Comparison of Great Britain and Ukraine railway systems based on their EMC capability and electrification systems

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Abstract: **In this paper, a comparison based on electromagnetic compatibility capability, electromagnetic interference susceptibility, signalling, and electrification systems of Great Britain and Ukraine's railway systems will be analyzed.**

***Index Terms*—traction system, EMC, EMI, signalling system**

I. Introduction

The railway system is usually exposed to magnetic and electric fields from the traction system, nearby power transmission lines and other related sources. These can generate conducted and radiated Electromagnetic Interference (EMI) which can affect the electronic and signalling equipment. The Ukrainian railway system uses old analogue devices in the control, signalling, and telecommunication systems [1]. There is a need to update these systems with new modern automatic devices without changing the existing infrastructure by improving the coexistence with lower implementation costs and develop techniques that can reduce EMI. The British railway system is implementing modern devices and several mechanisms to reduce the EMI effects and EMC issues.

As shown in Figure 1, from the total route length, 22,300 kilometres (Km), of the Ukrainian railway only 44.3% is electrified. In Great Britain (GB), only 38% of the railway system is electrified from a total route length of 15,874 Km based on the report from [2] in 2022 although the electrification system starts in the nineteenth century.

Signalling systems are used to determine the position of trains, points that control the directions of the trains, and operate the timetable.

The main aim of this paper is to make a comparison of both countries by identifying the type of electrification system, and technologies used in the signalling, telecommunication, and automatic devices of the railway system to reduce the EMI effect and capability of EMC issues.

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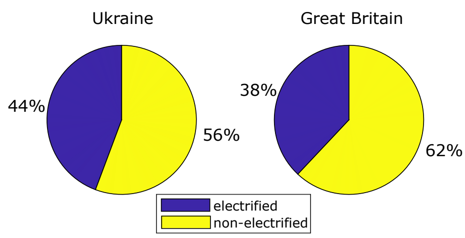

Fig. 1: Railway electrification of Ukraine vs Great Britain.

II. Types of railway traction systems

Railway traction system refers to the type of source used to power the locomotive system. The supply to the electric traction system can be Direct Current (DC), Alternating Current (AC), or a composite of both. In a DC traction system, the DC supply is supplied to the vehicle using third rial, fourth rail, or overhead lines while in an AC traction system, it uses overhead lines which are based on rail-return, boost transformer, or auto-transformer system.

In the United Kingdom (UK) railway system, the above three types of systems are implemented although they are changing most of the existing systems to 25 Kv 50 Hz AC. The DC system uses either a third and fourth rail with a voltage level range of 110 V to 850 V or an overhead line with the voltage value 750 V and 1,500 V while the AC system uses a 25 KV, 50 Hz overhead line (OHL). Ukrainian railway electrification uses 25 Kv 50 Hz AC system and 3 Kv DC system. In addition, 600 V and 825 V DC for trams and metro systems, respectively.

Based on the data from [2], Figure 2, the number of electrified routes opened for traffic increased only by 4.6%, in 8 years, in 2022 compared to the year 2015. This data shows that there is a lot of work to do to increase the percentage of the electrified system. Of the total electrified systems, 36% of it use 660 V or 750 V while the remaining 64% use 25 Kv 50 Hz AC. GB has a plan to electrify 11,700 single-track kilometers and replace 3,600 Km of diesel by using batteries and hydrogen by 2050 [3].

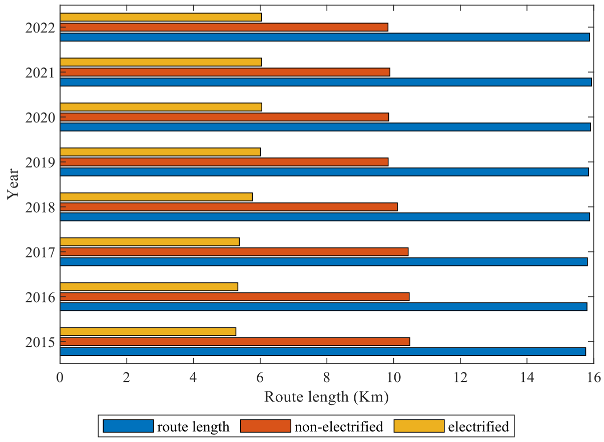

Fig. 2: Railway electrification of Great Britain.

