Method to Operate a System for Automatic Categorization/Degradation in Low Visibility Operations of an Airport Runway

Pedro Vitor

***Abstract*—**The operation of an airport in low visibility requires complex procedures involving the monitorization of equipment, usually performed manually and named Low Visibility Procedures (LVP). This paper presents a method to operate a system for automatic categorization/degradation in low visibility operations of an airport runway. The method is based on a set of actions that aim to support the airport controllers to facilitate the operational procedures. The real implementation of the method was performed by hardware and software with appropriate redundancies that has been developed, tested, installed, certified and operationalized in Lisbon Airport, proving the utility of the system to improve the safety of an airport.

***Keywords*—**Airport, low visibility, high-availability, runway category, cluster, redundant network, Instrument Landing System (ILS), Low Visibility Procedures (LVP).

I. Introduction

RECENT statistical data show that 62% of aviation accidents involving large aircrafts are caused by human error.

Included in this result are all known factors: failure of training, stress, fatigue, inattention, recklessness, malpractice, negligence, error of judgment, faulty planning, poor supervision, lack of coordination between the crew, communication failure, improper operation of the equipment and others.

The technology has been, over the years, used to replace routine tasks previously performed by humans as a way of minimizing human errors, contributing decisively to increase the safety of air transport.

As example to increase the safety of ground movements in airports it has been defined by ICAO and Eurocontrol the Advanced Surface Movement Guidance and Control System (A-SMGCS) [1]-[3].

To develop the traffic performance of airports was presented a static algorithm to solve the air traffic sequencing problem, determining in real time the optimum operation sequences [4] and looking for an Intelligent Transport System (ITS) was developed a communication scheme for airport service to improve efficiency and security of the airport over-ground traffic [5], [6].

Many contributions to the development of microscopic traffic have been made, with the objective to enhance the air traffic problem, maximizing infrastructures capacity and minimizing delay costs while meeting the goals of the airlines are necessary [4].

Airport risk reduction is one of the key objectives pursued by transport safety policies, that’s a reason for the development of risk assessment applied to airport runways, which becomes an important issue in airports development [7], [8].

The landing operation in the low visibility conditions on an airport is of the most complex one and largest technological involvement, ensuring continuity of airport operation, even in adverse weather conditions, using Instrument Landing System (ILS) and other navigation aids.

Airport runways operate according to weather conditions, status of equipment for landing support and other equipment important on these situations. So runways operate from category one (CAT I) in situations of good visibility up to category three (CAT III) in low visibility situations where the aircraft needs of all means of support to land fully automatically and with maximum safety [9], [10].

The operation of an airport in low visibility conditions requires complex procedures that ensure that there is no fault in the equipment and main systems available in the airport, which are key factors for safe operation. The monitoring of equipment, accompanied by the detection of failures or events that could endanger the operation, are variables that determine the operational categorization/ degradation of the airport runway in low visibility conditions.

The procedures mentioned above are called low visibility procedures (LVP) [9].

The higher is the level of category of operation of an airport runway more is required in the operation of equipment, considering that for each category the equipment and other elements involved must be available and with a certain level of operation. On the other hand, weather conditions define the minimum operating category of the airport runway, i.e. the category has to increase as the weather and visibility conditions worsen.

This work was supported by NAV Portugal, E.P.E. in a project for the development of a Low Visibility Supervision System for the Airport of Lisbon.

Pedro Vitor is with the Electrical and Computer Engineering Department, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais, 1, 1049-001 Lisbon, Portugal (e-mail: pvitor@tecnico.ulisboa.pt).

II. Problem Formulation

Currently the operational procedure for categorization / degradation of a runway is non-automatic, requiring, by the controller, to check the status and other equipment parameters and the analysis of documentation (tables), for him to decide the category level of operation of the airport runway.

This process, using support equipment, is performed manually, so susceptible to human error, and there was not working till now a system that performed these functions automatically.

The implementation of low visibility procedures in an airport with computer support certainly leads to an improvement in security in the airport operation, since it can mitigate some risks due to human intervention.

However it is important that any technological solution to support operations in a sensitive area as the landing in low visibility conditions, that technological solution must comply with very stringent requirements in terms of the quality of the system and with redundancies that must ensure the continuity of operation.

III. Problem Solution

A. Overview

Low Visibility Supervision System (LVSS) comprises a method to operate a system based on a set of equipment and computer programs that monitor the condition of equipment and systems needed in low visibility operations, besides the weather conditions mainly related to aircraft's runway visibility, providing information for airport controllers which category the airport must operate with maximum safety.

