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Authors: Mahmut TURHAN

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Smart Touch Voltage Limitation

Mahmut TURHAN*[1]

Abstract

In modern railway electric infrastructure design there are two major concerns that should be considered as touch voltage and stray current. The first problem is touch and step voltage which endangers human safety even to deathly situations. Second problem is stray current which leads to corrosion of metallic infrastructure. Since human safety has higher priority early on railway systems has grounded the rail voltage to the earth but this caused stray current problem. Thus these two problems should be handled together. In this paper we present a touch voltage control and stray current monitoring solution to handle both problems. Our solution presented here uses thyristor based grounding to limit touch voltage and monitor and report stray current

Keywords: touch voltage, stray current, railway electric infrastructure, thyristor

1. INTRODUCTION

Subway and railway systems running with DC power are supplied with AC power which is converted by redressors in traction power substations and carried over dedicated catenary to the train. Running rails are used for returning current back to traction power substation since a second catenary is not cost effective.

Although the rails are insulated from earth voltage and current happens on the running rails which can be high levels because of trains and faults like lightening. Touch voltage is the voltage potential difference between an energized object and other object some distance away. When voltage over the rails, reaches dangerous levels negative circuit must be grounded. This is a requirement both for personnel / public safety and protection of equipment. Stray current comes into existence where electricity flows unintentionally from materials other than regular electric circuit elements. Stray current leads to corrosion of buried metallic infrastructure. So, touch voltage mitigation and stray current protection are needed to be considered together when applied to infrastructure, equipment and personnel safety [1-7].

There are different types of mitigating touch voltage stated in [1] such as;
Solidly grounding: In this case leaking current leads to corrosion of infrastructure. This method is used in older railway systems.

Ungrounding: Ungrounding is dangerous for public safety since running rails can have higher voltage than ground.

Diode grounding: Diodes act as a one way controller which allows current to negative but disallows from negative to earth. This method solely does not give a solution to stray current to

*Corresponding author: mahmutturhan@medelelektronik.com
[1]Medel Mühendislik ve Elektronik San.Tic. A.Ş.,34956 , Tuzla/İSTANBUL
ORCID: https://orcid.org/000-0001-7633-4830

earth. Two alternative methods of this kind are auto-grounding and thyristor-grounding.

Stray current collection systems: By using mats underground stray current is collected and maintained either fully insulated earthling or drainage systems.

To achieve this protection, our implementation steps in at times determined by the standard curve to empty the load.

Our solution presented here uses thyristor based grounding to limit touch voltage and monitor and report stray current. The limiter has a high resistance until the voltage of running rail is below the pre-defined value. Whenever the voltage of running rail exceeds the pre-defined value the limiter step in and thyristor releases the transmission until the voltage of running rail drops down the pre-defined value. The limiter satisfies the time constraint (300 ms) indicated by the standard EN 50121. Moreover the standard it is possible to adjust the time constraint to decrease the voltage also to adjust voltage value to step in. [8-12].

2. ASPECTS OF AC/DC CURRENTS

Today's Aspects of ac/dc Currents Rail electrification schemes are either dc or ac. Usually, dc current is used for low voltages (up to 3 kV) and ac is used for higher voltages (15 or 25 kV). The grounding approach for both schemes is different. Historically, dc current was used for the good control characteristics of dc motors and electromagnetic compatibility characteristics, because dc currents do not induce voltages or currents in the surrounding metallic elements [13]. The main drawback of dc electrification is that it must be well managed, designed, and maintained throughout the whole life cycle of the line due to stray currents. Stray currents are inevitable because part of the return currents flows away from the rails. These stray currents provoke corrosion where they depart from the metallic material with a positive voltage potential [for example, when they leave the rail or any other underground material (pipes, conduits, or cables) to go back to the substation]. Several effective mitigation strategies can be employed, and the basis for each is the adequate isolation of the dc rails to Earth. The first strategy is to increase the isolation of the rails, but we need to ensure that no unsafe voltages are present between the rails and the ground. Additional mitigations consist of facilitating a return path to dc currents and, in doing so, returning them in mostly controlled ways by lowering the rail's equivalent impedance and using higher-quality materials with low resistivity. Another option commonly applied is the installation of a cable in parallel to the rails, which offers an additional path so that the current returns beside the rails rather than beside the ground. Other options also applied to mitigate the effects of dc currents (but not so effective in principle) include collectors or mats that attract dc currents to limit the corrosion effects. The problem that arises from strategies of this nature comes from the negative effects that may occur as a result of the increase in the amount of current that leaves the rail by facilitating an alternative return path. Leakage currents must be controlled, and we must ensure that collectors are properly designed; otherwise, they could have the opposite effect. On the contrary, ac-electrified lines do not generate stray currents because the time-varying characteristics of this electrification mode prevent a steady flow of currents in one direction. As ac voltages are relatively high, the best way to have a safe touch voltage between the rail and grounded elements is to ground the rails and connect them to all surroundings conductive elements, such as OCS poles, metallic walkways, signaling boxes or huts, and so on. For mixed environments where both dc and ac trains run over the same line, the mitigations are aimed at the ac elements that are already grounded and may include not grounding certain elements that reduce the stray current paths. The success of this strategy lies in determining the minimum grounding connections required to decrease corrosion and remaining within limits of touch potential, according to EN 50122-1. Other trackside elements, such as cables or fences, must be considered in terms of both effects (ac and dc) and provide a tradeoff solution to prevent dangerous ac voltages and dc corrosion. The European standard concerned with stray currents and contact voltages is EN 50122. The first part

