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Induced Voltage Study on a Traction System and Mitigation methods

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SUMMARY

High Voltage transmission lines induce a voltage on any nearby metallic objects. This induced voltage in railway system due to nearby high voltage transmission lines is a serious concern as it could cause harm to the workers or the public, damage the equipment, interfere with the measurement and control units, and also increase the maintenance cost. This paper presents the results of an induced voltage study for a rail traction system in the vicinity of a transmission line. To perform an induced voltage study, Electro Magnetic Transient (EMT) software is required. This paper presents the steps to perform the study in EMT simulation. In addition, the aim of this paper is to present the result of the study in a general matter as an initial assessment to indicate if there is a concern for induced voltage study with the absence of the EMT software. To find the worst case of induced voltage, the studies are conducted for the various operating scenarios including normal operation, single line to ground fault, and three phase to ground fault. The S&C Recommended Practice 1082 requirements stipulates the acceptable limit for rail to ground and rail to rail voltage as 5 V, and 25 V, respectively. The simulation result shows that the requirements are met for normal operation whereas it is violated for single phase and three phase fault cases. Thus, a mitigation strategy is required for limiting the induced voltage before energizing the mobile substation.

It is indicated that there are only few papers to discuss the induced voltage studies on the traction system and available papers are case specific. To ensure that this paper is not a case specific and to provide further assistance to the industry with the similar project, several operation scenarios are investigated, and results are provided in this paper. Following cases studies are proposed and the induced voltage at the traction rail is investigated in detail:

1. Various distance of the traction system to the high-voltage lines
2. Various parallel segments of the high-voltage line and the traction system
3. Various power system strength (Short circuit rating)
4. Various grounding resistance of the Main Power Transformer (MPT)
5. Various grounding segments for the traction rail

Results of these studies provide a generic guideline to indicate further studies in EMT if required. The result show that the most effective approaches to ensure the safety of the operations are either proper design of the Neutral Grounding Resistor (NGR) for the transformer or proper grounding of the traction rails along the parallel path with the high-voltage transmission line.

KEYWORDS

Induced Voltage, Electro Magnetic Induction (EMI), Inductive Coordination Study, Railway, High Voltage Transmission System.

INTRODUCTION

High Voltage transmission lines create time varying magnetic field around the transmission line due to the alternating current flowing through it. Due to this magnetic field, a voltage is induced in the neighbouring metallic objects, railway tracks, pipelines, etc., by Electro Magnetic Induction (EMI). This voltage is induced in the railway track due to the unbalanced load in the transmission line, and asymmetrical distance between transmission lines and the railway track. During a ground fault, a dangerously high voltages can be induced due to the increased unbalance in the current flowing through the transmission line [1-4]. The other factors affecting the amount of induced voltage are distance between transmission lines and railway track, length of track parallel to the transmission line, soil resistivity, magnitude of current flowing through the transmission line, etc. [4].

This induced voltage and current in railway track is a big concern for the railway operators due to the following reasons [5]:

a. Shock hazard to people
b. Service disruption
c. Plant and equipment damage
d. Increased maintenance cost

Due to the above stated reasons, the evaluation of electromagnetic induction in railway tracks and pipelines due to adjacent high voltage transmission is gaining a larger attention recently. Transient simulation studies using EMTP or PSCAD is more commonly used for inductive coordination studies due to its ability to model a complex system consisting of the various circuit elements [5].

This paper presents a case study performed to investigate the induced voltage on a traction system in the vicinity of a 69 kV transmission line. Furthermore, the impact of various parameters on the amount of induced voltage is also presented. Also, the various methods for mitigation of the induced voltage are included in this paper.

STUDY SYSTEM

The study system consists of a railway traction which runs parallel to a 69 kV transmission system, running between an existing substation and a mobile substation. The existing substation is under renovation, and mobile substation is brought up as a backup for the existing substation. The railway track is a standard gauge with steel tracks 4’ 8 ½” apart. The LLLG and SLG for the 69 kV system at the substation is 13.585 kA with an X/R of 4.686, and 10.198 kA with an X /R of 4.39 respectively. The 69 kV conductors are 336.4 ACSR 18/1 strand “MERLIN” conductors.

