The Secondary Voltage Regulation in Italy

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Abstract: Improvements in the automation of transmission network voltage control has nowadays becoming a challenging problem. In this framework the paper preliminarily describes the basic concepts of the Secondary Voltage Regulation (SVR) and the hierarchical control system under application to the overall Italian transmission network, for the voltage and reactive power regulation. At the power plant level this hierarchical control system operates through an innovative, microprocessor based, voltage and reactive power regulator, named REPORT. At the regional load dispatcher level, a Regional Voltage Regulator (RVR) controls in real time and closed-loops through the REPORTs, the voltages of the main EHV busses in the region. Both the REPORT and RVR control apparatuses have been designed and developed by CESI. The Italian Independent System Operator (ISO) has under way the general application of the REPORT apparatuses to all the main power plants, a large amount of them being already into operation, as well as of the RVR regulators at the regional dispatchers control rooms.
The paper describes the main characteristics and performances of the mentioned control apparatuses, the progress of their application in the field, their impact with the traditional operation, and comparison with alternative voltage control service; significant field test results are also shown.
Some considerations about the influence on the voltage service of the power system restructuring process are also given.

Keywords: voltage, reactive power, automatic control, secondary voltage control, voltage service, energy market.

I. INTRODUCTION

Considering the transmission network voltage control needs, the “manual” control practice is till now largely used round the world: the units reactive power dispatching, the power plant high side voltage scheduling as well as the control switching of capacitor banks, shunt reactors and in some critical network points requiring a more effective and timely voltage support, the use of static var compensators. This traditional way to face the network voltage control problems was often considered unsatisfactory because:

- the reactive power dispatching and the high side voltage scheduling are usually based on forecasting studies: the real situation is more dynamic and often different from the forecasted one;
- the dispatching/scheduling is operated by written requirements or it is requested by the system operator at the time he recognises it is strongly needed: untimely control action;
- there exists, in general, a lack of coordination among the different control actions “normally” operated by the plant and substation operators: no practical possibility to achieve simultaneous and optimised control actions;
- the control interventions are generally untimely with respect to the dynamic phenomena occurring in the network: an automatic voltage control system is requested;
- the system operator’s uncertainty about the real support given by the generators: the system operators need modern control systems which allow them a tangible control and monitoring of the power system reactive power resources and voltages, without doubts.

The need to increase the voltage control facilities in the transmission network has been always declared by the network utilities and a lot of approaches were followed and projects developed round the world.
In most cases the utilities approach was to correct the power factor by increasing the amount of capacitor banks installed in the system. Furthermore the availability, in some cases, of unit transformer on-load tap-changers (OLTC) is an additional chance to network voltage control, provided that they are controlled to support the HV side instead to maintain constant the voltage at the LV generator edges. Basically the idea of this conventional approach is to increase the availability of reactive power resources to face, through conventional control, the possible voltage problems. The way to automatically support the power plant high voltage side by AVR line drop is also largely used.
In Europe, hierarchical control structures were studies to achieve the automatic coordination of network areas reactive power resources with the aim of network voltage support: those innovative application called “Secondary Voltage Regulation” (SVR) were experimented in the past in Italy, France, Belgium and nowadays in Spain and some of them has been already extended at national level and operate to the real systems [1÷6]. It is interesting to point out that changing the utilities’ organisation in Europe and in front of the liberalisation of the energy market, those hierarchical control systems are appreciated and strengthened for the growing needs of the ISO to simply and automatically control the voltages of the overall transmission network as well as recognizing the

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contributions of the different actors to the voltage ancillary service.

The use of FACTS, particularly Static Var Compensators (SVCs), to network voltage support recently appear as a panacea for all the problem on the subject even if the related costs not always justify the choice (relocatable SVCs has been developed and applied) and also because they require, when extensively applied, the analogous co-ordination problem of the generators.

Recently, under the push of the electricity market liberalization, some manufacturers of unit excitation controls took the initiative to offer, as an option, the unit reactive power control functionality and, in a few cases, the power plant HV side voltage control. In North America, in fact, is growing the interest for a secondary voltage control simply based on power plant HV busses automatic voltage control. At BPA a wide are voltage control under development [7], based on the co-ordination of generator/load tripping, reactive power switching, TCSC/SVC modulation, power plant high side voltage schedule and tap-changing, shows strong link with the European SVR projects (network control view).

From the above mentioned progress and trends in the filed of transmission network voltage control and moreover taking into account the growing responsibility of ISO for guaranteeing and improving the system security, quality and economy through the power system operation, it appears unavoidable, at the beginning of the new millennium, an important evolution and innovation in the network voltage control by the use of a simple, effective and automatic control system, managed and supervised directly by ISO.

