The importance of common mode currents in high-voltage substations

AUGUST 25 – 29, 1997
MONTRÉAL, QUÉBEC, CANADA

10th International Symposium on High Voltage Engineering
10e Symposium international d'ingénierie haute tension

The Importance of Common Mode Currents in High-Voltage Substations

P.C.T. van der Laan, A.P.J. van Deursen

High-Voltage and Electromagnetic Compatibility Group
Eindhoven University of Technology

Abstract

We measured in a substation the common mode (CM) currents through secondary cables at the entry of a kiosk or a control room. Parameters of interest are the waveshape, the maximum dI/dt, the amplitude and the frequency content. With these parameters and the known transfer impedance of the cables one can test the adequacy of EMC measures to protect the electronic equipment. In addition, the measured parameters can be compared with calculated CM currents in substation.

1. Introduction

The instrumentation and control cables in substations act as antennas for the disturbing fields produced by transients in the high-voltage system. The induced net current on such a cable is called the Common Mode (CM) current. We collected information on the CM-currents in substations by measuring these currents just before the cables enter a kiosk or a control room. The information required are data on amplitude, on frequency content, and in general on the waveshape of the CM-currents.

The major EMC threat to the electronics in a kiosk or control room is - as is being accepted by more and more authors - posed by the CM-currents on the cables. This means first of all that the cable shields upon entry into the sensitive area should be well connected to a metal entry panel so that the CM-current can be diverted before reaching the electronics.

The proposed measurements provide an direct check on the seriousness of the EMC threat. That information indicates how much effort should be spent on

a) the quality of the connections at the entry panel, or

b) the quality, in particular the transfer impedance of the cables.

In addition a measurement of the remaining CM-current behind the entry panel can demonstrate whether the CM-currents are efficiently diverted at the entry panel. Such a measurement also checks for possible mistakes made during the installation.

Once the CM-currents are known, relatively small pulsed power units can induce comparable CM-currents in the cables for testing purposes. These tests can be carried out in situ, repetitively and reproducibly, without any need for high voltage or for switching in the high-voltage system.

The proposed approach resembles the Bersier test [1], which is more and more used for pre-compliance testing of general electronic equipment. The elaborate RF emission and susceptibility tests in an expensive anechoic room, can in many cases be replaced by the much simpler Bersier test, where we measure or inject CM-currents in the cables connected to the electronic equipment, to do the testing for respectively emission or immunity. Also here the argument is that the most important antennas are the cables to the equipment; the cables are almost always more effective antennas than the electronic device itself. For large size installations - and substations are clearly in that category - the Bersier or a Bersier-like test offer the only practical EMC-test; RF-testing in anechoic rooms are impossible.

Does this mean that the disturbances entering via conduction are more serious than those entering via radiation? This question implies a contradiction which in fact is not present in the actual situation. The cables act as antennas for the disturbance fields and a current is built up in the antenna. Just before the entry panel - in antenna terminology we might say just above the ground plane - we measure the conduction current. At this location the disturbances, if not diverted, would come in by conduction.

The cabling in a substation is very complex qua geometry, number of cables, in bundles and complicated paths. Calculations are therefore difficult, but in the future theoretically predicted (see e.g. [2]) CM-currents could be a valuable addition to or a check on the measured data.

2. Hengelo 380 kV open air substation

In an earlier study [3,4] for SEP - the Dutch Electricity Generation Board - we recommended to construct the kiosks in the field as EMC cabinets. All cables enter a kiosk through a single metal wall, in Hengelo the bottom. A single large entry plate connects the shield or armor of all cables over 360 degrees to the bottom wall. The entry plate is split up in 7 × 6 feedthroughs, which accepted a group of up to five cables. The entry plate is connected to the grounding grid of the substation under the kiosk. Inside the kiosk the cable shields are again grounded to the equipment racks.

The junction box at each part of HV equipment in the field is also carried out as EMC cabinet. Glands connect the cable shields or armor there. No special EMC provisions were made between HV equipment and kiosks; the cable were buried in sand. Between the kiosks and the control building the cables were laid in a concrete conduit.

The CM currents through the cables at a kiosk are measured either at the action of a pantograph disconnector switch or, more frequently, at the discharge of a HV capacitor. A 1:2 transformer connected the capacitor source to the HV grid near the kiosk. Both sources produced similar CM currents in the cables; the capacitor discharge resulted in a more reproducible current. As an example, Fig. 1 shows the CM current through a single cable, measured during pantograph action at the outside and the inside of the kiosk.