PSCAD MODEL DESCRIPTION

The study system is modelled cross sectionally as shown in

Figure *1*. The transmission line is modelled as frequency dependent phase model, and the railway track are modelled as a DC line [6]. The physical configuration of the T-Line and the railway track are illustrated in Figure *2*.

The mobile substation is modelled as an active generator based on the maximum load, voltage level, and ampacity rating of the overhead line. The existing substation is modeled as a PQ load to accurately represent the system as it is de-energized.

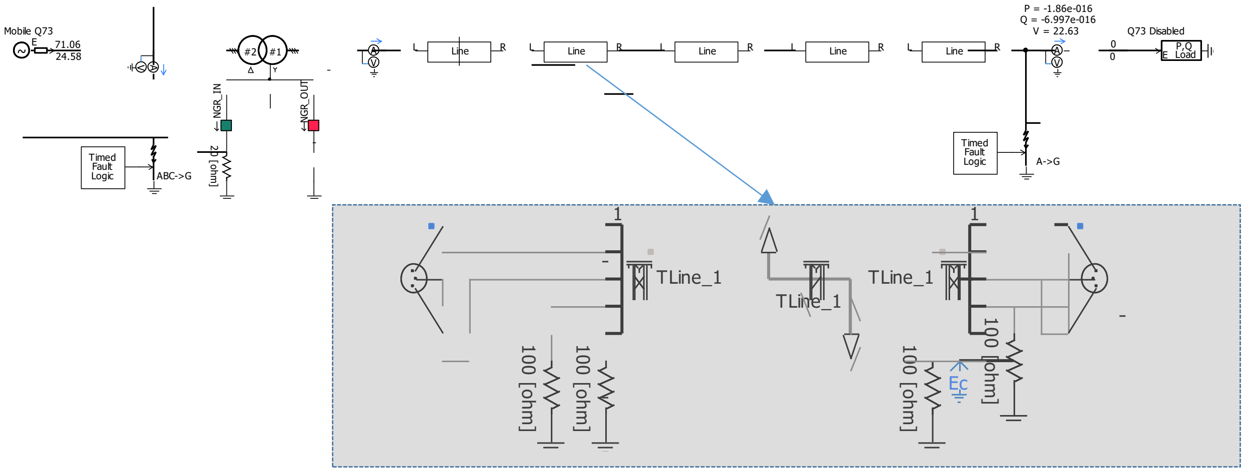

Figure 1. PSCAD Model of the study system

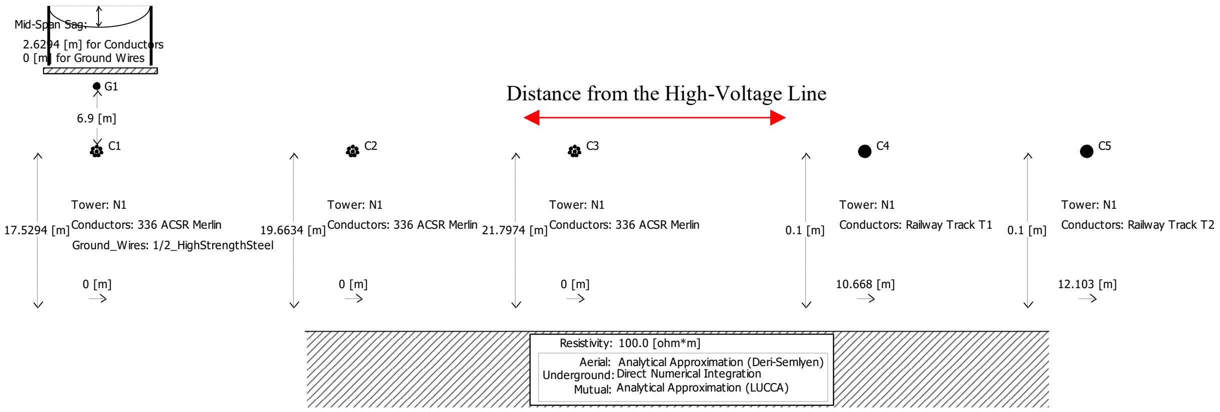

Figure 2. Configuration of 69 kV Transmission line and the railway tracks.

CASE STUDIES

Case 1: Estimation of induced voltage in railway traction system

In this set of studies, the induced voltage in traction system for various operating scenarios are calculated. The different operating scenarios considered are, i) normal operation, ii) single line to ground fault, and iii) three phase to ground fault. For the fault cases, a zero impedance fault is applied for 100 ms.

