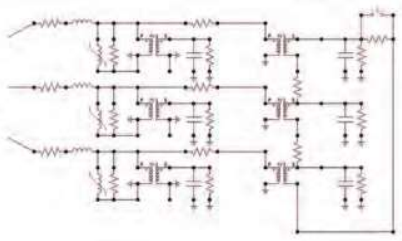
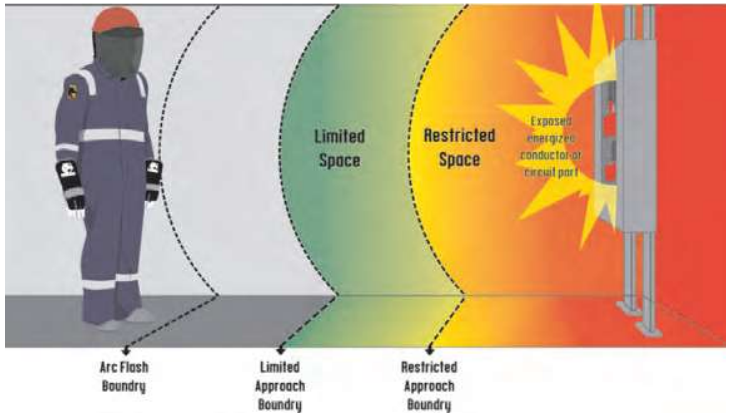


ELECTRIC ARC HAZARD

The possible occurrence of an electric arc is endangering everyone who works on or near energized electrical equipment, so it is very important to be aware of the hazard of electric arc and to wear appropriate PPE.

The arc risk assessment is performed in order to:

- Recommend appropriate work procedures;
- Determine boundary distances;
- Defines the necessary protective equipment.



MOST SIGNIFICANT REFERENCES (last 10 years)

1. Study of switching overvoltages in GCCIA interconnection network, , 2020.
2. Study of very fast overvoltages caused by the operation of a vacuum circuit breaker, within the OMAN LNG debottlenecking project, 2020.
3. Lightning and switching surge study, within ADNOC Onshore's BAB Integrated Facilities, beneficiary: China Petroleum Engineering & Construction Corporation, 2019.
4. CB Transient Recovery Voltage Analysis Study, SEWA Layyah PS, 2019.
5. Electric arc hazard assessment study, done for Adient Setings d.o.o. 2019.
6. Insulation Coordination and Arc Protection Studies, done for Lim HPPs, 2019.
7. Studies of Lightning, Switching, Very Fast Surges in GIS and Frequency Scanning, within the Saudi Aramco Marjan Development Program, 2018.
8. Insulation Coordination Study, conducted for Abu Dhabi Gas Industries (GASCO) - Taweelah Gas Compressor Station, 2017.
9. Study of Transient voltage and current regimes in the transmission system of Serbia 110kV, 220kV and 400kV, user EMS, 2014.
10. Study of Overvoltage protection of generator transformers in EPS power plants, 2012.