[14], “Electrical Safety, Earthing and the Return Circuit— Part 1: Protective Provisions Against Electric Shock,” establishes the maximum admissible touch voltages of both ac- and dc-electrified lines. Part two [15] addresses the provisions for the effects of stray currents caused by dc traction systems, and part three [16] discusses the mutual interaction of ac and dc traction systems. There are mixed dc and ac environments where both types of electrification coexist, sometimes using the same tracks (for example, dc third rail and ac OCSs for mixed-use lines and terminal stations). In these areas, there is a risk of corrosion to the grounded metallic elements of the ac grounding system because they provide a low resistance path to the ground. This problem could be solved by not mixing ac and dc systems; however, sometimes that is not possible. In many cases, lines are not greenfield but, rather, overhauled over time. Additionally, rolling stock has a long life cycle, which makes it difficult to completely upgrade one system from one day to the next. Elements, such as ac/dc changeovers or neutral or transition zones, can be implemented, thus hindering the passage of dc current into the ac area. Reducing the elements that are grounded in the ac area and hence susceptible to corrosion is a better way of managing the mixed-current scenario. Doing so decreases the number of areas where corrosion must be monitored and protects an increased number of assets against corrosion. Once the elements subject to corrosion are identified, they can be managed, and mitigation strategies, such as protective cathodic or anodic approaches, can be applied.

3. TOUCHVOLTAGE MITIGATION

As stated in [16], efficiency of rail voltage reduction is correlated with the grounding system quality. Mainly dependant on the grounding systems resistance reducing the rail voltage below the required level can be achieved in required time interval wrt0.1 ohm grounding is possible only above 55 V as simulated in [17-19] and depicted in Figure 2.

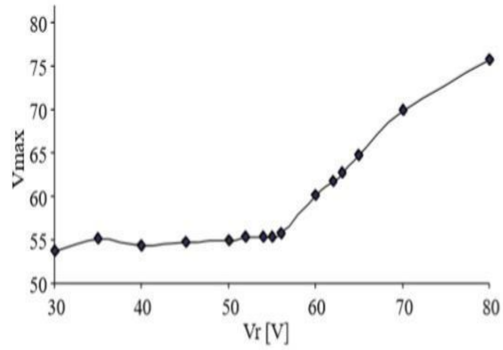


Figure 2 Reducible Rail Voltage wrt0.1 ohm Grounding

A simplified circuit schema of stray current and touch voltage is given in [1] in Figure 3 with equations in equations (1) and (2):

$$I = \frac{R_R\, R_T}{R_T+R_R+R_S} \quad (1)$$

$$V_T=R_R\ X\ I_R \quad (2)$$

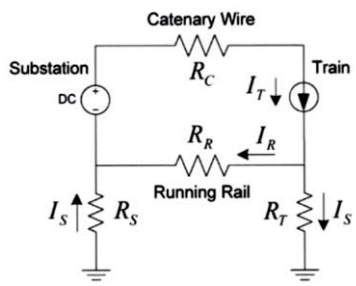


Figure 3 Circuit schema of stray current and touch voltage

In Figure 4, you can the prototype solution front view. The solution monitors the voltage difference between the running rail and the ground. Whenever this DC voltage difference is abovethan the preset value; it smartly discharges within time limitations of EN50122 standard.