Case 1.1 Normal Operation

The induced voltages on the two railway tracks for normal operation are shown in Figure 3. The induced voltage on railway track is 17.63 V, and the induced rail to rail voltage is 3.3 V. The induced rail to ground voltage for normal operation is less than 25 V, and rail to rail voltage is less than 5 V, and thus satisfies the safety requirements of S&C Recommended Practice 1082 [5].

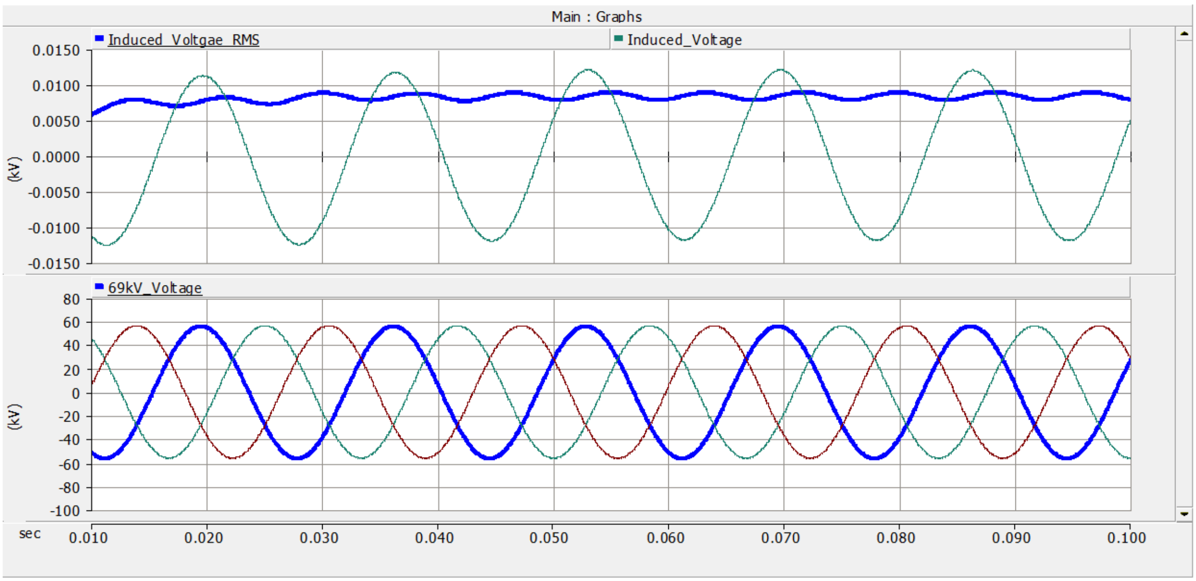

Figure 3. Induced Voltage at the Nearest Track to the Transmission Line during Normal Operation.

Case 1.2. Single Line to Ground Fault (SLG)

For this study, a single line to ground fault is applied at the existing substation for 100 ms, and the induced voltage at the railway tracks during the fault is observed. The induced voltage on the railway track are shown in Figure 4. The induced rail to ground voltage for nearest and farthest railway track is 933.21 V respectively. The results indicate that the maximum rail to ground induced voltage exceeds the acceptable level of 25 Vac rms which does not meet the safety requirements of S&C Recommended Practice 1082 [5].

