ISSN 2278-3091
Volume 9, No.1.1, 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse2191.12020.pdf
https://doi.org/10.30534/ijatcse/2020/2191.12020

Electromagnetic Interference in the Railway Spot Communication Systems

Siti Fatimah Jainal[1], Chia Chao Kang[2]
[1]Faculty of Electrical Engineering, Lincoln University College (LUC), Shah Alam, Kuala Lumpur, Malaysia
[2]Maintenance Engineering, Universiti Kuala Lumpur (MITEC), Masai, Johor, Malaysia

ABSTRACT

A review generally to inform of the European Railway Traffic Management System (ERTMS) with a background on the electromagnetic environment, electromagnetic interference in the railway track, type of sources that could cause the electromagnetic interference to other electrical and electronic system or equivalent, and some ways on preventing the electromagnetic interference in the railway track. Electromagnetic interference occurrence on the railway track has been given a severe attention. Interferences that cause several threat to the communication system such as telephone, television, radio and other communication equipment is actually due to the electromagnetic radiation from several sources in the railway itself. Source and effect of the electromagnetic interference that occurred in the railway track are discussed.

Key words: Railway, ERTMS, Electromagnetic interference.

1. INTRODUCTION

European high-speed rail network progress and developments were discussed in [1]. Relevant issues to the rail industry, research works and scheduling were elaborated in [2]. European rail service and integration in cross border investment and the progress of a single integrated EU railway services in recent development and organization of issues were presented in [3]. Transformation of railway transportation periodically in time such as the requirements of a mature railway system, standards and systems were elaborated in [4].Electromagnetic interference problem has been discussed in detail [5] and covered the type and mechanism of the sources of the problem occurred in the railway. Swedish railway is exposed to the open environment of electric and magnetic fields from train and other sources [6]. The sources of the electromagnetic interference have been identified and the impact to the electronic communication equipments such as audio video program has been covered in [7]. Several characteristic regarding the electromagnetic interference has been notified in order to build a desired Light Railway System [8]. The system requirements had proposed to produce a railway system that is shielded from electromagnetic interference, the railway systems that causes the interference and affect other system in between or around it, and other system required for the railway system to be operated that could cause the electromagnetic interference to the railway itself.

Sources of electromagnetic interferences in the railway during the high speed railway operation are discussed in [9]. Method of reducing the harmonic current generated by the communication equipment in the railway has been introduced. Sources that causing the electromagnetic interference problem in the railway has been discussed in many papers and one of the most important step in investigating this problem is to have the knowledge on how to measure and analyze the electromagnetic radiation that occurred in the system. This method has been covered in [10-12]. Furthermore, the knowledge about the railway system and its configurations are an essential [13-14]. The sources and the mechanism of electromagnetic interferences that come from the railway system that could affect other electronic communication system around it are discussed.

2. EUROPEAN RAILWAY TRAFFIC MANAGEMENT SYSTEM (ERTMS)

The European Railway Traffic Management System was introduced in the early 90's in order to standardize the difference of the railway system in the European country. Before this system is being set up, each European country had its own signaling system, thus when different train travel to different country, it would need a different equipment in order to follow standard of the railway system of the destination country. When the European country started to use the standardized system, the train operation between each country had become more organized and stabilized. The system had enabled the train to operate under easy-to-control circumstances and simplify its management system. These factors include the standardization of the train railway networks, safety, speed, controls and traffic management [15].

ERTMS is used to improve the safety and freight traffic management, to act as cross border interoperability and give a shorter headway an heavily trafficked lines; that is to drive on moving block and enabling exploitation of maximum track capacity. Besides that, it also strengthens the position of the European railway industry in the worlds market and enables preconditions for future harmonization in other areas of rail traffic management [16]. The ERTMS consists of other several systems such as the European Train Control System (ETCS) and the Global System for Mobile Communication – Railway (GSM-R). These two subsystems are different from each other as the ETCS is use to control or give command to the railway system while the GSM-R is a radio system for voice and data communication. Communication system on commanding the train is one of the main characters in modern electrified railway. The main focus on commanding the train is to analysis the frequency range as it is the main factor related to the existence of the electromagnetic environment in the railway track.

