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Fault diagnostics in a traction circuit by means of the stray current analysis

Abstract. *This paper deals with the forming of stray currents in industrial spurs, stabling tracks and special purpose tracks near DC-electrified tracks. It describes methods which can be used to identify failures that lead to the occurrence of stray currents. Some innovative measuring methods are also introduced, all of them are based on results and knowledge obtained by practical experiments. The data and measurement results used in this paper come from measurements performed in the Bohumín railway station depot. It was found out that at this railway station, traction current leaked into the lightning control system. The method that was used in tracing these parasitic current paths, as well as the failures which led to the occurrence of these currents, are described in this paper.*

Streszczenie. *W artykule analizowano prądy rozproszone w bocznicach przemysłowych i torach w pobliżu trakcji DC. Pozwala to na wykrywanie uszkodzeń prowadzących do wzrostu tych prądów.* ***Diagnostyka uszkodzeń w obwodach trakcyjnych DC metodą analizy prądów rozproszonych***

Keywords: stray current, ground current, electro-chemical corrosion.
Słowa kluczowe: prądy rozproszont, prdy doziemne, analiza uszkodzeń, trakcja DC

Introduction

Each traction circuit consists of a traction substation, supply lines (trolleys) and return lines, closing the current path from consumption back to the traction substation. In the Czech Republic, return lines in railways are always rails. Due to non-zero rail resistivity, their conductivity with respect to the ground, and also as a result of failures, reverse currents are re-distributed, so that they flow both through the rails and through the ground, in the form of stray currents. While in AC traction, the main problems are related to the supply network [1, 2], in DC traction, the most significant problems are caused by stray currents.

DC stray currents are undesirable, especially because when they flow through metal devices buried in the ground, it may cause electro-chemical corrosion. It is practically impossible to totally eliminate the possibility of the formation of stray currents. However, these currents can be effectively reduced. This can be achieved in two ways. The first method is based on increasing the quality of the reverse current path, especially by decreasing contact resistance when connecting rails, or rails resistance in general. The main limiting factor is rail resistivity, as a result of which voltage drops within tens of volts or more occur, even though significant effort has been made to increase the quality of the reverse current path.

Another common way of preventing the formation of stray currents is electrical insulating of rails from sleepers or generally from the soil. Insulation pads are used in places where rails get into contact with sleepers.

In failure-free operation, the above described measures are absolutely sufficient. If an failure occurs and rail insulation fails, reverse current is redistributed and flows both through the railway track and through the ground, in the form of stray current. Our goal here is to describe the process of identifying places where these failures occur.

Failure description

Just like any other type of failures, failures in the traction circuit are undesirable. Reverse path failures, which occur when insulation fails, are specific in the way they manifest themselves. Very often, these failures are not immediately obvious. The traction circuit is usually still functional, but these failures have a long-term negative effect on the area where they occur. Sometimes the effects are not perceivable in the place where the failure occurs, but they may be detected within long distances and seemingly having no relation whatsoever to the failure.

Direct connection of the reverse path with the ground:

In this case, currents flowing through rails leak into the ground, where they become stray currents.

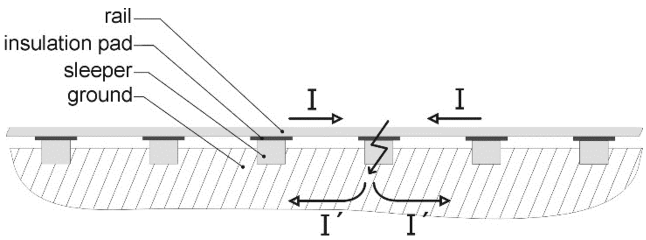

Fig. 1 Formation of stray currents due to faulty insulation.

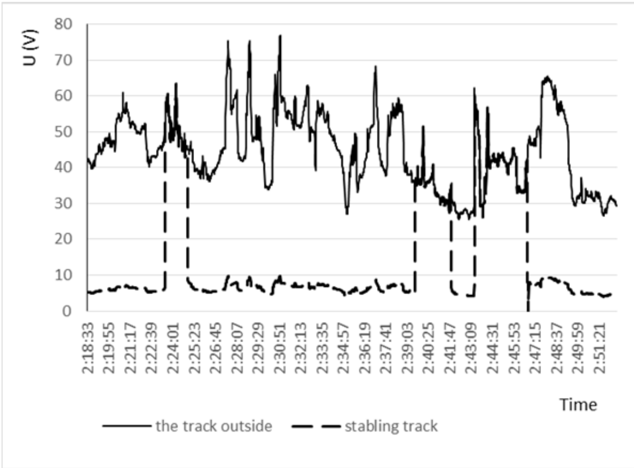

Fig. 2 Example of locomotive passing and short-term conductive connection of an insulated stabling track and an electrified rail. This case was investigated in Bohumín. This graph shows the potential of the measured rail with regard to a distant ground, in relation to time.