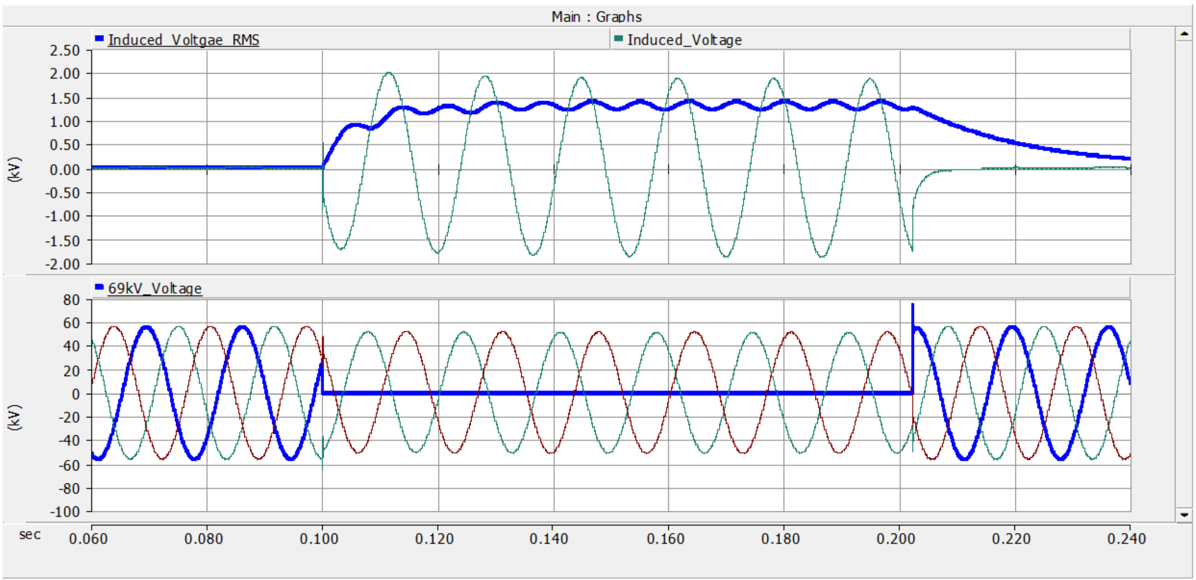

Figure 4. Induced Voltage at Nearest Track to the Transmission Line during a Single Line to Ground Fault.

Case 1.3. Three-phase to Ground Fault (LLLG)

A three phase to ground fault is applied at the existing substation for 100 ms, and the induced voltage at the railway tracks during the fault is observed. The induced voltage on the railway track is shown in **Error! Reference source not found.**. The induced rail to ground voltage on the railway track is138.89 V. The results indicate that the maximum rail to ground induced voltage exceeds the acceptable level of 25 Vac rms and the maximum rail to rail induced voltage (Ea -Ec) is greater than 5 Vac rms. Both values do not meet the safety requirements of S&C Recommended Practice 1082 [5]. Since the induced voltages in railway tracks are greater than the acceptable limit of safety requirements of S&C Recommended Practice 1082, a mitigation measure is needed before energizing the substation.

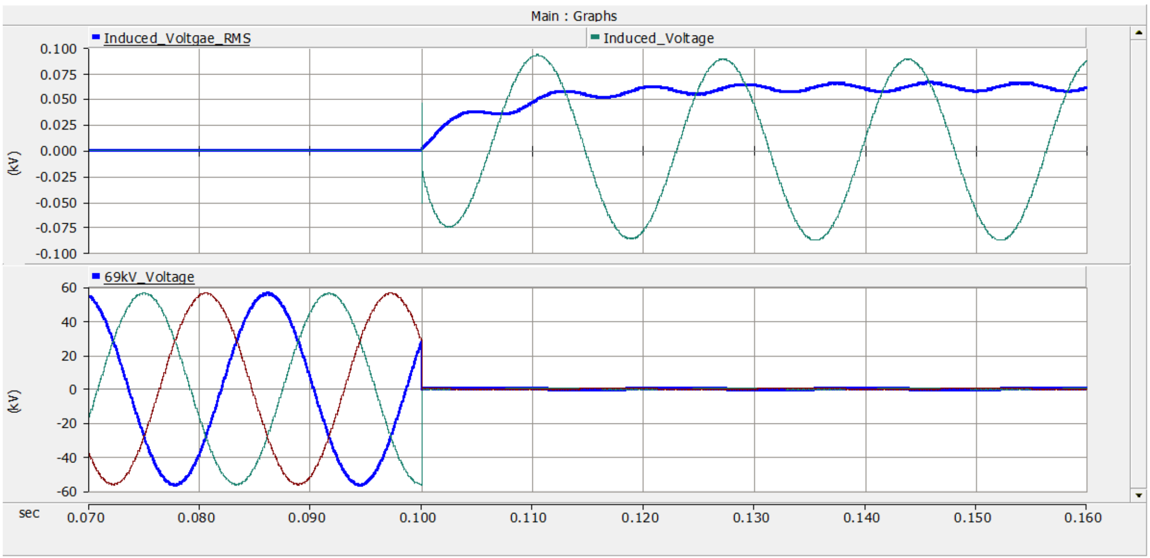

Figure 5. Induced Voltage at nearest Track to the Transmission Line during a Three Phase Fault.

