IMPROVING MV GRID CONTROL, REMOTE OPERATIONS AND RELIABILITY THROUGH ADVANCED TLC NETWORK AND SCADA ARCHITECTURE.

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ABSTRACT

The evolution of the Electric Grids in the next years will go through the development and the diffusion of many Smart Grids solutions. DSO's networks play a leading role in data acquisition, integration and processing to manage energy flows, automatic grid configuration, renewable DG dispatching and power losses optimization. Advanced TLC networks and SCADA's architecture are required to merge all these capabilities in a real smart grid.

INTRODUCTION

e-distribuzione (an Enel Group Company), the main Italian DSO, is renewing its whole remote control system since 2015 developing a new TLC network with very high bandwidth, full redundant links and devices, very rapid network paths rearrangement and a new SCADA architecture based on virtual machines, full disaster recovery with business continuity and an improved HMI.

All these technologies extend the system capability:

1) Improving real time electrical data acquisition adding new signals from MV/LV stations and DG to the ones already acquired from HV/MV stations (power flows, voltage, currents, switchgears status)

2) Moving real time data processing and correlation from central SCADA to "in field" devices thanks to IEC 61850 services suite for automatic fault detection and load shedding.

3) Improving data center and IED interconnections resilience.

TLC NETWORK ARCHITECTURE

Design Criteria

A proprietary IP multiprotocol network spreads all over the country, connecting all **e-distribuzione's** control rooms, one multipurpose national data center, three Enel Group ICT facilities and one headquarter "situation room" in Rome.

It consists of a backbone formed by twelve main meshed nodes and eighteen peripheral nodes. It uses several communication protocol such as MPLS (Multi Protocol Label Switching), BGP (Border Gateway Protocol) and OSPF (Open Shorter Path First).

It allows gathering real time data from the field and offers the possibility to remotely manage any station connected to the backbone (with wired or wireless technology such as LTE, UMTS, ADSL and FO) virtually from any control room in the country.

Furthermore, it allows data traffic supporting power system simulation, power quality monitoring and 35 million smart meters management.

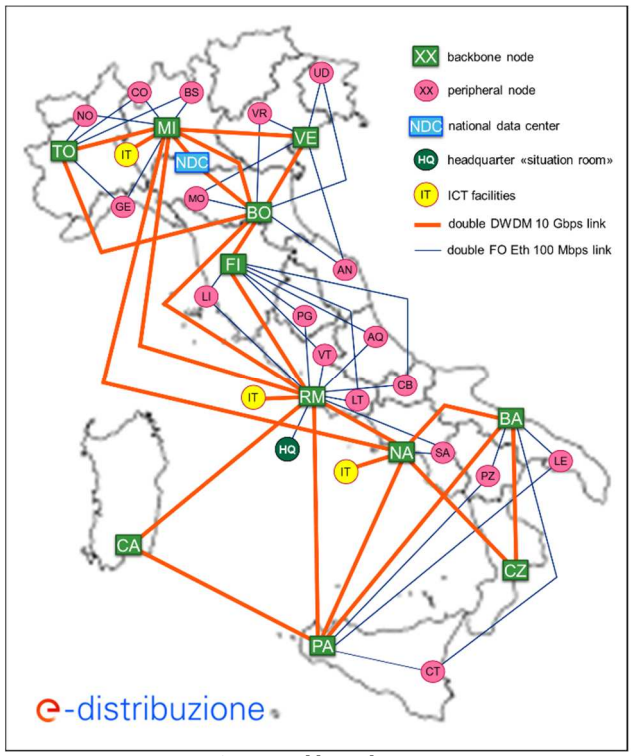

Fig. 1 Backbone layout

Resilience

The network is able to adapt itself in case of components failure (devices or links), thanks both to redundancy and to the choice of useful telecommunication protocols.