GB has the largest 3^{rd} rail system which is electrified using a 750 V DC system due to its cheap price. However, this system is very dangerous for humans, easily affected by floods and it needs more substations within a short distance. 3^{rd} rail electrification has eight times fatalities compared to the equivalent 25 Kv overhead electrification system [4]. In GB, the rail gauge (track width) is the same as the other European countries which is 1435 mm while for the Ukrainian railway, it is 1520 mm.

III. Signalling Systems

Train detection highly depends on the interaction with the electrification system. Based on this interaction, problems due to conducted or radiated EMI, incompatibility of the selected track circuit with the type of traction arrangement, and other similar issues can affect the train operation [5].

The use of running rails of the track circuit for signalling can create a coupling path between the interference source and signalling system. Train detection mechanism is mostly done either using track circuits or axle counters in most countries including UK and Ukraine. Compared to other electronic safety devices, track circuits have a high failure rate [6]. In GB, the DC track circuit was commonly used and are replacing by modern axle counters nowadays due to their benefits. In Ukraine, an audio frequency track circuit is commonly used and this system can be easily affected by the interference from the traction current [7].

The replacement of track-side signalling devices by modern in-cab computer displays is implementing in GB while most of the Ukrainian railway system uses track-side signalling. In GB, an old analogue-based radio-signaller communication is replacing by the digital one but the Ukrainian railway systems use mostly the analogue systems.

IV. Railway electrification - EMC perspective

All electrical, electronics, telecommunication, and ICT systems of the railway system have to operate based on the EMC Directive 2004/108/EC. Due to the complexity and dynamics of the railway system, it is not possible to totally eliminate the EMC problems rather than reducing them to acceptable values. Some of the common sources of EMI in railway systems are rolling stock, railway infrastructure, external to the railway and natural phenomena [8].

One of the main systems in the railway is the track circuit. This system has to function properly to reduce signalling system malfunctioning. However, the track circuit is commonly affected by the EMI of the traction supply system (harmonics of the power electronic devices and the overhead lines), nearby power lines, failure of electric contact systems such as pantograph arcing, and lightning. Therefore, EMI-reducing techniques have to be considered during the design and selection phase of the track circuit. The axle counter is less susceptible to EMI while the audio frequency track circuit is always susceptible to EMI [9].

V. Conclusion

Railway electrification in Great Britain and Ukraine is still far behind compared to the other European ones. Great Britain is changing the old systems to 25 Kv 50 Hz AC system and replacing the track circuits with axle counters while the Ukrainian railway system uses the audio frequency track circuit which is easily affected by EMI compared to the axle counters.

Based on an EMC perspective, the British railway system is better than Ukraine one due to the implementation of a new signalling system, electrification, rolling stock, and telecom technologies.

References

[1] "Railways," Available at: https://ukraineinvest.gov.ua/industries/infrastructure/railways/ [Accessed: December 12, 2022].

[2] "Rail infrastructure and assets," Available at: https://dataportal.orr.gov.uk/statistics/infrastructure-and-emissions/rail-infrastructure-and-assets/ [Accessed: December 8, 2022].

[3] "electric and hybrid rail technology," https://cdn.coverstand.com/66626/765778/6f040956414a1f17342f71769edba7800e2a1a86.2.pdf, [Accessed: December 12, 2022].

[4] "The third protocol," Available at: https://www.modernrailways.com/article/third-protocol , [Accessed: December 6, 2022].

[5] R. White, L. McCormack, A. Finlayson, and P. Hooper, "Electrical system integration, electromagnetic compatibility (emc) interface management of railway electrification systems," *HKIE Transactions*, vol. 13, no. 1, 2006.

[6] J.-L. Wybo, "Track circuit reliability assessment for preventing railway accidents," *Safety science*, vol. 110, 2018.

[7] I. Saiapina and M. Babaiev, "Reducing noise influence on an audio frequency track circuit," in *MATEC Web of Conferences*, vol. 294. EDP Sciences, 2019.

[8] C. Marshman, "Emc in railways," in *2008 IET Professional Development course on Electric Traction Systems*. IET, 2008.

[9] F. Foley, "The impact of electrification on railway signalling systems," in *5th IET Professional Development Course on Railway Electrification Infrastructure and Systems (REIS 2011)*. IET, 2011.