It allows the operation of a system that interfaces with different equipment and means; collects and stores information from these systems; processes the information through a management module; and, finally, presents users (controllers and technicians from the airport) relevant information for low visibility operations.

The LVSS system has a modular architecture and fault tolerant, operates in real-time reacting quickly to the different events, the software is based on an open source structure and uses mature and secure technologies.

The technical area of the system is multidisciplinary, comprising electrical engineering, network engineering, computer systems engineering and computer engineering.

B. Method

The method is based on a set of actions as represented in Fig. 1:

a) Monitor of the status of all systems related to low visibility operations and present it in a single screen;
b) Define the appropriate category to the operation of the airport runway;
c) Carry out automatically degradation (lowering) of the category of operation of the runway, if there is degradation in an essential system to the operation in that category;
d) Perform manually categorization (increase) of the category of operation of the runway, if weather conditions require and the critical systems are fully operational, allowing the operator to decide the rise to a new category of operation;
e) Perform manually lowering of the category of operation of the runway, if weather conditions permit and the operator decides to descend to a new category of operation;
f) Uses an application 'Alive' with the purpose to manage the switching between the main servers.

The first action (a) performs status monitoring of all systems related to low visibility operations and presents this information on the same screen in terminals located in the control tower of the airport and elsewhere, also presenting technical information for the technical support of the operation of the airport.

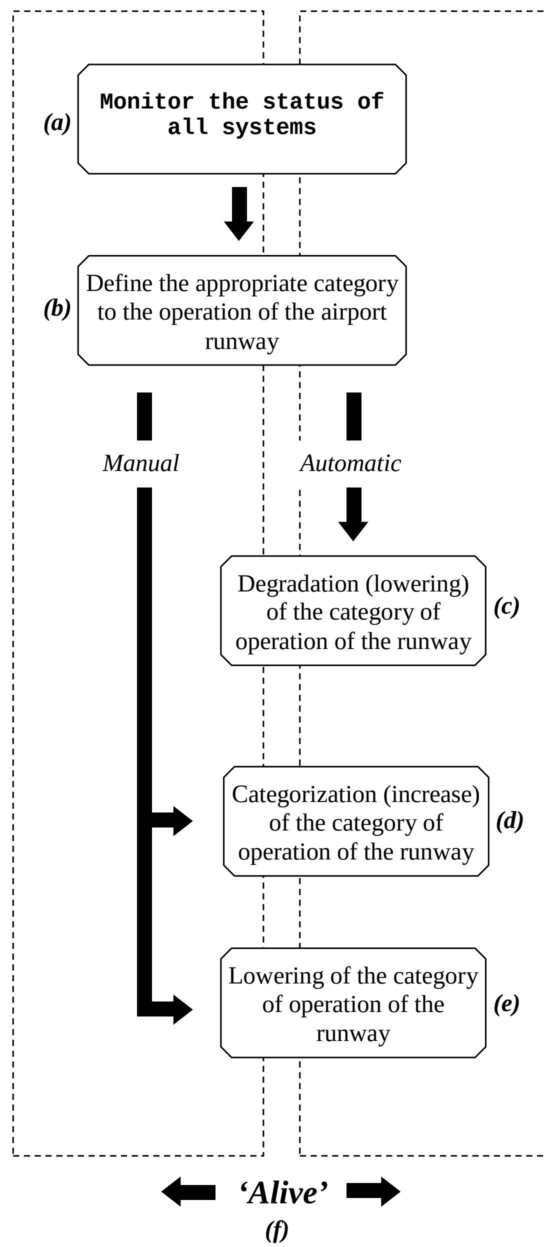

Fig. 1 Set of actions that defines the method.

The second action (b) defines the appropriate category of operation of the airport runway, by a calculation where from the information collected on all systems supporting the low visibility operation, coupled with a set of parameters that characterize the boundary conditions for the categories of operation, determines which category is appropriate to the operation of the airport runway.

The method further comprises three actions (c, d, e) allowing the rise or fall of category. In the event of breakdown of an essential system to the category in operation of runway, is performed automatically the descent of category, as provided in the action (c). If weather conditions require an increase in the category of operation of the airport runway, if the condition of the equipment allows that rise and the operator decides rise the category, at the suggestion of the system, the rise of the category will be carried out manually according to the action (d). If weather conditions are allowing a fall in the category of operation of the airport runway and the operator decides the fall of category, the descent of category will be held in a manual way, according to action (e).