The ERTMS application in the railway system follows in three steps procedure. First, the ETCS will transmit the control information and it will be received by the train. In this level, the trackside equipment consists of an encoder module called LEU and a Eurobalise transponder device, the latter fitted between the running rails. The LEU is used to determine the aspect displayed by the signal and passes a message to the Eurobalise transmission. It takes the form of a telegram containing the ETCS Movement Authority such as distance, speed restriction, gradient etc. The information such as speed restrictions, gradients, belies linking distance etc are programmed into LEU. Secondly, the train will then use the information in order to check its real position. The ETCS level 2 functional is similar to Level 1, the only difference is uses of GSM radio as the track to train transmission medium in place of track transponder.

Here the Eurobalise transponder is in use of initializing and periodically recalibrating the train-borne odometer. The GSM radio facilitates continuous track to train transmission to provide the potential for complete infill data in each block section with no need for track in fill. The GSM also provides bi-directional (duplex) transmission, real time data regarding train locations and speeds that can be made available to the signal control and train describer functions. The trackside sub-system uses a Radio Block Centre (RBC) in place of LEM connected to each signal, which interfaces directly to the interlocking system to obtain status information for the entire RBC control area. RBC is actually a centralized signal encoder module. RBC uses information from each train to determine train location and checks the interlocking status and block occupancy ahead of each train thus computes Movement Authorities to transmit via the GSM radio infrastructure. The train is actually control by the GSM-R communication in this stage. Lastly, the train is supervised by the information that it had received by the GSM-R.

3. ELECTROMAGNETIC INTERFERENCE IN THE RAILWAY TRACK

The ERTMS process is a step of sending and receiving signal from one system to another system in the railway track. All of these processes of transmitting of information consist of the frequency generated by each system that is included in the operation. Transmission of the frequency or signal between the sending source and the receiving system could cause the electromagnetic interference to any systems located in between or around the transmission operation. Thus it is a very essential to concentrate on the source of the electromagnetic radiation that occurred in the railway in order to eliminate or avoid any interference to other communication systems.

In the AC Electric Traction Systems is operated as single phase system and was firstly operated at 25kV in public grid frequencies of 50Hz or 60Hz. This electrification was then charged to 15kV 16Hz system which was supplied by dedicated 110kV in two phase transmission systems. The overhead contact system (OCS) placed about 5 to 8meter above the track supplies the power to the electric trains, the running rails and earth act as return circuit. In this area, there are a potential of inherent source of electromagnetic interference as a result of the unsymmetrical arrangement of the feeding and return conductors with respect to the earth or ground potential. This source leads to disturbances in line side equipment and installations of other systems.

Compare to the AC system, the DC traction system is usually used for urban railways and suburban such as underground, tram lines, rapid transit and light-rail as the spacing is less and the voltage is low which are needed for clearance of conductors. Rectifier substations used OCS or a third rail, in order to provide the traction power for the trains. The third rail is positioned next to the track about 25cm above the heads of the running rails, which the traction currents used the running rails in order to returns to the rectifier substations.

3.1 Sources of Electromagnetic Interference

The signal or frequency used in the ERTMS is 4.2MHz with 1MHz bandwidth. Signal from electronic communication equipment, radio system or electric sub-station could interfere within this frequency range. Interference is caused by these factors that generate electromagnetic field at different frequencies. Sources that give frequency that would interrupt other frequency range are called the noise source. Location of these sources may be inside the train itself or located somewhere outside or near the train track. The train could give electromagnetic interference, where the interference

comes from its power supply near the track. System causing the interference was named as the source while the system suffering or accepting the interference causing by the source is called as victim. A source could possibly be a victim or vice versa.

Three types of source have been recognized to cause the interferences in the railway track. Electromagnetic interference could cause by the electric substation and the traction power line of the railway, vehicles and traction drive of the train and equipment that could gives signal to interfere with the train frequency range. External signal could be an external source from the railway and train. Besides that, the electric substation that could interfere with the railway frequency is the rectifier substation, transformer substation and the track or traction line of the railway system. Two factors of electromagnetic interference that included in the vehicle and drive section are known as the Direct Current (DC) fed traction drives, Alternative Current (AC) fed traction drives and the radiation emission from the radio frequency interference sources within the traction.

