EMC Management of Smoke Detection System for High-speed Train based on Functional Safety

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Abstract. The EMC immunity requirements for smoke detection systems on high-speed trains based on functional safety are presented, and the process of EMC management of safety-related systems is introduced using smoke detection systems as an example.

Keywords: Functional Safety [3], Electromagnetic Compatibility, Smoke Detection System

1. Introduction
Smoke detection system is widely used on rolling stock as an important measure to detect fires on rolling stock, and with the application of a large number of new technologies on rolling stock, the installation of on-board electrical and electronic equipment is becoming more and more dense and complex, and the resulting electromagnetic compatibility issues are becoming more and more prominent. The smoke detection system itself is an electromagnetically sensitive system and is susceptible to interference in the electromagnetic environment on rolling stock, while the smoke detection system is one of the key devices to ensure the safe operation of trains. In high-speed trains, smoke detection system is considered as safety-related system [3], however, there is currently no relevant standard to harmonize EMC with functional safety in the field of rail transportation [1], thus bringing new challenges on how to implement EMC management for safety-related smoke detection system.

Traditionally, EMC and functional safety have developed independently of each other in their respective fields. For rolling stock, the best-known EMC standard is the EN 50121 standard "Railway applications - Electromagnetic compatibility ", but this series of standards does not cover functional safety. The most well-known standard in the field of functional safety is IEC 61508 standards, which is "Functional Safety of electrical/electronic/programmable electronic safety-related systems" and IEC 61508-2 [2] cites IEC 61000-6-2 [8] and other EMC-related standards. In general, the connection on EMC and functional safety is becoming closer and closer, and IEC 61000-1-2, which is "Electromagnetic Compatibility (EMC), Part 1-2:General – Methodology for the achievement of the functional safety of electrical and electronic equipment with regard to electromagnetic phenomena ", provides a method for implementing EMC management involving functional safety, while IEC 61326-3-1 provides the basis for immunity testing of products involving functional safety.
2. EMC test Requirements for Smoke Detection System

2.1. Immunity Test
EN 50121-3-2, which is "Electromagnetic Compatibility for Railway Applications Part 3-2: Equipment on Railway Vehicles", provides the electromagnetic compatibility test items and test level for electrical and electronic equipment applied to the internal environment of rolling stock and the external environment of railway, but for functional safety requirements these requirements are not sufficient. Referring to the IEC 61326-3-1 standard and literature [9], smoke detection system immunity requirements in high-speed trains are proposed, see Table 1.

Table 1. Immunity requirements for smoke detection systems in High-speed Train

| Port                              | Environmental phenomena | EN 50121-3-2:2016[5] | Functional Safety Requirement[6] |
|-----------------------------------|-------------------------|------------------------|----------------------------------|
| Battery referenced ports          | Fast transients         | ±2kV 5/50ns 5kHz Repetition frequency | ±3kV 5/50ns 5kHz Repetition frequency |
|                                   |                        | Performance criteria: A | Performance criteria: DS          |
| Battery referenced ports          | Surges                 | 1.2/50 μs ±2kV 42Ω,0.5 μF line to ground | 1.2/50 μs ±4kV 42Ω,0.5 μF line to ground |
|                                   |                        | ±1kV 42Ω,0.5 μF line to line | ±2kV 42Ω,0.5 μF line to line |
|                                   |                        | Performance criteria: B | Performance criteria: DS          |
| Radio-frequency common mode       | Fast transients         | ±2kV 5/50ns 5kHz Repetition frequency | ±3kV 5/50ns 5kHz Repetition frequency |
|                                   |                        | Performance criteria: A | Performance criteria: DS          |
| Radio-frequency common mode       | Surges                 | No Requirement           | ±4kV 42Ω,0.5 μF line to ground |
|                                   |                        | Performance criteria: DS | Performance criteria: DS          |
| Signal and communication, process measurement and control ports | Radio-frequency common mode | 150kHz~80MHz 10V 80% Amplitude Modulation 1kHz | 150kHz~80MHz 20V [9] 80% Amplitude Modulation 1kHz |
|                                   |                        | Performance criteria: A | Performance criteria: DS          |
| Enclosure ports                   | Electrostatic discharge | ±6kV Contact discharge ±8kV Air discharge | ±8kV Contact discharge ±15kV Air discharge |
|                                   |                        | Performance criteria: B | Performance criteria: DS          |
|                                   | Radio-frequency electromagnetic field | 80MHz~1GHz 20V/m 80% Amplitude Modulation 1kHz | 80MHz~1GHz 40V/m 80% Amplitude Modulation 1kHz |
|                                   |                        | Performance criteria: A | Performance criteria: DS          |
2.2. EMC Criteria for Functional Safety

