INTEGRAL TESTS OF ELECTROMECHANICAL SYSTEMS IN MOTORWAY TUNNELS

Felder H., Seirer S., Brandenberger+Ruosch Ltd., Switzerland
Heller A., Local Road Agency (vif) of the Canton of Lucerne, Switzerland

ABSTRACT

The reliability of the electromechanical systems on Switzerland’s motorways and in motorway tunnels gets checked periodically on behalf of the Federal Road Agency ASTRA. The Local Road Agency (vif) of the canton of Lucerne developed a very innovative approach with a standardised test procedure for acceptance tests and annual re-tests. Based on a “system function matrix” the number of tests could be minimised and therefore the functional capability of the electromechanical systems – in combination with all integrated systems – could be tested very economically. An especially created database enables systematic and traceable checks of all safety-relevant systems.

Keywords: integration test, acceptance tests, re-tests of tunnel equipment, operational safety of motorways and tunnels, lifecycle of electromechanical systems

1. INTRODUCTION

Due to major accidents involving fires that have occurred in road tunnels over the last few years (Montblanc-, Tauern- and Gotthard Tunnel), the safety of all Swiss motorway tunnels longer than 600 meters were reviewed. Necessary measures for improvement were implemented immediately (signalisation, traffic management system, lighting, ventilation). Apart from the normal maintenance, the Federal Road Agency (ASTRA) has so far been investing some additional CHF 50 million per year.

As part of the project to increase tunnel safety presented here, the canton of Lucerne has commissioned a group of experts with the implementation of the following objectives:

- A systematic, traceable and economical testing method must be developed which allows periodic re-tests of the safety-relevant electromechanical systems on the motorways both during acceptance and operation phases.
- The system documentation must be checked as regards their completeness and correctness.
- The proper work of the systems must be checked in combination with all linked systems and under real operating conditions (as close as possible).
- The standard and alternative data communication path as well as the normal and “standard error conditions” (e.g. power failure) must be verified.
- Errors must be rectified
- Compilation of the project documentation with the support of:
  - Check lists
  - Action plan
  - Final report
  - Test logs
  - To-do lists
  - Final report

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2. **ASSUMPTIONS**

It is assumed that all standard tests like factory tests of the equipment, data-point tests and commissioning were done properly, and all documents are complete and correct. Missing or not standardised documents of older systems were recreated as part of the project, or structured in a standard way.

3. **DEVELOPMENT OF DOCUMENTS AND TOOLS**

3.1. **Detailed description of each tunnel**

In the scope of the project the following documents were developed:

- General project and test documents:
  - Test specification sheet
  - “Function matrix” (overview of linked scenarios)
  - General test specifications (per system as basis for the check lists)
  - Address lists (control center, involved persons, third parties)

- Technical documents (for each tunnel):
  - Technical equipment
  - Emergency plan
  - Room arrangement and location of cubicles
  - Pipe and power line documentation
  - Longitudinal- and cross-sections
  - System documentation and manuals
  - Error messages and alarm lists

**Test description:**

- Test documents (for each tunnel):
  - Test flow chart with detailed timetable
  - Test requirements
  - Check and to-do lists
  - SCADA message logs

- Test reports for all tunnels:
  - Reference to basics
  - Timetable and test overview
  - List of detected failures (pending/rectified)

3.2. **Test data base**

Support by a software tool is a must, as the amount of results provided due to the traceability or surveillance can only be evaluated as required with the help of this tool. To this end, a database with the required recording screens and reports was developed.
The functional range of the software is:

- Table with all data points of the electromechanical systems in road tunnels of the canton of Lucerne (AKS code, name and technical detail information)
- Overview and definition of the general test specifications:
  - Preparation, implementation, final report
  - Assignment of the relevant systems (data points)
  - Qualification and number of staff required, tools required
  - Version management
- Overview and triggering of test requests:
  - Systems to be checked, test group formation
  - Link of the general test specifications to be applied
  - Resource planning
- Recording-tool
- Creating the final report or a pre-report
- To-do management

4. LIMITATION AND SCOPE OF THE TESTS

In addition to the safety-relevant systems of the tunnel, the drainage pumps, the structure (corrosion) as well as the emergency phones on the whole motorway network in the canton Lucerne were also tested.

Safety-relevant in accordance with the project scope are:

- Energy supply
- Emergency lighting
- Traffic management system
- Fire detection and fire alarm systems
- Emergency phones and fire extinguisher
- Break-in FM radio
- Passage lighting
- Ventilation
- Radio system
- Visibility
- Adaptation lighting

4.1. Tested operating modes

A “system function matrix” was defined for the integrated systems. The matrix shows the triggering element (column head), the responding element (line head) and the type of reaction as intersection of column and line. The scenarios generally represent the “normal operation mode”. The necessary tests are based on the intersections in the table. If the test run has been successfully completed, it is reasonable to assume that all involved elements work properly.

4.2. Non-tested operating modes

Preliminary studies have shown that scenarios beyond the “normal operating mode” of the systems are very difficult to test (technical and economical reasons). A sequence of events, even combined with a partial or complete system failure leads to a big number of possible combinations – that means a sharp rise of test-efforts.

Even the case of “normal operation mode” cannot be tested without any limitation. One example is so-called “tunnel red”. The traffic management system is not in the normal operation mode, because the test takes place in the tunnel and therefore a one-lane traffic management or a closed tunnel is necessary.
4.3. Test location

There are two groups of tests: First, tests which take place in the control centers, and second, tests which are carried out in the tunnel – during the latter the whole tunnel, or at least one lane has to be closed for the public traffic.

5. PROCEDURE

5.1. Preparation

The major work in the preparation period is to set the timetable as well as to provide information to all the participants (operating personnel, support personnel, experts and police). For instance, the police needs an advance period of approx. 2 months for their assignment and to prepare the traffic management.

5.2. Test phase

This period includes carrying out the tests based on flow charts and check lists as well as recording the results in a database. A general check of the documents, labelling and systems takes place.

5.3. Closing operations

Elimination of any existing defects with follow-up checks, data-management, devising of the final test report with to-do list and measures as well as check of the processes and check lists should be carried out. Adjustments for future tests are implemented, if required.

6. SCHEDULE

For the tests in the control center, a binding timetable is not necessary. The tests in the tunnel should be carried out at a time of maintenance work (costs, traffic management). This does, however, represent a problem/conflict of interests as regards the various objectives, test performance on one hand, and maintenance on the other side (light, ventilation etc.).

7. TRAFFIC MANAGEMENT SCENARIOS

The different scenarios are based on the traffic density, the type of tunnel and further risk assessments. For the tests in the tunnel, it should be blocked, but in special cases, it is sufficient to block just one lane. In rare cases the side-strip or other blocked areas can be used for the tests.

8. CONCLUSION / ADVANTAGES

Many tunnels in the Canton of Lucerne were designed in the 1970s. The tests showed that some of the electromechanical systems have reached the limit of their service life. It is increasingly important, that periodical tests take place and that an economical test method is available for this purpose. The advantages of the established procedures are: First, a low number of individual tests – even for highly integrated systems – are necessary, second, low efforts to add new tunnels or new tunnel-equipment to the test-procedure, and third, both, periodical as well as acceptance tests can be carried out in a proper way.

9. REFERENCES

Felder H., Brandenberger+Ruoch Ltd., Lucerne; specification sheet of integral test (IGT) of electromechanical systems; 21 January 2004