

Study on the Influence of Electrified Railway Interference on Outdoor Signals under High-speed Rail and Heavy Load Conditions

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Abstract: As an important guarantee for the safety and reliability of the system, the signal anti-jamming of electrified railway has always been an important part of railway signal research. In the high-speed and heavy-load electromagnetic environment, the core signal equipment is also facing greater challenges. Based on the EMC design of high-speed and Heavy-haul Railway Signal system, this paper focuses on the impact of strong EMI on railway signal and protection technology under high-speed and heavy-haul conditions.

1. Introduction

High-speed electrified railway is a huge and complex system. According to the different influencing mechanism, the electromagnetic hazards of high-speed electrified railway on signal system can be divided into four categories: inductive coupling, resistive coupling, capacitive coupling and high-frequency electromagnetic radiation interference. According to the different consequences of electromagnetic hazards, it can be divided into interference effects and dangerous effects. Interference impact refers to the impact that may affect the normal operation of communication signal equipment and lines, and reduce the quality of communication and signal transmission; dangerous impact refers to the impact that may bring dangers and hidden dangers to the safety of people or telecommunication facilities. With the rapid development of high-speed electrified railway, it is urgent and necessary to study the strong electromagnetic interference of traction power supply system, especially traction reflux system, on signal equipment. Especially for the transient electromagnetic effects under the special operating conditions of trains and traction network faults, more attention and in-depth study should be paid.

2. Effect of traction current conductive interference on track circuit

2.1 Influence of traction current harmonic components

Because electric locomotives and EMUs are single-phase non-linear loads with violent fluctuations, the current intake of locomotives is also changing under different conditions such as start-up and brake, and the harmonic current component will also change accordingly. In addition to the influence of large power frequency fundamental wave, the harmonic component of unbalanced traction current will also interfere with the same frequency signal of track circuit. Therefore,

in-band harmonics of signals should also be paid more attention when analyzing the harmonic components of traction current. According to the test and statistical data, the general distribution characteristics of harmonic components are that they decrease with the increase of frequency, so the frequency band of harmonic is relatively small.

2.2 Influence of traction component DC component

According to the time-domain waveform of traction current, besides the harmonic component, there will be obvious DC component in the operation of electric locomotive. In fact, due to the asymmetry of the upper and lower half-waves of the pulse current, the DC component also exists after the Fourier series expansion. The proportion of DC component in traction current can reach the total current. When the unbalanced traction current contains DC component, the magnetic flux density in the ferromagnetic elements such as choke transformer in the track circuit will be remarkably high, and the ferromagnetic saturation phenomenon will be brought quickly, and the inductance will decrease. The wave component will also appear in the secondary winding, which will cause the signal current transmitted in the track circuit to collapse, and in serious cases, the track relay will drop instantaneously. Under the conditions of high-speed railway and heavy-load, the components of traction current conductive interference are complex, not a single power frequency. When it reaches a certain range, it will have a negative impact on signal work, and even cause erroneous actions. Therefore, it is necessary to improve the protection scheme and technology of conductive interference on the basis of the original track circuit.

2.3 Inter-station track circuit interference protection based on impedance matching device

According to the design elements of EMC, it is necessary to suppress electromagnetic interference and improve the performance of the equipment itself. The final effect can be evaluated by the signal-to-interference ratio index. For conductive interference, in the interference source link, on the one hand, the unbalance of track circuit should be reduced, and the harmonic ratio of traction current should be reduced; on the other hand, the key point of reducing coupling is the design of interface link which interferes into signal channel. To reduce the conductive interference power, for track circuit equipment, the unbalanced traction current interference source is close to the ideal current source. The filter should use series resonance tunnelling, and then parallel with the interference source. On the contrary, if parallel resonance circuit is used in series with the interference source, the anti-interference effect is not good. Reducing the amplitude of exciting current of traction coil, the distribution ratio of fundamental wave and harmonic wave in traction current is related to locomotive type, but the dominant component is 50Hz fundamental wave, and power frequency is the main interference energy absorbed by filter. Therefore, a low impedance series resonant circuit is adopted to parallel with the interference source. In the transformer secondary parallel series resonant circuit of impedance matching device, the resonant impedance is very small, but the impedance converted to the traction coil is smaller, which can greatly reduce the excitation current of the traction pool. The secondary is equivalent to short circuit in the limit time, and the unbalanced current of the traction coil is mostly consumed in the series resonant circuit.