All the possible control solutions have necessarily to consider the voltage problem as a prevailing local problem, so the needed automatic coordination of reactive power resources mainly concerns the local reserves: unit capabilities, synchronous compensators, shunt capacitors/reactors, SVCs as well as the OLTCs. Therefore the objectives of the voltage control service to attain improvements in quality and security of the network operation can be pursued through a decentralized voltage control system operating a local coordination in each area/region in which the overall power system can be subdivided. Nevertheless in each region the considered coordination requires exchanges of data and control signals between the local dispatcher and the local power plants/substations The more the data are exchanged in real-time according with the power system dynamics, the best the voltage control system can increase its performances and effectiveness. On the contrary the economic benefits attainable through the network voltage control are strongly linked with an inter-area coordination and therefore requires an effective exchange of data and control signals among the regional dispatchers and with the central /national operating authority. Furthermore the measurements exchange with the surrounding utilities of the edge-busses voltages and tie-line reactive power flows as well as the coordination of the mutual control actions, are very important to reduce the losses.

II. BASIC SVR CONCEPTS

Being the main objective of this paper the description of the state of art and performances of the secondary voltage control system in Italy, in the following the basic concepts from which the idea of SVR grew in Europe are shortly described:

a) First of all it must to be stated that the idealistic idea to directly and automatically control in real-time and closed-loop the voltages of all (hundreds) the transmission network EHV busses is, in practice, too complex, very critical, not reliable and therefore not realistic and uneconomic approach.

b) The generator reactive powers are, obviously, the main resource already available on field, simple to control for network voltage support and available at low cost.

c) Talking about the control system the first simple but decisive and realistic idea was to control the voltages of a small number of EHV busses, taking care of their choice because they must be the most “important” in the transmission network (suboptimal but feasible solution).

d) The second good idea, related with the control system structure, was to consider joint busses those having on high electrical coupling and therefore voltages close to the value of the most important bus among them. This main bus, which strongly determines the voltage values in the surrounding busses, is called “pilot node”. All those busses define a network “area”.

e) The third good idea consists in regulating automatically the pilot node voltage value mainly by controlling the reactive power resources of the main generators operating in the pilot node area of influence, that is the most effective ones.

The last three simple ideas, which move from the network needs and related structural bonds up reaching to a coordinated control of the reactive powers of well defined aggregation of generators, are the mainstays of some European projects having as objective the practical design and the extensive application of a secondary voltage control system.

It is useful to point out that, notwithstanding the above mentioned starting ideas were dominated by the objective of minimizing the control system complexity, the effort to achieve the result of an effective control system is consistent when a large transmission network is involved, as also confirmed by the already undertaken experiences and existing applications. In one hand a new power plant control apparatus is needed for controlling the units reactive powers required time by time by the voltage regulator of the local area pilot node, taking also into account of the available capability of the generators in the plant. On the other hand a new network voltage regulator for the Regional Dispatcher is necessary to automatically maintain the voltages of the pilot nodes in the region at the planned values, through controlling by fast telecommunications the local power plant new regulators. These kind of control apparatuses are not available on the market and till now had to be specified designed and developed by the interested utilities by themselves. Furthermore high resolution and real time measures of the pilot node voltages through dedicated transducers and telecommunication channels are needed. They are also required simple and effective criteria for selecting the pilot nodes, the related areas and the area power plants participating to the local pilot node voltage control.

Lastly the SVR application impact can be consistent as far as it concerns the interaction and the possible integration with the existing EMS at Regional Dispatcher control room, as well as the interface with the unit AVRs and the operators at the power plants control room.

These efforts and related costs before to be undertaken must be obvisoully compared in one hand with the related benefits in terms of network security, voltage quality and network operation economy and on the other hand with alternative control solutions (i.e. by SVCs). The first analyses are in favour of SVR.

III. THE NETWORK VOLTAGE CONTROL SYSTEM UNDER DEVELOPMENT IN ITALY

The chosen hierarchical control system (see Fig.1) regulates, in closed loop, the voltages of some EHV buses (pilot nodes), selected from the strongest ones, through controlling in real-time the reactive powers of the generators which most influence those busses. In this way it is possible to operate the transmission network very close to the highest voltage limits, in security, through the real-time control of the main generators which are automatically forced to their limits when needed. The project is based on the idea of the network subdivision into areas around the pilot nodes. The areas are controlled by signals of "reactive power level" (one for each area) supplied by the RVR.

The chosen control system regulates, in closed loop, the voltages of the pilot nodes controlling the reactive powers of the generators, which most influence these buses, through the power plant regulator: REPORT. The combination of the RVR and REPORT apparatuses realise the Secondary Voltage Regulation. At a higher hierarchical level, the Tertiary Voltage Regulation co-ordinates, in closed loop, through, National Voltage Regulator (NVR), the actions of the regional controllers, establishing the voltage pattern of the pilot nodes and effecting slow corrections, in order to have a better balance of reactive power generation among the areas. The NVR operates in real-time, at national level, on the basis of the actual pilot node voltages and area reactive power levels, compared with a day by day forecast optimal voltage plan.

3.1. REPORT Description

REPORT, an innovative, microprocessor based, power plant voltage and reactive power regulator (see Fig. 2), allows two different control modes: reactive power level control mode, or EHV power plant bus voltage control mode. In the first control mode, REPORT regulates the reactive power delivered by the power plant generators following the RVR control signal. In the second control mode, the power plant is not directly controlled by the RVR, and REPORT regulates the EHV power plant bus voltage. In both these control modes, the reactive power generated by each unit is controlled by REPORT through a closed loop which overlaps the primary voltage control loop (see Fig.1).

