

Improving Hydro-Québec's EHV Transformer Test Program to Prevent Failures due to Internal High-Frequency Resonances

Louisville, Kentucky, October 31, 2017

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IEEE/PES TRANSFORMERS COMMITTEE



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- A paper was presented in a CIGRE colloquium in 2013 in Zurich, CH

CIGRE SC A2 & C4 JOINT COLLOQUIUM 2013
Zurich, Switzerland



<http://www.cigre2013zurich.org/>
ETH Zurich

CIGRE A2 & C4
2013

PS 1: Interaction between Transformers and the Power System

**Improving Hydro-Québec's EHV Transformer Test Program to Prevent Failures
due to Internal High-Frequency Resonances**

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How to prevent failures due to internal resonances?

An improved lightning testing series could be a solution...

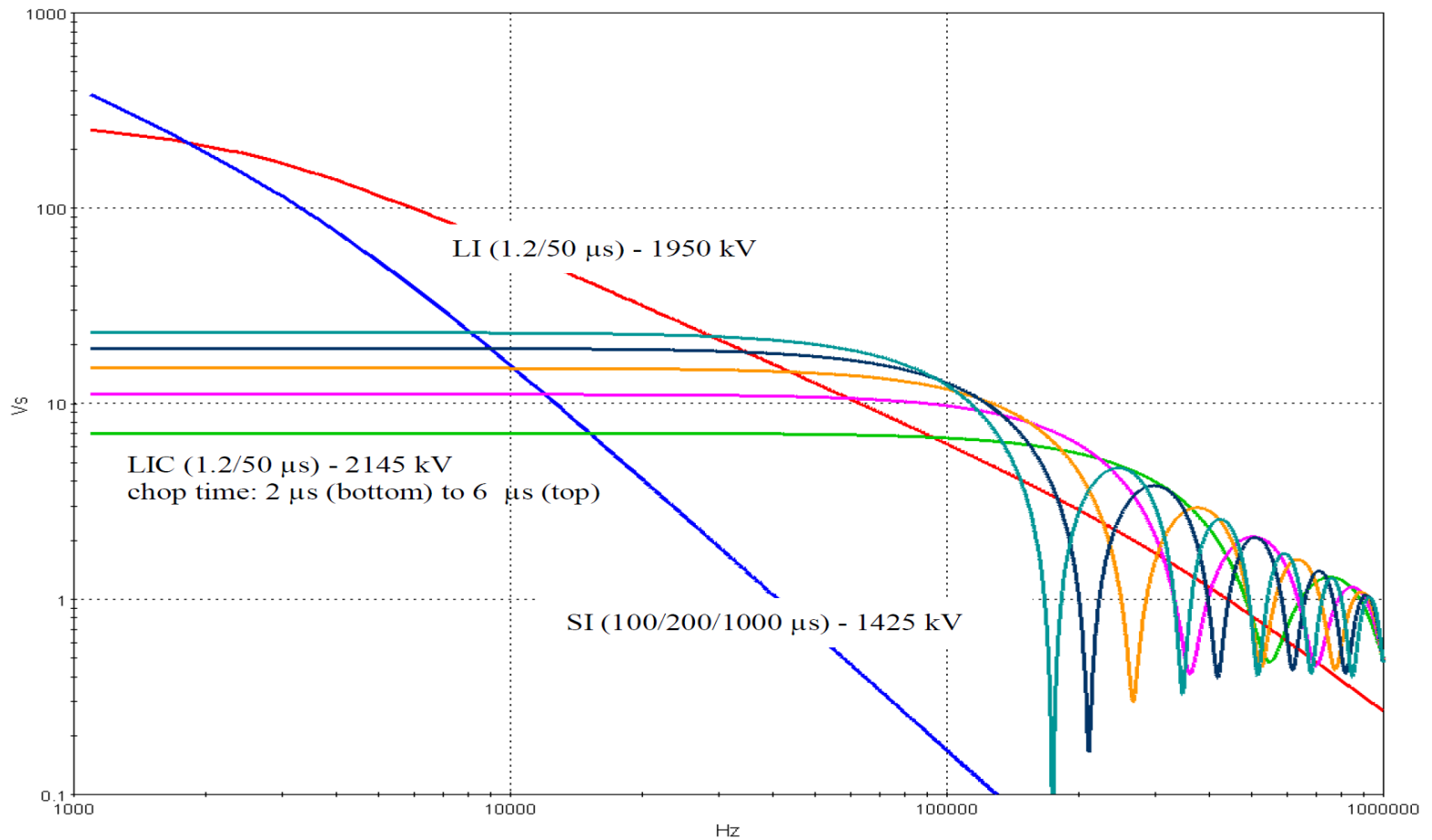
Case study

- Single-phase auto-transformer;
- HV: 735 kV/ $\sqrt{3}$;
- LV: 315 kV/ $\sqrt{3}$;
- TV: 12,5 kV;
- 550 MVA;
- ONAN/ONAF/ONAF;
- No on-load tap-changer;
- No de-energized tap changer.

Insulation levels

Terminal	BIL (kV)	Chopped Wave (kV)	SIL (KV)	Induced (Enhancement / PD) (kV r.m.s.)
HV	1950	2145	1550	880 / 750
LV	1050	1155	850	$(660/\sqrt{3}) / (570/\sqrt{3})$
Tertiary	95	105	N/A	34 (applied)
Neutral	95	N/A	N/A	34 (applied)

