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FINGRID

Study Committee C4

Power system technical performance

Paper 11012

OVERVOLTAGE SIMULATION STUDIES FOR A SERIES COMPENSATED TRANSMISSION LINE IN A MESHED SERIES COMPENSATED NETWORK

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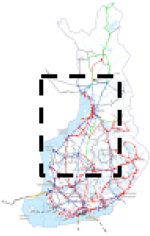
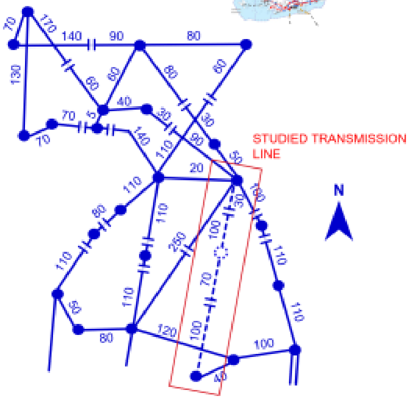


Motivation

- New highly series compensated transmission line with high current rating (2xFSC: 400 kV, 2500 A, 75 %) in a meshed series compensated network
  → Extreme overvoltages that must be studied and mitigated
- Avoid over dimensioning with highly detailed simulations and probabilistic approach

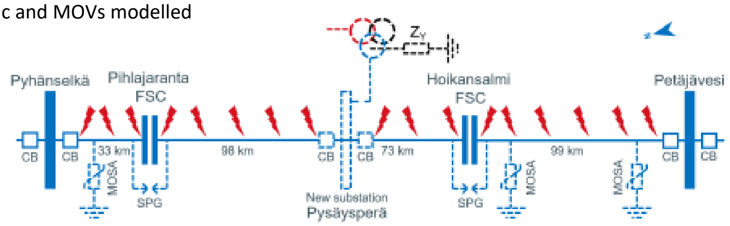
Simulations without and with the following six mitigation methods:

1. Force triggered spark gaps (SPGs),
2. Metal oxide surge arresters (MOSAs) for 3 different locations
3. SPGs, adding a new substation along the line
4. SPGs, adding a new substation and a transformer with a 0 Ω grounding impedance
5. SPGs, adding a new substation and a transformer with a 40 Ω grounding impedance
6. SPGs, adding a new substation and a transformer with a 120 Ω grounding impedance



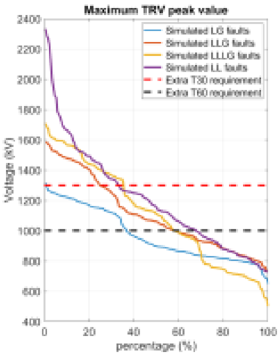
EMT Simulations

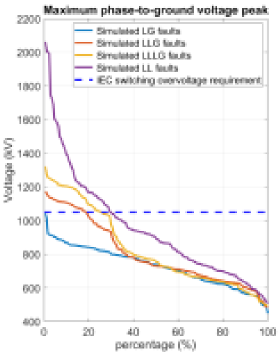
- over 6000 simulations
- LG, LL, LLG and LLLG faults with successful and failed reclosing
- 17 fault locations, 10 fault inception angles,
- distributions for delays (relays, CB, telecommunication)
- FSC bypass logic and MOVs modelled

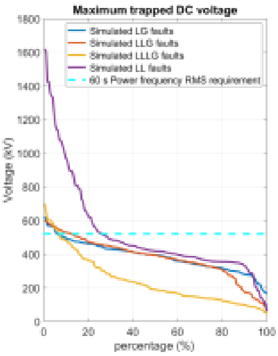


Without mitigation methods:

Extreme overvoltages detected especially in LL faults -> equipment ratings are exceeded with high probability







