Broadband wireless connectivity in automation and remote control of the DSO infrastructure

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ABSTRACT

ENEL is Italy's largest power company, and Europe's second listed utility by installed capacity. It produces, distributes and sells electricity and gas across Europe, North and Latin America. ENEL is interested in partnering with Cisco in this Smart GRID initiative.

INTRODUCTION

Within the energy landscape, both in the national and international context, a drastic revolution in the electrical power system management strategy is in progress. The ongoing trend leads to a gradual decentralization of energy production, which tends to be allocated close to the load in medium or small scale plants connected to Medium Voltage (MV) and Low Voltage (LV) distribution networks.

In this perspective, the Distributed Generation (DG) is one of the emerging technologies, presenting significant benefits in particular related to the ability to exploit locally available energy resources like renewable or cogeneration [1][2].

Increasing the DG penetration level, distributors necessary need to adopt new techniques for an appropriate control and regulation of the distribution systems, in order to maximize the DG penetration and simultaneously ensure adequate standards in terms of reliability, safety and quality of supply. The distribution networks, initially thought and now performed for a purely passive use, will be gradually translated into intelligent (smart), reliable, sustainable and economic systems [3].

ENEL- CISCO Smart Grid Pilot MOU

Cisco Systems and Enel signed a Memorandum Of Understanding (MOU) to formalize a partnership in terms of analysis and development of Communication and Application solutions for Smart Grid. Cisco and Enel collaborated be involved to define and implement on field different technological scenarios. The scope of the work was to implement a Smart Grid Pilot project providing permanent field lab.

The plan had three main steps:

- Building of a new architecture enabling real-time IP (Internet Protocol) (radio based) on always-on communication, between Primary and Secondary substations of the Enel Distribution grid.
- Testing of Transparent transport/ translation of Scada legacy protocols over IP network;
- Integration of new IP sensors to collect additional grid condition (fault) information.

The "IP everywhere" paradigm will be the base for all studied solutions**.**

Enel, Cisco and WiMax Italian provider have built a new IP network, installing some WiMax Base Stations and WiFi repeaters in two Enel primary substations (HV/MV substations) of a large town, in the central region of Italy. So, a lot of substations of the MV grid, in the same town, were immediately connected among each other and their primary substations, by broadband and always-on links. All these plants were also connected to the remote SCADA Center, which usually reaches the secondary substations by "dial-up" request and poor throughput connectivity (GSM).

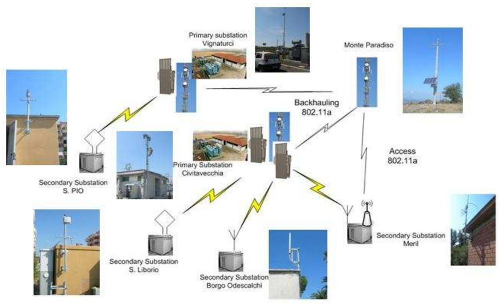

Figure 1 Civitavecchia Installation

Cisco-Enel Smart Grid pilot projected architecture is deemed to be properly working with respect to original ENEL requirements of connectivity between each one of chosen Secondary Substations and relevant Primary Substation within an originally given round trip time limit (300 msec end to end , minimum time for electrical protection) .

The above requirement is necessary to implement distributed substation automation solutions for Medium Voltage grid control.

300 ms permit to the substations to exchange and share information being confident that all tasks are executed in synchronization way. In fact Intelligent Electronic Device (IED), controlling the substations, is able to locally detect faults and to open or close switches in according with

each other adjacent node.
We successively enhanced with a stronger requirement: one way time <60 msec on adjacent CPEs. It is necessary to extend the range of solution applicability to the integration of Distributed Energy Resources (DRE). It is required to control digital relays installed in private secondary substations from the Primary Substation of DSO, exchanging opportune messages in time coherent with the specifications of exercise of the MV grid.