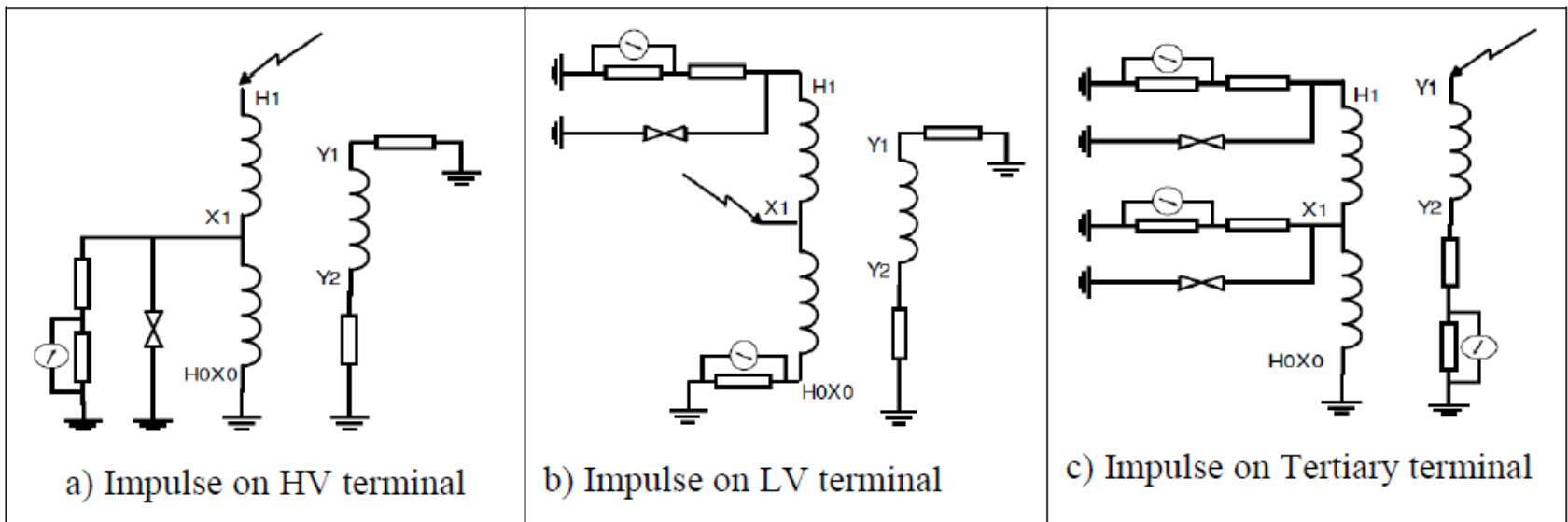
Frequencies involved



Simulations

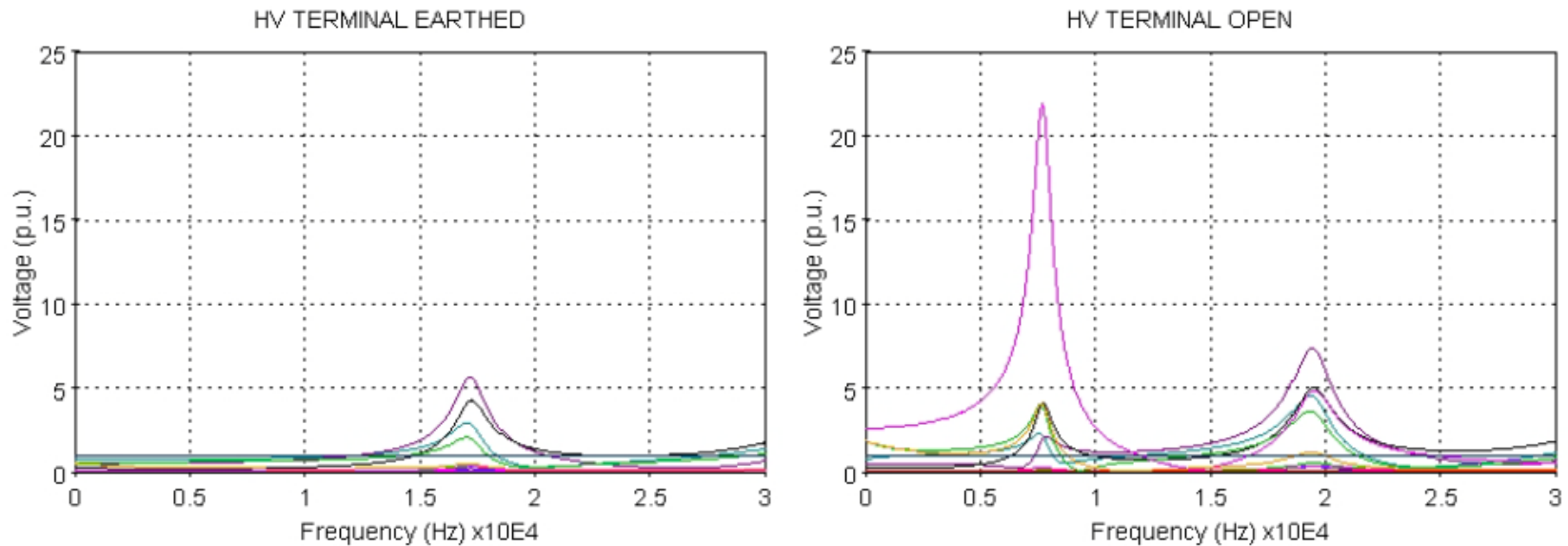
- A white-box model valid up to 30 kHz has been provided by the transformer manufacturer in an EMTP format;
- Simulations were performed for the following conditions:
 - Non-impulsed terminals in grounded conditions;
 - Non-impulsed terminals in open-circuit conditions;
 - Non-impulsed terminals in open condition terminated with a surge arrester or surge impedance.

