Fire Lifts, Escalators & Moving Walks Management System (FEMS) in an Airport

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Abstract. In December 2013 the management of the International Airports of Rome (ADR) decided to assign me to project a fire safety system similar to EN 81-73 : 2005[1], for the lifts installed in Leonardo da Vinci Airport of Rome Fiumicino. The specific requirement of the Direction of the airport was to implement a fully automatic system, with no human supervision, to prevent passengers in a lift to be stranded on a floor, or trapped in a lift, where a fire has broken out.

The Direction of ADR added some further specific project requirements:

- The hardware and software of the system was to have “open” architecture
- The system had to be reliable and with a high level of safety;
- Reduce to a minimum the probability of false alarms and safeguard the capability of the system to start with a real fire alarm.

The Satellite terminal G gates were chosen to start the project. Escalators and moving walks (EMWs) have also been included in the system. To reduce the probability of false alarms a 3D simulation model of a map of fire sensors, based on about 1400 sensors in the Terminal and statistical data coming from about 18,000 fire sensors, has been prepared and verified.

The requirements of open hardware (PLCs (Programmable Logic Computers) and electronic equipment) and open software (PLC and SCADA (Supervisory Control And Data Acquisition) software) have been fully accomplished and the system is now operative in the Terminal G gates. ADR management has recently decided to extend the system to the rest of Leonardo da Vinci Airport.

The FEMS project has been recently approved for lifts, escalators and moving walks in public transport by the Italian Ministero delle Infrastrutture e Trasporti (Italian Infrastructures and Transports Authority)

1 INTRODUCTION

Everything started when an external safety audit, conducted at the International Airport of Fiumicino, required a fire safety system that was capable of avoiding an accident similar to that one occurred at Düsseldorf Airport, Germany, in 1996 [2] to be applied to the lifts.

On Thursday 11th April 1996 a massive fire spread in a Terminal of the International Airport of Düsseldorf, Germany, with 17 casualties, 72 injured and hundreds of people with light wounds or symptoms of smoke intoxication.

Seven people died from toxic smoke inhalation in two lifts when they decided to escape from the fire by using the lifts and landed at the ground floor, where the fire had spread.

After this massive fire event several countermeasures were taken to avoid further future similar accidents and the EN 81-73: 2005 harmonised standard was issued to indicate the behaviour of lift units in case of a fire.

The procedure of FEMS for lifts is almost fully conforming to EN 81-73: 2005 and, as a brief reminder, the procedure is as follows:

- if the lift is at a floor with a fire, or it is at a different floor by a safe designated floor (to be specified later), its doors must close and it must reach the designated floor. Once it has arrived at the safe designated floor it opens the doors and stops;
- if the lift is already at the safe designated floor it opens the doors and stops;
- if the lift is travelling to a floor with a fire, or travelling to a different floor by the safe designated floor, it must stop at the first available floor along the path, not open the doors and then travel to the designated floor where it opens the doors and stops.

In all the cases, if the fire alarm has started, the lift does not respond to any call, internal or external, and once stopped at the designated floor it requires a manual reset, by a technician, to resume normal service.

In addition the photocells, or light barriers, that could be affected by smoke are excluded, without excluding the safety contact of the doors or the protective device of the door operator to re-open doors in case of an obstacle.

Practically the only real differences between EN 81-73 : 2005 and the FEMS system are: a special procedure of manual reset, to be performed directly on the controller of the unit by an authorised person, that it is not foreseen in the harmonised standard, and the extension of the system to escalators and moving walks.

The FEMS procedure for escalators and moving walks has been simply defined as follows:

- if the direction of motion of the escalator (moving walk) is in the same direction of the evacuation, in case of a fire, the escalator (moving walk) will continue to work;
- if the direction of motion of the escalator (moving walk) is in the opposite direction of the evacuation, in case of a fire, the escalator (moving walk) will stop.

This could be useful, for example, in case of an underground passage with two parallel escalators running respectively upward and downward. In case of a fire in the lower area of the underground passage the escalator running upward will continue to work while the other escalator will stop, increasing the evacuation route.

The possibility of reversing the direction of motion of EMWs in case of a fire has been carefully examined, but the procedure of an automatic restart in the opposite direction of motion could lead to a potentially dangerous situation for people not conforming to point 1.2.3. of 2006/42/EC Machine Directive.

The safe designated floor is a *variable floor* that is determined automatically by the software in function of floors with a fire alarm.