The set-point of each unit reactive power control loop is given by the reactive level signal, multiplied by the reactive power limit of the generator considered. The reactive limits in generation and absorption are computed, in real-time, as a function of the actual values of operating active power and voltage. Such capability limits take also into account of the actual

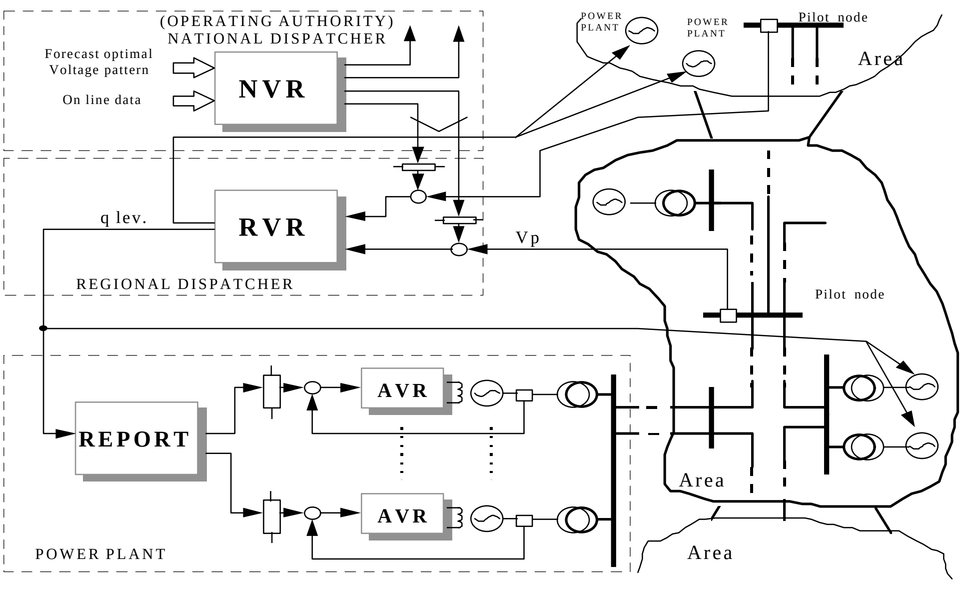

Fig. 1 Schematic diagram of Italian hierarchical Voltage Control System

Figure 2: REPORT power plant reactive power and bus voltage regulator (microprocessor-based version).

operating conditions of the generator cooling system.
In the first control mode the reactive level signal is sent from the remote RVR. In the second control mode the level is given by the output of the local Bus Voltage Regulator (BVR) integrated in the REPORT software. BVR regulates the EHV power plant bus voltage, according to suitable memorised voltage daily trends (otherwise the set-point is at disposal of the operator).
REPORT makes use of intelligent algorithms to recognise, in real-time and through local information, particular network contingencies (power plant islanding, bus-bars isolation, etc.), and correspondingly for choosing the most suitable control mode and adapting the regulation parameters. At steady state operating condition, the reactive level signal is limited between -1 and +1. Nevertheless, during transients, this level can exceed the normal limits, according to the capabilities of the generators. This allows the highest possible support of the network voltages in face of heavy perturbations. The design of the REPORT control system has been made with a view to insuring a complete non-interaction between the unit control loops, so as to avoid reactive power oscillations between different generators of the power plant.

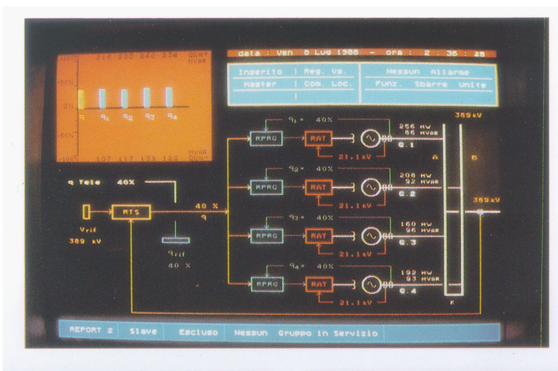

Figure. 3: REPORT: graphic and alphanumeric screen page.

The dynamic behaviour of the various overlapped control loops (unit primary voltage regulation, unit reactive power regulation, EHV bus-bar voltage regulation) has been chosen according to the time-decomposition criteria, for avoiding dynamic interaction between them. All the transitions between the REPORT working states (shutdown, turn-on, EHV Local Bus-Bar Voltage Regulation, Reactive Power Level Teleregulation, etc.), either demanded by the operator or ordered by the apparatus internal logic, are carried out through automatic procedures and tracking functions, which guarantee bumpless commutations. In order to avoid the operation of the units outside their voltage and capability limits, suitable protections has been implemented in REPORT: if one limitation appears on a unit, the action of the corresponding reactive regulator is stopped when it tries to go through that limitation. REPORT is also provided by rich supervisory and auto-diagnostic functions, which continuously control the correct running of the apparatus and its field interface effectiveness.
REPORT is provided with a very friendly operator interface and with rich monitoring features (see Fig.3).
The operator has at disposal sophisticated graphic-based screen pages refreshed in real-time (animated synoptic, signals and alarms, control parameters, memorised EHV bus voltage daily trends, etc.) and synthetic commands through a dedicated functional keyboard. During the normal operation, all the control parameters, as well as the EHV bus voltage daily trends, can be easily and directly modified via the REPORT user-friendly editor.