Electromagnetic interferences caused by the signaling equipment could be generated from the power and audio frequency track circuit, train wheel-rail contact vibration [] and signaling transponder. An external signal could be a source that comes from the inside the railway track and train for example an abnormal or unusual operation condition occurring under railway system fault. An uneven of the voltage supply to the train could also produce an uneven condition of the railway system frequency and cause unintentional electromagnetic interference. Unintentional frequency could be radiated by other communication device in the railway track such as mobile phone, radio and television, thus interfere with the operating frequency of the railway system.

3.2 Electromagnetic Interference in the AC and DC Electric Systems

Basically, there are four different type of coupling mechanisms in the alternating current traction systems that will accountable for electromagnetic interference such as conductive, inductive, capacitive and radioactive. But the dominant mechanisms are conductive and inductive coupling.

By using the correct screening and earthing method, it will control the capacitive coupling mechanism that caused by the electro induction. However, if the electrical contact was optimized, it will reduce the electromagnetic radiation that caused by the interference. As a results, the arching that exits in the current collecting pantographs, contacting wires of OCS and the traction units will be minimize. The contact wires that on the OCS should be suspended and aligns accurately above the train track.

The interference in the direct current in the traction systems is caused by the over high voltages and strong currents that exists between the earth and running rails or fluctuation and varying of electromagnetic fields. The general mass of earth is remove from the running rails so that it will minimize the direct current stray that possibly will cause corrosion in the line side structures such as buildings, bridges, tunnels, electricity, equipment of water and others. The removal may results in hazardous levels or unacceptable of touch voltages to the general public as a result of high rail to earth voltages. The traction current, produces a large magnetic fields, which will differ with the traction load. The time-varying direct current fields might affect the cathode ray tube monitors as well as the equipment in the laboratory and sensitive metering such as hospitals, nearby universities or industry plants.

4. IMPROVEMENT TO REDUCE ELECTROMAGNETIC INTERFERENCE IN THE RAILWAY TRACK

Many investigations and studies have been carried out in order to reduce and eliminate sources of the electromagnetic interference in the railway [18-22]. There are several possibilities that could be considered in order to reduce or eliminate the electromagnetic interference in the railway. In order to prevent the electromagnetic interference in the railway track one of the method is to produce electrical and electronic equipment which is electromagnetic compatible. This means that the ability of the equipment, subsystem and other system is function without generating signal to other electrical system or accepting electromagnetic radiation from other system. Three possibilities that could be considered in order to reduce or eliminate the electromagnetic interference in the railway are by installing the thyristors Controlled Reactor (TCR) in the railway network, shielding and grounding.

4.1 Thyristor Controlled Reactor (TCR) Installation

One of the methods to reduce or eliminate the electromagnetic interference is to produce electrical and electronic equipment which is electromagnetic compatible. It is the ability of the equipment, subsystem and other system to function without susceptible or radiate electromagnetic radiation to other system or specified electromagnetic environment. The method can be done by installing the Thyristors Controlled Reactor (TCR) system to the railway network in order to stabilize the voltage in the Voltage Booster (VB). The railway network consists of the substation, catenary line, signaling transformer, train and Voltage Booster (VB). Voltage Booster is the voltage conditioning device for the railway power system.

The method has been proof to reduce the magnetic field that is produced during the railway train operation [23]. In the supply system (catenary), the harmonic level in the system

burden with trains is better due to the filter that is included in the system which evidently shown Voltage Booster works together with the filter. High-voltage power system voltage and signalizing equipment are much less influenced by Voltage Booster operation than the substation voltage because it is depends on the short circuit current of the system (short circuit impedance).

4.2 Shielding

Shielding is a method to keep the external interference outside the specified electromagnetic environment and keep the internal signal inside its own system. This could be happened when through shielding method, the unwanted electric and magnetic field are attenuated and low impedance diversion could be provided to the unwanted current. This method could be used to improve the electromagnetic interference cause by the electronic communication equipment such as the audio video system equipment. Furthermore, it could also protect the electronic communication equipment system itself from susceptible the electromagnetic interference that could cause by the railway system.

