

DESIGN OF AN INTEGRATED COMMUNICATION AND CONTROL SYSTEM FOR THE MONITORING AND CONTROL OF GROUPS OF TUNNELS

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Abstract

In order to face the emerging requirements regarding the safety of the users and the flexibility of the management and maintenance, the Swiss Federal Roads Authority, together with the Territory Department of the Canton Ticino in the South of Switzerland, decided to equip its section of the E35 Motorway (130.5 km, 13 tunnels, more than 110 electromechanical installations) with a new communication and control system. This new communication network is based on a physically redundant fibre optic backbone, running along the entire motorway, and on a physically redundant Gigabit-Ethernet network with integrated video and voice services. The new control system is a unique, uniform and flexible information system based on a SCADA and the web technology. The main targets have been the enhancement of the safety of the users, the flexibility of the everyday work of the operators, the standardisation of the information architectures and the easy as well as cost-effective integration of the future installations.

1 Environment of the project

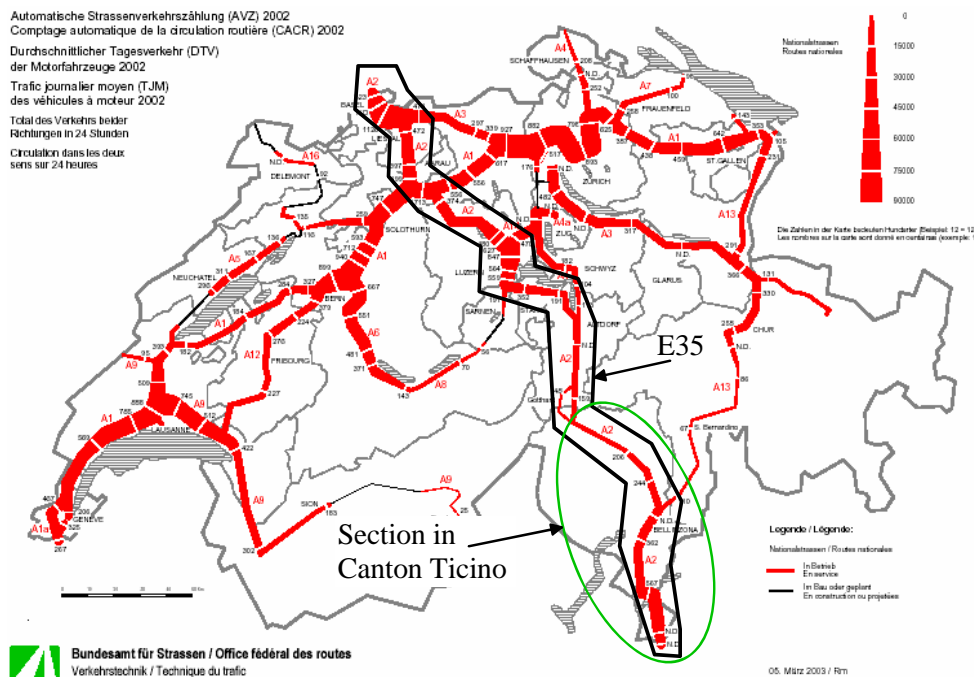


Fig. 1: E35 in Switzerland and its section in the Canton Ticino

The E35 Motorway is one of the most important mobility infrastructures in Europe, going from Amsterdam to Rome, crossing the territory of Switzerland from North to South, with 130.5 km of 285.5 km going through the Canton Ticino, from the southern portal of the Gotthard Tunnel to Chiasso (border to Italy). According to the traffic data from the Swiss Federal Motorways Office, the average of vehicles travelling on this motorway section varies from 206'000 (in the northern, towards