3.2. RVR Description

RVR requires a considerable data exchange with the areas into which the electrical region is subdivided (measures, signals and alarms coming from the network and power plants, control signals and commands sent to controlled plants, and substations.).
The RVR, installed at the Regional Load Dispatchers control rooms, consists of a workstation to be connected with the local EMS through a LAN Ethernet with TCP/IP communication protocol. (see Fig. 4).
All control functions of the RVR are implemented inside the workstation. Therefore the local EMS is the interface through which RVR exchanges data with the field.
RVR regulates at the same time, but with independent and parallel actions, the voltages of its pilot nodes through the remote control of reactive power productions of the power plants more affecting voltages of those nodes. To accomplish this task, RVR employs a Pilot Node Voltage Regulator (PNVR) separate for each pilot node of the controlled region.
The selection of a dominant time constant of the 50 s of the main control loop satisfies the need to keep decoupled in time this loop from those it overlaps. The proportional coefficient of the P-I control law is dimensioned in order to avoid undesired transients of the unit reactive powers.

It is possible to select a positive, negative or null static drop to the voltage regulation of the pilot node, depending on the network conditions and on electrical couplings with the adjacent pilot nodes.
The RVR design achieves the complete dynamic non-interaction among the different pilot nodes voltage control loops. This allows to avoid oscillating transients of reactive power between neighbouring areas, mainly when the electrical coupling among them is not negligible. PNVR defines and update in real time the values of the area reactive power levels on the basis of a voltage set-point of a pilot node (Vprif) which can be defined locally by the manual calibrator of Vprif (RVR manual local reference) or come from the voltage profiles locally stored (RVR automatic local reference) or is sent, in presence of Tertiary Voltage Regulation, by NVR via telecommunications.
The starting of each PNVR regulator, once the RVR is under operation, can be controlled by the operator without the need of preliminary manual alignment of control generators voltages and of pilot nodes set point values.
Vicarious pilot nodes are foreseen for each area, in order to face possible failures of the main pilot node teleoperation equipment or modification of the area network configuration. Generally, the PNVR output (area q level) is limited to values included in the -100% +100% range. In case area units allow the transient overloading then the PNVR is enabled to manage the overloading and the reactive power level of the area can ,temporarily, overcome the 100% value.
Tracking functions among the calibrators of the PNVR and the corresponding controlled magnitudes enable at any moment the bumpless switching between its different operation modes.
When one area approaching voltage/reactive power saturation conditions, the corresponding PNVR has the possibility to automatically telecontrol a configurable number of stations of its relevant area, concerning:
- lock of OLTCs transformation ratio;
- modification of OLTCs transformation ratio
- updating of voltage references of SVCs

Fig. 4: The Regional Voltage Regulator for the Lombardy Region

- capacitor banks on/off controls
- reactors on/off controls.

During the configuration of the RVR, it is possible to define the stations controlled by each PNVR and those excluded from the automatic control and, inside each controlled station, to enable the single component to be controlled. About the shunt capacitors and reactors, OLTCs and SVCs excluded from the automatic voltage control, their manual control is however possible through RVR by an appropriate station control panel available on the MMI.
RVR allows to modify on-line the configuration of the area regulation. This in order to enable the Regional Dispatcher to make quick reconfigurations when significant variations occur to the network structure and plants connections. In particular, it is possible to select the most adequate control and sensitivity matrixes for the present configuration of the regional network. Furthermore for each controlled area it is possible to define:
– The pilot node to put into operation among the available ones (vicarious)
– The peripheral stations which are outside the RVR control and achieve the voltage regulation of the high side bus-bar through the local generators under REPORT control .
– Stations enabled to the RVR automatic control and for each station, the components (capacitor banks, shunt reactors, OLTCs, ...) assigned to that control.

The RVR also enables the modification of its control parameters (time constants, data relevant to the plants and to the network of the controlled area, sensitivity matrix of pilot nodes, etc.). This to allow quick calibrations of the apparatus both during its commissioning and when possible modifications of the plants or of the network occur.
The parameter modification enabled by appropriate access keys (password) is achievable through an appropriate menu by authorised personnel.
The RVR has two classes of automatic storage functions of transient phenomena concerned with the network voltages regulation.
The first class relates to transient trends in ordinary operation and consists in recording every 5’ all measures adequately filtered, signals and alarms related to the RVR operation. These acquisitions are always active and do not require the presence of any type of trigger, since they document the operation of the SVR in ordinary operation conditions and for the last days.
The second class concerns fast transient and allows the high density recording of samples (one sample every 500 ms) for times of some minutes. This storage is oriented to the analysis of perturbations significantly affecting the RVR dynamics. This type of acquisition is enabled by appropriate triggers which recognise heavy disturbed situations in the network and allow also the documentation of initial phases of transients before the triggers themselves. The RVR includes self-diagnostic functions to detect and signal possible failures inside the RVR apparatus or placed in the interface with the EMS of the regional dispatcher.