Finally, the method uses an application with the title ‘Alive’ to manage switching between the main servers, which can be performed automatically upon failure of one of the two servers, or manually by operator's decision, according to action (f).

C. Implementation

To implement the method LVSS system uses a set of hardware and software applications, as described in next sections.

C.1. Block diagram

Figure 2 represents the block diagram of LVSS system.

It is composed of three main areas, represented inside the tree dashed rectangles presented in figure 2:

1) Input/Output: Interface with External Systems, e.g. ILS, airport energy, airport lights, radio and navigation aids, using SNMP – Simple Network Management Protocol – or Other protocols. This area is managed by a computer named I/O Server.

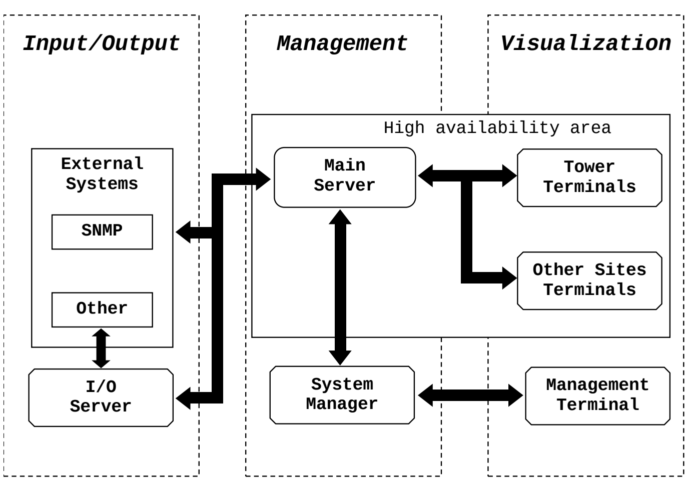

Fig. 2 Block diagram of LVSS system.

2) Management: Responsible for the operational management of the system and its technical management, held respectively by two computers, one designated Main Server and other System Manager.
3) Visualization: Presentation of operational information for controllers using the terminals located in the air traffic control of the airport, called Tower Terminals and installed elsewhere called Other Sites Terminals and presentation of technical information to technical support of the airport on a terminal called a Management Terminal.

The Main Server is responsible for the operational management of the system and for the viewing area which is composed of terminals for air controllers, named Tower Terminals and other type of terminals, named Other Sites Terminals, forming a high availability area using high-performance technology, which is the critical part of the system, that must have the correspondent redundancies in terms of hardware and software.

C.2. Geographical distribution

The system is distributed geographically into four areas (Fig. 3):

1) Equipment room - Place where is installed all equipment associated with the airport air traffic control;
2) Control tower - Airport Control tower where the terminals are installed to give support to air traffic controllers;
3) Other sites - Other sites such as traffic control center, airport operations/ramp control, central fire of the airport and others;
4) Technical management room - Room where is performed the technical monitoring of all equipment associated with the air traffic control of the airport.

These geographical areas are linked through an Ethernet communications network.

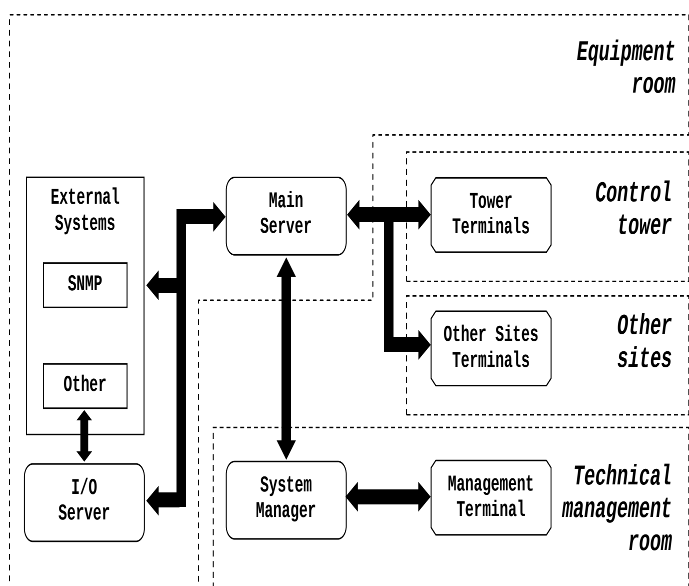

Fig. 3 Geographical areas of LVSS system.