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Gotthard's tunnel) to 567'000 (southern part, near the city of Lugano). On the E35 Motorway in Canton Ticino there are 13 double-pipe tunnels, with a length varying between 200 m and 1600 m. All tunnels are equipped with basic electromechanical installations, such as lighting, traffic control, power supply; most of them have a ventilation installation. In some tunnels and on dangerous open-air parts of the motorway, video-surveillance equipments have been installed in order to keep the traffic under control. The surveillance and the control of the traffic flow and of the tunnel installations are performed by policemen and by employees of the maintenance department in four control centres by the mean of information systems. The tunnels have been built in different periods, for some of them a revamping or a substitution of the old installations has already been carried out. The result is a mix of technological solutions and information systems, which implies problems in terms of different aging periods, different maintenance procedures, increasing need of space in the control centres and dedicated trainings for the operators; moreover the integrations of new equipments in the old information systems has no standard procedures and interfaces, thing that turns out in high integration costs.

2 Existing requirements

In the last past years, the directives of the Swiss Federal Motorway Office have significantly increased the safety level required for the motorway users. This requirement turns out in the need of a more effective predictive and corrective maintenance of the installations as well in the need of a more efficient video-surveillance system for the entire motorway section. Furthermore, the Territory Department of Canton Ticino, which is in charge of the management and the maintenance of the installations on the motorways, is experimenting an increasing demand of a higher flexibility in the every day work: the operators of different control centres must be able to control installations, which are not in their usual intervention area, the complete motorway shall be supervised from a single centre, as well as from different centres. Moreover, to reduce the costs and the complexity of the interventions, the future installations must be integrated in the new control system through "market-standard" interfaces and methods. Finally, a close interaction of the operators in the four centres with the communication and control systems of the northern part of the motorway (in charge also of the Gotthard Tunnel, a vital channel between North and South Europe) will be required in the near future, in order to assure a homogeneous management of the entire motorway on the Swiss territory.

3 The project

The Swiss Federal Motorway Office with the Territory Department of the Canton Ticino decided at the end of 1998 to launch the SGC-A2-TI project. The scope of the project is to equip the motorway in the Canton Ticino section with an integrated communication network for data, video and voice (sub-project RCOM), and with a unique control system of the electromechanical installations in the tunnels and on open-air motorway parts (sub-project SGE). The base infrastructure for these systems is a redundant fibre-optics cabling structure that extends along the whole motorway section (sub-project FO).

The project SGC-A2.-TI is totally performed by IM Maggia Engineering Ltd. and is developed according the SIA108 Norm; it started at the end of 1998 with the first analysis of the actual status, and proceeded with the evaluations of different solutions and costs (1999) and a detail-project phase (2000-2001). The detail-project was accepted in April 2002 by the Swiss Federal Motorway Office and also received the required funds. The tender-phase for sub-project FO started in November 2002,

for sub-projects RCOM and SGE started in July 2003 after a pre-qualification phase of the possible suppliers. By September 2003 the three sub-projects were awarded.

The development and the installation of the fibre-optics have been performed between June 2003 and March 2004. The development and installation of the communication network started in November 2003 and ended in April 2005 with the site acceptance test. The development and installation of the SGE started in November 2003; by now, the 40% of the work has been carried out.

4 Technical solutions

In order to be able to show the technological solutions, it is necessary to introduce the concept of “Object”, by which we intend the group of electromechanical installations, related to a single physical facility of the motorway. Some examples of Object are a tunnel, a group of tunnels, a maintenance centre, and an open-air motorway part. On the motorway section we identified 18 Objects: 9 single-tunnels, 2 groups of tunnels, 4 maintenance centres and 3 open-air motorway parts.

Fibre optic backbone: The base of the communication and control system is the new fibre optic backbone of the whole motorway. This backbone is a passive structure able to assure safety, flexibility and requested bandwidth from the communication and control system.

The motorway has been wired on one side with a ring-structure using 8x12 single-mode fibre optic cables connecting the Objects and the control centres. To enhance the safety-level, a second ring-backbone has been built as a redundancy along the other side of the motorway, partially using the infrastructures of the electricity corporation of the Canton Ticino (AET).