For managing all the mentioned functionality, the MMI monitored by RVR consists of a number of graphic pages each of them offering to the operator a very friendly and effective interface (see Fig. 5).

3.3. Application Scheduling

The activities related to the practical application to the Italian transmission network of the secondary voltage control system (REPORTs and RVRs) are very advanced and the conclusion is waited for the beginning of 2001 and will include the field commissioning of about 50 REPORTs and 8 RVRs apparatuses, the large amount of them being already into operation. The global hierarchical control system, inclusive of the tertiary voltage regulation and the new version of RVR required by the Italian ISO restructuring from eight to three regional dispatchers, will be ready at the beginning of 2002.

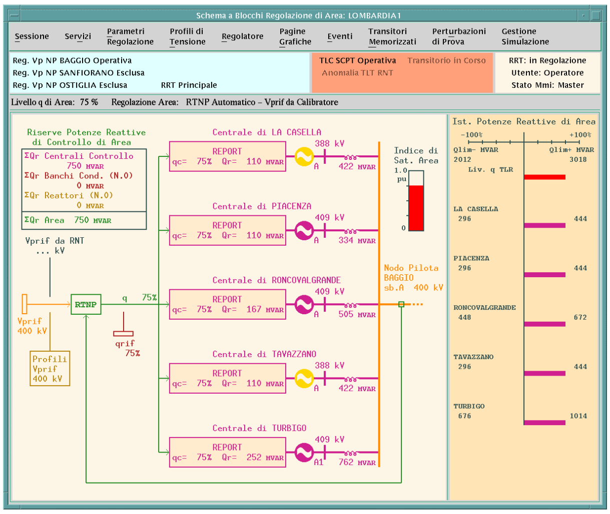

Fig. 5: MMI representation of a RVR single area regulation scheme

IV. EXPERIMENTAL RESULTS

The update studies for the choice of pilot nodes and respective control power plants in the Italian power system has provided the subdivision of the power network into 18 areas. The overall plant involves all the major power plants connected with the 400 kV and 220 kV network, for a total reactive power capacity of about 18,000 MVAR. Figure 6 shows the subdivision into areas of the Italian network, pointing out the pilot nodes and the corresponding control power plants according to the SVR application plan.

Nowadays a large amount of the REPORT apparatuses have been already installed in the power plants, and most of them are operating the local HV bus-bar voltage control waiting the RVRs activation.

Putting in service the REPORT apparatuses is the first but also the most onerous activity, among those related to the practical application of the SVR. In fact it requires a certain amount of effort, costs and organisation of the power plant for managing the plant modifications and the plant tests during REPORT commissioning.

Fig. 6: Application plan of the hierarchical SVR in the Italian grid

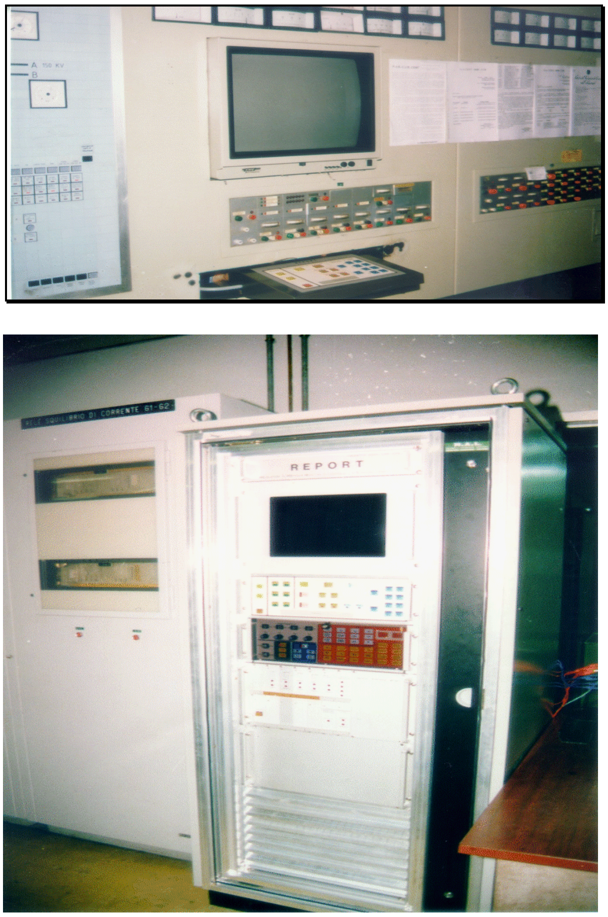

Figure 7: Termini Imerese REPORT installation.