C.3. Equipment room

The Equipment room according to Fig.4, contains:

1) HMI (Human Machine Interface);
2) Main Server that is a cluster of two servers working in a redundant configuration;
3) Printer, mainly to print reports;
4) Serial Ports Server for interfacing with external systems with serial communications protocol (ex. meteorological system, visual aids, energy power of the airport);
5) External Systems with other type of communications protocol, such as SNMP (Simple Network Management Protocol);
6) I/O Server that performs the processing of information from External Systems, located in the Control tower and in the Technical management room;
7) Switch 1 and Switch 2, that are packet switches for networks named ETH1 and ETH2, respectively, used to connect redundantly all the subsystems;
8) Router 1 and Router 2 that are network packets routers used to communicate remotely with the Tower Terminals located in the Control tower, using S.HDSL technology to communicate with the Control tower, using networks named ETH1 and ETH2, respectively.

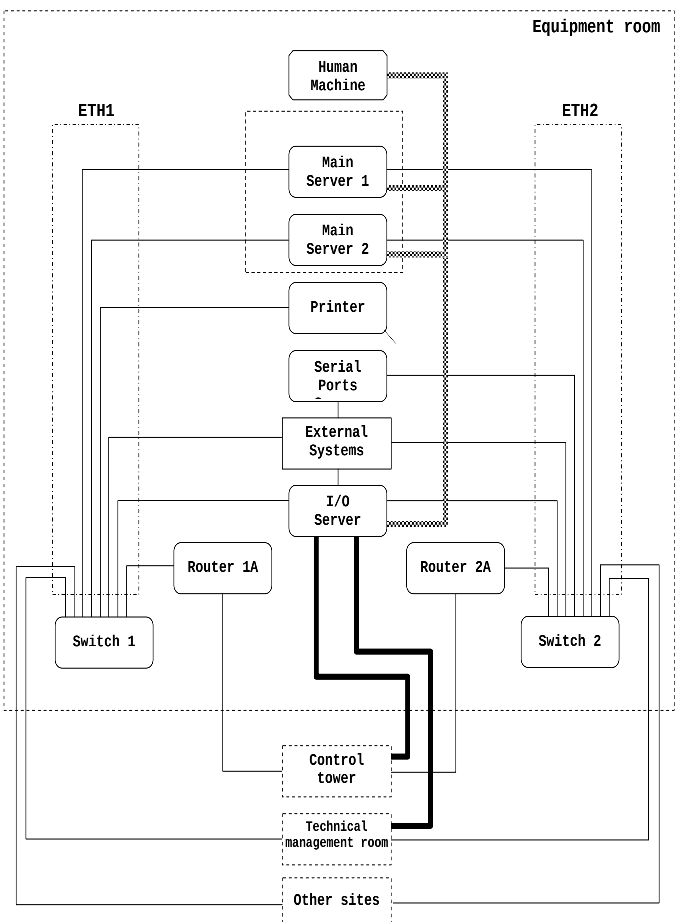

Fig. 4 Hardware in Equipment room

Networks ETH1 and ETH2 are two independent Ethernet networks that operate redundantly, ensuring that if one fails the other ensures communication between the different modules of the system.

C4. Technical management room

The Technical management room, as shown in Fig. 5, contains the following hardware:

1) Technical Terminal that allows operators to visualize information about airport category of operation in resumed form;
2) Printer used to print reports and other information from the System Manager;
3) Management Terminal to display the information from System Manager (monitor, keyboard and mouse);
4) System Manager composed of a server that performs technical management of LVSS system;
5) Category Selector M, located on Technical management room and connected to I/O Server to select the airport category: NO CAT, CAT I, CAT II, CAT IIIA and CAT IIIB;

The printer is connected through ETH1 network, the Technical Terminal is connected through ETH2 network and the System Manager is connected redundantly via the two networks, ETH1 and ETH2.

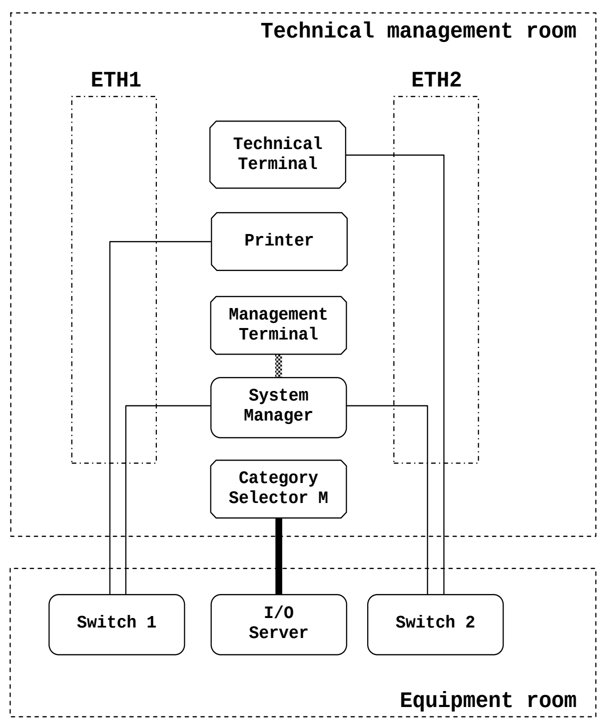

Fig. 5 Hardware in Technical management room

C.5. Control tower

The control tower, as shown in Fig. 6, contains the following hardware:

1) Terminal T1 to TN that allows controllers to visualize the information on the airport category of operation in

summary form and the number of terminals depends on the number of working positions of the control room of the airport and is connected to the Equipment room, alternately using networks ETH1 and ETH2, ensuring redundant links;

2) Routers 1B and 2B, that are network packets routers used to communicate with the servers of LVSS system, using S.HDSL technology to communicate with the Equipment room, extending respectively networks ETH1 and ETH2 to this location;
3) Category Selector T, located on Control tower and connected to I/O Server to select the airport category: NO CAT, CAT I, CAT II, CAT IIIA and CAT IIIB.

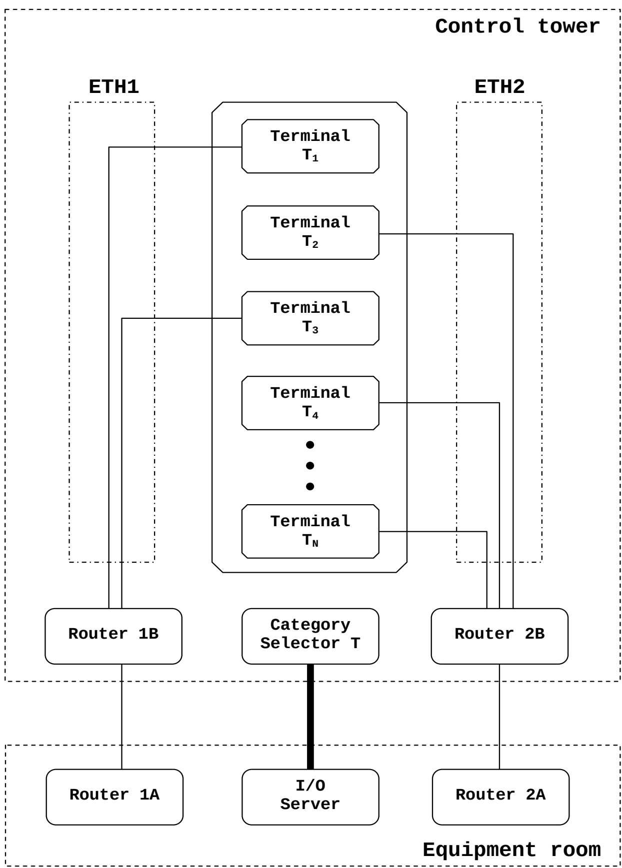

Fig. 6 Hardware in Control tower.

C.6. Other sites

The Other sites, as shown in Fig. 7, are places (besides the control tower) where are located other terminals, such as the operating room for air traffic control, airport operations/ram control, operating room for fire brigade and others, comprising the following hardware:

1) Terminals O1 to ON, that allow the controllers or other operators to visualize information about airport category of operation in summary form, are linked alternately using networks ETH1 and ETH2, ensuring redundant links.

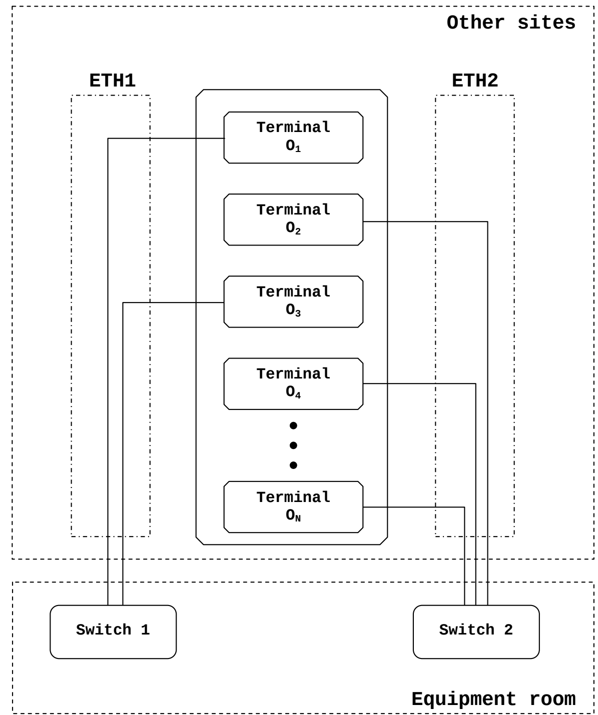

Fig. 7 Hardware in Other sites.

