COMPENSATION OF HARMONIC DISTURBANCES IN THE TUNISIAN SAHEL RAILWAY SUPPLY SYSTEM

Ouni Faten, Faouzi Ben Ammar
Université de Carthage INSAT : Laboratoire Matériaux, Mesures et Applications
Centre Urbain Nord BP N°676 - 1080 Tunis,
e-mail: feten_ouni@yahoo.fr, e-mail: faouzi.benamar@insat.rnu.tn

Abstract- The Tunisian SAHEL railway supply system of 68 km length track is fed by one electrical substation (ESS) 150kV/25kV. The overhead line is modeled as distributed circuit which presents parallel and series resonances. In the drive system, the DC motors are fed by half bridges which generate current harmonics in the line. The major supply system problems caused by harmonic current in the line are presented, as overvoltage and psophometric current in telecommunication cable. Moreover, the leakage current into the earth and the long distance from substation which produces electromagnetic interference are analyzed.

To reduce the disturbances in railway supply system, several solutions are studied. Indeed, the problems presented previously may be reduced by changing of drive converter or by changing of the topology of the line or by using filters.

Index Terms—Railway supply system problems, harmonic current, compensation of disturbances.

I. INTRODUCTION

The SAHEL railway supply system suffers from many problems. In fact, drive converters generate current harmonics in the line. The harmonic noise can excite parallel resonances and produce over current and over voltage [1] [2]. The overvoltage produces harmful influences on the equipment reliability.

Moreover, harmonic currents may interfere with neighbouring cables such as telecommunication line and produce disturbances in this line. The psophometric current measures this interference.

On the other hand the rail is not insulated from the earth, thus, a portion of rail current is shunted in to the earth, this current called leakage current increases the interference effects.

Consequently, it is necessary to reduce harmonics in the line to reduce overvoltage and psophometric current. Moreover, it is necessary to increase usable transmission distance to reduce electromagnetic induction effect.

In the first part of the paper, the major railway supply system problems are presented:

- The overvoltage caused by coincidence of resonance and harmonic frequencies.

- The psophometric current in telecommunication line induced by current harmonics in the contact line.

- The decrease of shielding effect caused by leakage current into the earth from return current in the rails.

II. MAJOR PROBLEMS OF THE SAHEL RAILWAY SUPPLY SYSTEM

2.1. The overvoltage caused by resonance

The overhead line of SAHEL Tunisian railway supply system is a transmission line, its input impedance presents parallel and series resonances. On the other hand, railway drive system generates current harmonics in the line. The harmonic noise can excite parallel resonances and lead to current harmonic amplification [3].

The current harmonic amplification causes the amplification of voltage because of significant impedances at resonance frequencies [4]. The overvoltage can cause overheating of transformers, motors and drive converter components [5].

2.2. The psophometric interference

Harmonic currents generated by drive converter may interfere with telecommunication lines. The measure of the communication disturbance is given by the psophometric current [6].

As presented in equation (1), according to the standard CEI 62236-3-1, psophometric current is defined as the addition of all weighted ‘rms’ harmonic currents

\[ I_{pso} = \frac{1}{P_9} \sqrt{\sum_{n=1}^{9} (P_n I_n)^2} \]  

Where

\( n \): Harmonic number

\( P_n \): Psophometric weighting factor of the \( n \)th harmonic

\( P_9 \): Psophometric weighting factor of the 9th harmonic

The psophometric weighting factor \( 'p_n' \) as a function of frequency ‘f’ is presented in figure 1, as shown in this figure, the psophometric factors are maximums in the frequency band between 800 Hz and 1200 Hz. In fact, in the frequency band the audible sensibility is maximum.

For the Sahel railway supply system, the study of the line impedance as a function of frequency shows that the first resonance frequency is at 1 kHz [4], which presented in the frequency band [800 Hz, 1200 Hz].
On the other hand, as shown in table 1, in communication system the reception frequency (f=1080 Hz) between Monastir and Bagdadi is coincided with the resonance frequency, the coincidence may be the origin of communication noise between the two cities.

2.3. The leakage current into the earth

As shown in figure 2, the return current in the rail \( I_R \) flows in the opposite direction to the contact line current \( I_C \). This return current produces induced electromotive forces (emf) with the opposite sign that the induced emf produced by overhead line current. Therefore, the rail has a protective shielding effect. However, the rail is not insulated from the earth and consequently a part of the rail current is shunted into the earth.