The power stations which will be equipped with the REPORT apparatuses are the largest hydraulic, thermal and combined-cycle plants in Italy. The amount of the Italian involved plants is nearby 50 (having in total more than 150 generating units). The 70% of the REPORT control apparatuses, are already into operation in the field (see Fig. 7). The remaining 30% will be activated before the end of 2001.

About the impact of the REPORT application, one of the main aspect is the different philosophy that the Regional Dispatcher has to acquire, as regards power system voltage and reactive power operation. While till now, in front of the network needs, the Regional Dispatcher demands the power plants more or less reactive power by phone or by daily plans, with the SVR the dispatcher fixes the voltage of the area pilot node and the reactive power will assume the value is needed to obtain the desired voltage. This more correct network operation method, different from the traditional one, can be achieved thanks to the REPORT control apparatus, which avoids the power plant operators to actuate manually the Dispatchers demands and also to justify the unavoidable differences.

Fig. 8 shows the voltage and reactive power transients of the thermoelectric units at the Piacenza power plant (Lombardy) controlled by REPORT, and the EHV voltage at the S.Rocco station, near Piacenza, following step perturbations of the area reactive power level and of the EHV bus bar voltage set-point. The typical characteristic of these transients is the concordant behaviour of all the plant units, following the set-point perturbation, without unnecessary transient exchanges of reactive power between the units. The new RVR has been submitted to very extensive functional tests and was put into operation in the Milan (see Fig. 9) and Naples regions respectively at the end of the past year and at the beginning of the current year. The RVRs for Rome, Naples, Venice and Palermo will enter into operation during the 2000.

All the studies, simulations and experimental results in the real power system are very satisfactory in terms of performances and reliability of the SVR.

RVR constitutes a very innovative regulator for the Italian Regional Dispatchers and will allow new and important chance in the framework of network operation, overcoming the traditional procedures for voltage and reactive power control. Moreover, RVR offers to the operators the opportunity to point out in real time the progressive and co-ordinated utilisation of the reactive power resources and the distance from the limit of the reserves at disposal. On the basis of this information the operator may take very supported and effective operative decisions.

Coming to the field test results, Fig. 10 shows the RVR performance applied to the Lombardy region:

Along a full day (10 October 99), the transient of the Baggio pilot node voltage overlaps the constant voltage set-point value (405 kV), maintaining the distance in the range: +1÷-1 kV. The differences are due to the

