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Ferroresonance in SVC - Onsite measurement, analysis with EMT simulation and selection of a mitigation solution

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RTE

Motivation

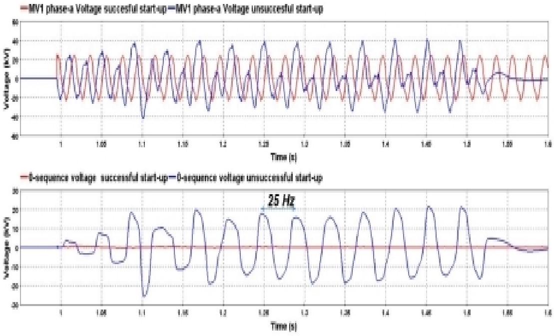
- Regulars **undesired trips** at start-up in **SVCs**
- Lost of time and money, need to have full control of our installation
- Understand the root cause of this phenomenon
- Find a solution to mitigate the phenomenon

Method/Approach

- EMT Simulation
- Replay and understand the phenomenon
- Sensitivity study and contributing factors analysis
- Cost-efficiency analysis to select best solution
- Test and validation of new solution with EMT model

Objects of investigation

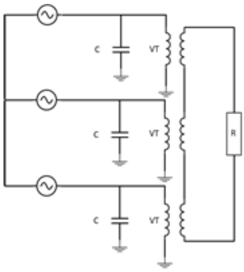
- Undesired trips at start-up
- Random behavior (sensibility to initial conditions)
- 2 pu of voltage amplitude, large 25 Hz component
- Most likely **ferroresonance**



On site measurements

Ferroresonance

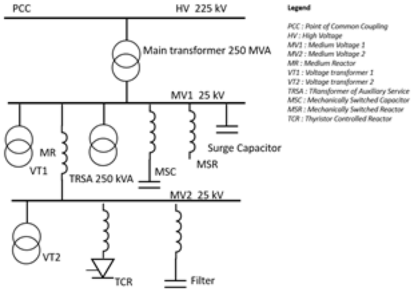
- Imply a resonating **non linear inductance**
- Several type of ferroresonance : fundamental harmonic, chaotic, **subharmonic**
- Appear often when switching on/off CB but is a permanent phenomenon (it can be damped however)
- Well known favorable grid configurations



*Configuration favorable for ferroresonance in **ungrounded MV grids***

SVC Configuration

- At start up no TCR, Filter, MSR or MSC energized
- 2 Bus Bar and one serial reactor



SVC configuration

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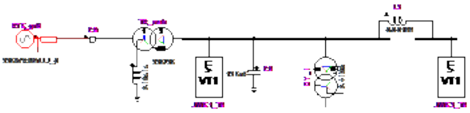
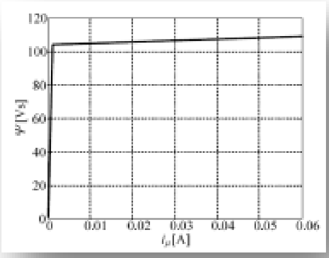
EMTP Model

- Simple grid model (Thevenin equivalent)
- Include saturation curve of all transformers
- Coupling of all transformers faithfully reproduced (broken delta for VTs)
- No saturation curve available for VTs - > Typical one chosen



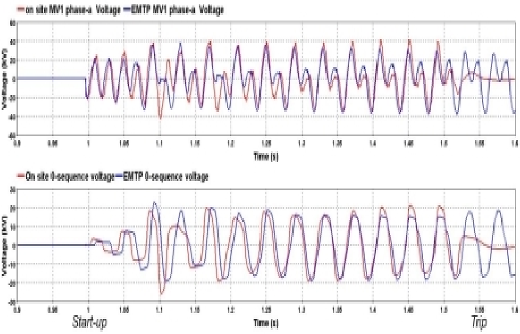
EMT model



Typical saturation curve for MV VTs

Results

- Phenomenon faithfully reproduced
- Random behavior, strong 25 Hz component
- Subharmonic ferroresonance between VTs and surge capacitor
- Main contributing factors are :
  - **Grid voltage amplitude**
  - **switching time** of main CB
  - **remanent flux of transformers** (main and VTs)



Comparison on site measurements and EMT simulation

Mitigating ferroresonance

- Numerous possible solutions such as :

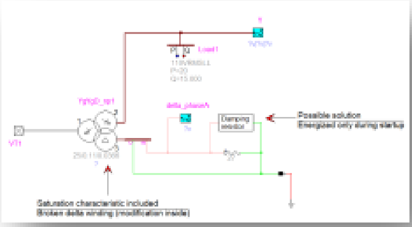
  -Add a damping resistance at start-up on VTs broken delta winding (classical)

  - Change Voltage transformer coupling

  - Change 125 nF surge capacitor value

  - Close MSR at start-up (provide load)

  - Change voltage transformer with better saturation curve
- Cost effective study -> Change of **surge capacitor value :** simple and does not need any control modifications



Classical mitigation solution

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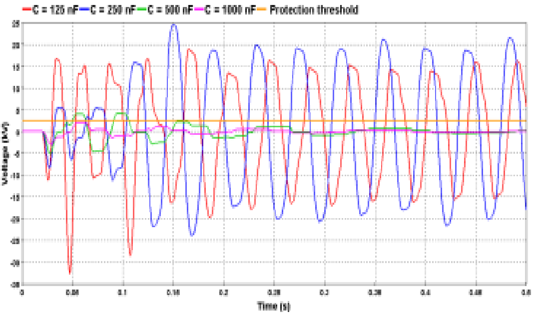
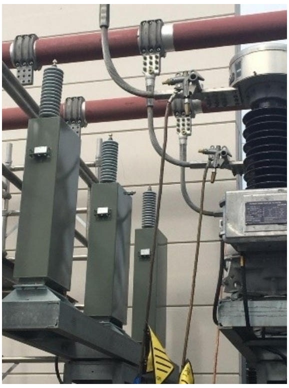
New surge capacitor design

- Ferroresonance phenomena is depending on the capacitor value
- **Parametric study** to cover all possible cases (several thousand based cases)
- **1000 nF** selected



0-sequence voltage



New implemented on site surge capacitor

References

[1] : K. Solak and W. Rebiant, "Modeling of Ferroresonance Phenomena in MV Networks," 2018 IEEE Electrical Power and Energy Conference (EPEC), 2018, pp. 1-6, doi: 10.1109/EPEC.2018.8598456

[2] : W. Piasecki, M. Florkowski, M. Fulczyk, P. Mahonen and W. Nowak, "Mitigating Ferroresonance in Voltage Transformers in Ungrounded MV Networks," in IEEE Transactions on Power Delivery, vol. 22, no. 4, pp. 2362-2369, Oct. 2007, doi: 10.1109/TPWRD.2007.905383.

[3]: CIGRE WG C4.307. (2014). Resonance and Ferroresonance in Power Networks. Electra - Cigré. 272. 81-85.

Conclusion

- **Subharmonic ferroresonance** caused by VT saturation is a well known and documented phenomenon **experienced in RTE SVCs**
- This phenomenon has **been reproduced and simulated in an EMT model** with the SVC parameters
- Different solutions tested and validated with the model
- Surge capacitor value changed from 125nF to 1000 nF to definitely avoid undesired trip at start-up linked to saturation of VTs
- For future works, it would be interesting to raise the question of the **impact of multiple VTs connections** on underground MV network as a major risk regarding ferroresonance.