A priority list of designated floors has been prepared with the cooperation and under the direct control of the Fire and Security Department of the Airport of Rome Fiumicino. Each floor has been assigned a ranking based on a priority list to determine the order of evacuation in case of a fire.

In case of a fire alarm, the FEMS software verifies if the first floor of the priority list is threatened by a fire.

If the first floor of the priority list is free from fire the software automatically assigns it the status of the safe designated floor; otherwise the software verifies the status of the next floor in the ranking, with the same decision procedure.

The procedure stops when the software finds the first floor in the ranking of the priority list that is free of fire and assigns it the status of designated floor.

I have to underline that the above reported procedure could lead to a priority list where *the safest floor is not necessarily the lowest floor.*

For example in a multi-level car park, in some particular cases, the safe designated floor could be the top level floor where we have favourable conditions such as an open-air space, with reduced danger of smoke intoxication, and fire-proof evacuation stairs leading to safe areas outside of the building.

Note: for security reasons some information and constructive details, concerning the airport and equipment installed in the airport of Rome Fiumicino, cannot be disclosed.

2 PROJECT FIRST PHASE

To start this new project the Terminal G Gates (also called Satellite) were chosen for the following simple reasons.

1) The terminal is the newest at the Airport, with a relatively simple architecture and only four levels, defined by altitude above sea level, consisting of one underground level and three different floors as described in table 1.

Table 1 Description of levels of Terminal G Gates

Level	Altitude above sea level [m]	Note on the area
Lower	- 1.90	Restricted area – no landing of lifts or escalators
Airfield	+ 1.80	Restricted area to passengers – machine and power rooms
Intermediate	+ 6.50	Passengers arrival area – shuttle station to Terminal 3
Top	+ 11.00	Departure gates area, duty free shops, shopping centres, restaurants, coffee bars, etc.

2) The fire detection system of the terminal is controlled by one fire central unit (FC 2080 Siemens) connected to about 1400 fire detectors and reporting alarms, failures, etc. to a remote control room, supervised 24 hours a day by an emergency team.

All the fire central units of Fiumicino Airport, included the terminal G gates fire central unit, are connected to a DESIGO™ INSIGHT fire supervision software system provided by Siemens.

In the next two tables, 2 and 3, are details about the distribution and typology of fire detectors.

Table 2 Distribution of fire detectors in Terminal G Gates

Level	Altitude above sea level [m]	Total number of fire detectors per level
Lower	- 1.90	73
Airfield	+ 1.80	391
Intermediate	+ 6.50	548
Top	+ 11.00	388
Total number of fire detectors		1400

Table 3 Typology of fire detectors in Terminal G Gates

Fire detector code	Number of fire detectors per typology	Typology
FDO241	1024	Smoke detector
FDM223	138	Alarm button (type A)
FDT214	40	Thermal detector
FDO221	17	Smoke detector
FDCIO221	112	Control module
FDM221	1	Alarm button (type B)
FDOOT241/8	64	Smoke / Thermal detector
FDOOT241/0	4	Smoke / Thermal detector
Total number of fire detectors	1400	

3) There are only 28 hydraulic lifts and 17 escalators, for a total number of 45 units mainly installed in the terminal by Schindler (in the other airport terminals there are about 270 units), with the following status:

- 12 lifts installed by Schindler with Elettroquadri controller currently connected to FEMS;
- 14 lifts installed by Schindler with Hydroware controller currently connected to FEMS;
- 2 lifts, currently not connected to FEMS, installed by Schindler with controllers to be replaced before the end of 2016 by Elettroquadri controllers;
- 17 escalators (16 Schindler / 1 Paravia), 30° inclination, about 4.50 m rise, connected to FEMS;

for a total of 26 lifts and 17 escalators currently connected to FEMS.

3 OPEN HARDWARE AND SOFTWARE ARCHITECTURE

To accomplish the management requirement, of an open hardware and software architecture, the status of the fire detectors (i.e. : failure, out of order, pre alarm, alarm, etc..) is received *directly* from the fire central unit with a LAN port, through an Ethernet cable, *by-passing* DESIGO™ INSIGHT system, based on the Windows™ NT operating system.

A Siemens NK 8237 [3] gateway has been interposed between the fire central unit and the FEMS system to translate the BACnet [4] Siemens protocol of the fire central unit to a standard protocol (in our case MODBUS™ TCP/IP [5, 6]).

The gateway also has the function of a *safety firewall* against uncontrolled revisions of the configuration of the fire central unit.

