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Assessment of VLD-F effectiveness on reducing rail potential in AC railways through modelling

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Abstract

In order to reduce rail potential on default conditions, Voltage Limiting Devices can be used to implement additional earthing point which would temporarily ground the rail when high rail potential appears. In this work, we use modelling to assert their efficiency, optimize their positioning and verify their ability to support default current.

Keywords: rail potential, voltage limiting devices, earthing, electromagnetic compatibility.

1 Introduction

In A.C railway lines, rail potential cannot exceed 645 V over 200 milliseconds in default state according to the limits allowed by the European Standard EN 50122-1 [1]. Increase of the power of substations, as well as the distance between two substations, has caused rail potential to exceed this limit in several lines. It is especially a problem in 2x25 kV – 50 Hz railway lines, in the sector between the sub-station and the closest autotransformers.

The best solution to reduce rail potential is to ground return rails regularly but technical constraints due to train detection systems such as track circuits forbid us to do so as much as necessary. Thus, it is necessary to find new, innovative, solutions to reduce rail potential in A.C railway lines. Several solutions are being investigated such as improving return circuit or limiting short-circuit current.

It also has been proposed to use Voltage Limiting Devices (VLD-F) in order to have temporary rail connection to the earth when a default occurs. These devices, connected between rails and earth conductor, will remain open when the voltage they are exposed to is inferior to their trigger potential. Electrical circuit will close when voltage exceeds this trigger value (here 300 V). Such VLD-F should be able to return to open condition when the default has disappeared. Being effective only when a default occurs, it would not affect track circuit proper functioning and thus circulation safety will still be guaranteed. To not perturb track circuit, their connection to rails must be done through a midpoint transformer. In this case, we implement one VLD-F for each track, which are not connected between them.

In this work, we used modelling of a real situation, in East European High Speed Line (*LGV EE*), with our in-house software Modalf, to validate VLD-F implementation. In particular, we were able:

- To confirm efficiency of VLD-F to reduce rail potential,
- To optimize VLD-F positioning,
- To validate electrical design and ability to withstand short-circuit current

2 Methods

In this paper, the rail potential and currents will be evaluated by simulation using our in-house software Modalf. This calculation tool is developed on transmission line theory principle and is based on Carson's theory [2] [3]. The Fixed Installations of Electric Traction (IFTE) are discretized in cells, thanks to Kaibuchi's algorithm method [4], in order to determine the voltage and current at each point of these elementary cells. All the particular points of the IFTE are taken into account in a given cell. Linear parameters such as the impedance and admittance of the linked conductors within the network are determined using the Carson's theory and complex image method respectively. The calculation of the voltage and the current in all the conductors using a matrix-based method gives access to the emitted current.
The railway electrical and geometrical characteristics are necessary for calculation. On one hand, in this aim the longitudinal scheme linearizes the railway system and its components and indicates their position (feeding point, grounding, paralleling point…). On the other hand, the transversal railway track characteristics are represented. The specifications of each conductor are recorded and extracted from a constantly upgraded database.

For this study, we modelled the LGV EE from km 320 to km 370, using known parameters and electrical measurements to get accurate results.
Our method consisted first in calculating rail potential in each point to identify areas where rail potential was superior to 645 V (exceeding areas). In these areas, it was necessary to implement VLD-F.
Based on these positions, we calculated coverage area for each VLD-F. To do so, we calculated tension between transformer's mid-point and earth conductor (Figure 1):

Figure 1 : Determination of VLD-F potential

When this potential exceeded VLD-F trigger value, it means VLD-F will close. We were then able to determine all short-circuits positions for which VLD-F would be active (coverage area).
The coverage area has to match the exceeding area determined earlier, to effectively reduce rail potential when necessary.
Once we determined the coverage area, we could simulate once again rail potential with each VLD-F being activated when there is a short-circuit in its respective coverage area. This calculation allowed to determine, by iterations, rail potential for each situation all along railway line.
Ultimately, we could calculate current going through all active VLD-F in default conditions to verify compliance with VLD-F technical specifications.

3 Results

First, we calculated rail potential in default conditions from km 340 to km 370 (Figure 2). In this case, the default is a short-circuit between catenary and both rails on track 1. Results are similar on track 2.

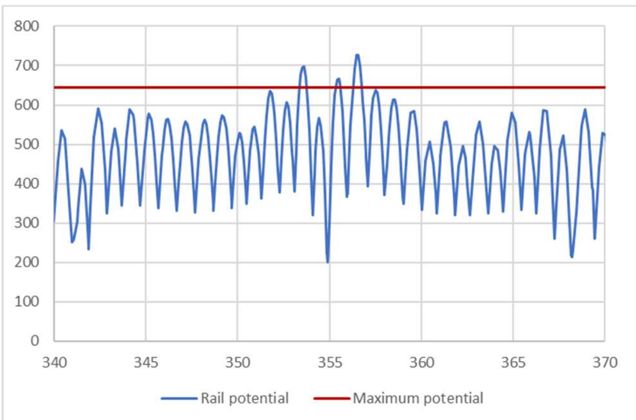

Figure 2 : Rail Potential on short-circuit conditions

We identified 3 areas where rail potential exceeds 645 V called exceeding areas, as shown on Table 1.

