THE UPGRADE OF SNAM RETE GAS TELECONTROL SYSTEMS

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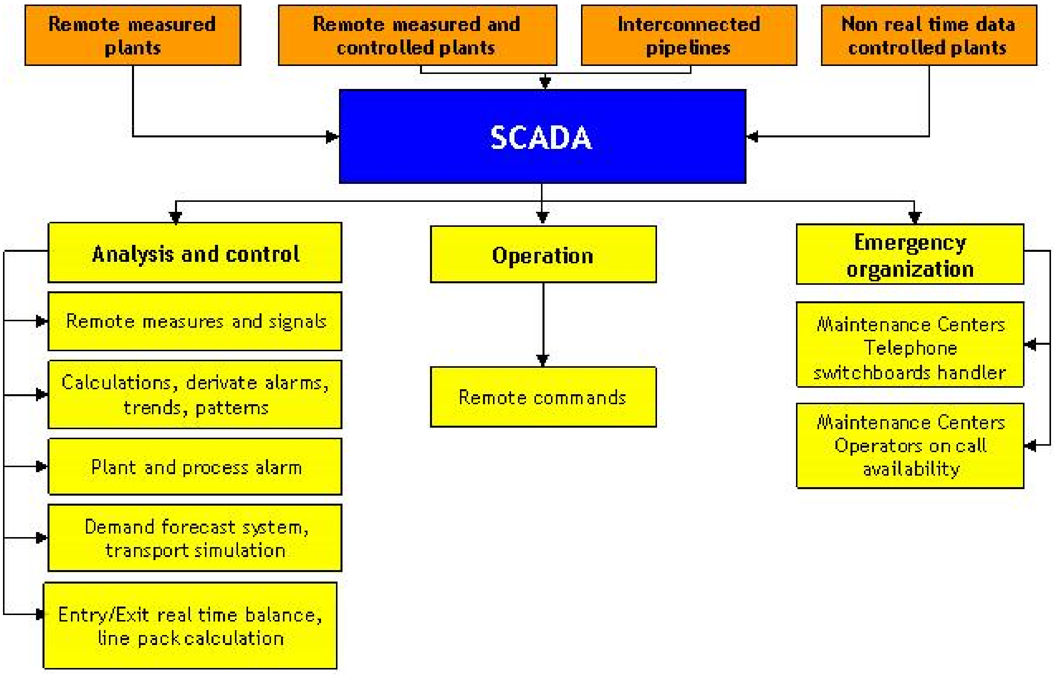
Background

Snam Rete Gas owns and operates the Italian gas transmission network which, with more than 31,000 km of high pressure pipelines, is one of the biggest in Europe.

The Dispatching Center operates and controls the transportation system to ensure its safety, reliability and efficiency through a complex technological architecture, described hereafter. A Supervisory Control and Data Acquisition [SCADA] system is used to ensure the remote control of about 32,000 km of pipeline network all over Italy, with more than 3,000 plants and 11 compressor stations.

The decision to remote control, from a single Control Room located in Milan, the pipelines and the compressor stations, was made by the Company since the 70': this early strategy resulted in the today 12,000 km long copper and optical fibre communication network, built together with the main gas infrastructures and which is almost totally dedicated to the Company's telecommunication needs. Today the SCADA system handles, every minute, more than 25,000 data, coming from both the 80,000 control points related to the gas plants and other 130,000 points, related to the telecommunication system.

In the picture below, a representation of the main functions of the old SCADA.



Nevertheless, in this long span of time, different technologies and solutions have been developed to respond to newly emerging needs, creating quite a multiform and complex technological architecture, composed of remote terminal units, both real time and updated by event, cable telecommunication devices, satellite and microwave routers, front end and back end servers.

The SCADA system became a patch of 5 different software applications, each one governing a part of the whole system: the main SCADA, dedicated to real time controlled plants, the telecommunication [TC] network SCADA, governing all the remote terminal units [RTU] for real time applications, a more recent SCADA for updated by events plants, plus two different software tools used to design and configure the databases.

In this paper we describe the challenge of deciding to utterly move towards a new technology and a new architecture, entrusting a single integrated SCADA system [NSI: new SCADA Integrated] featuring what was featured by 5 different application systems, not perfectly homogenous and developed in different periods of time.

The project had to be timely coordinated with other important activities: the renewal of the Control Room, the replacement of the 1985 synoptic electro-mechanic panel with an electronic videowall based on retro projecting technology and the engagement of distributed intelligence into the TC network, by the insertion of Master Terminal Units [MTU], in order to increase the transmission capacity of the TC network.

Aims

Scope of the project was to replace the existing SCADA system with a new one, integrated in a unique solution, based on a single database [DB], with a homogeneous user interface, leading each basic hardware [HW] component and software [SW] tool to a single infrastructure.

Preliminary specifications of the project were:

- Based on market product: the NSI is a well known, Microsoft based product, which enables an efficient real-time acquisition process with high reliability characteristics;
- Usability: a single application is used by the Control Room, the pipeline network Maintenance Centres and the TC network Supervisors; each User interacts with the same SCADA, but for different purposes and with different data cones and responsibilities;
- Ability to drive a new retro projection video wall, with more than 2,022 real time objects, replacing the 1985 synoptic panel located in the main Control Room.