The system requirements had proposed to produce a railway system that is shielded from electromagnetic interference, the railway systems that causes the interference and affect other system in between or around it, and other system required for the railway system to be operated that could cause the electromagnetic interference to the railway itself. In traction circuits, shielded cable is applied as a method of preventing emissions, which both ends are bonded with a good conductor such as the earth. This is because the shield current occurring on the loop circuit (consisting of a good conductor and shielding) cancels the magnetic fields of the interference current. Single-end bonding has a shielding effect for electric fields, but not for magnetic fields. Shielding method is applied in all European electric rail cars which have bonding to both ends and at many points. It is possible all bodies are grounded with earth brushes and earth resistors. Shielding method has been proven to reduce emissions.

4.3 Earthing

Audio video program (TV) is one of the victims that suffer the effect of electromagnetic interference from the railway system. Audio frequency 'humming' in the audio video program is the most affected part in this interference. The source causing this problem is the high grounding resistance of equipment that would cause static interference coupling with the electrified railway network. In addition, the electromagnetic interference of the electrified railway could also coupling with the sound transmission line and cause 'snapping' sound. The method to reduce the electromagnetic interference to this system is to reduce the earthing resistance. It has been proof that when the earthing resistance is lower than 4 ohm, the electromagnetic interference cause by the railway system has been reduced significantly. Thus, the electromagnetic interference cause by the electrified railway could also be reduced.

Earthing and equipotential bonding are considered as a central part of the electromagnetic concept as they are strongly influence the lightning protection, electrostatic and electromagnetic compatibility. Mostly bonding concept design and earthing has follows the following principles such as the bonding and earthing for the traction power systems, of the 15kV, 16.7Hz and 750V DC railway lines, exposed conductive parts in 400V, 50Hz and 10kV, 50Hz distribution installations and neutral points, protective earthing and functional for railway related signaling, earthing and equipotential bonding of conductive metal part are enforcement of buildings and non-railway buildings along the line, telecommunication and control systems, utility installations (electricity, public telecommunication, water, functional) and protective earthing for telecommunication and IT equipment in neighboring signal boxes and buildings, earthing and equipotential bonding for building (conductive metal parts for heating and air conditioning systems).

5. CONCLUSION

There are many sources could be identified that causes the electromagnetic interference in the railway track. These sources could produce from internally and externally to the railway system itself. The effect of the electromagnetic interference to the internal and external system has also been identified. Understanding and to identify the sources from the beginning of the railway network designation and all other equipment and devices that are related will improve the electromagnetic interference in the railway track.

REFERENCES

1. F. Lacote, **50 Years of Progress in Railway Technology, Evoluation of Railway Technology**, *Japan Railway & Transport Review*, 27, pp. 25-31, 2001.
2. C. Turner, A. Tiwari, A. Starr, K. Blacktop, **A Review of key Planning and Scheduling in the Rail Industry in Europe and UK**, *Proceedings IMechE Part F: J Rail and Rapid Transit*, vol. 230(3), 2016, pp. 984-998. https://doi.org/10.1177/0954409714565654
3. J. Marti-Henneberg, **European integration and national models for railway networks**, *Journal of Transport Geography*, 26, pp. 126-138, 2013.
4. F. Lacote, **Alstom-Future Trends in Railway Transportation**, *Rolling Stock and Manufactures (part 2), Japan Railway & Transport Review* 42, pp. 4-9, 2005.
5. R. J. Hill, **Electric Railway Traction: Part 6 Electromagnetic Compatibility – Disturbance sources and equipment Susceptibility**. *Power Engineering Journal*, pp. 31-39, 1997.