Table 1: Exceeding areas

Exceeding areas	Maximum rail potential Track 1	Maximum rail potential Track 2
From km 353+443 to km 353+709	698 V	696 V
From km 355+394 to km 355+550	668 V	665 V
From km 356+350 to km 356+761	727 V	728 V

It was proposed to implement one VLD-F by track on each exceeding area. The positioning was decided by SNCF signalling department based on existing installations (see Table 2).

Table 2: VLD-F implementations

VLD-F	KM
VLD-F 1 / 2	353+243
VLD-F 3 / 4	355+746
VLD-F 5 / 6	356+461

Given these positions, we determined coverage areas for each VLD-F calculating potential at the terminals of each VLD-F for each possible position of short-circuit. In figure 3, we can compare positions of exceeding areas calculated previously in red and coverage areas for each VLD-F in green.

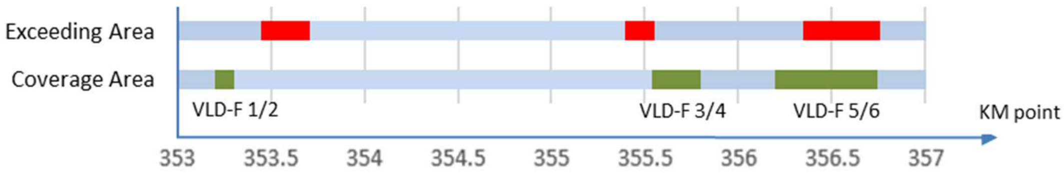

Figure 3 : Comparison between exceeding areas and coverage areas

This comparison showed us that, if implemented at these positions, VLD-F 1/2 and 3/4 would not operate when short-circuits appear in most dangerous zones. We then had to optimize their positioning.
To do so, we re-calculate potential at the terminals of VLD-F 1/2 and 3/4 for new possible positions. Figure 4 and Figure 5 show tension between midpoint transformer and earth conductor at various kilometric points (possible implementations for VLD-F 1/2 and 3/4) for all short-circuit positions.

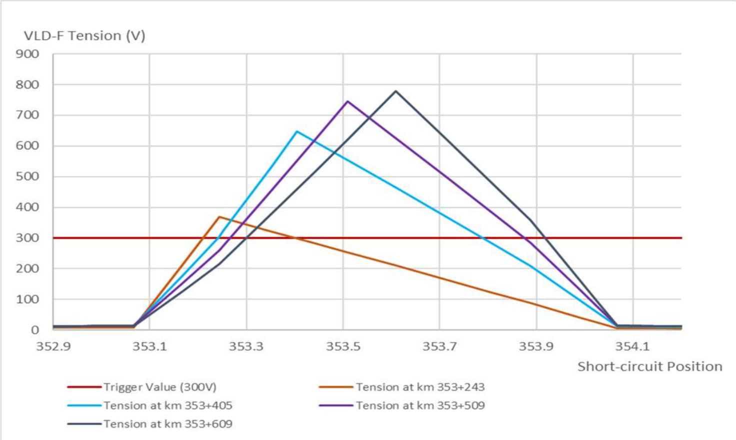

Figure 4 : VLD-F 3/4 Tension for possible positions

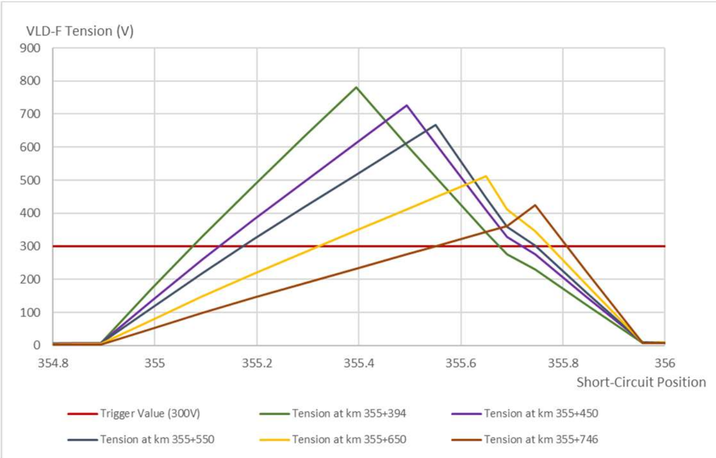

Figure 5: VLD-F 3/4 Tension for possible positions

We effectively observe on these graphs that previous VLD-F positions have a very narrow coverage area (area over red line). These calculations allowed us to propose new positioning which had been validated by signalling department (see table Table 3).