The formation of a current path between a rail and the ground does not need to be due to disrupted insulation only. Sometimes parts of the rail may become buried in the ground, to dirt can cumulate around them. Such partly buried or dirty segments can often be found on stabling tracks or non-electrified tracks and industrial spurs. When a locomotive moves over the insulated place of contact between electrified and non-electrified railway or spur, a conductive connection is formed and stray currents appear even in places within a significant distance from electrified tracks.

Connection of the reverse path with surrounding steel structures:

Another failure which may be observed on a reverse traction path is a conductive connection of a rail and a conductive structure located nearby. This type of failures may often be found in halls or depots. They may lead to the current path being closed by the ground and the formation of stray currents, or unwanted currents may get into the PE conductor in the network or into lightning protection systems.

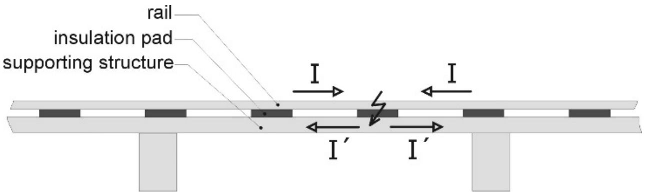

Fig. 2 Current leaking into a steel supporting structure due to a faulty insulation pad

This type of failure (reverse current leaking into a lightning control system) occurred in the technical and hygienic maintenance hall of the Bohumín railway station. Due to damaged insulation pads, a conductive connection was created between rails and their steel supporting structure. As a result, a parasitic current path was formed and current was conducted from the outside track to rails in the hall, the structure of the hall, the lightning protection system and then into the ground. Fig. 4 shows measurement results at a specific time.

Fig. 4 describes situation in the technical and hygienic maintenance hall at the Bohumín railway station. A parasitic current path was formed, leading from the tracks outside across the hall and the lightning control system into the ground. Measurement results are shown for a specific time. Tracks inside and outside the hall are interconnected with insulation parts, and they are fixed with a copper cable. Track 2 was in use when the measurement was performed.

This situation did not have any influence on the functioning of the traction circuit. The problem was only found out when overheating of lightning arresters in the lightning control system was observed.

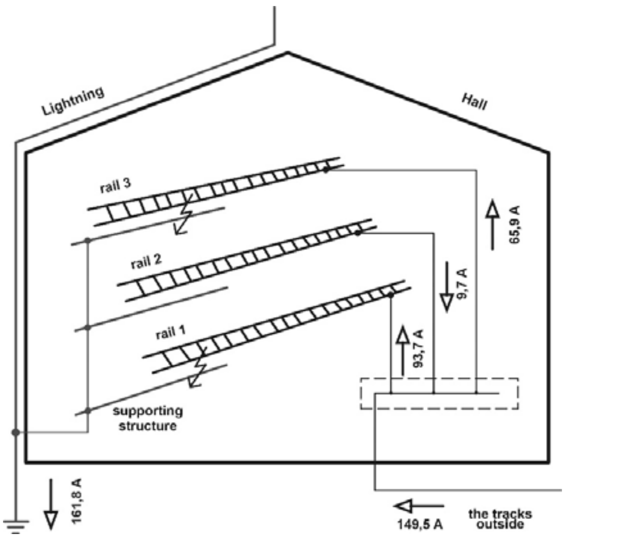

Fig. 4 Situation in the technical and hygienic maintenance hall at the Bohumín railway station

Suggested measurements

To be able to fix damaged insulation pads and interrupt parasitic current paths, it is important to identify them first. The suggested measurement method is based on evaluating current which is flowing through the rail, between the individual insulation pads. The diagram illustrating this measurement is shown in Fig. 5.