C.7. Network

The Ethernet network is used to communicate between servers and the foreign systems and to ensure redundancy is doubled (ETH1 and ETH2).

The terminals T1 to TN and O1 to ON are connected to this network in such a way that they have redundant links in case of failure of a communication network, there is always one terminal connected through one of the two networks, as illustrated in Fig. 6 (for the terminals Control tower T1 to TN) and Fig. 7 (for terminals Other sites O1 to ON).

C.8. Software

The Main Server is the core processing of all information in LVSS system that is presented to controllers and technical operators. The information comes mainly from External Systems and I/O Server (Fig. 2).

The applications developed for this server are shown in Fig. 8:

1) Alive application - Application that manages the switching between Main Server 1 and Main Server 2. The server operation is referred to as MASTER and the server that is not operational is called SLAVE. The server switching is performed in a manual way or after MASTER server failure;
2) • MainServer application - Processes information from External Systems and I/O Server to perform the following functions:
   2.1 calculate the category of operation of the airport according to the condition of the External Systems required for the operation of airport runway and the settings of LVP system;

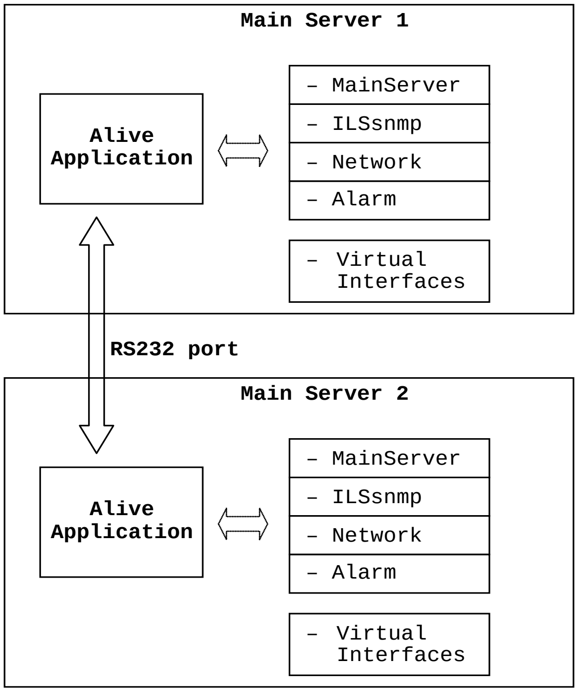

Fig. 8 Main Server Software.

2.2 statistics calculation of operating equipment for the External Systems;
2.3 suggestion for the category of operation of the airport under the atmospheric conditions and settings of LVP system;
2.4 construction of pages to terminals T1 to TN and O1 to ON;

3) • ILSsnmp - Application the interfaces with External Systems, using SNMP (Simple Network Management Protocol) communication protocol for reading the status of the equipment;
4) • Network - application that tests the connectivity of network equipment;
5) • Alarm - Application for the management of alarms.

All servers and computers have installed Linux as operating system, the databases are MySQL and the information of the terminals is obtained via HTTP protocol supported by Apache server software.

The applications have been developed using PERL and PHP languages for the key tasks and using JAVA for the graphical information with detailed status of all systems involved (internal and external), presented on Management Terminal (Fig. 2).

The communication between any element of the system and the Main Server is accomplished through Ethernet TCP/IP communication protocol, called Virtual Interfaces.

For the fastest switching between servers in the event of a fault, the server communication interfaces, on Main Server 1 and Main Server 2, are in operation, while the MASTER server interface is enabled and the SLAVE server interface is disabled.

In case of failure of the server that is in MASTER mode, the server that is in SLAVE mode activates its virtual interfaces, achieving the switch of the servers (SLAVE to MASTER and MASTER to SLAVE) in a short time interval. The server changes from MASTER to SLAVE mode disabling its virtual interfaces.

C.9. 'Alive' application

The 'Alive' application represented in Fig. 8, manages the switching mode of one of the main servers from MASTER to SLAVE mode and the other server from SLAVE to MASTER mode, assuming the last server the operation of the system.