The portion of current \( I_R \) called leakage current decreases the shielding effect and increases the induced emf in communication line.

Moreover, as shown in figure 2, the inductive interference in telecommunication line can be increased due to the large loop area composed by the substation, the contact line, the locomotive and the return current in the rail.

### III. Compensation of the Disturbances in Railway Supply System

The problems in railway supply system presented previously could affect satisfactory function of railway system. Consequently, to improve the reliability of the latter, it is necessary:

- To reduce the overvoltage in the line by minimizing the current harmonics.
- To reduce the telecommunication noise by:
  - Minimizing psophometric current (using CEI 62236-3-1 Standard).
  - Reducing the leakage current into the earth and increasing the shielding effect.
  - Reducing the loop area composed by substation, contact line, locomotive and rail.

To ensure these requirements, three solutions are proposed in diagram of figure 3.
3.1. Change of drive converter

The PWM (Pulse Width Modulation) converter is one of common static converter used to power the induction machine such as asynchronous machines. The additional advantage of the technique is the elimination of harmonic currents[8].

Figure 5 presents the topology of drive system witch may reduce harmonics in the line. In this configuration two PWM converters are used, the first is connected to the overhead line (25 kV, 50 Hz) and the second is connected to asynchronous machines.

3.2. Change of the line topology

3.2.1. A Booster transformer system with rail return (BTRR)

The primary winding of booster transformer (BTRR) is connected in series with the catenary and the secondary winding is connected in series with the rail [9]. The 1:1 turn ratio of this transformer explicates that the current in the contact line ‘IC’ will be very nearly the same as the current in the rail ‘IR’. Consequently the leakage current into the earth ‘IE’ is reduced and its harmful effects on telecommunication cable are minimized.

This kind of booster transformer are insulated at distances of 1.5 to 3 km, as a result, the loop area composed by transformer, contact line, locomotive and rail is reduced compared to the Sahel railway system.

3.2.2. A Booster transformer system with return conductor (BTRC)

As shown in figure 4, in the feeding system, a third conductor called return conductor is used, the primary winding of transformer is connected in series with the contact line and the secondary is connected in series with the return conductor.

The 1:1 turn ratio of booster transformation means that the contact line current will be very nearly the same as the return conductor current. Moreover, periodically, the rail presents breaks provided by insulated rail joints. The latter ensure that the current flows only in the section where the locomotive is present. At all other sections, the inductive interference from contact line current is cancelled by that from the return conductor current. Consequently, the interference effects are reduced.

The booster transformers (BTRC) are insulated at distances of 3 to 6 km.
3.2.3. The autotransformer system

In the autotransformer system called also 2*25 kV system, the voltage between the catenary and rail is 25 kV and the voltage between the rail and feeder is also 25 kV.

In this system, consider the locomotive drawing the total current I, this current split and merge just in the section where the locomotive is. Only in this section, rail carries current, in all other sections the catenary and the feeder carry equal current but opposed in sense. That’s why the inductive interference in autotransformer feeding system is reduced.

3.3. Filtering

The two first solutions presented previously witch need a change in railway drive system or in railway supply system are generally expensive. For this reason, it is necessary to use harmonic filters by inclusion of a filter in the substation or by inclusion of a filter in the supply system (at the end of the line).
Moreover, in literature, several solutions of active filters are studied such as multilevel converters with imbricated switching cells or cascaded multilevel converters [10][11]. The resonant filter is also largely used to limit the harmonic currents and to compensate reactive energy. Moreover, resonances can be eliminated completely by using the characteristic impedance at the end of the line. However, this filter presents significant losses. Nevertheless the RLC filter in the line can be installed to eliminate the resonances of the line and without significant dissipation at the fundamental frequency.

IV. CONCLUSION
In the paper, the harmonic disturbances in Sahel railway supply system are presented, as the overvoltage caused by the resonance and the harmonic current generated in the line. The psophometric current and its harmful effects on telecommunication line is also studied. Moreover, the leakage current into the earth which incrases the shielding effect is presented.

To reduce the harmonic disturbances and the interference effects, the change of the topology of drive system is proposed. However, this solution is expensive. The change of the topology of supply system by using booster transformers or autotransformers is analysed, but, this solution is as the previously solution (it is costly).

For this reason, harmonic filters, used to limit the harmonic currents and to decrease the resonance effect causing current amplification, may be the perfect solution to decrease railway supply disturbances.

REFERENCES