Constrains to be considered in the engineering phase are as follows:

- No changes to field apparatus, with the only exception for the MTU, the new components (about 200) to be located in strategic positions of the TC network;
- Obligation to maintain continuity of service, during the transition from the old SCADA system to the new one, by keeping the two systems aligned and exchanging data for the whole transition phase, in terms of data received from the field, database configuration and alignment, completeness of data displayed on both the synoptic panel and the videowall, after completion of works;
- Possibility to roll back, during the transition phase, from the new system to the old one, in case of severe problems affecting security of service;
- No need to test all field apparatus after they have been transferred to the new system, thus developing automatic software tools and manual procedures, in order to ensure that the old and the new database are perfectly coincident and that the command and alarm addresses are the same;
- Strong coordination with other ongoing projects: “Videowall”, “Upgrade of Scientific calculation systems” and “Business Continuity and Disaster Recovery”, among which the refurbishment of the Control Room is included;
- High reliability of data transfer, to other internal systems (such as Gas Management System, Transportation Simulation Tool) and to SCADA systems of the other interconnected gas network Operators;
- Full integration with a deep, extensive plan of HW renewal: replacement of front end [FE] servers with protocol handler [PH] servers, use of new intelligent components (the MTU) in the field, to distribute part of the logics of the TC system, therefore generating extra transmission capacity on the TC network.

Scope of the project included, in particular:

- Communication protocols, needed to interface NSI with the real time RTU and updated by event devices into the gas network;
- Functions of data acquisition, elaboration and visualisation, in hot backup modality, for all data (both real time and updated by event) needed by gas network supervisors;
- Functions of data acquisition, elaboration and visualisation, in hot backup modality, for all real time data needed by TC network supervisors;
- Configuration tools, dedicated to definition and update of all the objects being part of the SCADA database;
- Alarms and events handling, historical archives and publication of process data toward external systems/users;

- Tools for creation of trend charts, reports and summaries;
- Draw of the layout to be projected on the videowall and full integration with the videowall control system;
- Software application to be installed on MTU;
- Complete remake of all the layout drawings of old SCADA, adapting and optimising them to new software specifications and characteristics;
- Full integration with other tools used by the Dispatching Center, such as Gas Management System, Transportation Simulator, Process Data Visualize;
- Transmission and reception of process data to/from other SCADA systems of interconnected Operators.

The new system, therefore, integrated in a single SW platform the functionalities to manage the layout drawings and the configuration of plants, and the remote control functionalities in use to both the Control Room supervisors and the TC network supervisors.

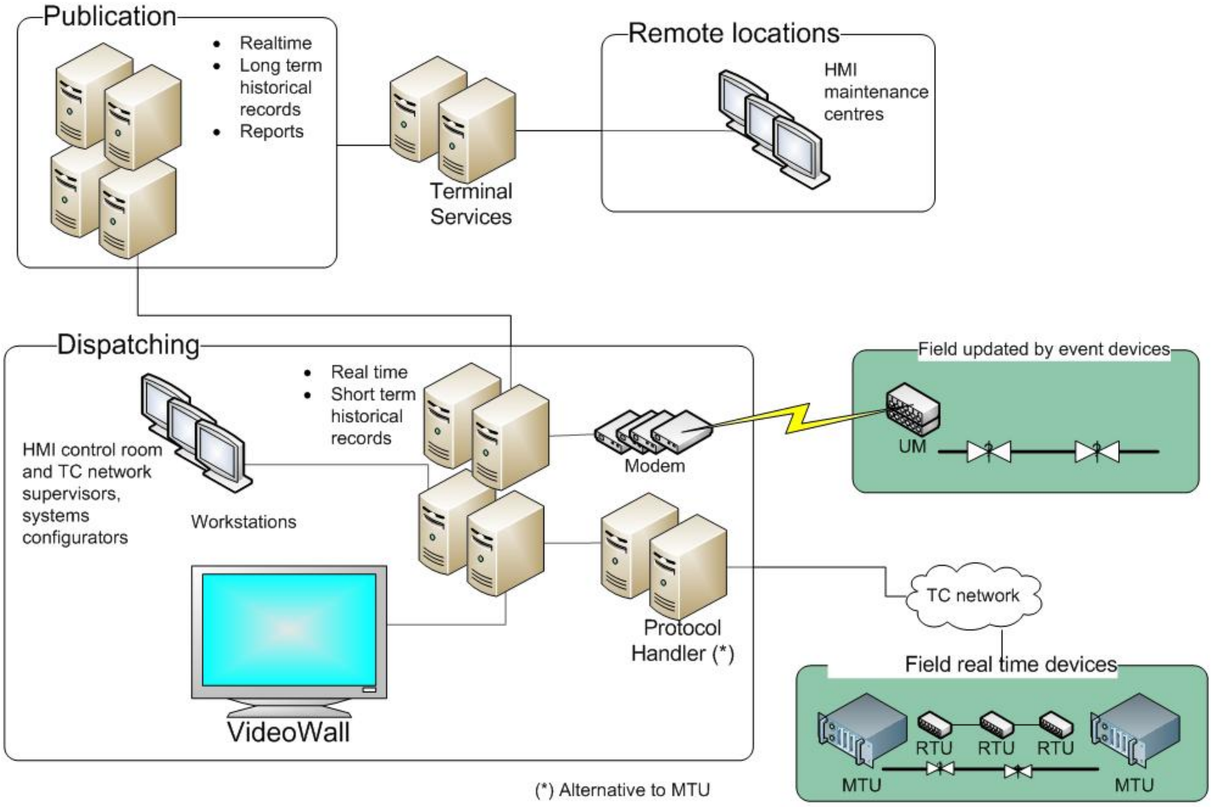
The system is composed by several components, which have allowed, carefully combined and tuned, to build a complete and specialized set of functionalities and profiles for any different system user.