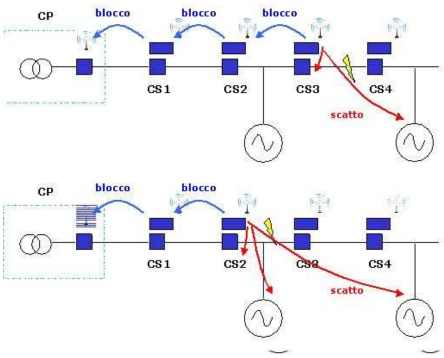

Figure 2: new scenario RC&A + switch off DER

The goal of this additional requirement is build a new architecture of data communication network to help electrical Utilities (DSO) to solve some problem about:

- grid monitoring and full distribution automation
- interconnection with DER (Virtual Power Plant)

and transform electrical network from Passive to Active Network.
Connect using a real time link from Primary Substation to DER to transport and exchange voltage and frequency value. These signals exchanged regard essentially a better management of the protections destined to separate the generators from the network, technically notes like Interface Protections.

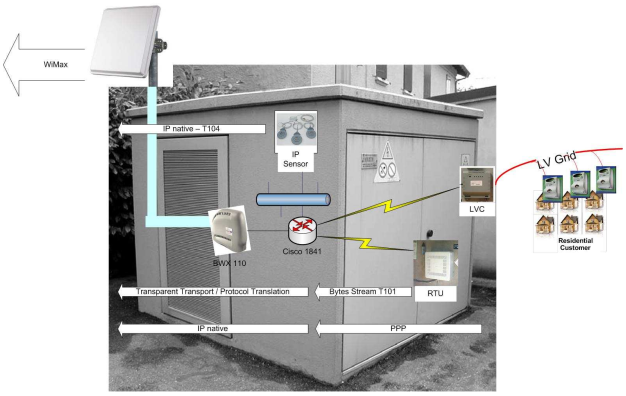

Figure 3: Secondary Substation Logical Connection

Multiservice Access Solution has been deployed. The network nodes installed in secondary substations were designed to support over IP both bytes stream applications (e.g. IEC 60870-5-101 for remote control) and native IP services (AMM for smart metering). In additional Quality of Service and Store and Forward features guaranteed reliability of information.
In addition the network node is directly linked to Remote Terminal Unit (SCADA application) and Low Voltage Controller (AMM application), via RS232 serial interfaces and to IP Sensors via Ethernet interfaces.
External Wimax CPE offered the access to wide area network.
Additional Enel requirement was the support and integration of existing SCADA and RTU hardware and software, in order to improve the control and monitoring of the secondary substations involved in the Pilot by always-on communication model.
Enel and Cisco have checked two different scenarios in the new broadband IP network:

- Transparent transport of the current IEC 60870-5-101 (T101) byte streams, between RTUs and SCADA, over IP network is realized using Cisco software platform with BSTUN encapsulation protocol. (Fig. 4) The two Cisco routers are connected over an IP network and the T 101 frame is BSTUN encapsulated and forwarded via IP network to the other BSTUN Peer.

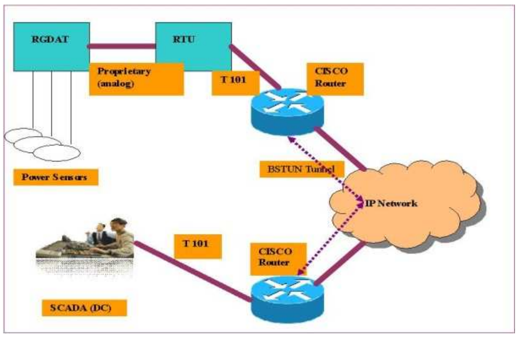

Figure 4: BStun transport

- Protocol translation of IEC 60870-5-101 to IEC 60870-5-104 (T104) and vice versa, by Cisco routers at SCADA and RTU side (Fig. 5). The edge Cisco Routers, linked to the RTU, intercept the T101 messages sent to the SCADA Master Controller and translate it to T104 messages and vice versa. This Function Specification addresses the details of implementing this solution in an experimental version of Cisco IOS operating system.