Case 2. Impact of System Parameters on the Induced Voltage

The impact of various system parameters on the induced voltage is studied, and results are discussed in this session. The various parameters considered are distance between the rail and the transmission system, short circuit level of the transmission system, and length of parallel session of railway track and transmission system. The studies for this case and next case are done by applying a Single Line to Ground fault (SLG) at the existing substation, because worst case of induced voltage occurs for SLG as observed in Case 1.

The impact of varying short circuit current and distance between the railway line and the transmission system on the induced voltage is shown in Figure 6. It can be seen that induced voltage increases as the distance between transmission line and the railway track reduces for all short circuit level considered. The induced voltage is higher for higher short circuit current (Stronger system).

The impact of the System Short circuit level and length of the parallel segment between the traction system and the transmission line on the induced voltage is depicted in Figure 7. As the length of the parallel segment between the traction system and the transmission line increases, the induced voltage increases for all short circuits considered.

From these studies, it is observed that magnitude of induced voltage increases when (i) distance between transmission line and railway track reduces, (ii) length of the parallel segment between the traction system and the transmission line increases, (iii) short circuit level of the transmission system increases (weaker system).

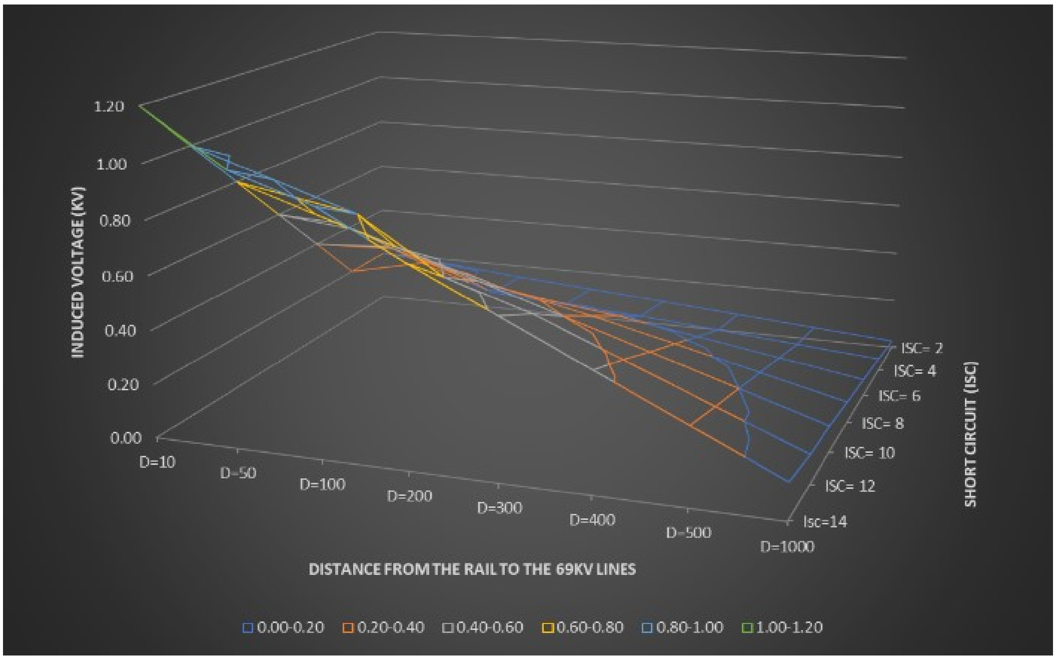

Figure 6. Impact of System Short circuit level and Distance between traction system and the transmission line on induced voltage.

