Study Committee B5

Protection & Automation

Paper ID - 10374

Practical investigation of the operation of optical current transformers and electronic voltage transformers under transient conditions at 500 kV substation

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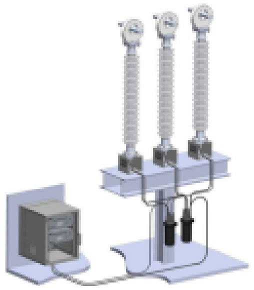
Motivation

- Application of optical sensors for non-conventional instrument transformers in EHV networks.
- Comparative analysis of measurements from conventional and non-conventional instrument transformers under transients.
- Increase of speed and sensitivity of existing relaying protection due to more "high-quality" measurements.
- Building up of new algorithms for relaying protection and automation in joint operation with non-conventional instrument transformers



Electromagnetic CTs **(EMCTs)**
Capacitive VTs **(CVTs)**

EVOLUTION

Electronic fiber optical current transformers **(EFOCTs)**
Electronic voltage transformers with capacitive dividers **(EVTCDs)**

FIELD TEST #1.

SINGLE LINE-TO-GROUND FAULT AT 500 KV OVERHEAD LINE

Test description and procedure

Prior to test, the 500 kV overhead line, connecting two electrical substations, stayed energized without load. Single line-to-ground fault was intentionally induced at the power line.

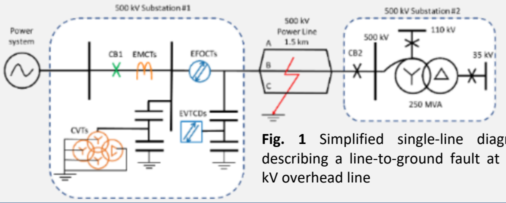


Fig. 1 Simplified single-line diagram describing a line-to-ground fault at 500 kV overhead line

Waveform and harmonic analysis of fault

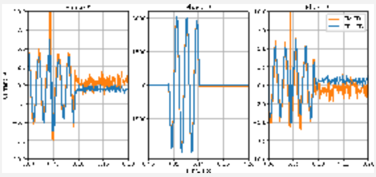


Fig. 2 Comparison of the short circuit current for three phases

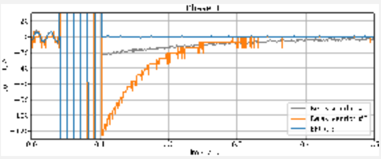


Fig. 3 Current in faulty Phase B

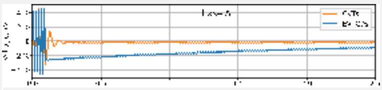


Fig. 4 Waveform analysis of voltage measurements from **EVTCD** and **CVTs**

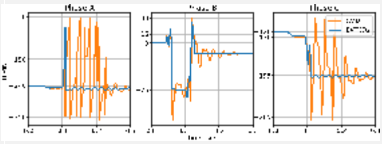


Fig. 5 Waveform analysis of phase angle from **EVTCDs** and **CVTs**

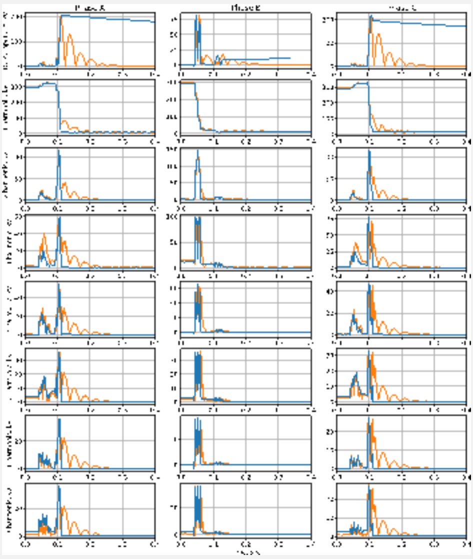


Fig. 6 RMS values of voltage from zero up to 7th harmonics for **CVTs** and **EVTCDs**

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FIELD TEST #2.

RE-ENERGIZATION OF A 250 MVA AUTOTRANSFORMER

Test description and procedure

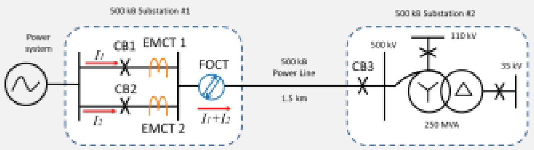

Fig. 7 Simplified single-line diagram describing a re-energization of a 250 MVA autotransformer

The inrush current analysis is based on **EMCTs'** and **EFOCTs'** measurements during re-energization procedure of the 500 kV auto-transformer (AT) installed in substation #2.

The main concern with the inrush current is that it misleads the power transformer protection by appearing as a differential current for the corresponding relays.

Waveform analysis of inrush current

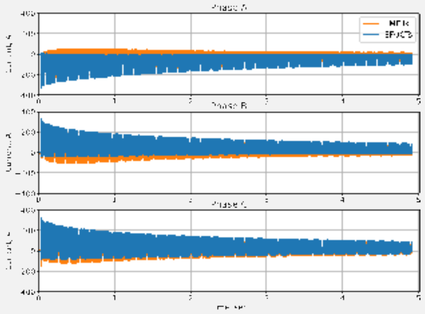

Fig. 8 The first 5 sec of the inrush current from **EMCTs** and **EFOCTs**.