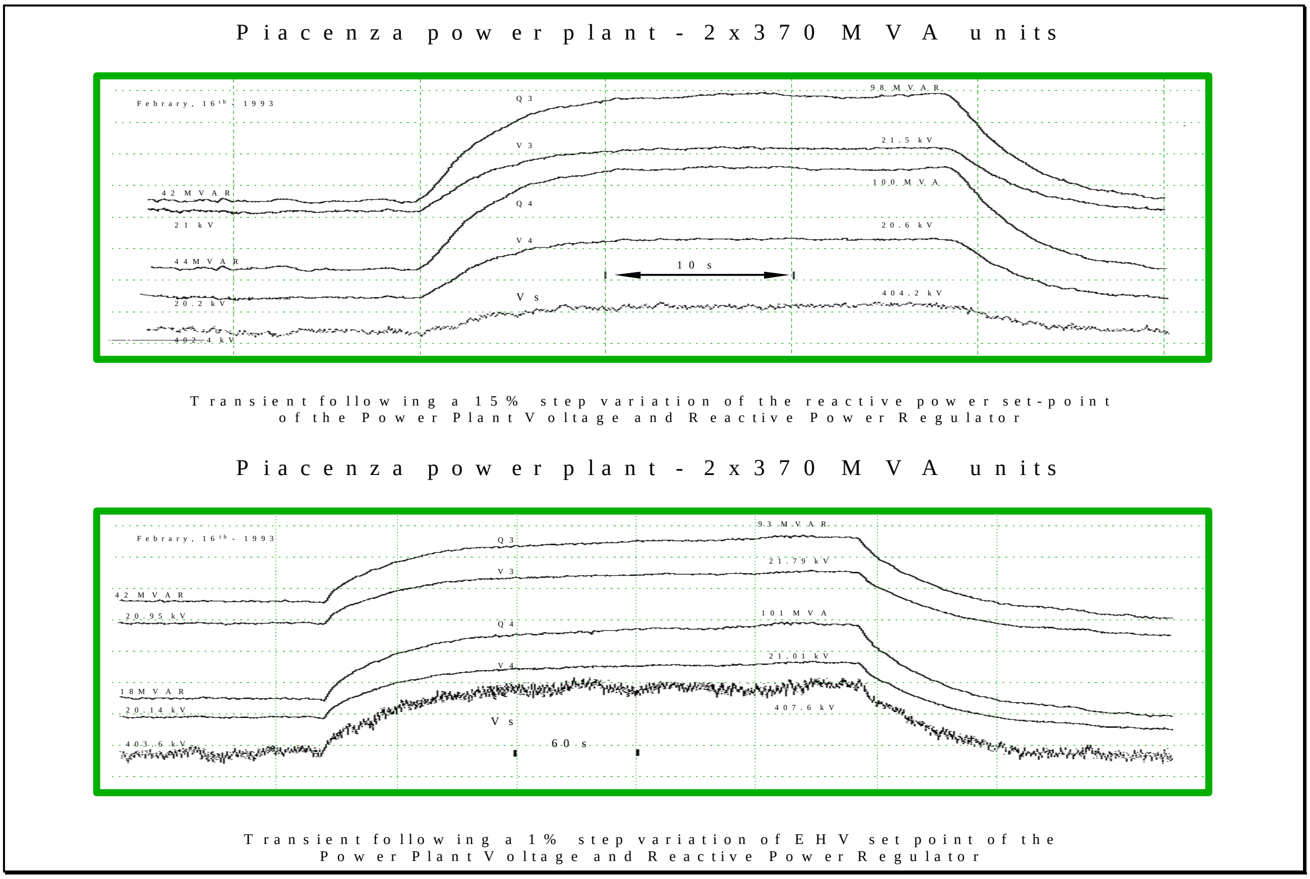

Figure 8: Dynamic transients at the Piacenza thermal power plant

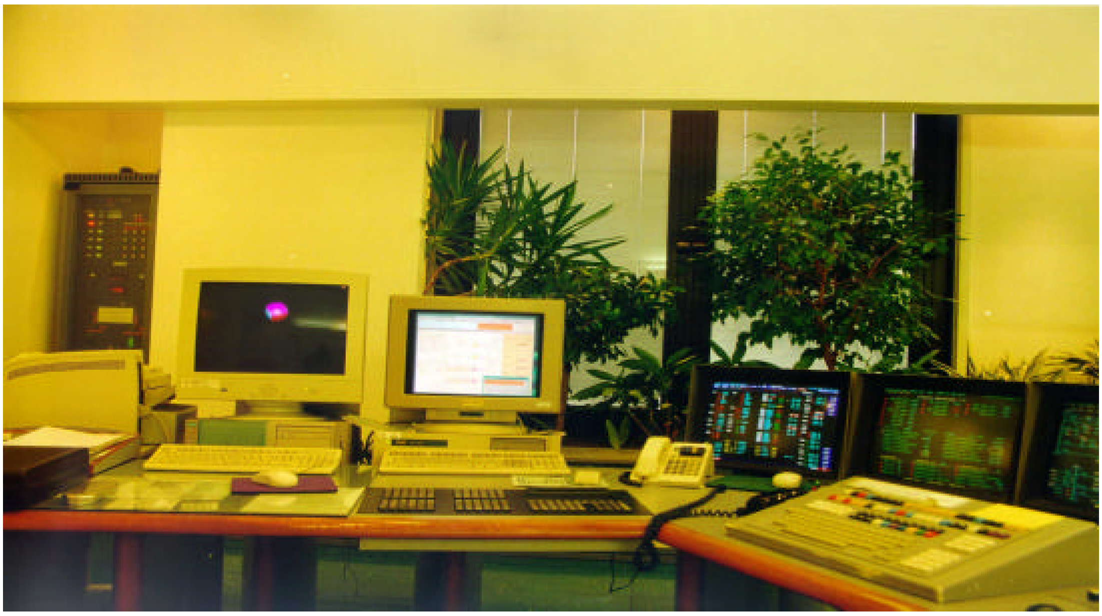

Fig. 9: The RVR operating at the Regional Dispatcher control room in Milan

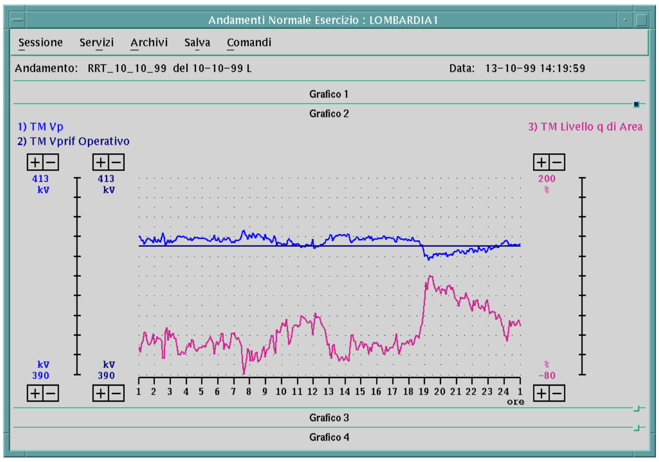

Fig. 10: RVR monitoring of a full day Baggio pilot node voltage and related reactive power level transients

