INTEGRATION OF DSO CONTROL SYSTEMS AND TSO AUTOMATIC LOAD SHEDDING SYSTEM TO IMPROVE THE SECURITY OF THE NATIONAL GRID

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ABSTRACT
The document describes the approach adopted by ENEL Distribuzione in integrating remote control systems in the TSO system architecture, in order to improve network security by new techniques of load shedding.

INTRODUCTION
TERNA is responsible for the transmission and dispatching of electric energy throughout the entire Italian territory, and therefore for the safe management of the balance between electricity supply and demand all the year round. The modern term used for this kind of company is: Transmission System Operator (TSO).

Usually some services are required to assure a good level of security of the National Grid, to face events where generation may be reduced or disconnected following a system fault, to relieve localized network overloads, to maintain system stability, to manage system voltages and to avoid the so called “Black outs”.

One of the classical method to manage these situations is the “Load shedding”, a technique that today can be applied in a very modern way thanks to the new available technologies.

In this direction, TERNA developed a modern Load shedding application (called BME) that, connected to remote control systems of Distribution System Operators (DSO) makes possible a very effective automatic procedure for emergency situations.

ENEL Distribuzione, that is the main DSO of the Country, played a consistent role in the project as far as system integration is concerned.

MAIN FUNCTIONS OF THE SYSTEM
Among the possible countermeasures against national Black Outs, a special load shedding application was developed in the ’80s by the Italian TSO (old BME).

The operator in one of the national control centres could manually disconnect some loads in the network by special grouped remote commands, so as to reduce the power by a specific amount.

The system, apart from being technologically obsolete, has two main limits:
- when the opening is activated, the disconnected load is not known exactly because it is based on an average estimated value, updated only once a year;
- the action is performed manually by the operator therefore, in many situations, the response time is not as short to avoid the network collapse.

The new application (New BME) overcomes these problems and performs the load shedding with a new solution.

Thanks to the communication between the TSO central intelligence (Centralized Computer for automatic Load shedding, called EDA) and DSO peripherals, the loads are monitored in real time to have the real value of the power available for disconnection.

The action is performed automatically by central EDA in case a “Critical event” happens; in very few words EDA:
- foresees any “Critical event” and calculates the amount of power to be disconnected to avoid network problems;
- sends appropriate messages to all the Loads to be disconnected for each critical event, in order to make them prompt to open (Arming messages);
- programs the “Sentinels” (Special RTUs installed in critical sections of the grid that sense each Critical event) to send a Multicast messages directly to the armed loads in case of each foreseen event.

In case a particular Critical Event happens, the Sentinel will send a multicast message over the network to reach the relevant loads. All and only the loads armed for that kind of event will disconnect in a while, avoiding major problems in the network.

Of course, in same cases (energy line overloads), the delay time between the event and the disconnection of the loads must be as short as to avoid the trip of line protections. This requirement was the main constraint in the development of the system architecture.
SYSTEM ARCHITECTURE

System architecture is based on the following functional blocks:
- A central computer (EDA) to analyze the current network status, evaluate the possible “Critical events”, calculate the corrections and send “Arming messages” to all the relevant loads;
- Several “Sentinels” installed in correspondence of the critical sections of the network;
- Some peripherals in correspondence of the Loads that can be disconnected;
- A telecommunication systems to connect central system with all the peripherals.

Taking into account that TERNA is the developer and the owner of the system and manages the central EDA and the Sentinels, using a private IP network, the point to be solved is the managements of the loads that are under the control of ENEL Distribuzione.

A solution adopted for some other distributors consists in the installation of special RTUs inside Primary substations. Of course a direct connection of these devices with the TSO communication network is also needed. Nevertheless this solution is very simple, the corresponding investment is quite big, taking into account the number of substations to be connected, the requirements of communication links (delay times, reliability, etc), the cost of the RTUs and their installation in DSO premises.

This is why TERNA and ENEL agreed to interconnect its remote control systems with TERNA BME communication network, in order to make the system work using the existing infrastructures.

Theoretic and practical verifications have been planned to assure the feasibility of the solution, setting up a pilot project in south of Italy (area of Naples).

Interfacing the systems

The scope is interfacing TERNA systems with ENEL ones by means of a communication infrastructure with defined levels of performance, security and reliability.

Taking into account that ENEL Distribuzione controls the Italian territory through 28 SCADA systems (called STM) connected to about 2000 RTUs installed in every Primary substation, the following communication links are needed:
- One logic connection between each ENEL STM system and central EDA server, based on standard application protocol IEC 60870-5-104; some extensions are needed to manage arming messages towards the loads;
- Logic connections between TERNA sentinels and ENEL RTUs, based on UDP transport protocol and IEC 60870-5-104 application protocol.

Of course all the unicast and multicast messages in both direction must be encrypted to assure the requested level of system security.

Data exchange during everyday running is limited to:
- information regarding the instantaneous load values coming from the primary substations: these data are sent to EDA by STM continuously;
- arming/disarming commands towards the loads: they are sent by EDA to STMs that forward them to the RTUs using the existing communication links;

In case of a critical event, disconnection commands are sent by the sentinels directly to all the RTUs of the network, using a multicast message (UDP). Only the loads armed for that specific event will be disconnected. The maximum delay time between the event and the disconnections must be assured by a proper design of the system.