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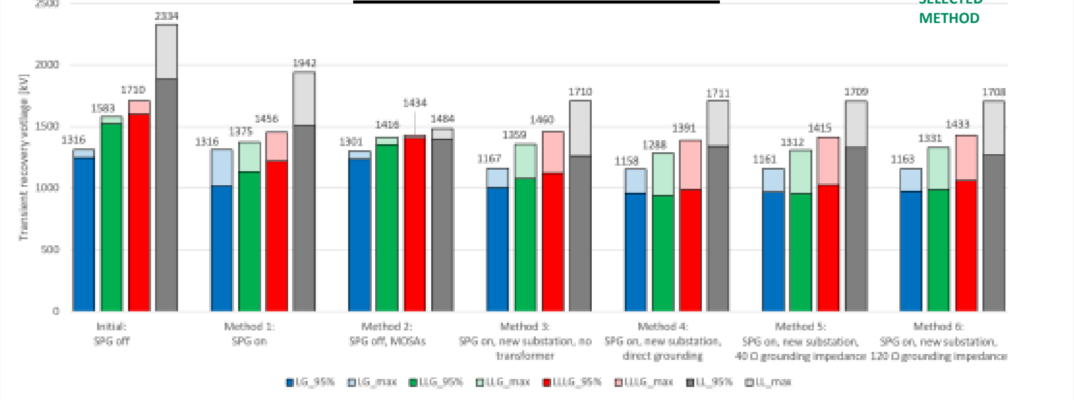
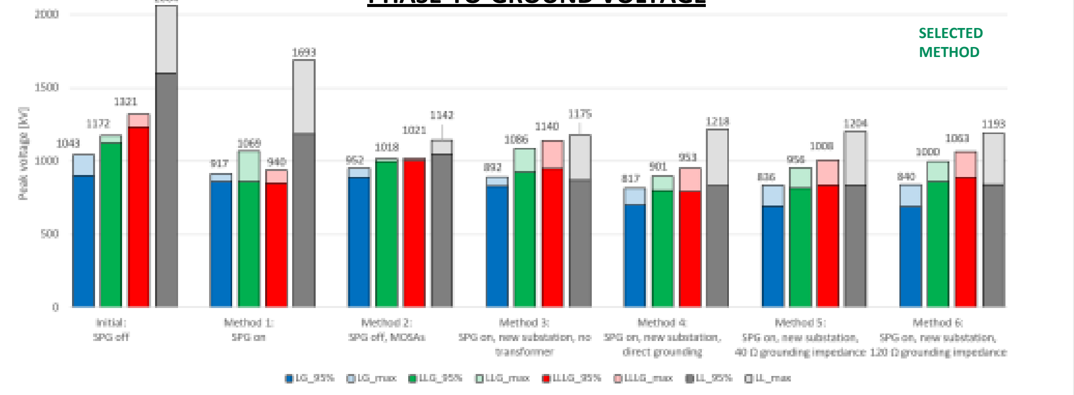
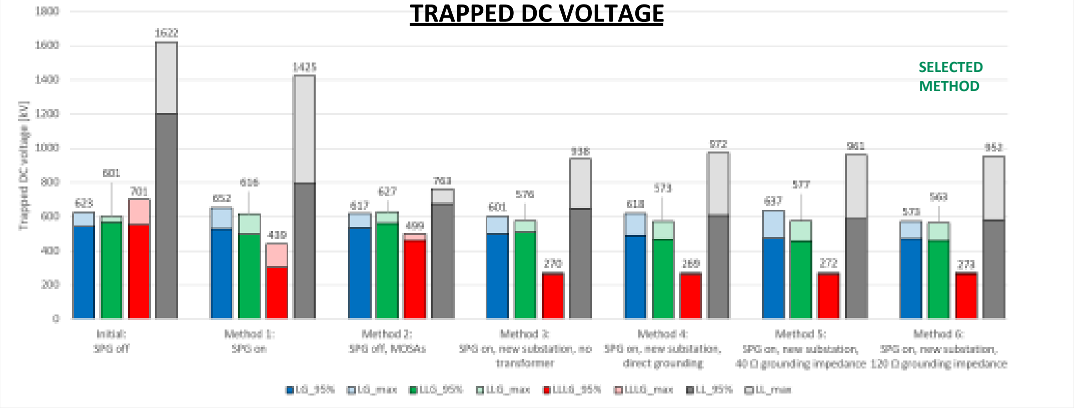
TRANSIENT RECOVERY VOLTAGE



PHASE-TO-GROUND VOLTAGE



TRAPPED DC VOLTAGE



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Conclusions

Without any mitigation methods overvoltages, too high for typical 400 kV equipment ratings, are observed. The results highlighted the need for extensive EMT simulations with extensive variation of uncertainty factors.

Maximum overvoltages

None of the mitigation methods seemed to be effective in keeping the maximum simulated overvoltages below the relevant standard values. LL faults caused the highest overvoltages with every mitigation method. Method 2 (MOSAs) was the most effective to limit the maximum value in all studied overvoltage types. One key concern with MOSAs was a high accumulated energy (average 5.4 MJ/phase for three locations).

95 % percentile overvoltage values

All studied overvoltage types in all fault types were below the relevant standard value with two mitigation methods: Method 3 (SPGs & new substation) and Method 6 (SPGs, new substation & transformer with 120 Ω grounding impedance). Method 2 (MOSAs), was not effective to limit 95 % voltages.

Selected mitigation method

Method 6 (SPGs, new substation and transformer with 120 Ω grounding impedance) was selected as the most suitable mitigation method for the studied transmission line. The method has an advantage that it allows connecting renewable generation to the new substation. Method 6 does not guarantee a hundred percent safety for different overvoltages, but the risk was found acceptable.

Choosing the right simulation software is essential

Always choose EMT simulation software for detailed overvoltage analysis. RMS simulation software can't be used to estimate trapped DC voltages because it is incapable to take into account

- Successive unsymmetrical conditions created by a different timing of the breaker opening of the phases
- Non-linear characteristics of the MOVs and the bypass logic of the series capacitors

Figure highlights the need for EMT simulations. The RMS calculation results predicted the relative change in the trapped DC voltage between different grounding impedances totally opposite way around.

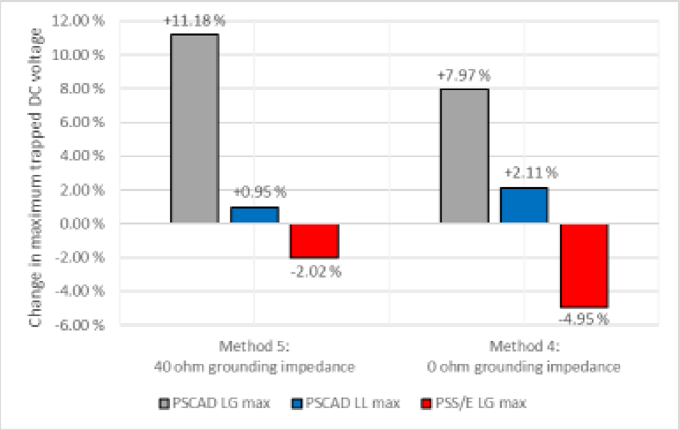

FIGURE: THE CHANGE IN SIMULATED MAXIMUM TRAPPED LINE DC VOLTAGE VALUES COMPARED TO METHOD 6 (120 Ω GROUNDING IMPEDANCE).