This application runs concurrently on the designated Main Server module comprising two servers - Main Server 1 and Main Server 2, represented in Fig. 4.

The application 'Alive' in the operational server (MASTER mode) initiates the operation of the following applications: MainServer, Network, ILSSnmp and Alarm. Then it activates the Virtual Interfaces. The server that is operating in SLAVE mode the Application 'Alive' stops the operation applications MainServer, ILSsnmp, Network and Alarm, and disables the Virtual Interfaces.

The switching process can be performed manually or automatically. The manual switching is executed by an operator and automatic switching occurs when the server that operates in MASTER mode fails or crashes, the server that is operating in SLAVE mode switches immediately and automatically to MASTER mode of operation.

Figure 9 illustrates the flowchart of 'Alive' application that is responsible to switch the redundant servers (Main Server 1 and Main Server 2) and performs the following steps:

1) Start of application, with implementation of the following:
   1.1 Reading of configuration parameters;
   1.2 If detects no reception of character starts the server as MASTER and if detects the reception character begins as SLAVE;
2) Reading RS232 port, checking the mode of operation of the other server;
3) Tests whether received characters;
4) Tests whether the received signal is a TRAP type;
5) Tests the type of character received: MASTER OR SLAVE;
6) Tests the current mode of the server: MASTER or SLAVE;
7) Switches the server to SLAVE mode: stop the main server applications and disables the Virtual Interfaces;
8) Switches the server to MASTER mode: start the main server applications and activates the Virtual Interfaces;
9) Send character SLAVE by RS232 port, that shall be received by MASTER server;
10) Send character MASTER by RS232 port, that shall be received by SLAVE server;
11) Tests whether a signal received QUIT to exit;
12) Application exits (END).

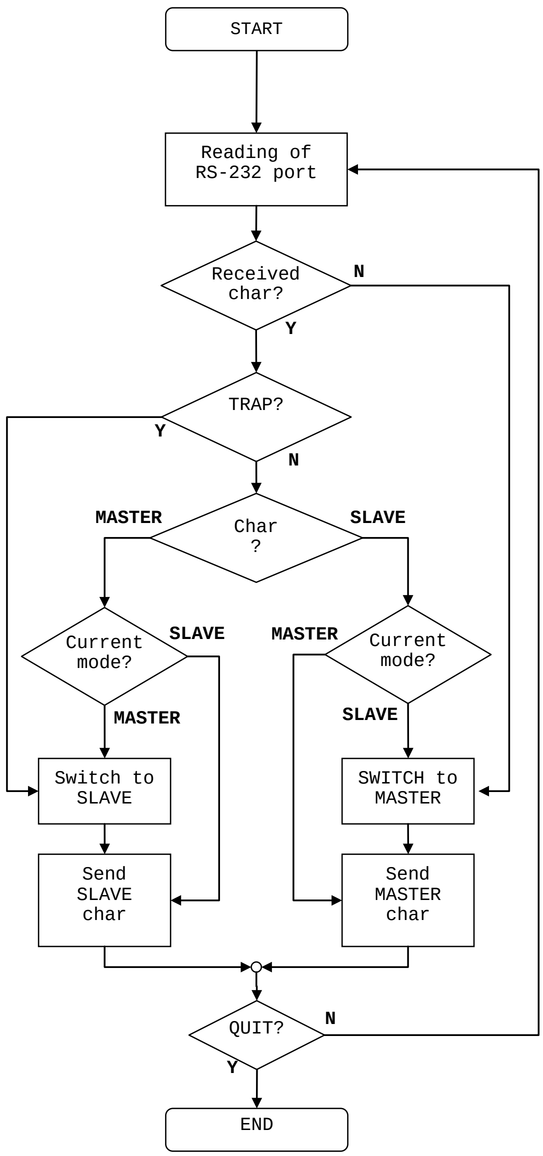

Fig. 9 Flowchart of ‘Alive’ application.

D. *Real implementation and results*

LVSS project has been implemented in Lisbon Airport in a project with the following phases: development, tests, installation, certification and operationalization.

The system is fully operational, certificated for CAT IIIB on runway 21 and CAT I on runway 03 at Lisbon Airport (in future CAT IIIB on runway 03) and had 100% up time, excluding preventive maintenance, demonstrating the high availability for the hardware and software developed.

Since the certification phase all low visibility operations at Lisbon’s Airport have been controlled and monitored by the system, giving a better safety operation for the airport in such conditions.

The great success of LVSS system at Lisbon Airport is expected to be exported for other international airports in Portugal, such as located in Porto and Faro ones, in the near future.