Table 3 : Optimization of VLD-F implementation

VLD-F	Previous position (KM)	Optimized position (KM)
VLD-F 1 / 2	353+243	353+405
VLD-F 3 / 4	355+746	355+550

Next step was to calculate rail potential for all short-circuit positions, with VLD-F active when short-circuit occurs in their coverage area.

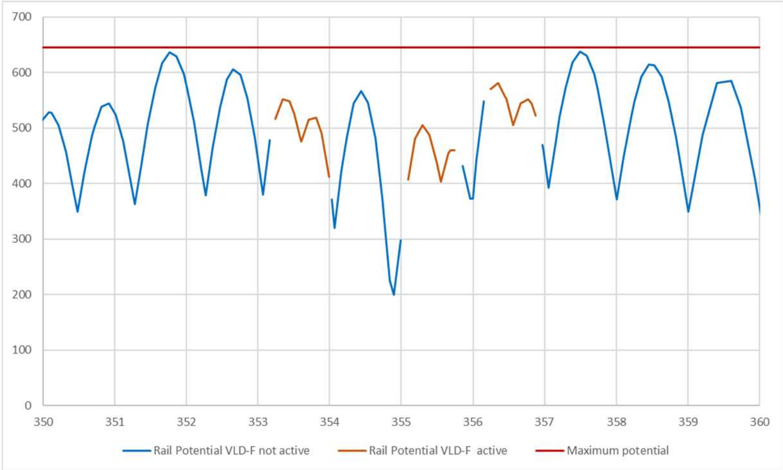

Figure 6 : Rail Potential on short-circuit conditions with VLD-F

In Figure 6, blue curve represents rail potential when VLD-F are not active and the orange one rail potential when active.
We can conclude that VLD-F are efficient and permit respect of normative limits.

Last point was to calculate short-circuit current passing through VLD-F when active. Results are shown on Figure 7.

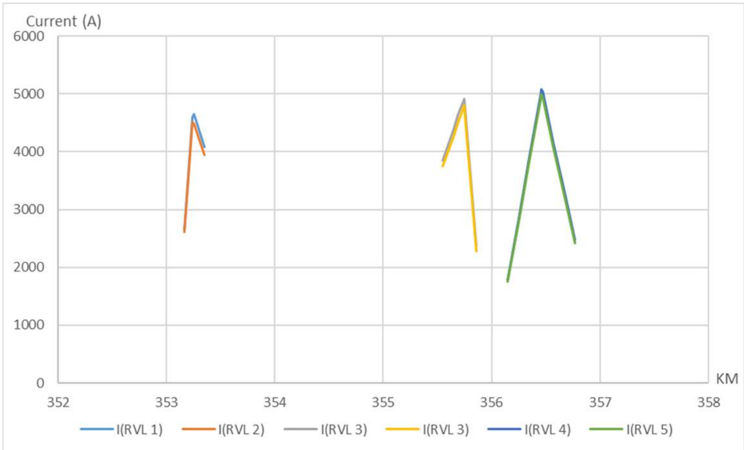

Figure 7 : Current going through VLD-F in default conditions

Table 4 : Maximum intensity through VLD-F in default conditions

	I_{VLD-F} (A)
VLD-F 1	4647
VLD-F 2	4514
VLD-F 3	4914
VLD-F 4	4800
VLD-F 5	5086
VLD-F 6	5004

Calculated values comply with VLD-F specifications (see Table 4).

4 Conclusions and Contributions

This study allowed us to validate a new way to efficiently reduce short-circuit rail potential in AC Lines, using Voltage Limiting Devices (VLD-F) as temporary earthing solutions in case of default, as this solution does not affect the good functioning of signaling installations, in particular the track circuits.

This validation could be made using only modelling, thanks to our in-house software Modalf. We were able to calculate coverage area of VLD-F, and thus, to verify their ability to effectively reduce rail potential. Study showed first VLD-F implantation was not adequate, but we could calculate coverage area for all possible VLD-F positions and find the best implementation.

We were also able to ascertain VLD-F's ability to support short-circuit current by calculating current repartition in all conductors and current going through the VLD-F. This was necessary to validate the product.

Thanks to this study, VLD-F can be implemented on LGV EE, and this solution can now be considered on other lines in which rail potential values exceed normative limits.

In case it is decided to use VLD-F on other lines, this validation method through modelling can be extrapolated to verifiy that they comply with rail potential requirements and to determine an optimized implementation for all VLD-F.

References

[1] Railway applications – Fixed installation – Electrical safety, earthing and the return circuit –Part 1: Protective provisions against electric shock. *European Standard EN 50122-1. August 2011.*

[2] J.R. Carson. Wave propagation in overhead wires with ground return. Bell Systems Technical Journal, 5, 1926.

[3] G. Pingeon. Etude de la réponse des lignes par la méthode multiconducteur. SNCF engineering tools for EMC design.

[4] S. Kaibuchi, H. Lorke, P.Persson, S. Takashima. Activities of CCITT study group v in the field of telecommunication-line interference. IEEE transactions on electromagnetic compatibility, 25, 1983.