Functional safety certification method for in-use escalators

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Abstract—As an emerging technology, functional safety technology has been widely used in escalators. In this article, the background and application of functional safety are briefly introduced, the definition of functional safety is given, and the method of documenting functional safety certification is a very effective and simple method, and the specific application of escalators in use is proposed. By providing reasonable safety certification documents in compliance with the prescribed procedures, risks can be effectively reduced, and the overall safety and reliability of the escalator can be improved. The content, scope, and development procedures of the escalator safety function certification document and the on-site verification of the escalator safety function were discussed.

1. INTRODUCTION

The concept of functional safety is proposed to solve the problem of functional safety assurance of complex safety systems [1][2]. Enable manufacturers, users and third-party organizations to coordinate and unify product development, use and certification within a common scientific framework. At the same time, ensure product safety and provide sufficient proof. The concept of functional safety has been proposed for nearly 40 years, but it lacks theoretical basis and quantitative indicators. Multiple safety components with high reliability are often used, resulting in higher costs, but the overall safety has not been improved. In 2000, after the International Electrotechnical Commission promulgated the IEC61508 "Safety Standards for Electrical and Electronic Programmable Electronic Safety Related Systems", the concept of functional safety has been widely used, and safety applications that use safety components to reduce risks include mechanical automation, mining, and petroleum, such as chemical industry and special equipment[3].

As an emerging technology, functional safety technology has been widely used in escalators. Whether it is from a safety point of view or from a cost perspective, in the foreseeable future, more and more safety parts and components using functional safety technology will be used on escalators. It also brings corresponding questions, how to improve the reliability of functional safety components? How to verify that it has played an effective role in the inspection process? Even further consideration, does this part conform to the original intention of design and manufacture? Or is the use of the safety component compliant?

Many of the malfunctions of functional safety equipment are not self-evident and must be regularly tested and maintained to ensure that the functional safety system responds appropriately to actual safety issues. In order to make the safety functions of functional safety components play well, strict inspections by a third party are required. Only through approved safety components can it be proved that it meets the relevant safety requirements and can effectively control risks in the anticipated application. In the audit, different standards are generally followed in different fields, but for functional safety, it mainly includes four aspects of standards [4] [5]. The first is the basic standard of functional safety, the second is the...
relevant electrical machinery standards, and the third is the environment, the fourth is a standard for specific functional requirements. Generally speaking, the certification standards are more complex, and need to be comprehensively weighed in terms of overall cost and safety control [6] [7].

In the field of foreign functional safety, one of the more common methods now is to use safety certification documents for management. The safety certification documents provide the design and operation methods of the equipment, as well as information on the main risk sources of the equipment. Through the safety certification documents, it can be proved that the risk of the design and installation of the equipment has been reduced, and the only reasonable level is maintained as low as possible, so that the safety constraints fully take into account the original design and future engineering modifications.

2. VERIFICATION METHOD OF ESCALATOR SAFETY FUNCTION

In the framework of the existing escalator functional safety theory, the method of document certification is adopted, through the completeness of matching documents, and a number of material certifications, which can better satisfy the proof of the integrity of the safety function in the maintenance link and solve the problem. There is a problem that the completeness of the escalator function cannot provide a valid proof during the use and maintenance link.

2.1. SAFETY FUNCTIONAL INTEGRITY LEVEL OF ESCALATORS

The safety function verification of escalators is inseparable from the PESSRAL/PESSRAE programmable electronic safety circuit device. PESSRAL/PESSRAE refers to programmable electronic safety loop devices used on elevators and escalators or sidewalks. This device is a very important electrical safety device for elevators and escalators. The main function is to detect the dangerous operation of the elevator or escalator and introduce a safe operating state. Most of the important safety components of escalators are equipped with PESSRAE devices, so PESSRAL/PESSRAE devices are very important for escalators, and they are also within the scope of the EU Elevator CE Directive certification [8] [9] [10].

Document 6 stipulates the technical consistency, performance requirements and rationality of the system composed of programmable electronic components and programmable electronic systems used to implement the safety functions of escalators and moving walks [6]. After investigation and research, the distribution of safety functions included in domestic mainstream elevator brands is concentrated in seven items, including overspeed, non-control reversal, working brakes, additional brakes, lack of steps or pedals, speed deviation of handrails, overhaul covers and floor panels. The braking distance exceeds 1.2 times the maximum allowable distance, monitoring, brake state detection, and stopping accidental movement, which are not included in GBT 35850.2-2019 [11].

2.2. Difficulty in verifying the integrity of safety functions during use

In the design and manufacturing stage of the escalator, under the functional safety system, the required reliability index is finally obtained by calculating software, hardware, environment, failure rate and other factors. In the process of using escalators, it is necessary to verify the expected reliability index of design and manufacture. As the units and personnel who use and maintain escalators do not have the ability to calculate functional safety expectations in terms of skills, it is even more difficult to obtain relevant failure rate data. Even under the condition of equipped with automatic monitoring devices, under the framework of existing escalator functional safety, it is difficult to process the obtained data, and it is almost impossible to calculate the functional integrity level.

2.3. Traditional escalator safety inspection

The traditional escalator safety inspection method involves checking the reliability of various safety switches when it comes to specific components. When simulating various safety faults, whether the corresponding safety functions can be realized, such as reporting a fault or stopping the elevator. The functional safety system has relatively high requirements for logic control and corresponding
communication, and even corresponding sensor modules and actuator modules, due to the introduction of more complex control computing units. It is necessary to provide methods for functional verification.