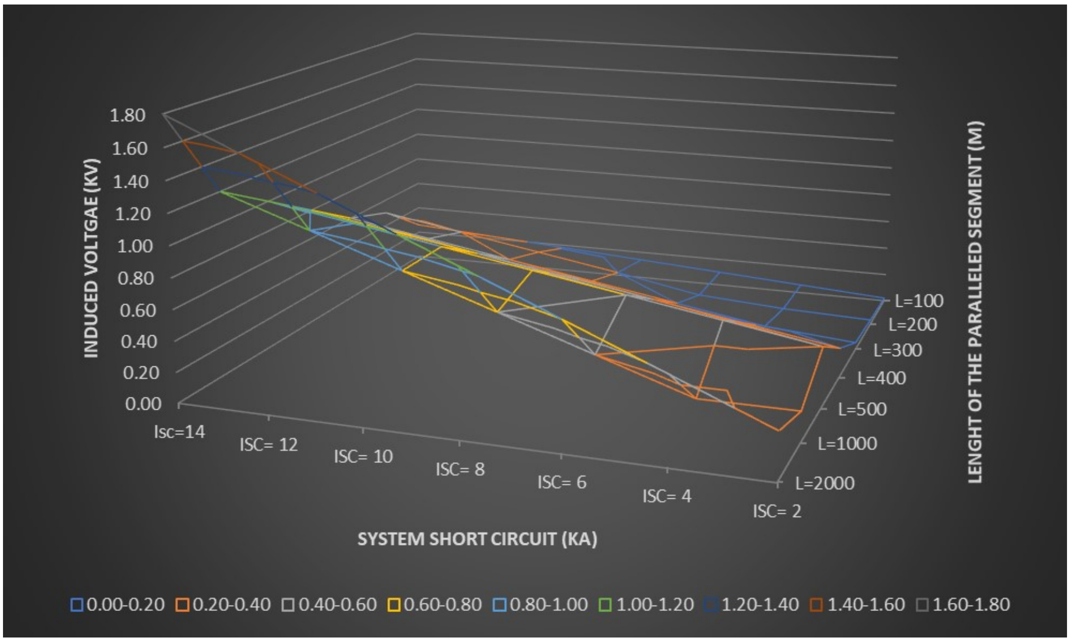

Figure 7. Impact of the System Short circuit level and length of the parallel segment between the traction system and the transmission line

***Case 3.* Evaluation of mitigation measures for induced over voltage.**

The induced overvoltage issue can be addressed by either substation neutral grounding, or by grounding the railway track at regular intervals. In this session, the impact of both methods is assessed for various short circuit levels of the transmission system.
The impact of transformer neutral grounding resistance (NGR) is shown in Figure 8. The NGR is varied between 1 ohm to 20 ohm. The studies are done for various short circuit levels to capture the response in strong system to various system strengths. It can be seen that in a strong

system the induced voltage is higher for all the NGR considered. The induced voltage reduces with increase in NGR. Thus, it concludes that induced voltage can be reduced by using a higher NGR. The proper size of NGR can be achieved through a detailed EMT studies.

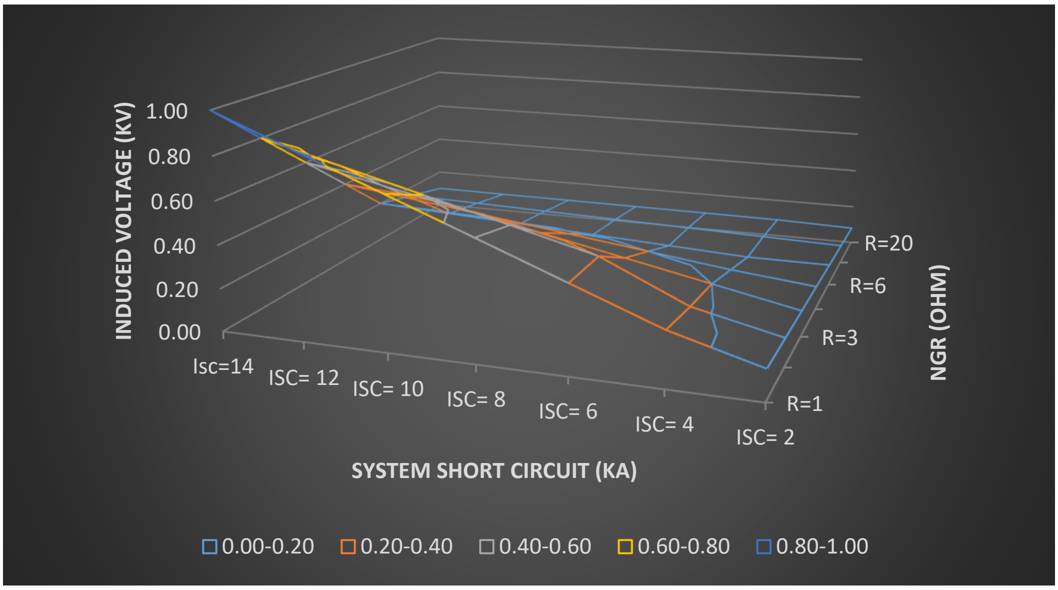

Figure 8. Impact of transformer Neutral Grounding Resistance (NGR) on induced voltage in railway track for various short circuit levels.