With this system it has been possible to receive the status of the fire detectors, in a standard protocol, that can be read by industrial PLCs. In the following table (table 4) it is possible to see an example of some fields contained in one MODBUS™ register of the file, corresponding to a fire detector (Loop 16 / Element 44 / Smoke detector) installed at 6.50m above sea level, translated by the gateway in a CSV (Comma Separated Value) file.

Table 4 Example of a MODBUS™ register of a fire detector

NodeId	MODBUS™ SlaveAddress	ParentDescription	ObjectName	MODBUS ™Table	MODBUS™ BaseAddress	MODBUS ™Address
8373022	2	L16 E44 6D77	FIDEDEGE96453406	WT_LogCh	3000	1398

The MODBUS™ Table field contains a word of 16 bits (0 – 15 bit): WT_LogCh, where if the digital value of bit number 15 is 1, the fire detector is in a fire alarm status.

The master PLC of the FEMS system receives the alarm status from the fire central unit and starts a software procedure that will be detailed later, to determine if it is a real alarm or a false alarm.

If the software procedure determines that we have a real fire alarm it assigns, based on the priority list of the evacuation floors, the safe designated floor and starts the procedure for lifts and escalators that has been described in the previous paragraph.

The master PLC, a model of the Schneider Electric TSXH57XX family, has been programmed with a standard language Unity Pro™ [7] compliant to IEC 61131-3 standard, and connected to lifts and escalators through seven Input / Output modules (I/O) installed in seven different machine rooms at the 1.80 m airfield level.

Each I/O module controls a different cluster of about 6 – 7 units (lifts and escalators) in order to divide the area of the Terminal into seven smaller areas to control all the 26 lifts and 17 escalators.

The controller of each lift, or escalator, is connected to a FEMS customized module (that we define as the FEMS interface) that works as an interface between the unit and the I/O module.

The FEMS interface has been made by Elettroquadri, Hydroware and Schindler on my technical specification and can be reproduced for each unit, (lift, escalator or moving walk) if the complete and updated wiring diagram is available.

In the next figure (Figure 1) it is possible to see an example of a FEMS interface module made by Hydroware for 14 lifts installed in the Terminal.

Figure 1 FEMS interface for Hydroware controllers

The master PLC receives all the signals concerning the status of the unit: moving up, moving down, doors open, door closed, failures, etc., from a specified I/O module through the FEMS interface and sends the commands to the unit, in case of a fire alarm, to the I/O module and then to the FEMS interface, with a two way data communication flow.

Furthermore, the master PLC is reporting all the data (alarms, failures, status of the units) to a SCADA system with software provided by Wonderware Inc. by Schneider Electric.

4 HIGH LEVEL OF SAFETY AND RELIABILITY

The EN 81-73 : 2005 does not require a specified level of safety and reliability but, anyway, the FEMS has been projected and designed with redundancy and reliable components in order to be prepared to meet, for other future projects in the Fiumicino Airport, at least a SIL (Safety Integrated Level) 2 [8] level[1] in some sub-systems.

The current architecture of the FEMS system is:

- two MODBUS™ gateways (master and slave) with the slave gateway in *hot backup;*
- two industrial PLCs (*master and slave in hot backup in order to have a HFT (Hardware Failure Tolerance) ≥ 2*), installed in two machine rooms at about 90 m of distance, connected with fiber optic cable, with the following performance levels [9]:
    - *MTTFd (Mean Time to Dangerous Failure) ≥ 30 years working;*
    - *PFHd < 10-7 (Probability of dangerous failure per hour)*
    - *EN ISO Performance Level e grade (PLe) < 10-7;*

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[1] SIL 2 level is equivalent to probability of failure in the next hour (PFH) < 10^{-6}

- seven I/O modules installed in seven different machine rooms, in order to have a *distributed logic network*, connected in a closed loop. The reason of a *distributed logic network* in closed loop is to reduce the loss of control on the units if one I/O module, or the connection cable, is damaged by a fire or an accident;
- command to stop the unit given with a double contact command (for the lift the command is given only if the PLC receives the confirmation signal, from the unit, that the lift has reached the safe designated floor and has opened the doors);
- a firmware for PLCs *developed for industrial environment* certified IEC 61131;
- a standard protocol (MODBUS™ TCP/IP in this case) with data coming directly from fire unit, *bypassing operating systems Windows NT based*;
- two servers for data recording, connected in hot backup, installed in two different data centers *at a distance of about 5.0 km*, for a crash recovery;
- a UPS (Uninterruptible Power System) installed in a machine room with a minimum *of 60 minutes* of certified power supply, to FEMS apparatus, in case of a black-out.