6. A. Wisten, S. Niska, J. Ekman, D. Bjorklof, J. Delsing, **Experimental Investigation of EM Noise Environment Surrounding Detector Systems in Swedish Railways**. *IEE Proc-Elec Power Application*, 153(2), pp 191-196, 2006. https://doi.org/10.1049/ip-epa:20050040
7. Y. Ebara, T. Koizumi, H. Sone, Y. Nemoto. **A Measurement on Electromagnetic Noise and Change of Surface in Arcing Electric Contacts**, *IEEE Transactions on Components and Packaging Technology*, 23(2), pp 293-299, 2000.
8. B. Yefei, **Test and Study of Impact of Electrified Railway on Audio Video Program Production**, *Asia Pacific Conference on Environmental Electromagnetics*, May 3-7, 2000, pp 402-407.
9. R. J. Kemp, **Light Rapid Transit On-Street Electromagnetic Compatibility in Light Rail System**, *Light Rapid Transit o Street, IEE Colloqium*, 16th May 1989, pp 1-5.
10. D. Vujatovic, Q. Zhang, **Harmonics Generated from Railway Operation**, Power Engineering Society General Meeting, IEEE 1-3, 2006. https://doi.org/10.1109/PES.2006.1709352
11. Z. Chen, Z. Yianting, **Measurement and Analysis of Electromagnetic Radiation of City Rapid Guided Transit Systems**, *Electromagnetic Compatibility Proceedings, IEEE*, 21st-23rd May 1997, pp 190-193.
12. M. Halgamuge, C. D. Abeyrathne, P. Mendis, **Measurement and Analysis of Electromagnetic Fields from Trams, Trains and Hybrid Cars**. *Radiation protection dosimetry*. 141, pp 255-68, 2010. https://doi.org/10.1093/rpd/ncq168
13. Z. Chen, H. Jidong, **Predicting the General Electromagnetic Radiation Level of High Speed Railway by the Static Parameters of Pantograph and Networks**, *Electromagnetic Compatibility 3rd International Symposium, IEEE*, 21st-24th, May 2002, pp 387-390.
14. B. Bhargava, **Railway Electrification Systems and Configurations**, *Power Engineering Society Summer Meeting, IEEE*, 1, 18th-22nd July 1999, pp 445-450.
15. J. del Portillo, M. Osinalde, E. Sukia, I. Sancho, J. Mendizabal, J. Melendez. **Characterization of the EM environment of Railway Spot Communication Systems**, *Electromagnetic Compatibility, IEEE International Symposium*, 18th-22nd August 2008, pp 1-6.
16. R. Bloomfield, **Network Rail: Fundamentals of European Rail Traffic Management System**, *IEEE, Railway Signalling and Control Systems*, The 11th IET Professional Development Course, 5-9 June 2006, pp 165-168. https://doi.org/10.1049/ic.2006.0684
17. H. M. Yatim, F. M. Ismail, S.J. Fatihhi, A. Bakri, S. Effendy. **A Development of Piezoelectric Model as an Energy Harvester from Mechanical Vibration**. *Chemical Engineering Transactions*. 63. 2018.
18. A. Collina, A. Facchinetti, F. Fossati, F. Resta. **An Application of Active Control of an High-Speed Pantograph: Simulation and Laboratory Tests,** *Proceeding of the 44th IEEE Conference on Decision and Control*, Seville, Spain, December 12-15th, 2005, pp 4602-4609.
19. S. Ostlund, A. Gustafsson, L. Buhrkall, M. Skoglund. **Condition Monitoring of Pantograph Contact Strip**, *Railway Condition Monitoring, IEEE 4th IET International Conference*, Derby, 18th-20th June 2001, pp 1-6.
20. B. Tellini, M. Macucci, R. Giannetti, G. A. Antonacci, **Conducted and Radiated Interference Measurements in the Line-Pantograph System**, *IEEE Transactions on Instrumentation and Measurement*, 50(6), pp 1661-1664, 2001. https://doi.org/10.1109/19.982964
21. P. Ferrari, A. Mariscotti, P. Pozzobon, **Reference Curves of the Pantograph Impedance in DC Railway Systems,** *IEEE International Symposium on Circuits and Systems*, May 28-31, 2000, Geneva, Switzerland, pp 555-558
22. A. Mariscotti, P. Pozzobon, **Proposal of an Artificial Traction Line Network for the Measurement of Locomotive Conducted Emissions**, *IEEE International Symposium on Electromagnetic Compatibility*, Istanbul, 2003, pp 1188-1191. https://doi.org/10.1109/ICSMC2.2003.1429130
23. Z. A. Styczynski, S. Bacha, A. Bachry, I. Etxeberria, **Improvement of EMC in Railway Power Networks**, *Harmonics and Quality of Power, 10th International Conference*, 2, 2002, pp 754-759.