2.4. Safety inspection of escalator function
The realization of functional safety depends on the correct response of the system to the input. The relevant system should be able to perform actions within a specified time, and the reliability should meet the specified response probability. Structurally, the functional integrity related system is divided into three parts: sensor and safety switch sub-module, control system sub-module, and actuator sub-module, and the probability index of the three parts to complete the action is quantified.

For the sensor, it needs to be cleaned regularly and checked for looseness; visually check whether the switch is in good condition, check whether the position of the safety switch is normal, whether the fixing is reliable, whether the switch gap is within the normal range value, and whether the triggered fault information is normal.

For the control system, its safety board and safety actuators are installed in the control cabinet, and the control cabinet needs to be cleaned regularly to check for loose fixation and loose wiring plug-ins. Simulate the occurrence of various safety faults over speed, check whether the system reports corresponding safety faults, and observe whether the fault code displayed by the control cabinet is correct.

For actuators, it mainly performs functional verification of brakes/additional brakes and related circuits, including switch simulation and field function verification.

3. DOCUMENTARY CERTIFICATION METHOD FOR THE FUNCTIONAL SAFETY OF ESCALATORS
As an important part of escalator safety, functional safety includes system safety functions and safety function execution capabilities, corresponding data confirmation and function confirmation two methods.

3.1. Confirmation of functional safety documents
Data confirmation is based on standards and type test reports, a document review method that simplifies the work process. Including the safety integrity of the safety function, the structural constraints of the hardware safety integrity, the target failure quantity of the integrity level (such as PFH, the effective probability of danger per hour), and the review of general measures for design and implementation.

3.1.1. The content and scope of safety certification documents
The scope of the safety certification documents depends on the risk and complexity of the functional safety certification project. Since the type testing organization has controlled the risk in the design and manufacturing process, the risk has been well controlled and the risk level is low. The verification in this aspect only requires a simple and clear document to prove that the existing risk is acceptable
argument. The safety certification documents of type testing institutions have complex functions that need to be verified. According to the author's research, the certification documents are a comprehensive document that includes comprehensive safety verification. Specifically, it includes instructions provided by the manufacturer including assembly, connection, commissioning, maintenance, repair, and functional verification cycles; general requirements for maintenance and repair of functional safety components; maintenance test design requirements and time intervals; other aspects include EMC immunity and Contents such as test level regulations.

The maintenance and testing methods for the functional safety of the escalator in the safety certification documents should conform to the functional safety theory, and refer to the documents provided by the manufacturer to check the various parameters of the equipment, such as failure rate, failure mode and test interval, etc., to check whether it is consistent with the actual situation is similar, or whether it is reasonable. It is necessary to have a sufficient understanding of the entire process operation and hazards, carry out a comprehensive analysis, and also need to cooperate closely with each test link. From the perspective of the safety life cycle, there should be a complete set of detailed system documents, and follow the design process to ensure that there are no omissions and no dead ends. For the use link, a set of documented and auditable design documents must be generated, which can refer to the content of the standard and type test report.

3.1.2. Review and responsibilities of supporting documents
The certification documents need to specify a responsible party responsible for the preparation, maintenance and submission of safety certification documents. As far as we know, the existing elevator maintenance companies and users do not know much about functional safety and safety certification documents, especially the front-line maintenance and safety responsible persons. Therefore, it is necessary for the inspection agency to carry out the certification work. Previously, a simple framework of security certification documents was submitted. As a safety basis, the audit framework usually includes documents such as safety assessment reports, safety certification documents, and the corresponding safety plans and design safety operating specifications of the enterprise should also be attached. The framework of safety certification documents should include summary, introduction, system definition, quality management, safety management, technical safety, and related safety certification documents and conclusions. It specifically includes purpose, description, changes, and functions; brief design, development, and operation process summary; evaluation and review process summary; testing and operation specifications; and a risk list that outlines the current security status. The various versions of the safety certification documents submitted are submitted and controlled by the project management party, and the versions are recorded in the safety plan, and the safety inspection agency reviews and agrees, and the inspection agency also conducts a safety review of these documents.

3.2. On-site verification of functional safety
For the on-site verification of escalator functional safety, the specific items of the escalator safety function project should be combined with the type test report content to check the hardware model and version, the number of parts, brand and model, installation location and other information, including Functional verification of switch simulation and field functional verification, including:
- Sensor, control system, and actuator are checked on site to check the effectiveness of each part of the function;
- After simulating the trigger switch, check whether the brake mechanism can work, and check whether the detection switch is normal;
- When the overspeed protection action occurs, check whether the escalator can effectively stop.

4. Results and discussion
In the actual operation of the functional integrity level, my country adopts the method of type test report in product design and manufacture, and the content of the type test report is more complicated. Institutions engaged in type testing are relatively more professional than users. Therefore, it is necessary
and feasible to adopt the method approved by the type test report and the method proved by the safety document for the results of the type test organization.

Since my country's existing type test report does not specifically list the selection of the device, only the device model is listed in the appendix of the type test report. This part of the content itself is not in the main text, and does appear in the actual use link. It is recommended to add this part of the content in future reports when the company changes the equipment brand and model.

This paper proposes that the functional safety certification document method is a very effective and simple method, and proposes the specific application of this method in public transportation escalators. By providing reasonable safety certification documents, risks can be effectively reduced and the overall safety and reliability of the escalator can be improved.

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