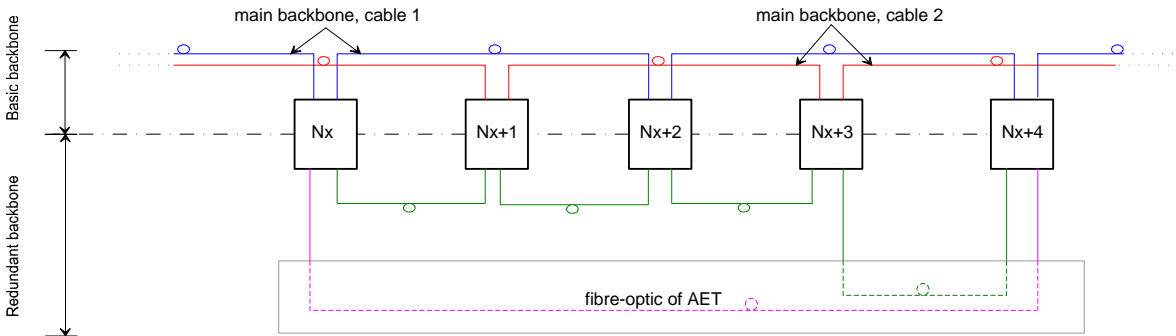


Fig. 2: Structure of the FO backbone, principle

Communication network: The basic requirement for the communication network is to be able to carry the services (data, video and voice) in a sure, accurate and fast way from the Objects to the control centres and vice-versa. Furthermore, it has to ensure the functioning autonomy of each single Object. The communication model of the network has been based on a core (Core network, CN), responsible for the transport of all the services between the Objects and the control centres. The access to the CN is granted through User Access Networks (UAN), allowing the local communication in the facility (Object). The installations of the UN are connected to a Customer Premises Equipment (CPE), which transforms the different services towards standardised interface of the network, in order to grant a homogeneous access to the CN.

The technological solution of the communication network was the choice of Gigabit Ethernet (IEEE802.3z) for the CN and of Fast Ethernet (IEEE802.3u) or Gigabit Ethernet itself for the UANs.

The communication network is built on a node-based structure. Each node is able to integrate locally all the required services; basically a node is placed by each Object. The products used for the nodes are Cisco Catalyst 4507R.

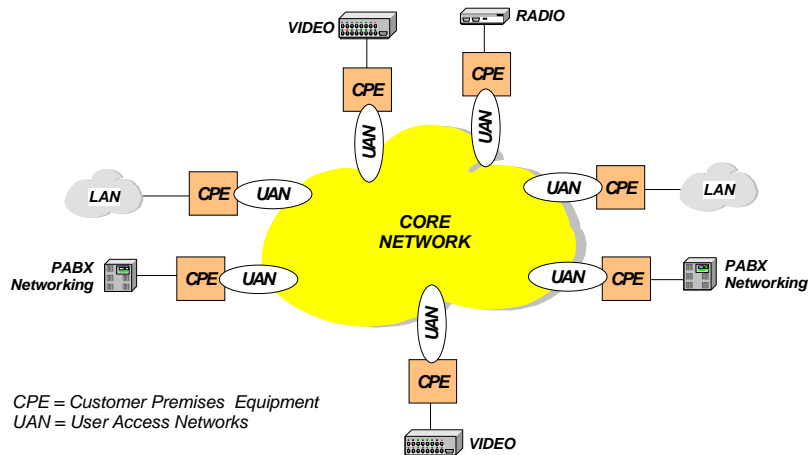


Fig. 3: Model of the communication network

On layer 3 of the ISO/OSI model, the IP protocol allows the transport of data as well as video and voice in a reliable way. The IP mechanisms, which assure the quality of service (QoS) and the bandwidth, are already well established and well known in the IT world.

Main features of the communication network are:

- autonomous and continuous functioning without interventions, fault tolerance through redundancy of the installations;
- possibility to build VLANs in order to separate communication flows in a coherent way;
- dynamic traffic distribution, in order to avoid congestions;
- prioritisation of the different services.

To ensure a high level of safety, the communication network RCOM is a closed network. The access from outside is managed through firewalls and a call-back mechanism to predefined phone numbers.