The EMC criteria used for safety-related systems are different from those used for non-safety-related systems. The criteria applied to non-safety-related systems are described in Table 2, from the standard EN50121-1 "Railway applications - Electromagnetic compatibility - Part 1: General" [4].

| Performance criteria | Performance criteria description |
|----------------------|---------------------------------|
| A                    | The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. |
| B                    | The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. During the test, degradation of performance is however allowed. No change of actual operating state or stored data are allowed. |

Table 2. EMC performance criteria for non-safety related systems

To safety-related smoke detection system, conventional electromagnetic compatibility tests shall be executed in accordance with the requirements of EN 50121 standard, and extra electromagnetic compatibility tests must be performed for safety functions in accordance with the DS performance criteria. The test results need to be based on conventional and extra electromagnetic compatibility. The test is comprehensively evaluated.

| Performance criteria | Performance criteria description |
|----------------------|---------------------------------|
| DS                   | The functions of the EUT intended for safety applications are not affected outside their specification or may be affected temporarily or permanently if the EUT reacts to a disturbance in a way that detectable, defined state or states of the EUT are maintained or achieved within a stated time. Also, destruction of components is allowed if a defined state of the EUT is maintained or achieved within a stated time. |

Table 3. EMC performance criteria for safety-related systems
3. Functional Safety Electromagnetic Compatibility Management

EMC management is the development and implementation of scientific planning, organization and control of EMC activities to achieve EMC requirements. It is the process control of EMC-related content throughout the product life cycle from a system engineering perspective, and its responsibilities are planning, organizing, supervising, controlling and guiding, and the management of all EMC-related activities in the process of R&D and design, production and manufacturing, and use and maintenance.

During the implementation of the project, the person in charge of electromagnetic compatibility organized an electromagnetic compatibility investigation to identify sensitive equipment and interference sources in the rolling stock, and also to identify other railway transportation-related systems. For systems applied to safety-related systems, in addition to improving the immunity test standard, which is significantly higher than the expected electromagnetic environment in which to work, faults and defects that can reasonably be expected throughout the life cycle, such as: The conductive gasket is damaged; failure of surge protection devices etc.. IEC 61000-1-2 provides information on how to consider designing and testing those EMC effects that involve functional safety, see Figure 2:

![Diagram](image-url)
For the smoke detection system of High-speed Train, the impact of electromagnetic interference must be fully considered when performing hazard and risk analysis, and the electromagnetic environment description of railway transportation should be added to the smoke detection system in the safety requirements specification under the guidance of IEC 61000-1-2, the safety functions of the
system and the response to failures or related time constraints are specified. The EMC management and control plan is developed in accordance with IEC 61000-1-2. At the same time, the impact of factors such as the reasonably foreseeable changes in the electromagnetic environment and the aging of smoke detection system products during use must be considered, and described in the product manual and maintenance manual to ensure that electromagnetic protection is ensured through the reasonable use and proper maintenance of the product. Compatibility does not decrease during the life cycle, thus ensuring functional safety.

4. Conclusion
At present, the electromagnetic compatibility management of rolling stock related to functional safety is still in its infancy, and the knowledge of related measures and methods is relatively superficial. Although this paper proposes EMC immunity requirements related to functional safety for smoke detection systems, it still follows the traditional EMC test concept and does not fully consider the factors that different electromagnetic disturbances can occur simultaneously in a real environment [10]. The problem of functional safety and electromagnetic compatibility still needs to be summarized through a lot of practical work, especially the SIL level [1]. The connection between electromagnetic compatibility is an issue that deserves special attention.

References
[1] IEC 61508-1 "Functional Safety of electrical/electronic/programmable electronic safety-related systems Part 1: General requirements"
[2] IEC 61508-2 "Functional Safety of electrical/electronic/programmable electronic safety-related systems Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems"
[3] IEC 61508-4 "Functional Safety of electrical/electronic/programmable electronic safety-related systems Part 4: Definitions and abbreviations"
[4] EN 50121-1, "Railway applications - Electromagnetic compatibility - Part 1: General"
[5] EN 50121-3-2, "Railway applications - Electromagnetic compatibility Part 3-2: Rolling stock - Apparatus"
[6] IEC 61326-3-1 "Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - General industrial applications"
[7] IEC 61000-1-2 "Electromagnetic Compatibility (EMC), Part 1-2: General – Methodology for the achievement of the functional safety of electrical and electronic equipment with regard to electromagnetic phenomena"
[8] IEC 61000-6-2 "Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments"
[9] Ade Ogunsola and Andrea Mariscotti, "Electromagnetic Compatibility in Railways", Springer, 2013, Chapter 5
[10] Keith Armstrong: "EMC for the Functional Safety of Automobiles — Why EMC Testing is Insufficient, and What is Necessary", 2008 IEEE Int’l EMC Symp., Detroit, 18-22 Aug.