Although the base components of the SW system cover the largest part of the required functionalities, they have been integrated with quite a few custom made components, in order to acknowledge Snam Rete Gas peculiarities, especially regarding communication protocols and TC network supervisory tools.

The NSI system, therefore, clusters all the components needed for connecting with the RTU and supports a number of communication devices, handling all the different transmission modes today used by Snam Rete Gas: Synchronous Digital Hierarchy [SDH] on cables, satellite, microwaves, public switched telephone network [PSTN] and Global System Mobile [GSM] communication.

The native real time component of NSI system dialogues with RTU by using custom SRG protocols and, when necessary, modular protocol translators conveniently implemented in the Protocol Handler system.

The logical architecture of NSI system is represented below:

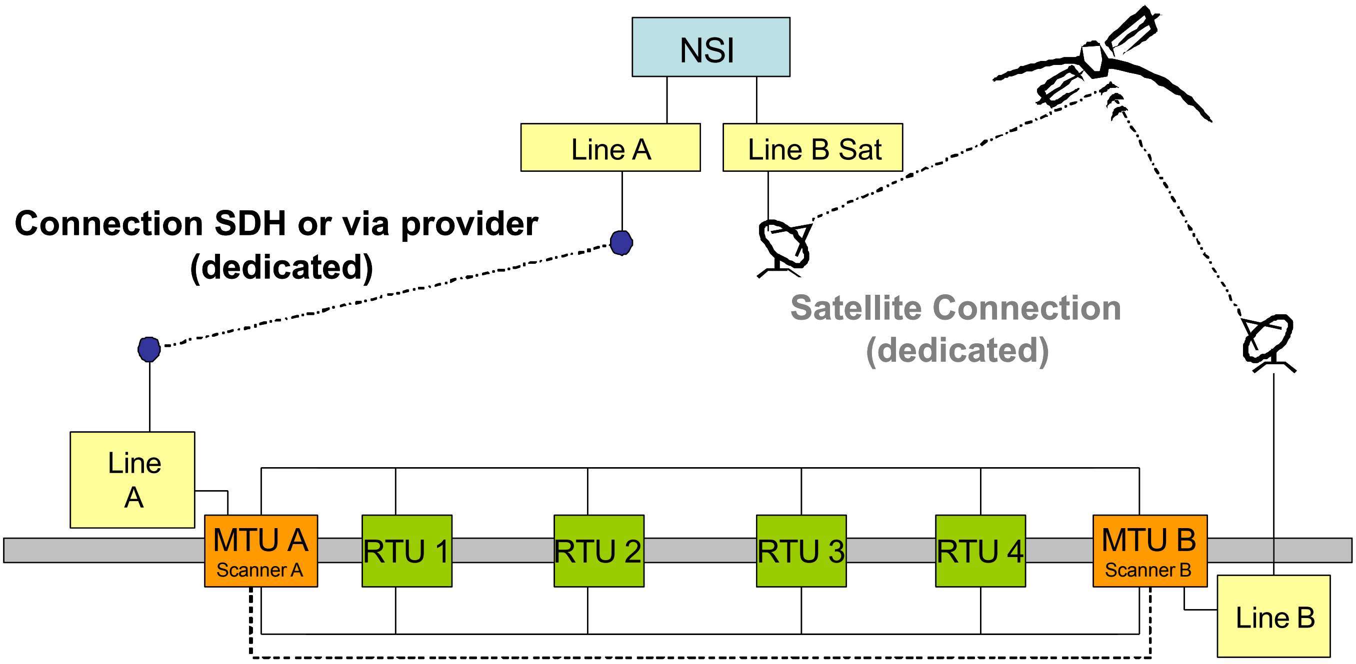


The user stations have been distinguished by role of activity:

- Engineering Station: used for developing layout drawings and distributing them to any other user stations;
- Control Room Station: used by the control room supervisor, to monitor and operate from remote the gas network;
- Decentralised Monitoring Station: used by maintenance personnel to acknowledge maintenance alarms and visualize real time operation;
- Supervisory Station: used by TC network supervisors, to monitor and operate from remote lines and apparatus of TC network.

The widely custom made component for real time TC network, allows the gathering of real time data from the RTU, such as the state of functioning of RTU and TC channels, error codes, etc.

SRG has decided, in the past, to outsource the service of TC network supervision to an external firm, whose supervisors use the SCADA system and coordinate maintenance activities on the TC apparatus and cables.



Methods

Since the beginning a particular care has been given to the design of transition phase from the existing systems to NSI.

The transition phase design took into consideration both the complexity of the architecture and the criticality of the processes involved into the project. It was necessary to define precisely the sequence of actions needed to transfer the control of the apparatus from the existing systems to the NSI, in the same time minimizing the impact on Control Room daily activities and reducing, ideally to zero, any risk for the process during the Commissioning.