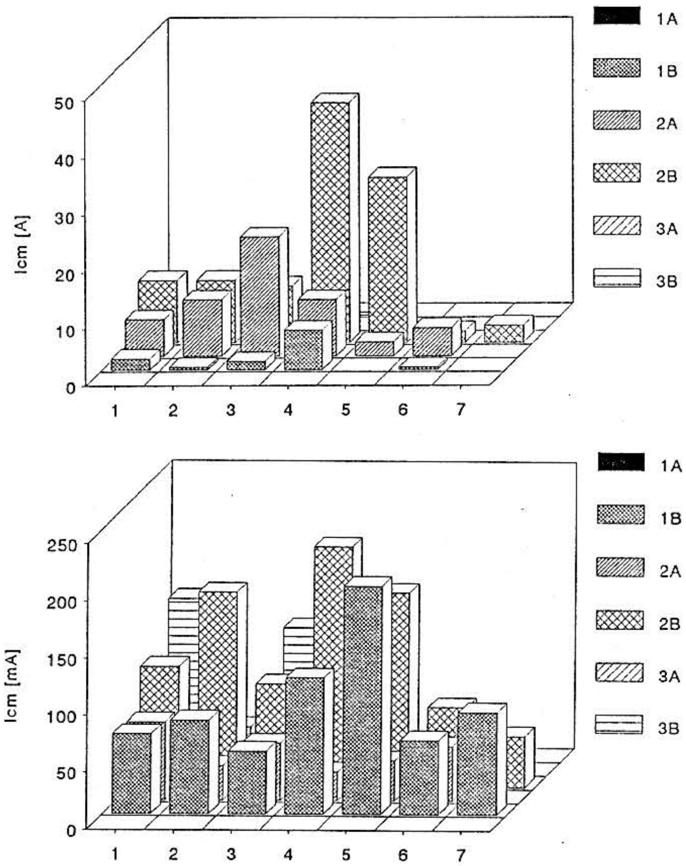

Fig. 2. The amplitude of the sum of the CM current through groups of cable at the outside (upper part) and inside (lower part) of the kiosk. Note the difference in scale of the ordinate.

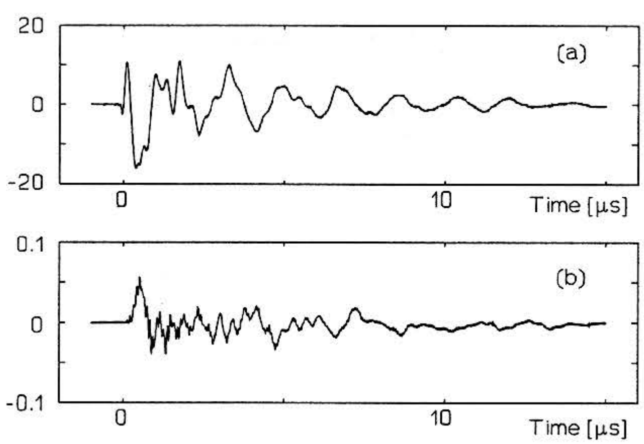

Fig. 1. Common mode current in ampere through a cable during actions of a disconnector switch in the Hengelo 380 kV substation, (a) outside the kiosk, (b) inside the kiosk.

We tested the quality of the cable connection at the entry plate. In Fig. 2 we compare the total CM current amplitude for each cable group outside and inside the kiosk. The ratio of the amplitudes is a factor 200 or larger. A more detailed analysis showed no correlation between the waveshape and amplitude measured outside and inside the kiosk. We expected a better quality of the entry plate than indicated by the measurements. A coupling path for interference around the bottom was indeed found.

The contribution by the cabling itself to the interference voltage at the inputs of the electronic equipment, can be calculated from the transfer impedance Z_t of the cables which was measured separately. The cables between the HV equipment and the kiosks as well as the cable mounting inside the kiosk contributed certainly less than 100 V. As the final major source for interference we identified the mounting of the signal cables in the HV equipment.

3. Meeden 380 kV GIS substation

The HV equipment and cabling was installed by the manufacturer. All cables had a shield of corrugated copper foil; high quality connectors provided a good contact between shields and equipment racks in the control room. Different metal walls of a rack served different cable bundles; we would have preferred a single panel for all bundles together.

The measurements were performed during the final check of the installation. In Fig. 3 we present the CM current through a cable of a current transformer during the action of a disconnector switch. We also measured the interference voltages inside the rack at the end of the cable. The values obtained were lower than the contracted limits.

4. Geertruidenberg 380 kV open air substation

Earlier we measured the CM currents in the Geertruidenberg substation [4,5], which was built in 1969. In Fig. 4 we show the CM current through a cable of a disconnector switch measured outside the kiosk. The armor or shields of the cables were grounded inside the kiosk to a grounding rail, as was practice at that time. The CM interference voltage at the inputs of the equipment was mainly due to this grounding procedure, and was about an order of magnitude larger than found in Sect. 2.