This project is innovative in modern airport concept, considering its high availability structure, the automation of human procedures, the management of information from different types of air traffic control systems (like ILS, visual aids, airport power supply, communications, navigation aids and meteorology) and the quick response to airport controllers in a condensed and precise way, assigning or proposing to controllers the best runway category of operation of airport.

IV. Conclusion

It was described a system, named LVSS (Low Visibility Supervision System), to support air traffic control operation in low visibility conditions for airports, which provides automatically for the operators, in the same screen, status information of the systems required in low visibility operation, meteorological information and runway category of operation, making easier the work of the controller and increasing airport safety.

The method is based on the monitoring of the status of all low visibility operation systems, the calculation of the category more adequate for the operation of the airport runway, the automatic degradation (down grade) when it degrades a key system and the manual upgrade or downgrade of the category by operator decision.

The system has an architecture oriented for high availability with three blocks (Management, Input/Output and Visualization) and uses an application ‘Alive’ that performs quick automatic switching between servers, in case of failure or malfunction of one of them, increasing the availability of the system.

The application ‘Alive’ is responsible for the fast switching of the two redundant servers and is based on a serial channel which keeps signaling between the two servers.

LVSS system has been developed, tested, installed, certified and operationalized in Lisbon Airport, giving an important contribution for the safety of low visibility operations in this airport.

The excellent results obtained in a real implementation, demonstrate the utility of the system and its ability to be exploited in other airports.

Those results can contribute significantly to the safety in critical operations in airports, such as low visibility procedures (LVP).

Acknowledgment

We want to acknowledge NAV Portugal, E.P.E., for the cooperation in the implementation of the project, giving a special support for the certification of LVSS system.

We consider that the participation of Lisbon University (Instituto Superior Técnico) has been a key factor for the technical innovation of the system.

REFERENCES

[1] *Manual of Surface Movement, Guidance and Control Systems (SMGCS)*, International Civil Aviation Organization (ICAO), Doc 9476.

[2] *A-SMGCS Project strategy*, Eurocontrol, September 2003.

[3] Augusto Casaca, Gabriel Pestana, Isabel Rebelo and Tiago Silva, *Airports: Performance, Risks, and Problems, Chapter: A Platform to Increase the Safety of Ground Movements in the Airside Area of Airports*, Pierre B. Larauge and Martin E. Castille Books, 2009.

[4] E. Romano, L. C. Santillo and P. Soppoli, "A static algorithm to solve the air traffic sequencing problem", *WSEAS Transations on Systems*, Issue 6, Volume 7, June 2008, pp. 682-695.

[5] Tomas Zelinka Miroslav Svitek, "Communication scheme for airport service vehicles navigation", *Proceedings of the 11th WSEAS International Conference on Communications*, Agios Nikolaos, Crete Island, Greece, July 26-28, 2007, 228-234.

[6] Tomas Zelinka and Miroslav Svitek, "Identification of Communication Solution designated for Transport Telematic Applications", *WSEAS Transactions on Communications*, Issue 2, Volume 7, February 2008, pp. 114-122.

[7] L. Guerra, T. Murino and E. Romano, "Airport risk assessment: a probabilistic approach", *10th WSEAS Int. Conf. on Automatic Control, Modelling & Simulation (ACMOS'08)*, Istanbul, Turkey, May 27-30, 2008, pp. 359-369.

[8] L. Guerra, T. Murino and E. Romano, "Airport system analysis: a probabilistic risk assessment model", *International Journal of Systems Applications, Engineering & Development*, Issue 2, Volume 2, 2008, pp. 52-65.

[9] *Manual of All Weather Operations*, International Civil Aviation Organization (ICAO), Doc 9365 AN/910, Third Edition – 2013.

[10] *European Guidance Material on all Weather Operations at Aerodromes – Fourth Edition*, International Civil Aviation Organization (ICAO), September 2012.

Pedro Vitor Lisbon, Portugal, 21/2/1960. B.Sc. in Electrical and Computer Engineering, by Instituto Superior Técnico, University of Lisbon, 1983. M.Sc. in Electrical and Computer Engineering, by Instituto Superior Técnico, University of Lisbon, 1986. Ph.D. in Electrical and Computer Engineering, by Instituto Superior Técnico, University of Lisbon, 1993. Major field of study microwave electronics, telecommunications and real time systems.

He is Assistant Professor at Department of Electrical and Computer Engineering, Instituto Superior Técnico, University of Lisbon, since 1993 and CEO of SIRESP company, national operator security end emergency mobile communications operator in Portugal.