3. Influencing factors of in-band harmonic interference

The characteristics of electrified fundamental wave interference are large energy. Time domain filtering can effectively filter out the interference components. In frequency domain, the spectral line has high amplitude and is far from the signal spectrum, which will not affect the discrimination of useful signals. For the in-band harmonic interference which is close to the signal energy, it

cannot be eliminated by time-domain filtering. In frequency-domain processing, because its energy may exceed the signal spectrum line, which cannot be simply distinguished by a single spectrum line, but must consider multiple spectrum lines and their relationship.

3.1 Influencing factors of in-band harmonic interference

The microprocessor-based track circuit uses crystals independent of the power supply frequency as the signal frequency source, that is, the filter passband does not change with the fundamental wave offset, so the harmonic frequency drift may worsen the signal-to-interference ratio. For the given traction current and unbalance coefficient, the corresponding in-band harmonic interference current is shown in Table 1.

Table1. Measured and disturbed current data

Frequency(Hz)	Range (mV)	Proportion (%)	Max current (mA)	Interference current (mA)
1700	9.53	0.74%	1168	594
1750	63.84	4.56%	7771	3886
1950	23.72	1.82%	2094	1454
2000	9.76	0.74%	1192	597
2050	46.93	3.58%	5721	2861
2250	39.67	3.03%	4843	2439

When the out-of-band invitation wave migrates into the passband, it will significantly exceed the reliable working value of the signal current. If two harmonic interferences are considered at the same time, the synthesized harmonic is larger. When there is harmonic offset, the energy of traction current conductive interference may reach or even exceed the signal intensity of track circuit, which causes the signal to be disturbed and drifted away; the position of harmonic in band overlaps or approaches too close to the signal spectrum, which may also destroy the spectrum structure of the signal and cause the wrong decision of signal reception on the ground and locomotive.

3.2 The necessity of studying rail circuit protection against harmonic interference

As the traction current of high-speed railway or locomotive increases under heavy load conditions, the immunity index of the receiver to in-band harmonics also increases. Secondly, the number of carrier frequencies of high-speed railway or heavy-load locomotive is expanded, and the corresponding carrier frequency error requirement is not more than (+0.15Hz), and the modulation frequency error is not more than (+0.03Hz), so the spectral resolution of frequency domain demodulation is more demanded. At the same time, the high-speed railway adopts train control center to code the track circuit, which requires accurate and timely decoding of the modulated signal. The technology of DSP is used in the transmitter and receiver, which creates more basic conditions for the new algorithm of frequency domain processing and the comprehensive analysis of signal and harmonic characteristics. Rational use of these technologies can improve the anti-jamming level of track circuit.

4. The effect of transient high energy interference on outdoor signals

Aiming at the phenomena of insulation joint and rail burning in high-speed railway station, when the voltage at both ends of insulation joint is about 54V and the current is 30A, a weak arc

phenomenon will appear; when the voltage is about 90-100V and the current is about 350A, which corresponds to the power condition, a strong and obvious arc phenomenon will appear. According to the test data, it is confirmed that the insulation joints and rails are burned by the high temperature of the arc, which provides a quantitative basis for the formulation of specific protective measures. The main reasons for the arc are: on the one hand, the rail potential is high under the condition of high-speed railway and the power of motor vehicle is high; on the other hand, the characteristics of the motor vehicle itself and the transient change of the state of the insulation joint through the cut-off point. In order to eliminate arc burning of insulation joint, the cut-off point of traction current should be set reasonably.

5. Conclusions

Based on the EMC design of high-speed and Heavy-haul Railway Signal system, the influence of strong EMI on railway signal and protection technology under high-speed and heavy-haul conditions are mainly studied. The influence of strong electromagnetic interference brought by electrified railways on track circuits and signal cables is studied, mainly aiming at conductive interference of traction current and transient interference of high energy. This paper has a strong engineering background, and designs and implements the anti-traction current interference scheme of track circuit in the station. In addition, the problems of mechanical insulation burning and signal cable burning caused by high energy transient phenomena in high-speed railway stations are studied. It is of guiding significance to clarify the characteristics and mechanism of interference sources in the environment where the equipment is located and to adopt corresponding suppression techniques.

References

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