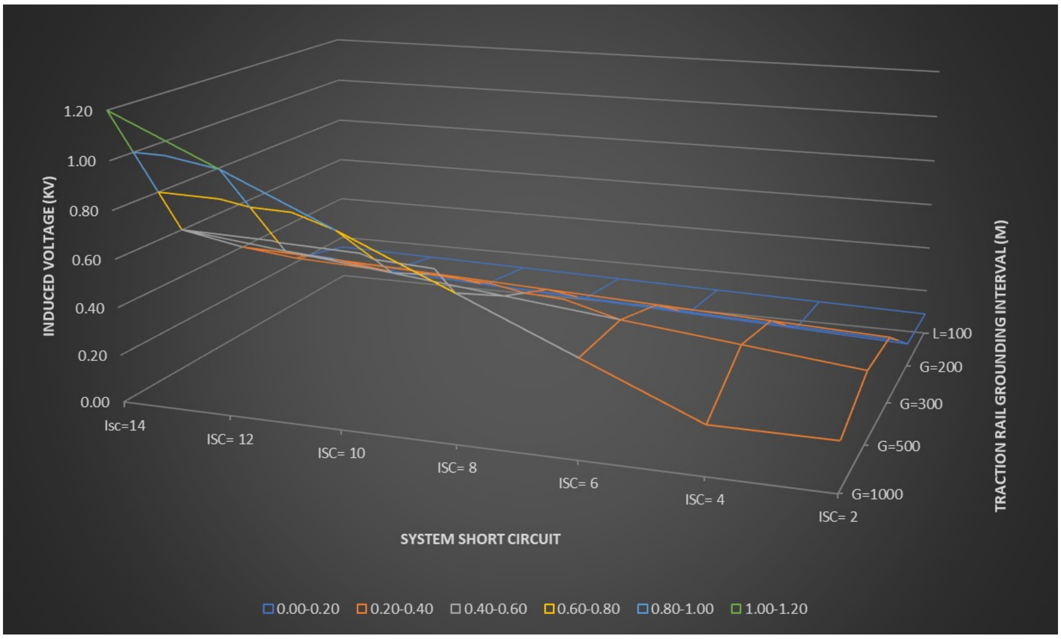

Figure 9. Impact of traction system grounding intervals on induced voltage in railway track for various short circuit levels.

Another possible method to address NGR is to ground railway track in regular intervals. In this study, the length of the railway grounding intervals is varied between 100 m to 1000 m and results are illustrated in Figure 9. It can be seen that as the grounding level decreases the induced voltage reduces for all the short circuit levels considered.

From these studies, it can be observed that induced voltage can be reduced by adding a higher neutral grounding resistance to the substation transformer, or by grounding the railway track at a shorter interval.

CONCLUSION

An inductive coordination study is done for a 69 kV substation having railway track in its vicinity using PSCAD/EMTDC. The objective of the study was to determine if the induced voltage in the railway system due to the 69 kV transmission system is within the safety limit. The studies are conducted for the various operating scenarios including normal operation, single line to ground fault, and three phase to ground fault.

The S&C Recommended Practice 1082 requirements stipulates the acceptable limit for rail to ground and rail to rail voltage as 5 V, and 25 V, respectively. The simulation result shows that the requirements are met for normal operation, whereas it is violated for both single phase and three phase fault cases. Thus, a mitigation strategy is required for limiting the induced voltage before energizing the mobile substation.

The studies are further done to study the impact of various parameters on the induced voltage. The various parameters considered are distance between the rail and the transmission system, short circuit level of the transmission system, and length of parallel session of railway track and transmission system. It is observed that magnitude of induced voltage increases when (i) distance between transmission line and railway track reduces, (ii) length of the parallel segment between the traction system and the transmission line increases, (iii) short circuit level of the transmission system increases.

The impact of two mitigation strategies to address the induced over voltage issues are investigated for various short circuit levels. It was noted that induced voltage can be reduced by adding a higher neutral grounding resistance to the substation transformer, or by grounding the railway track at a shorter interval.

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