Simulations connections



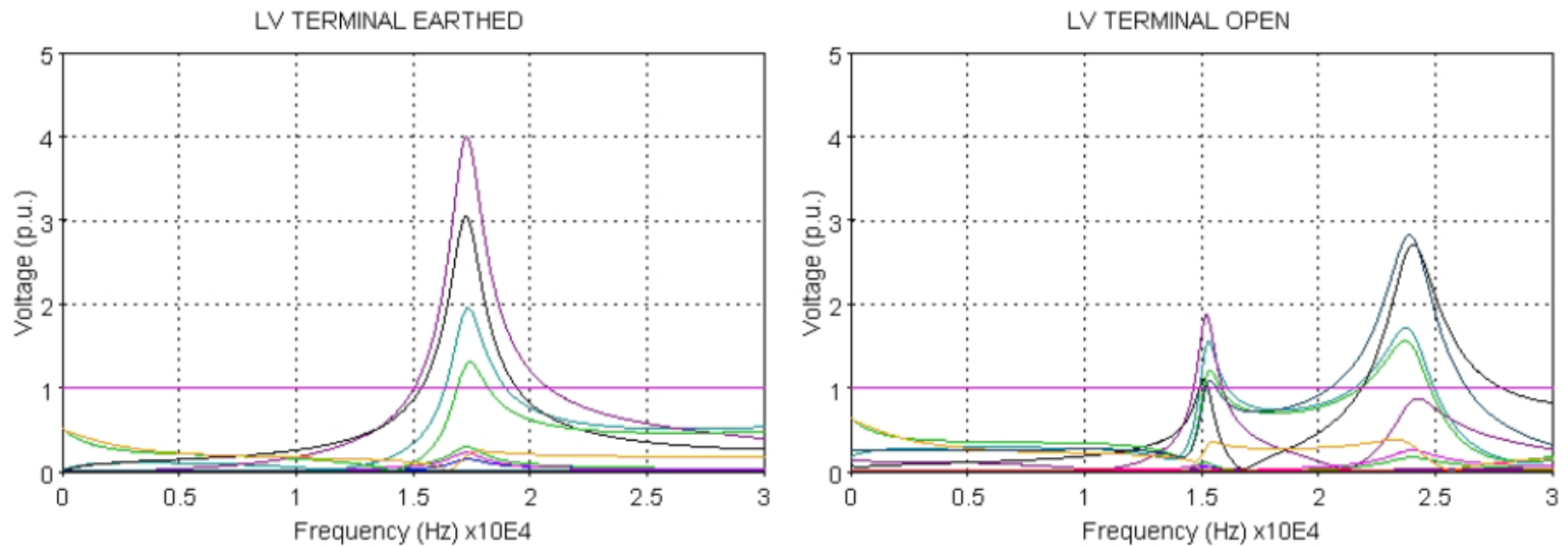
Applied voltage on the impulsed terminals: 1.10 x lightning impulse protective level (LIPL), 100% rated BIL on TV.