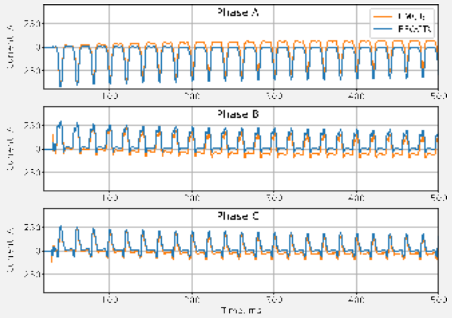

Fig. 9 Measurements of inrush current from **EMCTs** and **EFOCTs**.

Harmonic analysis of inrush current

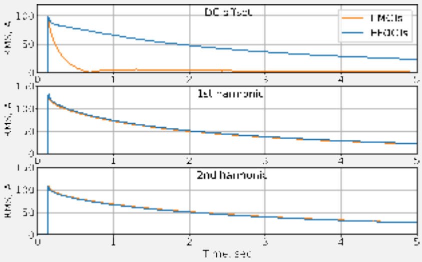

Fig.10 Difference in RMS values for DC, 1st and 2nd harmonics between **EMCTs** and **EFOCTs** in phase A.

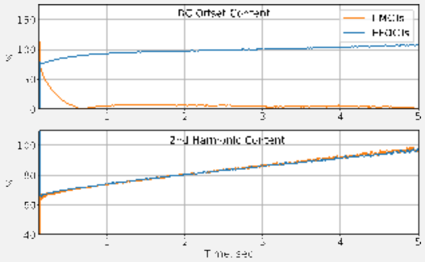

Fig.11 Difference in DC content and 2nd harmonic content relative to 1st harmonic between **EMCTs** and **EFOCTs** in phase A

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PROPOSAL AFTER TEST FILED ANALYSIS

DC blocking method

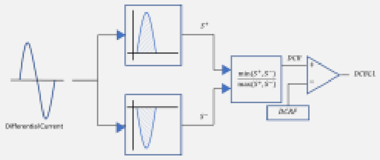

Fig. 12 DC blocking logic.

The DC blocking method's idea is to consider the areas under the positive (S+) and negative (S−) values of the current measurement curve over one cycle, i.e., for S+ and S-:

$$S^{+} = \left|\sum_{k=1}^{N} i_k\right| \rightarrow (i_k > 0) \quad (1)$$

$$S^{+} = 0 \rightarrow (i_k \leq 0) \quad (2)$$

$$S^{-} = \left|\sum_{k=1}^{N} i_k\right| \rightarrow (i_k < 0) \quad (3)$$

$$S^{-} = 0 \rightarrow (i_k \geq 0) \quad (4)$$

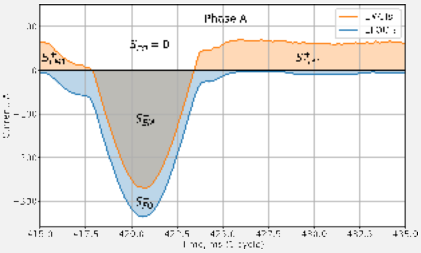

Fig. 13 The first 5 sec of the inrush current from EMCTs and EFOCTs.

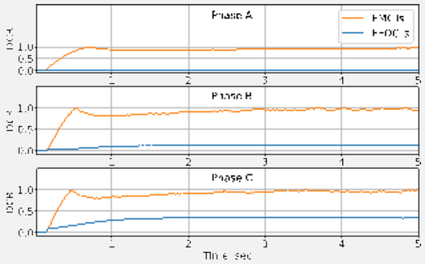

Fig. 14 Comparison of DCR_{EM} and DCR_{FO} during the inrush current.

Comparative analysis of DC blocking method and 2nd harmonic blocking method

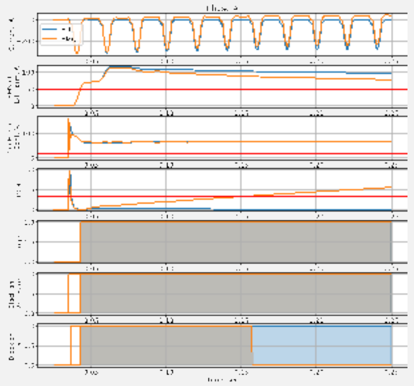

Fig. 15 Waveforms and discrete signals for the scenario with high content of the 2nd harmonic

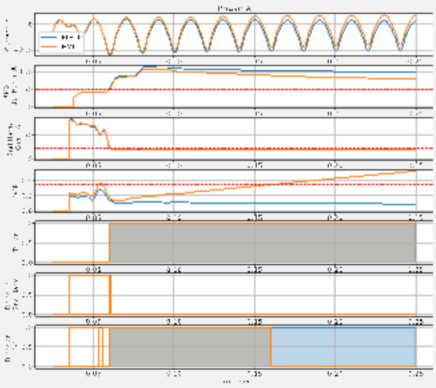

Fig. 16 Waveforms and discrete signals for the scenario with low content of the 2nd harmonic

CONCLUSIONS

- During pilot operation and field tests, non-conventional instruments transformers proved their applicability to be deployed in EHV networks.
- Non-conventional instrument transformers can provide a «high-quality» measurement, thus giving a ''true'' picture of transients with detailed information about electro-magnetic processes occurring in power systems.
- Usage of «high-quality» measurements from non-conventional instrument transformers opens up possibilities for refinement of existing relaying protections algorisms to increase their speed and security.
- As was shown by DC blocking method, deployment of non-conventional instrument transformers at power facilities makes conditions to modernize relaying protection by building more efficient and adaptable algorithms.