The different phases of developing the NSI project have been as follows:

- Transformation analysis: identification of the technical architecture best fitting Snam Rete Gas needs and priorities;
- Architectural design: basic design of technical architecture and identification of strategy to be followed during the transition phase (transition from ‘AS IS’ systems to NSI);
- Feasibility study: production of functional and technical specifications for the cost-benefit analysis and the bidding process;
- Call for tender: with the selection of both the market product and the system integrator;
- Realization: Final Design, Development, Testing and Commissioning of the NSI.

The project master plan

The milestones of the project were:

- Final design
- Development, with a sub-milestone for completion of layout drawings
- Testing (factory tests, functional tests, operation tests)
- Commissioning (production environment readiness, real time and updated by event NSI commissioning)
- Start up technical support and warranty

The project organization

SRG's know how on SCADA systems, built upon two decades of experience in updating and developing its own systems, has allowed to carry out internally the definition of the system's architecture, the feasibility study and the bidding phase.

The project was assigned to a temporary business association, constituted by the supplier of the selected market product and the system integrator.

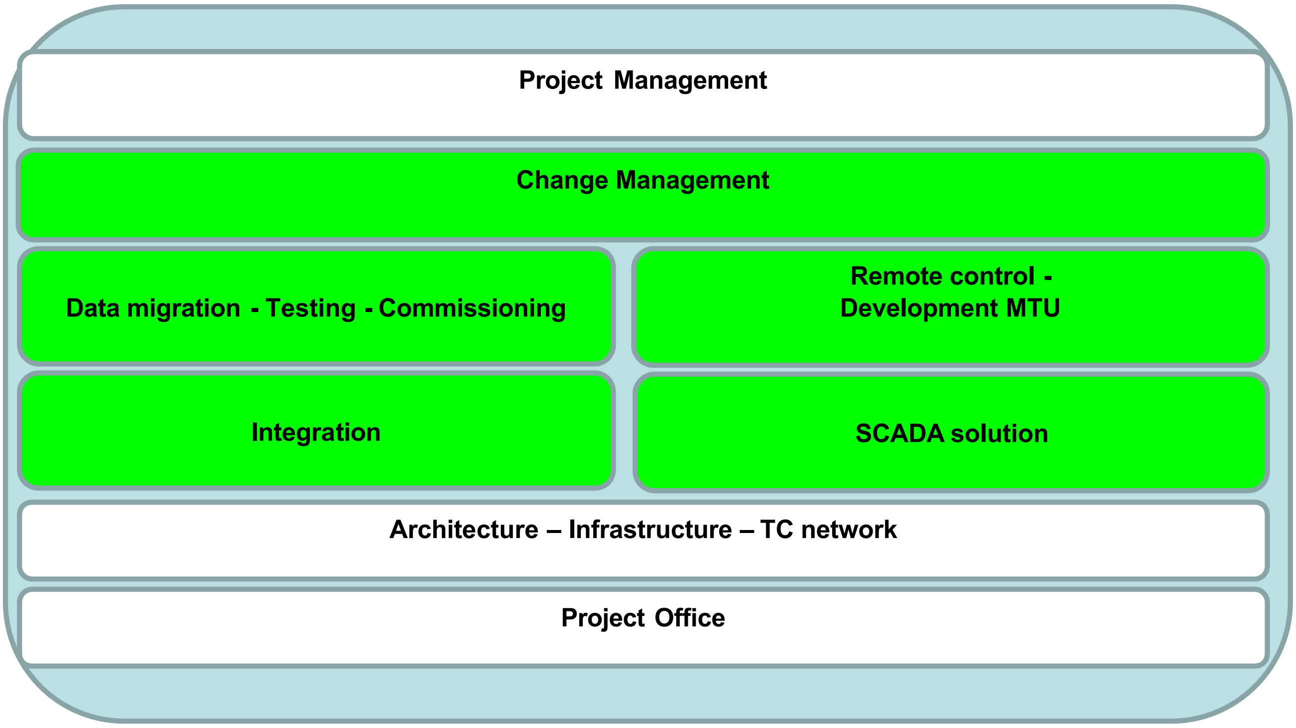
The management of the project has been assigned to a manager within the Dispatching Center organization, with a consolidated personal experience in IT projects.

The project team, on SRG side, is composed by about 25 people, coming from different organizations, but other people have been involved as key users, such as network maintenance technicians, with competencies on instruments and other field devices, TC network supervisors, SW and HW experts.

The SRG team has been supporting the product supplier and system integrator team in developing the final design, by operating in different process sub teams, working independently on the various items under the coordination of the project manager.

SRG people involved into the project were not full time: depending on the different stages, the involvement of internal people has been modulated in terms of expertise and effort, in order to enable the carrying out of other business activities (for example, during the final design only the process owners have been involved, while during the tests and the commissioning many other people have been involved in turn).

In the table below the different areas of activity involved in the project and interested by changes.



Final design

The final design has been carried out by the system integrator and the product supplier, with the support of SRG process owners, with the system integrator carrying out project management and coordination activities.