Redundancy

Every network node, backbone ones as well as peripheral ones, consists in a double chain of devices (routers, switches and firewalls) ensuring full network performances in event of failure of one component. In order to achieve the same aim, two different TELCO operators provide links between the nodes (dual homed).

In this way, the network still offers full performances even in case of a very unlucky double failure (appliance and link) in a single node.

Convergence

Specific features of the OSPF (Open Shorter Path First) dynamic routing protocol, such as LFA (Loop Free Alternate) and BDF (Bidirectional Forwarding Detection), allow very rapid convergence time (few tens of milliseconds) in case of device or link failure.

High Capability

This TLC network is able to quickly transport a huge amount of data, granting a full real time control over grid operations thanks to 50 DWDM 10 Gbps leased links interconnecting the backbone nodes and to 72 Ethernet 100 Mbps leased links connecting the peripheral nodes to the backbone ones.

DWDM

Dense Wavelength Division Multiplexing is an optical technology, which works transmitting over a single fiber multiple signals at different wavelengths (lambda). It offers the possibility to connect directly two distant sites with high bandwidth - 2,5/10 Gbps - and high availability at an affordable cost.

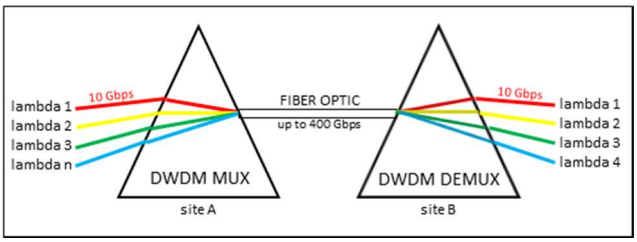

Fig. 2 DWDM

Cyber Security

Network and system segregation is one of the main pillar in OT (Operation Technology) system cyber security.
Although the network has not connections with the public network (web), its borders are equipped with security appliances, in order to filter and monitor data traffic.

All the ICT best practices, in terms of firewalling, intrusion prevention, antivirus and risk monitoring, are adopted and adapted in the e-distribuzione's TLC network to get the best security and resilience results.

SCADA ARCHITECTURE

Server farms and control rooms lay-out

The new grid control system is based on 11 server farms spread all over the Italian country. Each farm is built in a key site and hosts a SCADA system. Each SCADA system controls one part of the whole grid as shown with different colors in Fig. 3 and has one Master Control Room (MCR) and 1, 2 or 3 Slave Control Rooms (SCR).
MCRs are typically located in the same building of the server farm and manage HV/MV stations and a portion of the MV and LV grid.
SCRs are located in different cities and are connected with a 100 Mbps link to the competent SCADA system [Fig. 3].

Fig. 3 Grid Area Subdivision, Server Farms, MCR and SCR

Server Farms are spread all over the country to achieve the "geographical resilience" of the system. Each server farm has a twin farm to manage its real time backup. The system will automatically reconfigure in case of failure or loss of a server farm ensuring business continuity.

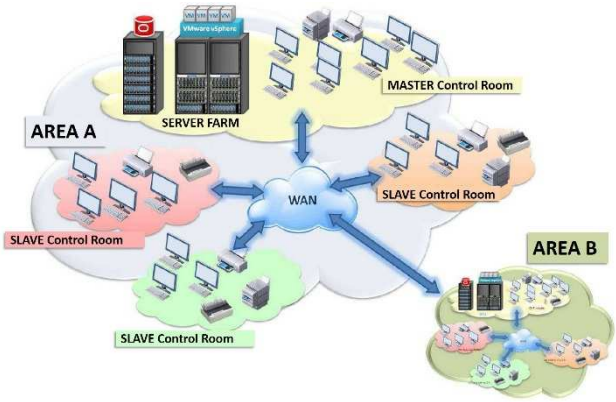

Fig. 4 SCADA layout

Virtual Machines

SCADA is based on Virtual Machines architecture which allows a sensible increase of computational performances with dynamic resources allocation to processes that, time by time, have priority. This technology also allows the full disaster recovery with business continuity.