Simulation results



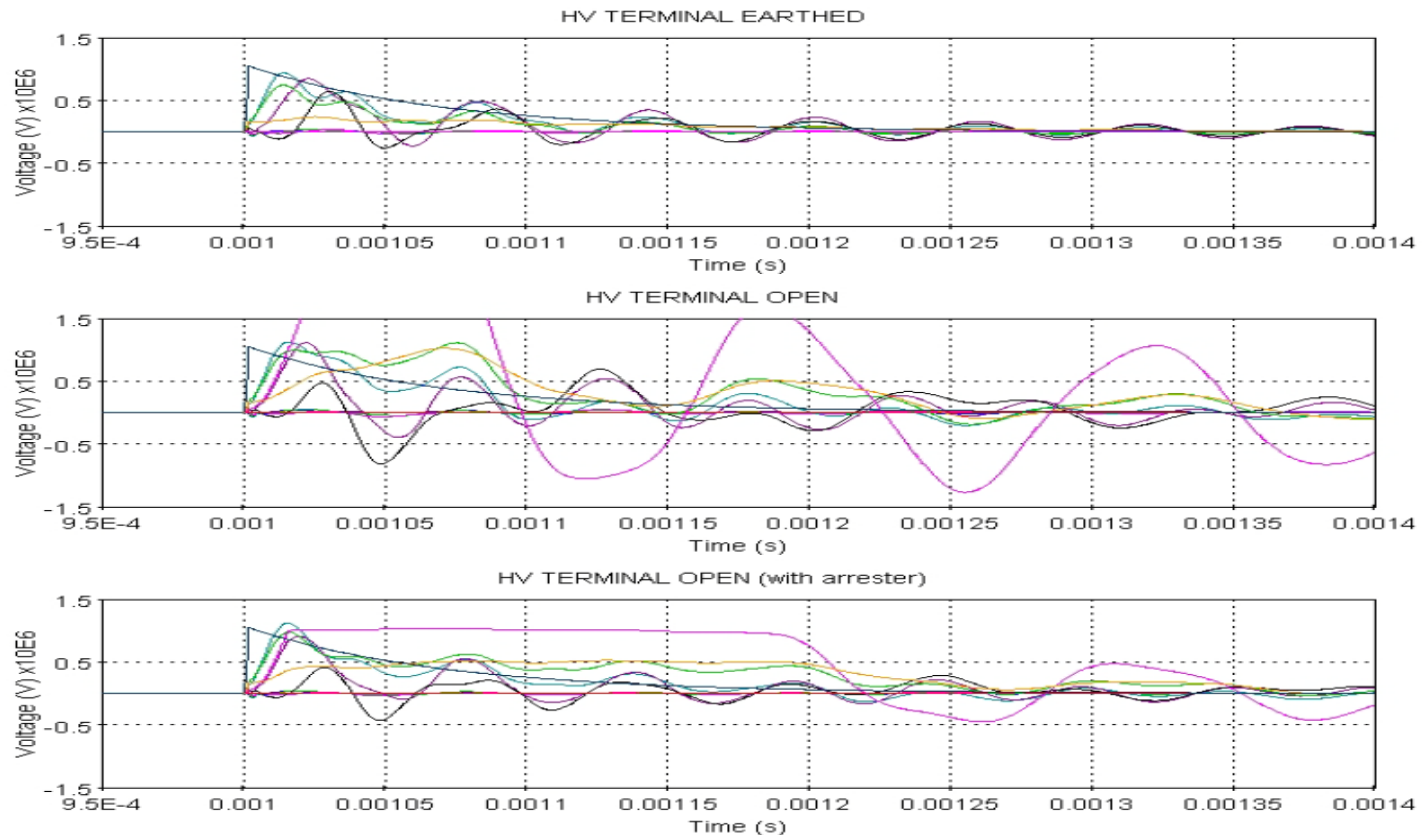
Frequency domain; impulse on LV

Simulation results



Frequency domain; impulse on HV

Simulation results



Time domain; impulse on LV (different probe locations within the winding)

New impulse tests

- Hydro-Québec's specification is now requiring, as a special test, a lightning impulse test with line terminals terminated by their respective surge arresters and surge impedance (as presented by American Electric Power in an IEEE transaction papers dated 1994 and 1996);
- TV terminals shall be terminated with their surge impedance (typically 30 Ω , HV cable connections, no arresters);

New impulse tests

- Winding stresses with line terminals in open circuit and terminated with their respective surge arrester and surge impedance is now part of the technical issues discussed during design reviews.

Conclusions

- Lightning impulses with open line terminals terminated with a surge arrester and surge impedance are producing different stresses within the windings than the usual impulse test connections;
- In some configurations and locations within the windings, the produced stress may be dimensioning for the transformer design;
- Open line terminals terminated with surge arrester and surge impedance is a closer network condition than with line terminals earthed;

Conclusions

- Open line terminals without surge arrester or surge impedance termination shall be avoided, the produced stress could be too high;
- EHV transformers are recommended to be tested using earthed and arrester protected line terminals (with and without a line surge impedance).



Questions?

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