The design of the functionalities kept into consideration the changes on the process that had been already decided before the bid, but also those arising, as opportunities, during the design itself, as a consequence of the increased knowledge of the product. Some of these new functionalities, or operational modes, have been selected because already in use by other gas transmission operators around the world: this was exactly one of the goal that SRG expected by deciding to go for a market based product.

Before final design phase completion, change requests have been evaluated in terms of contractual consistency, effort and cost, before proceeding with a revision of the contract to formalize them.

Development

The production phase involved the customization of the base product, in terms of developing new parts or adapting existing parts of SW, and integrating them with the standard SW.

The production phase has been entirely carried out in the product supplier's factories, with an involvement of SRG team in factory tests and intermediate verification meetings.

The development phase included the redraw of about 1,600 plant sections (e.g. reduction plants, compressor stations, manifolds etc.) in a new CAD (computer aided design) application. All the new sections had to be connected with the NSI database and finally checked during the functional tests and the commissioning phase.

At the end of the development phase, the system integrator:

- Implemented the SW package into the testing environment, supplied by SRG and located within its own data center;
- Designed the test cases;
- Coordinated and supported the testing activities, carried out by SRG team.

Testing

The testing process has been a very demanding part of the project, not only for the heavy involvement of control room and TC network supervisors, which had to be removed alternatively from the shift duties, but also because during this phase an important fine tuning work had to be carried out on the SW package, in order to meet requirements.

During tests, it became clear the importance to group together into the same place the SW producer, the system integrator and the customer process owner, in order to respond effectively and quickly to the testing outcomes.

Testing phase, because of the corrections and changes that had to be carried out to the SW package, introduced a delay into the project of about six months, resulting in a delay of go live from end of May 2001 to end of November 2011.

The following types of tests have been performed during this phase of the project:

- User functional tests: test of functionalities and other specific issues not covered by factory tests;
- Integration Tests: checking the interfaces with external systems;
- Process tests: checking consistency of SW with SRG operational procedures;
- Data migration tests: checking the tools and the procedures to be used for data migration from the old database to new one;
- Performance test: checking, in a simulated environment, the performance of the system under different stressing conditions (number of simultaneous data variations, terminal server log in, etc.).

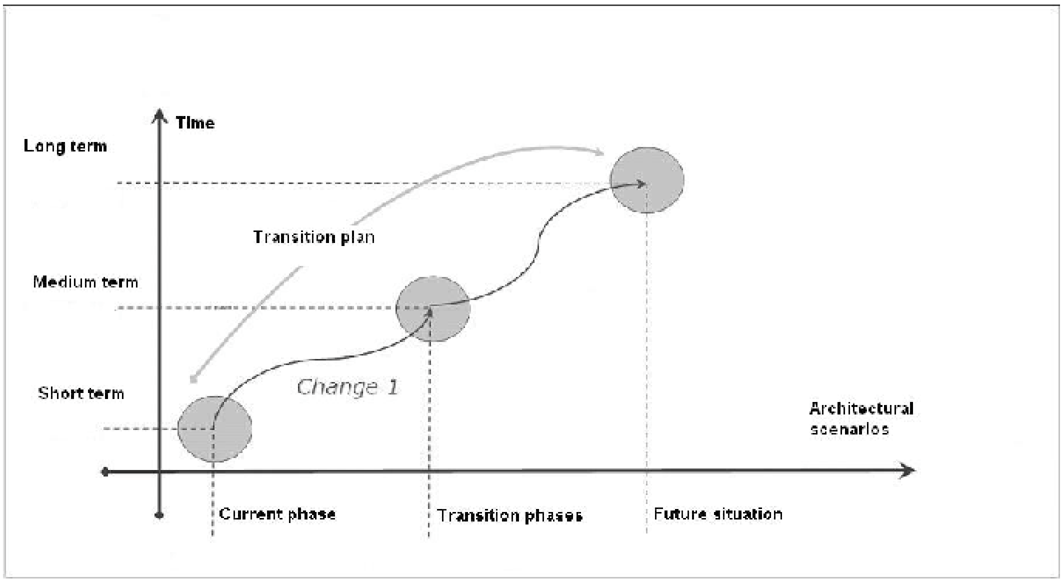
Transition plan

Considering the complexity of the environment (HW components, TC network, field devices, central - peripheral SW systems) affected by the NSI project and taking into consideration the need of business continuity, a particular care to the transition phase has been taken.

To allow the gradual transition toward the new system, a transition plan (i.e.the sequence of activities needed to complete the project through its different stages) has been defined.

During the architectural design a few different strategies emerged. Then, in the feasibility study, through a deep analysis of critical points, the best transition strategy has been defined, consisting in a multiple step process, leading the transition of real time and updated by event network to NSI. The transition plan so defined has been taken as a strong project constrain.

The transition plan detected a few intermediate architectures (architectural scenarios) in order to distribute and balance costs, efforts and benefits in a reasonable span of time.



