How to test the influence of 25kVac traction supply systems on existing 1500VDC railway infrastructures?

NAME : Van Waes
COUNTRY : The Netherlands
REGISTRATION NUMBER :

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Q3.1 *With the increasing use of sensitive electronic equipment in protection and control circuits, what is the experience of power utilities on the EMC aspects of transient EMI produced by disconnect switching operations in Air Insulated Substations (AIS) and secondary circuits?*

Electronic equipment is usually sensitive to interference over a wide range of frequencies, also at low amplitudes. The (transient) overvoltages are determined by the source, the coupling mechanisms and path, and the layout of the sink. Not only transient voltages, but also the 50Hz interference on secondary circuits is in practice difficult to predict. This contribution illustrates some of the backgrounds, and the practical choices to be made in the analysis.

In general one starts with indicative simulations. Most calculations use a two-dimensional model to calculate the current distribution and the interference voltages. The network is divided in independent sections. Lumped circuit elements represent the mutual coupling between the various conductors. These frequency dependent circuit-elements are often based on the Carson-equations. In regions where the E-field has a radial component (e.g. near a substation), the 2D models may be insufficient to solve the 3D Maxwell equations. More complicated calculations might be necessary. However one often chooses a 2D approach to obtain an indication of the current distribution [IEEE02].

A correct prediction of interference voltages is not only dependent of a correct mathematical algorithm, but also by the reliability of the input parameters. One needs to have an exact overview of the as-built situation:

- The surrounding network has great influence on the effect of interference. Any (often unknown) metal structure/cable in the soil near the substations will influence the current distribution;
- Installation details such as the mounting of cables, can have significant influence on the disturbance voltages;
- For structures with steel elements, material parameters as the magnetic permeability may play an important role for higher frequencies.

Regarding EMC-studies, the approach for railway systems is comparable to ones used for transmission and distribution grids [Cigre00]. The considerable length of circuits in railway systems is an important difference compared to local systems in substations. As illustration, an approach will be presented related to the EMI of two different traction power supply systems.

In the Netherlands two new major railway lines are currently under construction, HSL-Zuid and Betuweroute. These new lines will be electrified with 2x25kV$_{AC}$. Both AC lines are projected in close proximity of existing 1500V$_{DC}$ lines, which have a different grounding philosophy: the existing infrastructure is floating; the 25kV$_{AC}$ system is solidly grounded.

1500 V$_{d.c.}$ 2 x 25 kV$_{a.c.}$

Figure 1a: *1500V$_{d.c.}$ track next 2x25kV$_{a.c.}$ track*

A research project was initiated by the Dutch railway infraprovider ProRail, to study the interference of the 25kV systems on its existing infrastructure. Studies on safety and the possible interference of signaling and telecommunication systems were carried out to guarantee:

1) Personal Safety (Step- and touch voltages on tracks, touch voltages on cables, …);
2) Safe operation of safety related train detection systems[1];
3) No negative influence with respect to availabilty (standstill).

[1] These circuits have 75Hz as operating frequency.

Various failure modes in the $1500V_{DC}$ as well as in the $25kV_{AC}$ system and both normal operation as well as short circuits needed to be considered. A 2D model was chosen to calculate the interferences, also for yards. As modifications in the existing railway infrastructure are expensive, a minimum set of circuits to be modified was determined by the simulations.

Uncertainties in both input parameters as well as in the mathematical approach, are comparable to those in power systems. For some of the considered systems, the calculated safety margin was very small. During the final phase of the project, measurements were therefore carried out to verify the effects of the proposed measures.

An efficient test program was required, given the limited amount of time available to prepare and to perform the tests. Both test methods and measurement techniques played an important role. Several test methods were considered, of which three were used:

1. Tests with generators (Figure 2a): A 48Hz current simulates the load current of a train in the 25kV system. The influence is measured. A large number of configurations and the 50Hz effects failure modes can be tested in a short period of time, to verify the 50Hz model [CIR03];
2. Short-circuit tests (2b): These types of tests give insight in non-linear phenomena (e.g. effects on overvoltage protection, insulation defects);
3. Tests with rolling stock (2c): This relatively inefficient method was used to test all aspects, which couldn't be tested with the other 2 methods (Traction harmonics, etc...).

Method 2 and 3 include effects of the EMI produced during switching operations.

Figure 2a: *Generator setup*

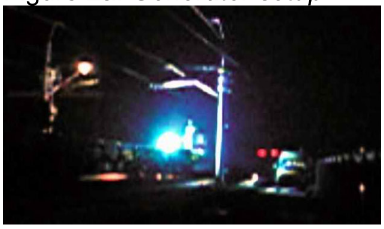

Figure 2b: *Short-circuit tests*

Figure 2c: *Rolling stock*

Concluding remarks based on a first impression of the measurement results:

- Most deviations between simulations and measurements, were caused by deviations in the input parameters;
- The combination of a 2D model and selective measurements resulted in an optimal set of mitigating measures. The modifications are already implemented for most locations;
- No negative influence was reported in the secondary circuits during switching operations;
- The project resulted in a new standard, which includes practical guidelines to avoid negative influence of the 25 kV_{AC}-system on the existing ProRail infrastructure.

ProRail would like to thank HSL-Zuid, Betuweroute and all the subcontractors for their cooperation.

[Cigre00] Interference between three-phase and traction power supply overhead lines, H. Vennegeerts, H.-J. Haubrich, A. Kox, J, Schaarsmidt, Cigre session 2000, paper 36-107.

[IEEE02] J.B.M. van Waes, A.P.J van Deursen, M.J.M. van Riet, F. Provoost, "Safety aspects of GSM systems On High Voltage Towers: An Experimental analysis", *IEEE Transactions on Power Delivery*, Vol. 17, No. 2, April 2002, pp. 550-554.

[CIR03] J.B.M. van Waes, F. Provoost, M.J.M. van Riet, A.P.J. van Deursen, "Measurement of the current distribution near a substation during a single phase to ground fault", *17th International Conference on Electricity Distribution*, CIRED Barcelona, 12-15 May 2003.