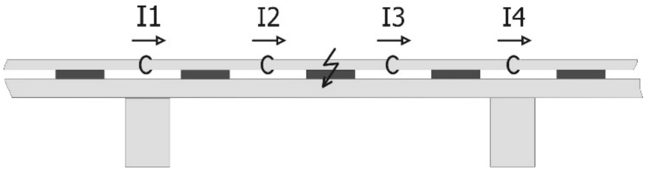

Fig. 5 Measuring of insulation pads with the use of the current comparison method

The leaking current is localised by comparing current flowing through the rail before and after the insulation pad. If:

(1) $$I1 = I2$$

- no parasitic current is flowing through the pad, which means that the pad is working properly

(2) $$I2 \neq I3$$

- parasitic current is flowing through the insulation pad, i.e. the pad is faulty

During normal operation, current flowing through rails is not constant. For this reason, it is necessary to perform both measurements, i.e. before and after the insulation pad, synchronously, or it is also possible to insulate a segment and use a separate power source.

The above described measurement method can be used to find faulty pads as well as to learn more about the extent of the damage and about the size of the leaking current. It can also be used in the assessment of the quality of larger rail units and to learn about the size of leaking current in larger areas.

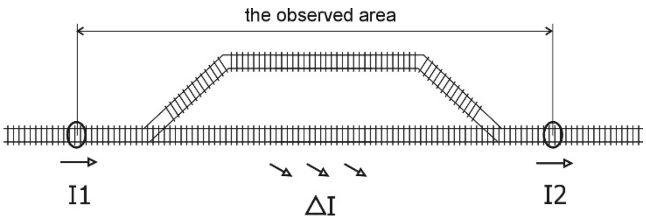

Fig. 6 More possibilities of the use of the suggested solution

The measurement:

In practical measurements, this method proved rather inefficient. The estimated number of insulation pads on one track at the technical hygienic hall in Bohumín was around 1,500. Investigating each and every pad would significantly prolong measurement time. Another problem is that common measuring equipment requires the inclosing of the whole measured object.

For this reason, a method was designed and implemented to measure current with the use of a modified instrument transformer [3]. The transformer is shown in Fig. 7.

For the actual measurement, individual rails were insulated from the rest of the track and powered from a separate AC power source. As a result of the passing of AC current through the rail, voltage is induced in the coil of the instrument transformer, which is measured and then converted to current values, according to a calibration table which has been prepared in advance.

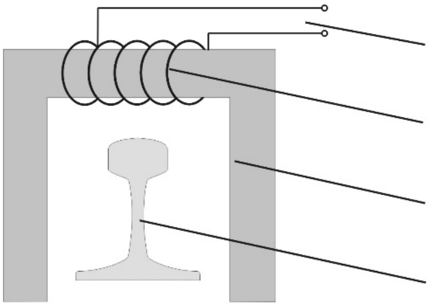

Fig. 7 Schematic diagram of the instrument transformer

Practical measurement describes Fig. 8. Current values are taken with the use of a measuring transformer moving along the track.

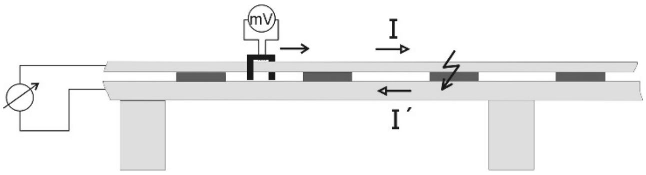

Fig. 8 Practical measurement

This method proved very efficient, especially in terms of measurement speed. Values can be taken while moving the transformer along the rail. Reliable error localisation can be done even without closing the magnetic circuit, and measurement accuracy is sufficient.

Conclusion

This paper deals with the identification of failures which lead to the occurrence of stray currents. The data and measurement results used in this paper come from measurements on tracks at the Bohumín railway station depot, where current leaked from the traction system to the lightning protection system.

In all probability, the problem was damaged insulation pads between rails and the supporting structure. Another problem was to come up with an accurate and efficient method which would make it possible to check all the pads on a given track.

In the actual measurement, a instrument transformer built for this purpose was found out to be the most efficient option. Basically, this transformer consists of a coil wound around a ferromagnetic part, made of U-shaped transformer sheets. Measurement tolerance was sufficient and the U-shape transformer sheets made it possible to move the measuring transformer along the rail very quickly. A faulty pad was detected whenever the current flowing through the rail before the pad was different from current after the pad.

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