The guidelines for the transition phase were:

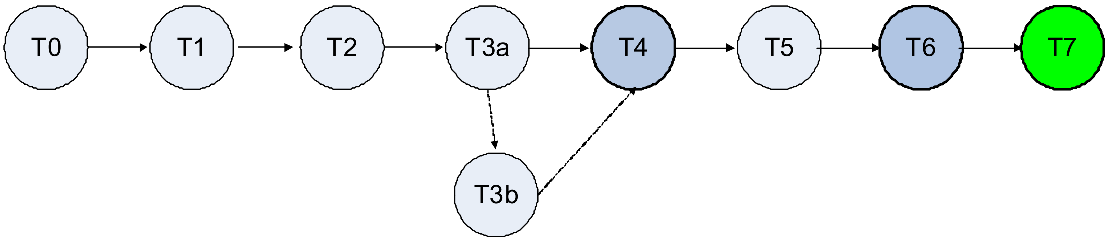
- Real time connection between the new and the old system, in order to visualize all the data on the old synoptic panel and the old SCADA, throughout the whole Commissioning phase;
- Massive data migration from the existing system to the new database, gradual and incremental release of NSI functionalities in the pre-production environment, in parallel with the testing phases and following predefined priorities;
- Real functional testing of NSI with RTU, in the production environment, has not been performed to reduce cost and risks; field testing, during the Commissioning, have been replaced by a series of congruency tests on RTU address and on remote commands, before migration into the NSI;
- The replacement of the existing electromechanical synoptic panel with the new video-wall to be undertaken only after the completion of all transition activities;

The transition plan foresees 7 phases, representing the steps needed to move all RTU and updated by event devices from the old SCADA to NSI.

In each step of the process it had to be defined, for the two systems:

- Configuration status of both systems;
- If and how the two system are exchanging data;
- Which goals are expected, at the end of each phase.

The main phases of the transition are represented as follows:



Synthetic Diagram of transition phases

Phases from T0 to T3a/T3b are related to preparing the production environment.

The construction of the production environment foresees that as new groups of functionalities are tested and accepted, they are moved from testing to production environment, while completing the tests on the other functionality groups, according to a predefined priority order.

The goal is to release the go live moment from the sequence finish test – start production, in order to increase efficiency of the process.

The selection of groups of functionalities, to be moved into production, is crucial for the success of this part of the strategy.

During these phases the following activities are carried out: transfer of selected groups of functionalities into the production environment, test of the interface between the old and the NSI, migration of data from the old database to the new one.

Until phase T3a the new system is not yet connected to field devices (RTU), but it receives data from the old SCADA. In this stage, for example, it is possible to check the correctness of the lay out drawings, in terms of positions and tags of the acquired real time variables (flows, pressures, status, etc.). It is also possible to check the data transfer process between RTU/MTU and the NSI, by means of laboratory tools.

During phase T3b (which has been defined as a spot check) the testing of real time communication between NSI and a few field devices (valves, flow/pressure reduction rate sets, compressor units) is carried out. In these tests, the communication line is moved from the existing front end system to the new protocol handler: doing so, it is possible to check database and communication configuration, in terms of protocols, synchronism and error codes.

At the end of this sequence the production environment is ready to receive field devices (RTU) and the real commissioning can start.

Phase T4 consists of the commissioning phase, which is the migration of all RTU communication line from the old SCADA to the NSI. During this phase, which is extensively described hereinafter, all the interfaces are tested and verified.

Phase T5 identifies the installation of the new videowall system into the control room, after removal of the old synoptic panel.

Phase T6 consists of the commissioning of updated by event field devices, which is carried out massively only when all the other steps and related issues have been completed.

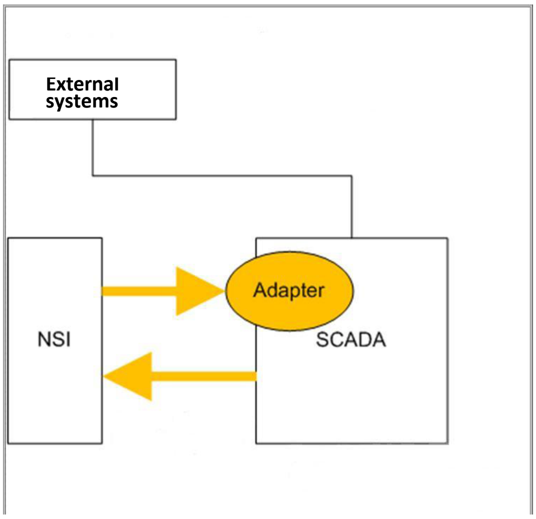
Phase T7 is the decommissioning of the old SCADA and all related HW and SW systems.

The commissioning phase

The commissioning of NSI is, by far, the most critical phase of the project from the point of view of business continuity.

Key factors during the commissioning are:

- Old SCADA and NSI exchanging data between them, by means of an interface (Adapter), for the whole duration of the phase;
- Possibility of roll back option: all RTU already migrated to NSI can be returned to old SCADA, in case of severe malfunctions affecting security of business.



The scenario foresees the following choices to maintain double run and to postpone the updating of external systems interfaces:

- Direct data exchange from SCADA to NSI, for stations not yet migrated to NSI;
- Data exchange from NSI to Adapter, for stations already migrated to NSI;
- External systems fed by SCADA during commissioning.

By using the Adapter and keeping the historical records constantly updated in double run, the option of roll back becomes actually applicable.

Migration of real time devices RTU can be shortly described as follows:

- The minimum entity to be migrated is the drop, which is the group of RTU insisting on the same communication line;
- Number and type of RTU, together with complexity and importance of associated gas plants, are different and the commissioning plan shall keep all these variables into consideration;
- Drops are moving from old SCADA to NSI gradually, with an estimated time effort of about 6/7 months;
- As the commissioning moves forward, the old SCADA will control fewer plants, unlike the NSI which will acquire more and more plants.