Figure 4 Front view of prototype solution.

Although the EN50122 standard requires the discharge of voltage by means of 300 sec. our solution has the capability to do this in 0.2 sec and this time requirement can be adjustable. The comparison of the standard and the capability can be better seen in Figure 5. Purple line depicts the standard requirement red line depicts the performance our solution.

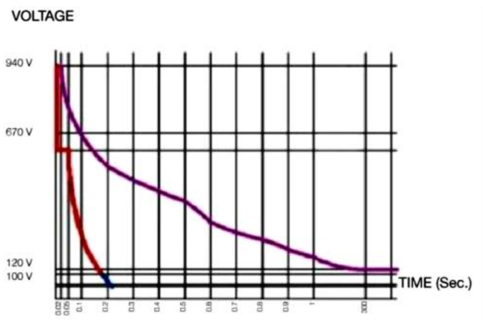


Figure 5 Comparison of the standard and the capability. (Red line: PresentedSolution, Purple Line: Standard).

Block diagram of the solution is given in Figure 6.

Figure 6 Block diagram of the solution.

4. TEST RESULTS

To prove that the solution is working properly, activates whenever the voltage is higher than the preset value and discharges the voltage, it is tested under simulated laboratory. To simulate the voltage difference between the device and the ground a potential generator is used giving different voltages. By charging the condansator at the beginning of the circuit the activity of the device has been inspected. Condansator is charged over a variac by a tri-phase rectifier diode and an appropriate resistance. The preset values to become active are set to 70,80,90,100,110,120 V one by one and the current and voltage values of activation times are recorded by an oscilloscope. Results can be seen

in Figure 7-12.

A sample references list is given below;

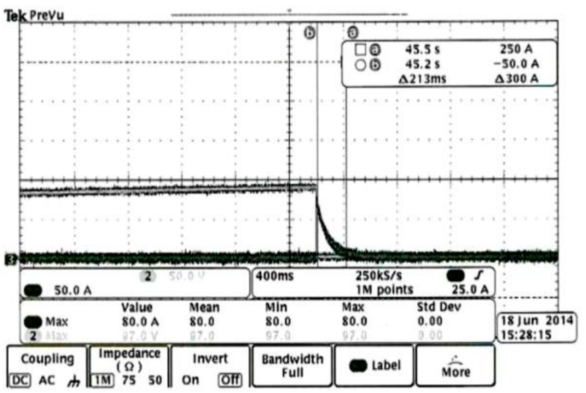


Figure 7 Test result with 70 V

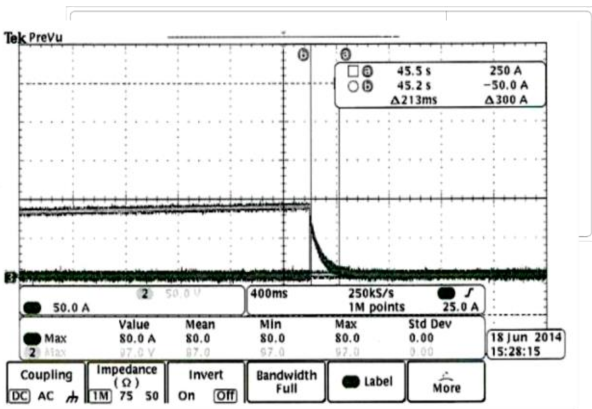
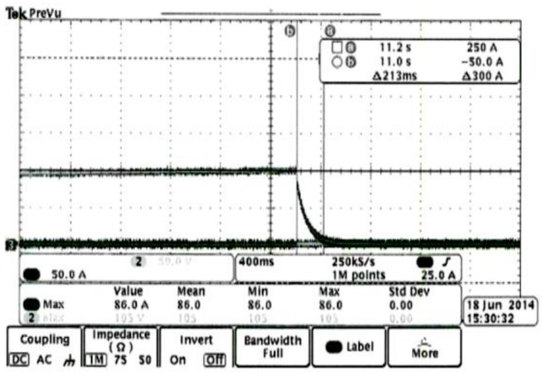


Figure 8 Test result with 80 V.



