Effects of earthing systems on stray current for corrosion and safety behaviour in practical metro systems

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Abstract: Running rails are used as the return path for the train current in most DC electrified rail transit systems. The resultant rail voltage causes stray current to return to the DC supply source via other paths, such as nearby metallic infrastructure. Stray current is the main cause of corrosion in metallic parts located in the railway proximity. This study reviews various earthing schemes including thyristor earthed, diode earthed, floating and solidly earthed and corrosion phenomenon in DC railway traction systems. Then, based on simulations, a comparative study of safety and corrosive effects of the stray current, produced by various earthing schemes is presented. The study is part of the concept designed to control the stray current at Tehran Metro Line 3. Results of the study have been validated by simulation studies using a multi-train simulation software tool and the system data from Tehran Metro Line 3. The study shows some interesting findings such as corrosion damage increases near traction substations.

1 Introduction

Owing to economic purposes most DC traction systems use running rails as the return path of the train’s current to the supply source. Consequently, the resultant voltage drop on the running rails produces stray current leaking off the rails onto earth and embedded infrastructures. The stray current produced by DC transit systems plays a major role in the corrosion of rails and buried metallic structures, which are located within proximity of the railway. In addition to the corrosion damage, leaking stray charges create interference problems with the signalling equipment of traction systems (see Fig. 1).

Underground transit systems are proposed as a solution to traffic and air pollution problems in metropolitans. Tehran with a population nearing 10 million is not an exception and a great deal of construction and extension work is being carried out on its mass rapid transit (MRT) system. Problems caused by the stray current corrosion in Tehran underground provided motivation for the authors to run a study about the effect of the various earthing schemes on stray current corrosion. As Tehran Metro Line 3 was in the design period, it could be considered as a best test-bed for comparing different schemes. Tehran Metro Line 3 is one of the new MRT rail lines, which uses a 750 V DC power supply system. It is made up of two parallel tracks, 32 stations with 26 traction sub-station. There is 523 m difference in altitude between the line end stations that are, respectively, located at the southwest and the north east of the Iranian capital. More descriptions of Tehran Metro Line 3 will be given later in this paper.

Decreasing rail resistance and increasing rail-to-earth resistance by coating and improving insulations are the preliminary measures proposed in the literature to reduce stray current. Declining running rail resistance increases the proportion of current flowing through the rail, whereas elevating track to earth resistance reduces the amount of current leaking off the rail [1]. Also rising DC source voltage to higher levels, hence lowering the train current for a constant power, is another measure for solving stray current problems [2]. Nowadays, most modern DC metro systems are designed for 750 or 1500 V DC supply voltage. London Underground is an exception that uses 630 V DC and a fourth rail as the return path. Reducing the distances between traction substations (TSS) is another measure that can be taken for controlling stray current. However, this solution increases the construction cost as the optimum placement of TSS should be carried out on the basis of peak service conditions and rectifier ratings.

Schemes adopted in the earthing of TSS include solid earthed, diode earthed, and floating and thyristor earthed [3–8]. It will be shown in this paper that various earthing schemes can change stray current quantity. Depending on the flowing direction, the stray current can play a protective or corrosive role for metallic objects. The corrosion damage in underground structures is more destructive and costly than other sections of a rail line. Constraining stray current is therefore important to prevent corrosion of infrastructures in adjacency of running rails.

A possible alternative earthing scheme for Tehran Metro Line 3 has been discussed in [9]. A new earthing scheme titled ‘Reversed Diode Earthed scheme’ is presented and