

ELECTROMAGNETIC COMPATIBILITY OF CONTROL AND MONITORING SENSORS WITH AUTOMATION AND TELEMECHANICS DEVICES

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Abstract. The article discusses issues of ensuring electromagnetic compatibility (EMC) of sensors for monitoring electrical power parameters and battery management systems with railway transport automation and telemechanics devices. The influence of high-frequency interference from inverters, switching processes and pulse sources on the stability of measuring systems is analysed. The parameters of LC filters, general-purpose chokes and precision shunts that ensure compliance with international EMC standards are calculated. Solutions are proposed for protecting DC circuits from impulse overvoltages and ensuring measurement reliability. The results confirm the possibility of improving the reliability of automation and telemechanics devices in complex electromagnetic environments.

Keywords: electromagnetic compatibility, railway transport, PMIC, BMS, LC filter, common mode choke, TVS diodes, shunt.

Introduction. Electromagnetic compatibility (EMC) is one of the key factors determining the reliability of automation and telemechanics devices in railway transport. High-voltage lines, switching processes in AC and DC circuits, inverter converters, and impulse interference from diesel generator sets create a complex electromagnetic environment. Under these conditions, power monitoring sensors (PMIC) and battery management systems (BMS) must be resistant to electromagnetic interference and have minimal levels of their own emissions.

Methods. The research methodology is based on a comprehensive approach that includes both analytical calculations and engineering solutions aimed at ensuring the electromagnetic compatibility of control and monitoring devices. The work involves calculating the parameters of LC filters that suppress high-frequency switching interference characteristic of inverter converters and switching processes in AC circuits. To prevent the spread of electromagnetic interference along signal circuits, galvanic isolation is used in combination with modern digital data interfaces such as RS-485, CAN and Modbus RTU.

Particular attention is paid to modelling the characteristics of common mode chokes, which reduce parasitic radiation currents and radio interference, which is a key condition for the stable operation of automation and telemechanics systems. At the same time, the selection of precision shunt parameters required for high-precision current measurement in battery management systems is justified, taking into account their thermal stability and ability to operate under significant loads. To increase the resistance of equipment to impulse overvoltages in DC circuits, transistors (TVS diodes) are used, the parameters of which comply with the requirements of the international standard EN 61000-4-5.

Solutions. PMICs perform synchronous voltage, current, and power measurement functions in AC circuits. The main aspects of EMC compliance for this class of devices include the use of input LC filters to suppress high-frequency interference from inverters and network switching, the use of galvanic isolation and digital interfaces (RS-485, CAN, Modbus RTU) to prevent interference from spreading to telemechanics systems, and the implementation of common mode current suppression using ferrite core chokes.

For inverters with a switching frequency of $f_{sw}=100$ kHz, attenuation of at least 40 dB must be ensured.

The resonance frequency of the LC filter is determined by the expression:

$$f_c = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

where L is the inductance and C is the capacitance of the filter.

When $L = 1$ mH and $C = 0.47$ μ F:

$$f_c = \frac{1}{2\pi\sqrt{1 \cdot 10^{-3} \cdot 0.47 \cdot 10^{-6}}} \approx 7.3 \text{ kHz}$$

The attenuation at a frequency of 100 kHz will be:

$$A \approx -40 \log_{10} \left(\frac{f_{sw}}{f_c} \right) \approx -40 \cdot \log_{10} \left(\frac{100000}{7340} \right) \approx -45 \text{ dB}. \quad (2)$$

Thus, the selected LC filter provides the required level of high-frequency interference suppression.

A choke with an inductance of $L_{cm}=1$ mH is used to suppress common-mode currents. Inductive resistance at a frequency of 100 kHz:

$$Z_{CM} = 2\pi f L_{CM} = 2\pi \cdot 100000 \cdot 0.001 = 628 \text{ } \Omega \quad (3)$$

This resistance ensures reliable suppression of common mode currents and reduction of electromagnetic radiation in communication lines.

The BMS monitors voltage, current and temperature in DC circuits (12/24/48 V). The following measures are implemented to ensure EMC: the use of transistors (TVS diodes) to protect against impulse overvoltages, the use of shunts with a low temperature coefficient of resistance to measure current, and the shielding and filtering of signal circuits to prevent false alarms.

For a maximum current of $I_{\max}=100$ A and a permissible voltage drop across the shunt of $U_{sh}=50$ mV, the resistance is selected according to the formula:

$$R_{sh} = \frac{U_{sh}}{I_{\max}} = \frac{0.05}{100} = 0.5 \text{ m}\Omega \quad (4)$$

Power dissipation:

$$P = I_{\max}^2 \cdot R_{sh} = 100^2 \cdot 0.0005 = 5W \quad (5)$$

Therefore, a shunt with a power rating of at least 5 W and a four-wire (Kelvin) connection is required.

For a 48 V bus, a transistor with an operating voltage of $U_{\text{standoff}} \approx 58$ V and a breakdown voltage of $U_{br} \approx 64\text{--}70$ V is used, which meets the requirements of the EN 61000-4-5 standard for immunity to impulse noise.

Conclusion. The calculated parameters of filters, chokes, and measuring elements confirm the possibility of ensuring electromagnetic compatibility of control and monitoring sensors with automation and telemechanics devices. The set of proposed solutions improves the system's resistance to electromagnetic interference, ensures the reliable operation of signalling and remote control systems, and lays the

foundation for the introduction of intelligent technologies for managing the energy infrastructure of railway transport.

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