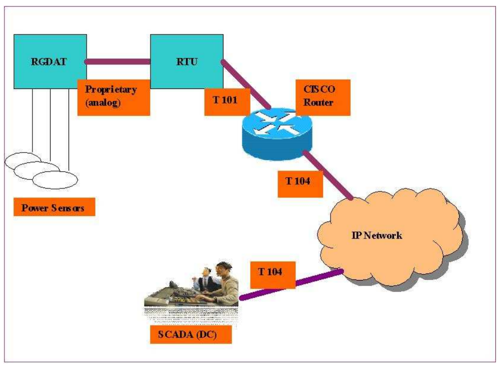

Figure 5: T101-T104

The Pilot project has also provided a new kind of wired IP sensors, which were installed inside the secondary substations. A commonly used fault detector was modified, introducing hardware and software due to implement IEC 60870-5-104 protocol; the data acquisition from the IP sensors was integrated in the router, in order to offer to the SCADA additional calculated measurements. Enel required the support of IEC 60870-5 information objects in order to implement a real time monitoring of the status of MV electrical lines.

The list of information is the following:

> Voltage level per phase - Active Power - Reactive Power - Fault Earth - Fault Domo - Fault Poli - Log buffer

The local router needs specific measures by sensors to reserve resources to compute the above parameters.

The designed IP sensor for measurements is an evolution of the current fault detector (RGDAT) used in Enel MV grid. The role of this board is to capture the sensor data and perform some real time digital signal processing on this data in order to detect different type of faults.

Civitavecchia Pilot Project

Cisco and Enel have decided to face new connectivity technologies and so they have used WIMAX technology to realize radio network coverage for Rural and Urban area of Enel electrical grid of Civitavecchia, a sea town, close to Rome, in the central Italian region of Lazio.

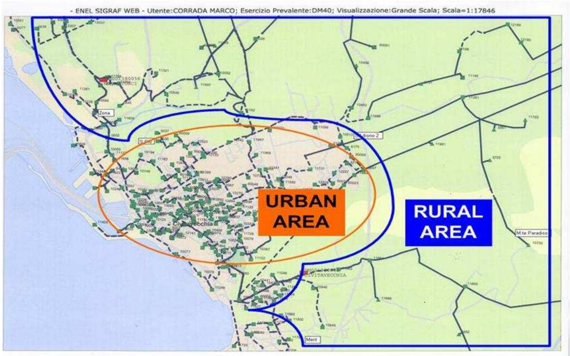

Figure 6: Gis image of Pilot Area of Civitavecchia

In Civitavecchia, the two Enel Primary Substations (HV/MV Substations) are involved in the project, and there, the WIMAX Base Stations were installed.
Cisco proposed architectural design from 200 up to 400 Secondary Substations per BTS could be connected; current radio (3.5 GHz) coverage is 2.3 km^2 per single cell in urban environment using a Radio Planning and Simulation program (Planet EV) predict propagation model.
Wimax RF design has some planning notes:

- RF Planning accomplished with free 100m terrain and one clutter setting (residential) for entire polygon
- Overall design limitation was 2 sites (the two Enel Primary Substations) and 3 BTS. Design priority one is to cover 4 CPE locations within the given polygon. Design priority 2 is to cover as much of the polygon as possible.
- RF Design based upon outdoor CPE (13 dBi) with a height of 3m.
- All RF plots based upon OUTDOOR Coverage.

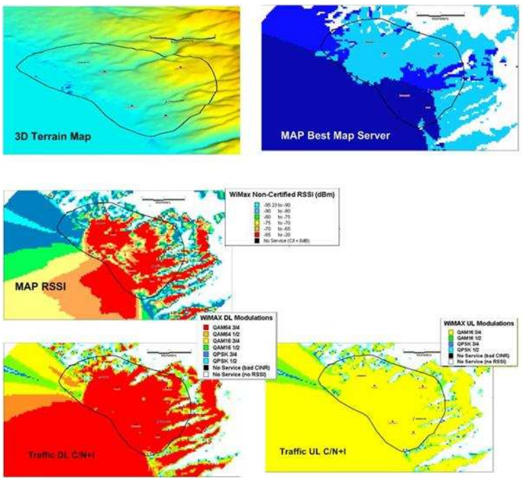

Figure 7: Radio Planning results (Irregular Polygon)

Total area (Urban and Rural) to cover is represented from a polygon that has a size to **22.5 sq km.**

The other main items of the architecture are:

- Transformation of current "wired link of communication" of Secondary Subs into a Lan based on Ethernet technology using a like 61850 model
- Transport and translation of SCADA Protocol (used in wired link communication)
- Introduction a new sensor IPRGDAT that connects, LAN by exchange of some data with the router - the SCADA gateway module in the router elaborates these data and send them to Master Sensor Console (Active Power and Reactive Power)

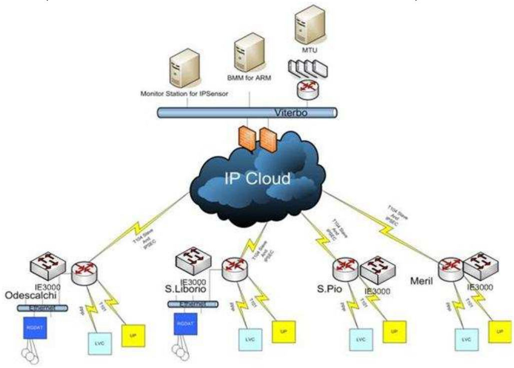

Figure 8: small "smart grid" network

So, the Civitavecchia test field includes:

- the regional Enel SCADA Center in Viterbo, with competence on HV and MV grid of Civitavecchia
- 2 Enel Primary Substations with 3 WIMAX base

stations and routing equipments to connect both the Enel SCADA Center (via Frame Relay) and the Enel Secondary Substations by the new WIMAX infrastructure

- 5 Enel MV Grid sites, 4 Secondary Substations and a MV pole equipped to be used as a radio repeater. Every site is equipped with routing and switching equipments and in the 4 MV/LV substations the new IP fault detectors, the RTUs and LVC (Low Voltage Concentrator of Enel AMM system) are connected to the router.

Pilot test results

Cisco and Enel has provided on field a **running** solution of Smart Grid architecture characterized by:

- **Ethernet as a reliable technology in harshed environment through on field tests;**
- **WIMAX as a great opportunity to have a large and distributed connectivity in the field ;**
- **transport and translation of IEC 60870-5-101 protocol (into T104);**
- **introduction of a new generation of IP Sensors (“IP-RGDAT”, the “IP” evolution of the current fault detector)**
- **the first attempt to find synergies among communication equipments and electric equipments** (just for experimental use, the CISCO Router IOS software was modified in order to calculate, aggregate and store electric measurements)

The Performance Tests have been focused on:

- network availability
- latency
- throughput

Above performance tests were divided in three sub testing parts:

1. Testing traffic from Secondary Substation to Wimax BTS LAN in the Primary Substation
2. Testing traffic from WiMax BTS LAN to ENEL Primary Substation Router
3. Testing traffic from Enel Primary Substation router to SCADA LAN of the Enel Control Center

The second subtesting part is a segment fully closed in the Primary Substation and it’s a kind of intra-vlan traffic. The third part is not really interesting for this pilot result because it’s the current and running Enel Distribuzione IP network solution connecting its own 30 Scada Center and 2000 Primary Substations.
The most important and interested results are in the following table, about the first subtesting parts. In presence of a good coverage, in terms of radio signal, the new network is able to satisfy the requirements for a reliable and effectiveness way in the remote control and the automation of the Secondary Substations. The throughput of the segments, among Primary and Secondary Substations, is good to face also AMM Systems needs, in order to connect the Concentrator in the same Secondary Substations.

	Customer Requirement	Obtained Result
Throughput (from PS to SS)	128 Kbps	Met
Round Trip Time (Latency)	300 ms	From 49 to 115 ms
Jitter	Minimum (computation)	From 8 msec DWN To 50 msec UP
P2P on meshed grid Stronger RTT	< 120 ms (60 ms one Way)	Met

Table 1: Synoptic of Tests results

Figure 9: Secondary Substation Box

All data reporting in this table is obtained using software “instruments”.
The quality of a link is tested as follows:

- Latency (response time or RTT) is measured with the “SmokePing” application.
- Jitter (latency variation) id measured with an Iperf UDP test.
- Datagram loss is measured with an Iperf UDP test.

The bandwidth is measured through TCP tests. To realize this test is used Filezilla FTP server and client.

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