Control system: Every single Object has been equipped with an own SCADA-based server named GO. The GO is responsible for the local management of the installation of the Object, mainly assuring local safety-reflexes between them, collecting the alarms and the events. The autonomy of an Object is assured by its GO, which also interfaces with the control systems of each installation of the Object.

In order to coordinate the motorway Objects and to present a supervision of the status of the motorway, a higher information level, called the GG level, has been designed. This level is also in charge of other important tasks, such as the storing of the historical data of the entire motorway section in a central database, permitting a statistical data-management by the operators (query of operation hours of a fan, number of faults of each equipment, and so on – the so called “Computer Aided Maintenance”), the management of the users’ profiles shared in the SGE and with the installations, the management of the whole information-system (software updates, system parameterisation) and the simulation of parts of the system for training purposes.

Physically the GG level is built on a double redundant couple of SCADA-based servers, installed in different places, and on a couple of redundant data servers. The two SCADA servers of each couple are in charge, respectively, of the management

of the northern and of the southern part of the motorway section. This assures that four different configurations of the server's status (up/idle) permit the management of the motorway section without interruption. To the GG level belong also the equipments in the control centres, by which the operators perform their tasks. These equipments are, mainly, 13 workplaces (each with two 20" LCD display) distributed in the four control centres, 4 mobile workplaces (laptops) and 1 video-wall consisting in 5 x 3 LCD-DLP rear-projection 50" cubes.

The requirements of having a distribute and flexible access to the system, as well as assuring a cost effective integration of new installations, have been met with the use of the web technology. GG, GO and Control-systems of the new installations are web-server, that is, they "publish" their information in the motorway's intranet.

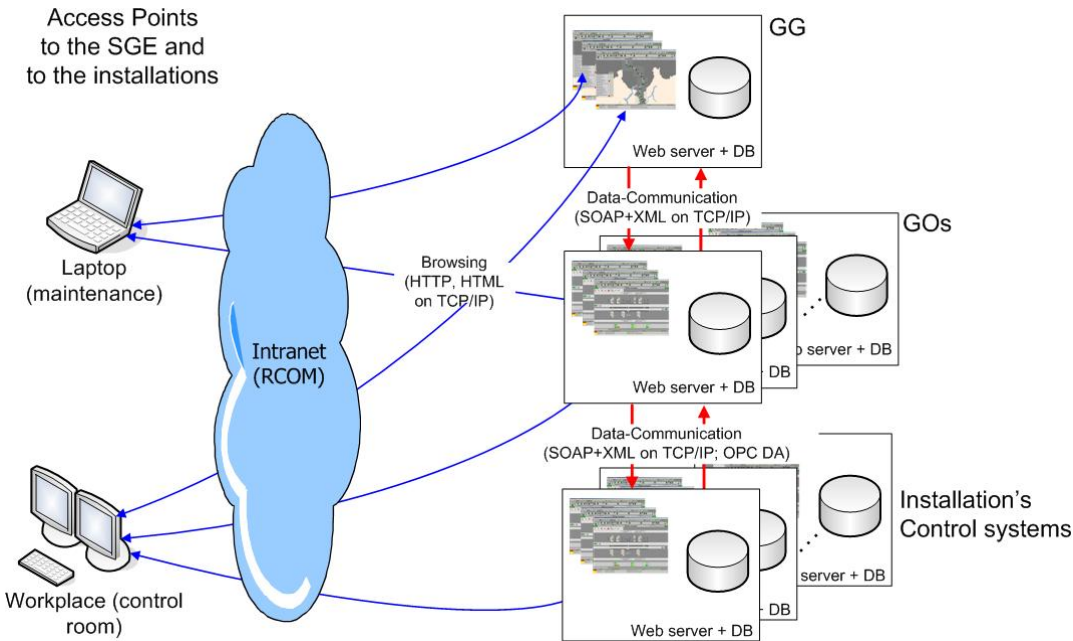


Fig. 4: Distributed-access philosophy

A common detailed "style-guide" for the development of the aspect for the MMI of GG, GO and of each installation's control systems has been defined. Moreover the definition of the users with their rights and settings are managed centrally in the SGE and then distributed to the whole system and to all the installations. This way, the operators "navigate" in a homogeneous environment, reaching the information with the desired precision degree: general information on GG, Object-information on GO, detailed installation information on the control system of the single installation.