The available functionalities for each state, which can be assumed by a drop during the commissioning (remaining in old SCADA or migrated to NSI), are showed in the below picture.

	 **Drop NSI**	 **Drop SCADA**
NSI 	▪ Send out remote commands ▪ Visualizing field measures (HMI) ▪ Visualizing alarms ▪ Modifying alarms runtime ▪ Visualizing measures and alarms on videowall ▪ Dataflow with external system after their adaptation	▪ Visualizing field measures (HMI) ▪ Visualizing measures on videowall ▪ data flow with external systems not yet updated
SCADA 		▪ Send out remote commands ▪ Visualizing field measures (HMI) ▪ Visualizing alarms ▪ Modifying alarms runtime ▪ Visualizing measures and alarms on synoptic panel

The commissioning process is based upon a sequence of checking points, developed with the purpose to ensure that all the remote commands sent by the two SCADA are perfectly equal.

A special procedure has been developed, in order to intercept remote commands sent out by the existing SCADA before their arrival to RTU, which would generate massive unintended changes of state of real time controlled equipments.

A synthetic description of the main check points, to be made on each drop before migration from old SCADA to NSI, is given below.

- Check of configuration: checking NSI configuration parameters, such as supervision, database and communication parameters.
- Check of the communication chain: checking the communication chain linking NSI, protocol handler, RTU.
- Check of measurement acquisition: checking consistency of variables acquisition by old SCADA front end.
- Check of back end: general checks on the back end, before launching remote commands to RTU;
- Check of remote commands sent by old SCADA: remote commands are generated according to a predefined order, which is checked after the commands have been intercepted and recorded within the old SCADA.

- Check of remote commands sent by NSI: remote commands are generated in NSI, according to the same order, recorded and confronted with the list of commands sent by old SCADA. The two lists must be 100% identical in order to transfer the drop from the old SCADA to NSI.
- Check of real time plants migrated to NSI: plants migrated to NSI are made available to control room and TC network supervisors, for visual checks. Any misalignment which might be found at this stage must be promptly resolved, but is not considered a major failure.
- Check of switching to emergency control room: checking that all functionalities are available for migrated plants, also into the emergency control room, which is served by 'hot' stand-by SCADA (both the old SCADA and NSI must be available at the emergency control room).

Migration of updated by event devices, differently from what described above, is done almost simultaneously from the old system to NSI.

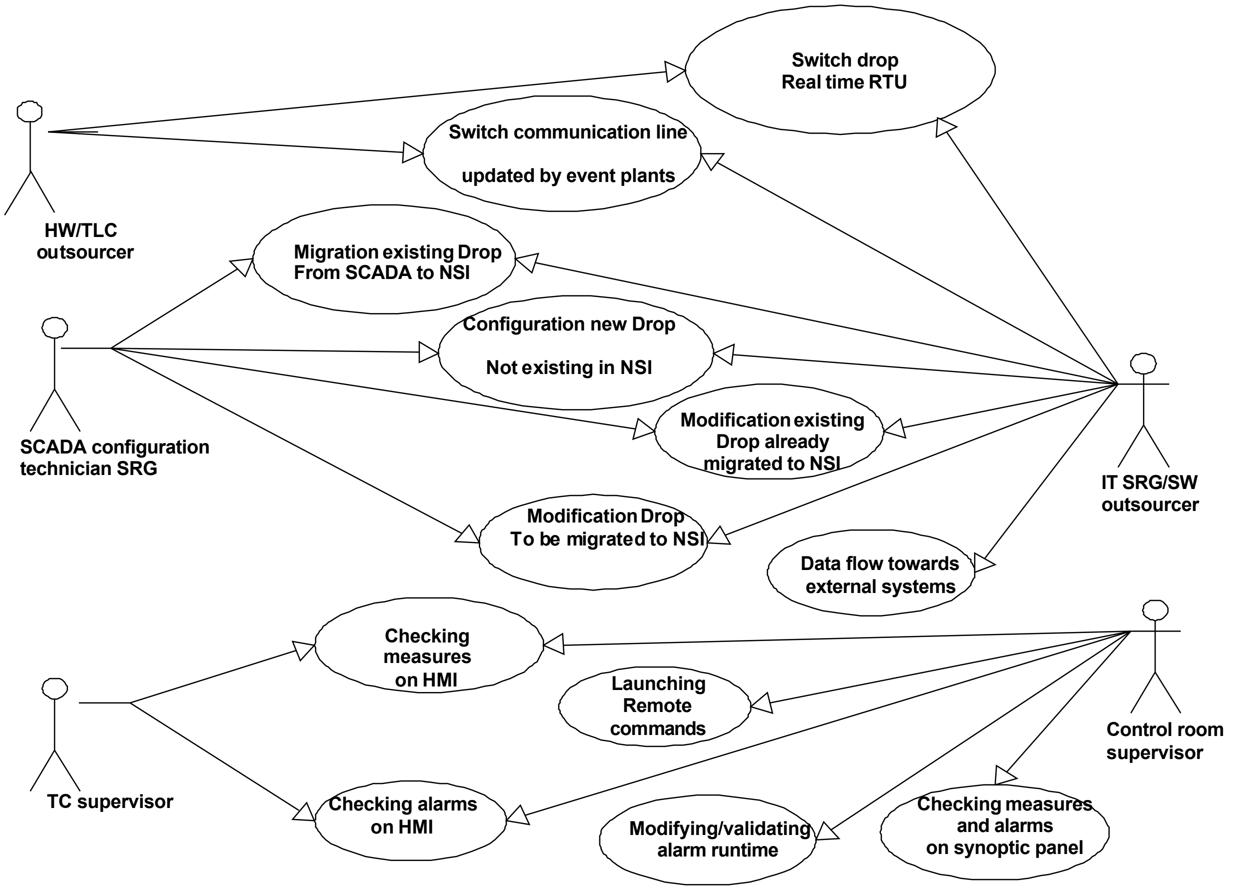
No double run has been planned, in this case, also because the existing system for updated by event plants is different from the real time SCADA and the cost of a brand new adapter was not justified, considering the short time duration (about a week) and the minor priority of the plants.