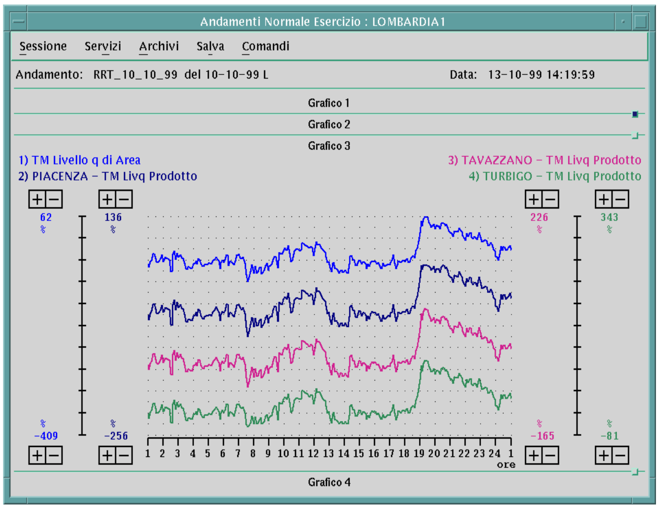

Fig. 11: RVR monitoring of a full day Baggio area reactive power level and the reactive powers of the controlled power plants

operating negative drop to the voltage regulation of the pilot node. In the figure, the lower transient represents the area reactive power level. The same transient is represented in Fig. 11 together with the reactive powers produced by the Baggio area control power plants (Piacenza, Tavazzano and Turbigo). The perfect unison through which all the area control power plants move their reactive powers under the RVR control is the key of the success of the SVR.

V. THE INFLUENCE OF THE ITALIAN POWER SYSTEM RESTRUCTURING PROCESS ON THE VOLTAGE SERVICE.

The Italian electricity market recently moved from one strongly integrated national company to an economy/administrative unbundling among Production, Transmission and Distribution independent companies. The changes affect aspects of the system operation which requires high interaction among the separated companies, as required by the voltage service, even if this service will be managed as unbundled. From this point of view, the next organization of the voltage service will surely be different from the present one, but not necessary less expensive, with possible slowing down or increasing of the initiatives for future additional improvements in dependence of the market real competition. Conversely, as far as it concerns the link between the past developments at Enel for achieving a top level voltage service and the present needs of the Italian ISO, we can undoubtedly say that the past and present efforts for improving the voltage service totally fit the needs of the new ISO.

The participation to the network voltage control system of the main Italian power plants and EHV- MV stations, determines a strong interaction among the Italian's Production, Transmission and Distribution companies which have to define, also for the voltage service, the role they play. Because the Italian new network voltage control system is automatic, to the managerial/ administrative unbundling concretely corresponds an operational bundling: the unit reactive powers are telecontrolled by the Regional Dispatchers while the Distribution's customers take advantage of the benefits. This unavoidable interaction links the decision of the independents entities on the voltage service. From this point of view an automatic voltage control system already into operation, fixes de facto the operational link among the independent entities so simplifying the agreements and roles and the operative modalities which must be coherent with the designed control solutions. That is, the units will operate up to their capability limits, all together contributing with the same percentage of the control effort; the Regional Dispatchers Regulators (RVRs) will require the plants to produce the amount of reactive power strictly necessary to maintain the optimal voltage profile in the network; the automatic control of the optimal voltage plan will allow to reduce the network losses and to increase the network reliability with obvious benefits for the customers.

The independent entities shall comply with the prescriptions of an agreed convention which will define the modalities and the time limits for the maintenance interventions and the service restoration as well as the penalties for the not-timely or unfulfilled due actions. For achieving this mutual effective cooperation it is very important to refer to clear new roles for the Italian ancillary services market.

Possible problems concerning the sharing of the voltage service returns will surely push to improvements in the monitoring of the unit performance either for those controlled by REPORT or those under primary voltage control only.

Analogously the monitoring of the voltage service improvements in term of the quality, security and economy of the network operation will be surely powered. In comparison with the past rough monitoring of the voltage service, the future interests on the related economic returns will also push for checking in detail the congruity of the other actors' returns in comparison with their monitored contributions.

The voltage service economic returns will also push for improvements of the present Italian rules on the subject, whether for the technical or economical or social aspects.

VI. CONCLUSIONS

The traditional voltage duty is worldwide under evolution, both from the administrative and operational point of view, under the pressure of the restructuring of the electric sector. The paper has presented the problems and the possible solutions, particularly the Italian control system, at present partially and in the next future fully obtained through highly efficient secondary and tertiary automatic regulations, offering top performances both in static and dynamic system behavior. The "voltage service" keeps a relevant importance for improving the quality, security and economy of the power system operation. In fact this allows a more rational and effective use of the reactive power reserves already available, first of all those of the generating units, with the complete guarantee of the machinery security. Furthermore the SVR, in the configuration above proposed, allows to drastically reduce the investments for the network power factor correction which, for achieving a comparable operating quality, should be obtained with SVC equipment.

The alternative of a SVR simply based on voltage control of power plants HV busses is included in the Italian control system where the REPORT apparatus also allow the local HV busses voltage regulation modality (see paragraph 3.1). Obviously this interesting approach which considers the units equivalent to SVCs, determines some problems when the amount of the generators (or SVCs) is consistent: stability and co-ordination problems and missed network optimisation.

The Italian long experience on the SVR, strongly supported by a very extensive application at national level, able to operate on field meanwhile grows thanks to the flexibility of the available control laws (local HV bus voltage regulation or pilot node voltage regulation), is based on a large amount of significant results which demonstrate the high level reliability, availability and effectiveness of the hierarchical voltage control system already extensively applied to the Italian power system.

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