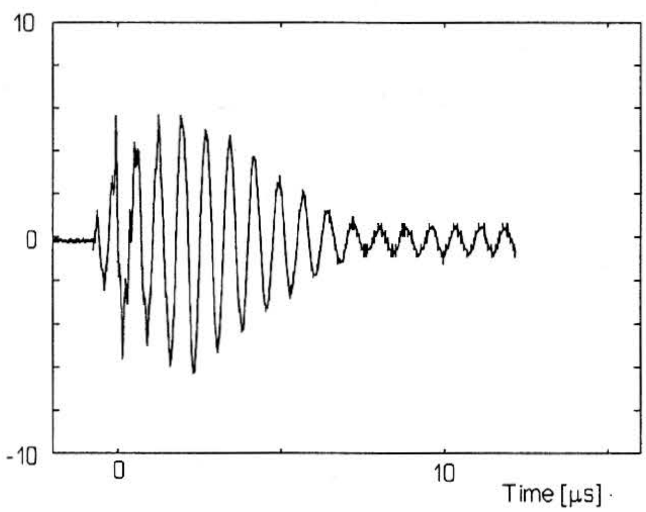

Fig. 3. The CM current (in ampere) through the cable of a current transformer during the action of a diconnector switch in the Meeden substation.

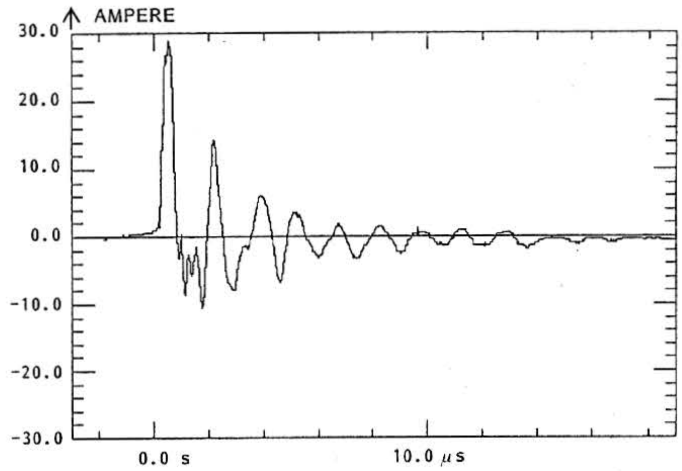

Fig. 4. The CM current through the cable of a disconnector switch in the Geertruidenberg 380 kV substation.

5. Conclusions

The CM currents through cables can be measured at the cable entry in a kiosk or a control building, or a junction box. A comparison of the measurements and EM field calculations would be possible in principle, if the cable paths are known.

The CM interference voltage at the terminals of the control equipment is determined by 1) the CM currents, 2) the transfer impedance Z_t of the cable, and 3) the impedances at the input and output of the equipment connected to the cable. Important is also 4) the finishing of the cable connections at both ends, or more specifically the local Z_t between kiosk entry and the equipment terminals.

The interference due to power frequency short circuit currents, due to actions of circuits breakers or disconnect switches, or due to lightning can be treated is very much the same way.

When CM currents and Z_t's are known, the quality of a cable, of the connector and of the cable mounting can be adapted to the requirements set by the equipment specifications. It is however questionable whether EMC quality should be relaxed since more and more normal 'consumer electronics' is being used in or near substations.

6. Acknowledgement

The measurements at Hengelo and Meeden were performed under contract of the Dutch Electricity Generation Board (SEP). We thank ir. M.H.P. Dagelickx (Demad, Eindhoven, the Netherlands), ir. R.P.J.M. Vandenboorn, ing. P. Bruins, ing. P.F.M. Gulickx and ing. R.G. Noij for their assistance in the measurements and the evaluation. The cooperation of the SEP at Geertruidenberg is gratefully acknowledged.

7. References

[1] R. Bersier and B. Szentkuti, 'Rational and new experimental evidence for the adequacy of conducted instead of radiated susceptibility tests', Proc. Int. Symposium on EMC, Zürich 1985, p. 257.

[2] D. Tabara, M. Ianoz, B. Krummen, 'Calcul du Rayonnement de l'Enveloppe lors de Manoeuvres dans un Poste sous Enveloppe Metallique', Actes du Colloque CEM, Lille 1996, p. 15.

[3] F. Schoren, A. van Deursen, P. van der Laan, 'Eindrapport Sep-contract' (in Dutch), group EHC, Eindhoven University of Technology 1990.

[4] A.P.J. van Deursen, P.C.T. van der Laan, 'Interference Currents in 380 and 150 kV Substations', Proc. 6th Int. Symposium on EMC, Zürich 1991, p.673.

[5] P.C.T. van der Laan, A.P.J. van Deursen,' Protection of Electronics in High Power installations; Theory, Guidelines and Demonstrations', Rapports/Papers Cigré Symp. Lausanne, 18-20 Oct. 1993, paper 600-08.

Address of first author: Prof. P.C.T. van der Laan, group EHC, Department of Electrical Engineering, Eindhoven University of Technology, POB 513, NL 5600 Eindhoven, The Netherlands