After the commissioning of updated by event plants is completed, all devices will communicate with NSI and the integration of all the field devices, under a single SCADA, will be realized.

Roles and responsibilities during the commissioning

During the commissioning a team composed by control room supervisors, SCADA configuration technicians, IT technicians, HW TC network supervisors, NSI supplier and system integration project team have been worked together in order to guarantee both progress of commissioning and troubleshooting, facing every issue in a day by day routine.

The following picture tries to illustrate, in a very synthetic pattern, the main roles and responsibilities during the commissioning.



The role of the control room was crucial, both during the testing phase and the commissioning phase: configuring alarm set, performing checks on migrated stations, giving timely feedback for malfunctions or improvements, some of the tasks of control room. This extra job was done by increasing the normal working day duty of control room supervisors.

People working in maintenance centres and in compressor stations have been doing their part of the job in this project, by giving a very important support in testing and confirming equipments status, and by ensuring continuity of operation in a few occasions, when major problems occurred.

Results - Lesson learnt

One of the most important characteristics of this project was the non reproducibility, into the testing environment, of all the scenarios resulting from the complexity of the architecture and from the real functioning of field devices, HW components, SW applications and TC network.

As a result, configuration tuning of the new system into the production environment has been more critical and time demanding than expected, also because massive and automatic configurations not always were available or suggested.

As a matter of fact, the technological gap between the old SCADA and NSI often resulted in need of brand new parameters and objects to be defined and implemented. As an example, the need to redraw all the 1,600 plant section became clear only after the deployment of the SW solution into the testing environment, creating extra work for the team and unplanned costs.

Another crucial point was the planning of real time plants to be migrated into NSI, considering the need to operate with a double running system for quite a long time. The weekly plans of normal gas operations, such as pig inspections, plant and TC network maintenance, testing of real time and TC network devices, were to be carefully analysed before deciding if a certain part of the network could be scheduled for commissioning.

A few problems arouse from the need to redistribute RTU on the TC lines (drops): through the years, distribution of RTU onto such lines had been carried out according to telecommunication optimization criteria, and not according to gas network operability. Drops with too many RTU had to be reorganized, trying to keep into consideration the type of RTU and the quality of the connection, in order to allow their commissioning within the same day.

Especially at the beginning, some time was necessary to tune the synchronism between 'hot' and stand-by servers of NSI and protocol handler, as well as the behaviour of the whole architecture during switches to emergency control room: a multidisciplinary team (with HW, SW and TLC competences) operated during all the commissioning phase.

The main lesson learnt was the importance to have a complete testing environment that could reproduce realistically the production environment (and eventually a field simulator), to test all the patterns of SCADA functionalities without any impact on the gas system operation. This goal might be kept into consideration and achieved with the next step of technical upgrade currently under schedule, the introduction of intelligent components (the master terminal units) into the TC network.

The importance of change management was confirmed, especially in this project, were an almost 20 years old SCADA have been replaced with a brand new, Windows based market product. Effective communication and coaching techniques have been widely used especially during the first part of the commissioning phase, when resistance to change was stronger, even because of the stressing period (commissioning started by the end of November, at the beginning of the winter season, the most critical for our control room) and the frequency of little tuning and configuration problems encountered at the beginning.

Summary

The SCADA system and the dedicated telecommunication network enable real time operation of Snam Rete Gas transportation system, consisting of about 32,000 km of pipeline network all over Italy, with more than 3,000 plants and 11 compressor stations remote controlled.

The Control Room, located nearby Milan, operates and controls the transportation system to ensure its safety, reliability and efficiency through a complex technological architecture composed of servers, cables, satellite routers and telecommunication devices.

Remote controlled plants are connected with the telecommunication network (owned SDH cables, dedicated via provider or dedicated satellite) by means of remote terminal units, while updated by event plants are monitored via a communication chain composed by field devices, mobile GSM public network and central modems.

All the architecture was governed by means of 5 different custom applications, realized over a long period of time with different technologies, and some HW components needed urgent replaced. The project included the new integrated SCADA based upon a market product, the refurbishment of the control room, the replacement the old synoptic panel installation with new videowall system, the introduction of a new generation of intelligent components into the telecommunication network and other new application systems used by the Dispatching Center .