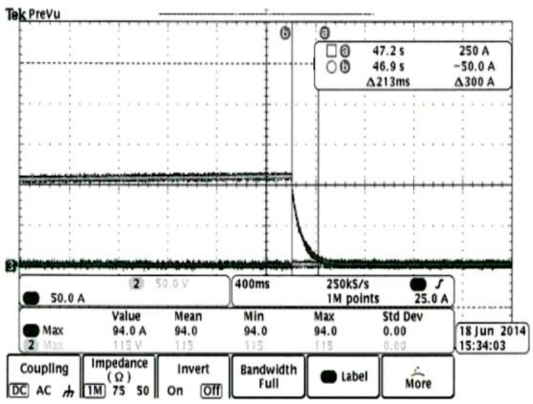


Figure 9 Test result with 90 V.

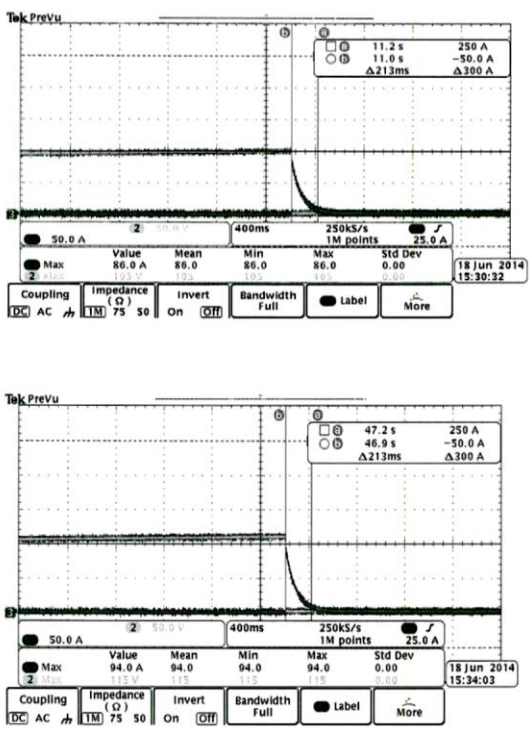


Figure 10.Test result with 100 V.

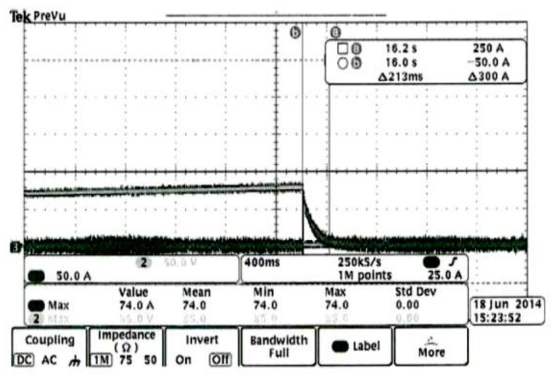


Figure 11 Test result with 110 V.

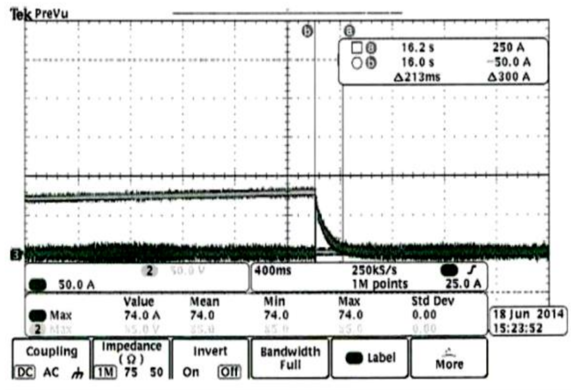


Figure 12 Test result with 120 V.

As seen above the device achieves the desired discharging by times between 213 ms-277 ms which satisfies the EN50122 standard. In test setup a 2 Ω resistance has been used torepresent ground resistance. When the grounding resistance gets smaller, higher current can pass through the device and time to discharge decreases.

5. CONCLUSION

The presented solution for touch mitigation satisfies EN50122 standard approved by laboratory tests. Although the EN50122 standard requires the discharge of voltage by means of 300 sec. our solution has the capability to do this in 0.2 sec and this time requirement can be adjustable. Adding a wireless communication capability and monitoring over web platform is a future work.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

Authors' Contribution

The author contributed equally to the study.

The Declaration of Ethics Committee Approval

The authors declare that this document does not require an ethics committee approval or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the article and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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