One of the most important technological issues that the design and the implementation of such a wide Control System bring along is the interface to the installations' control systems and to the external systems. The case of the SGE is even more complex, as it has not been designed starting from the green field, which is always the happy-days scenario, but as a substitute to a variety of existing systems. This caused the splitting of the problem in two main branches: the interfacing existing installations and the interfacing future installations.

The first part of the problem has been resolved by using hardware and software "gateways" for the translation of the existing protocols and, in some cases, for the direct collection of I/O signals from the installations. The choice for the interfacing of a new installation was a strategic one for the Customer. The selected protocol would have been the communication standard for the whole motorway section in the next

10-15 years. The goals were to select a well-known protocol and to simplify the tasks to the suppliers of the installations, in order to reduce the integration periods and risks, as well as to contain the related costs. Our solution was the implementation of a standard software module loaded on each installation's control system, called MI, which encapsulates the complexity of the interfacing (time-stamping, redundancy management, store&forward, etc.) and offers a very well-known interface to the installation's control system: OPC DA.

5 Conclusion

The major benefits of an integrated solution for the monitoring and control of the installations in groups of tunnels are evident and can be confirmed by the experiences made by IM Maggia Engineering Ltd. in Switzerland with analogue systems in the past years (communication and control systems of Canton Vaud and Canton Fribourg).

The availability of a rational, effective and easily using tool for the surveillance of the installations on the motorway enhances the overall safety of the motorway's users: potential dangerous conditions on the road and in the installations can be detected earlier and removed immediately and an organised predictive-maintenance can be systematically carried out.

The flexibility of such a system allows an effective organisation of the operators in the control centres. The surveillance of thirteen tunnels and of the open-air road is now carried out by four operators in two control centres. The operators are interchangeable and the scope for the surveillance of the centres is configurable according to the different organisational needs.

The choice of well-known and wide-spread technologies assures, on one hand an easy interfacing to similar other systems on motorway sections, as well as of other bodies (Police, media, etc.) and, on the other hand, a "long life" of the system, as the necessary hardware and know-how will be available in the next years (the expected life is 15 years). The use of the web technology assures, on one hand, flexibility and low integration costs, but, on the other hand, requires efforts for the design, the implementation and the maintenance of common communication and MMI standards to be supported from different suppliers, which are also not yet very confident with this technology. The experience made with the SGE says that the web approach, if compared with a traditional SCADA approach, pays off when the number of installations to be integrated in the system is high; this means that a trade-off analysis between the costs of the two different approaches must always be carried out in advance.

The introduction of "standard" interfaces and architectures for the new installations allows their easy and cost effective integration in the system, so that the SGC will also cover in future the complete range of the installations on the motorway.

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7 Abbreviations

FO:	Fibra Ottica (Fibre-Optic)
GG:	Gestione Generale (General Manager)
GO:	Gestione Oggetto (Object's Manager)
IP:	Internet Protocol
MI:	Modulo di Interfaccia (Interface Module)
MMI:	Man-Machine Interface
OPC DA:	OLE for Process Control Data Acquisition (see www.opcfoundation.org)
RCOM:	Rete di COMunicazione (Communication Network)
SCADA:	Supervisory Control and Data Acquisition
SGC:	Sistema di Gestione e Comunicazione (Communication and Control System)
SGC-A2-TI:	SGC of the motorway A2 (=E35) in Canton Ticino
SGE:	Sistema di Gestione (Control System)
SIA:	Società Svizzera degli Ingegneri e degli Architetti (Swiss architects' and engineers' association)
VLAN:	Virtual Local Area Network