In particular the total delay time is the addition of the following parts:
- time to detect the event by the sentinel;
- time to send the disconnection message by the sentinel;
- latency of the communication network (physical links, routers, firewalls, etc);
- time to receive and elaborate the command by the RTU in primary substation;
- time to actuate the command by the breaker.

To resolve the situation even in case of overloads on energy transportation line, this delay cannot exceed 800ms that corresponds to the trip time of over current line protections.

Communication architecture

The scope was to set up a standard communication architecture to be implemented first in the pilot project but deployed in all the Italian territory after the test phase. According to this guideline, in the pilot project, TERNA and ENEL communication networks interfaces in a single connection point, located in correspondence of STM-Naples. This point is connected to TERNA access points of Pozzuoli and Rome (backup).

ENEL RTUs are connected to STM by means of the IP connection normally used for remote control.

The direct connection among sentinels and ENEL RTUs is assured by a net of Virtual IP connections between
TERNA and ENEL data Networks.

In the connection point there is a Gateway to provide the necessary interfacing, firewalls and encryption/decryption functions between the networks. The structure of the gateway has been engineered so as to assure a very high reliability (critical equipment are doubled) and to distinguish clearly the responsibility areas of ENEL and TERNA (see the above figure).

System security
In the gateway cabinets 2 firewalls are installed one on ENEL side the other on TERNA side. Both are doubled to improve availability and meet the reliability requirement.

According to project requirements, encryption is needed for both kind of messages: unicast (arming messages) and multicast (disconnection messages). In the pilot project several encrypting solution have been evaluated to find the best way to do it from the economic and efficiency points of view. At the end of the test phase a “Router to router” solution has been chosen, avoiding additional HW into the substations.

NEW FUNCTIONS PROVIDED BY ENEL STM CENTRAL SYSTEMS

Disconnection of Loads is performed by opening the circuit breakers located on the MV side of HV/MV transformers in Primary substations. Therefore the value of the load transmitted to EDA corresponds to the active power measured in correspondence of that transformers. The measures are sent every 20s, the position signals on variation. In case of breaker position signal, a time tag is attached to the signal in order to monitor time delays. After the opening, the breakers will be “Locked” in the open position until an “Unlock” signal is transmitted from EDA.

The ENEL operator at the Control Centre receiving this permission can reclose the breaker by a remote command.

For each Load that temporary cannot be disconnected, for example for maintenance, STM sends a specific notification to EDA to cancel arming actions in progress and discard it in the calculations.

As far as peripherals are concerned, upgrades regard:

- **ENEL RTUs**, in order to manage IEC 60870-5-104 protocol and to support new application;
- A GPS controlled clock to be installed to synchronize the RTU with EDA clock;
- Substation Router, in order to manage UDP protocol and data encryption.

**Test function**

In order to monitor the working status of the equipment and to measure periodically the value of the delay time to carry out load disconnection, EDA runs continuously a special “Test Procedure”:

- a special dummy load, that each RTU has built in, is armed for the test;
- a Sentinel is activated to send the multicast message to disconnect the dummy load; a notification is also sent to EDA with the time tag of the event;
- when the dummy load is opened a notification is sent to EDA with the time tag of the event;
- EDA, comparing the time tags of the notification received from the sentinel and from the dummy load, can calculate the real time delay of all the trip.

EDA applies the Test procedure periodically to all the RTUs in the fields so as to monitor the behaviour of all the components of the system.

**SYSTEM TESTING**

The Test Plan has been arranged into several steps:

- Laboratory Test;
- Field test on pilot in Naples.

The laboratory test has been performed in the ENEL test centre in Milan where a test platform had been set up for the purpose: real EDA and STM systems, Sentinels and RTUs have been used in order to be as close as possible to the real field as possible. A direct connection to TERNA made possible to simulate all kind of situations using the real central EDA in Rome.

The activity included functional and performance testing. To simulate communication network congestion and disturbances, special traffic and noise generators have been used.

Thank to the positive results obtained in laboratory the field test phase started quickly in Naples at the beginning of the year 2008.

A Gateway was built up and activated to connect the remote control system of Naples with the EDA central system in Rome. Seven Primary substations are connected in real operation and monitored for half an year to check:
The application was a real success and the delay times measured all the time were better than the expected ones.

In fact, the total delay time between the event and the actuation on the RTUs in Primary substations did not exceed 400ms. Adding the average operation time of a circuit breaker, it is possible to say that 500ms is the total time needed by the application to react to a Critical event. This value is far away from the stated limit of 800ms.

EXTENSION TO ALL THE ITALIAN NETWORK

The positive results of the pilot project lead to an application plan to extend the application to all the Italian territory.

First of all 8 gateways have been activated to connect the 28 STM system to TERNA Network.

A roll out plan is in progress to connect the south of Italy first and then going up toward the central and the north regions.

In the current year the system should be extended to all the territory.

Fortunately, so far, there was no need of TERNA BME and we hope the same will happen in the future.