In addition there is already a project to improve the reliability of the FEMS interface with lifts or escalators with *redundant electronic relays.*

5 REDUCE FALSE ALARMS

There are about 18,000 fire sensors (thermal, smoke, alarm button, thermal/smoke) installed in Fiumicino Airport in terminals, office buildings and airport facilities.

Our records of about 3 years (period 2011 – 2014) report an average of about 200 false alarms per year, with about 1 false alarm every two days.

Unfortunately we do not have *detailed failure analysis* to separate data due to internal causes (failures) or external causes (for example: smoke from kitchens, cigarettes, etc.). Therefore the statistics is (1):

MTBF (parent population) = 365 / 200 = 1.825 days. (1)

From this we can assume, in first approximation, the average life time of a sensor with the following formula (2):

Average life time = (50% Parent population)/false alarms per year = 9000/200 = 45 years. (2)

The above number is in accordance with an average life time of about 50 years of a fire detector (life time derived from the technical data sheets available on the web sites of the main manufacturers of fire sensors).

For Terminal G gates population of fire sensors we can estimate the average number of false alarms with formula (3):

Number of false alarms / years = 700 / 45 = 15.56 false alarms per year. (3)

Hence the probability of a failure in the next hour (PFH) for a fire sensor can be computed with the following formula (4):

$$PFH = 1 / (45 \times 365 \times 8) = 2.54 \times 10^{-6}. \quad (4)$$

The estimate is in accordance with the statistics of the last 4 years with an average of about 12 false fire alarms per year in Terminal G gates.

This means that if we had set the FEMS system to start with only one sensor, in alarm condition, we should expect at least one false alarm per month, and this is absolutely unacceptable for an airport management.

For this reason a matrix, based on the database of fire sensors of the Terminal G gates, has been prepared with the following fields (table 5):

Table 5 Example of records of Terminal G gates fire sensors matrix

ParentDescription	ObjectName	MODBUS™Address	X [m]	Y [m]	z [m]	Typology
L16 E44 6D77	FIDEDEGE96453406	1398	113,26	157,01	6,50	Smoke
L14 E5 2057	FIDEDEGE96454793	1230	82,54	24,09	1,80	Smoke / Thermal
....	…..	….	…	…	…	…

Furthermore a weight (w_i) for each typology of fire detector has been determined in function of the criticality of the detector as reported in the following table (table 6).

Table 6 Criticality weights of fire sensors

Fire sensor	Weight (w_i)
Smoke	0,3
Thermal	0,5
Button	0,2
Smoke / Thermal	0,8

With a computer simulation a certain number of sensors at the same time have been randomly shifted in alarm state and the software has computed the number of times when a determined number (x) of sensors were in alarm inside a circle of a pre-set radius R.

After about 10^7 simulations the following rule, for PLC programming, has been determined to start a FEMS procedure:

IF $\sum_i (w_i) > 1.00$ (threshold value) of fire sensors in alarm status

AND all sensors are inside a 10.00 m radius circle

AND all sensors are at the same z coordinate (same level)

THEN start FEMS procedure

With this rule the probability of a false alarm in the next hour has been computed to be less than 10^{-15} for the distribution of fire sensors of Terminal G gates.

The FEMS system has been recording data from July 2015 and so far no false alarms have been reported.

Furthermore data recorded from the system are used to compute Key Performance Indicators (KPI) of maintenance such as MTBF, MTTR, MTTA, Machine Availability, etc. of the lifts and escalators.

REFERENCES

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[6] TCP/IP – Transmission Control Protocol – DARPA Internet Protocol – September 1981

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[8] IEC EN 61508 – Functional safety of electrical / electronic / programmable electronic safety related systems

[9] ISO EN 13849-1 – Safety of machinery – Safety related parts of control systems – Part 1 General principles for design

BIOGRAPHICAL DETAILS

Giovanni Pappalardo has graduated in Mechanical Engineering in Italy and post-graduated in University of Milano in Production. He has worked for Aerospace and Electronic Industry in Italy before entering Otis Italy in 1991 as Quality Product Manager. Since 2000 he has worked as a project engineer and consultant for Italian Real Estate companies. He is also an external consultant for the Italian National Committee for Maintenance (CNIM), for ANACAM (Italian Association of Lift Companies) and for Aeroporti di Roma S.p.a. (ADR).