Disaster Recovery

The system architecture allows an high resilience to failure or unpredictable events (floods, earthquakes, attacks,…).

Hardware failure is guaranteed with the full redundancy of all devices. Each SCADA system is built in a couple of twin racks. The system is capable to run in the n-1 condition: doesn't care which is the damaged component.

The protection against the lost of a farm due to unpredictable or natural events is guaranteed with real time backup between twin farms. Thanks to Virtual Machines technology each server farm runs its own SCADA system and the whole twin system in hot spare. The high bandwidth TLC network and LANs configuration over the WAN allow real time database alignment and disaster recovery capabilities in business continuity.

There is also disaster recovery for control rooms. In case of building unavailability due to natural events or attacks the control of the grid is switched to the MCR (in case of SCR problems) or to the twin MCR (in case the problem is in a MCR).

Each MCR has a set of hot-spare operator's desks to host operators from other CR. They can be used in case of disaster or to extend the control capabilities of the room in case of grid emergency.

Control Rooms and new HMI

SCADA system is not the only key element for a great grid management. Versatile control rooms with H24/7 shifts, offer full control over electric network operations. Human supervision is required to achieve high reliability levels and effective operations.

The HMI (Human Machine Interface) is the core element to gain an easy interaction with SCADA offering all the most important information in a glance. Dedicated large format display solution guarantee a simple and quick interaction.

The operator's desk is 2.5 meters large and hosts one 55'' large format display in the center and four 22'' displays (two on its right side and two on the left one). [Fig. 7]

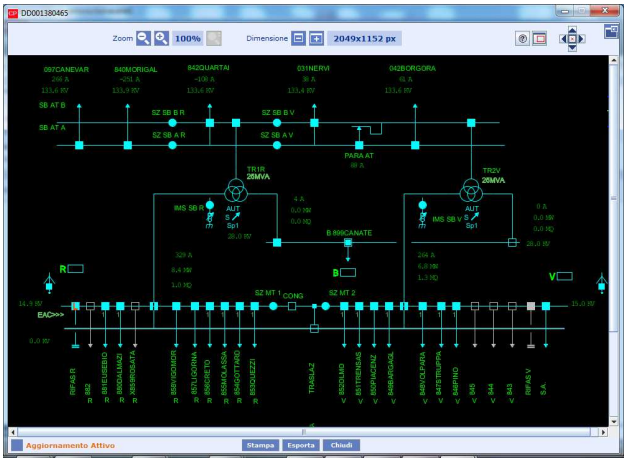

Fig. 5 Operations tab for HV/MV station

The main display shows grid layouts and all the tools for operations.[Fig. 5]

The top right display [Fig. 6] shows all the events on the grid in text line format. Different line colors define specific clusters of events: protection trips, operations, switchgears status, alarms… The operator can see all the detailed events on the grid and their temporal succession.

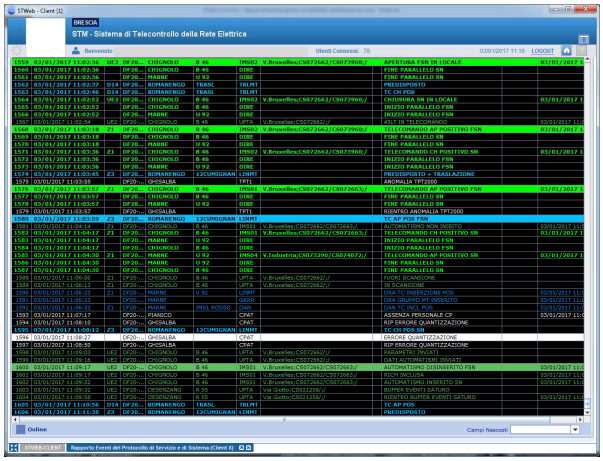

Fig. 6 Grid Events

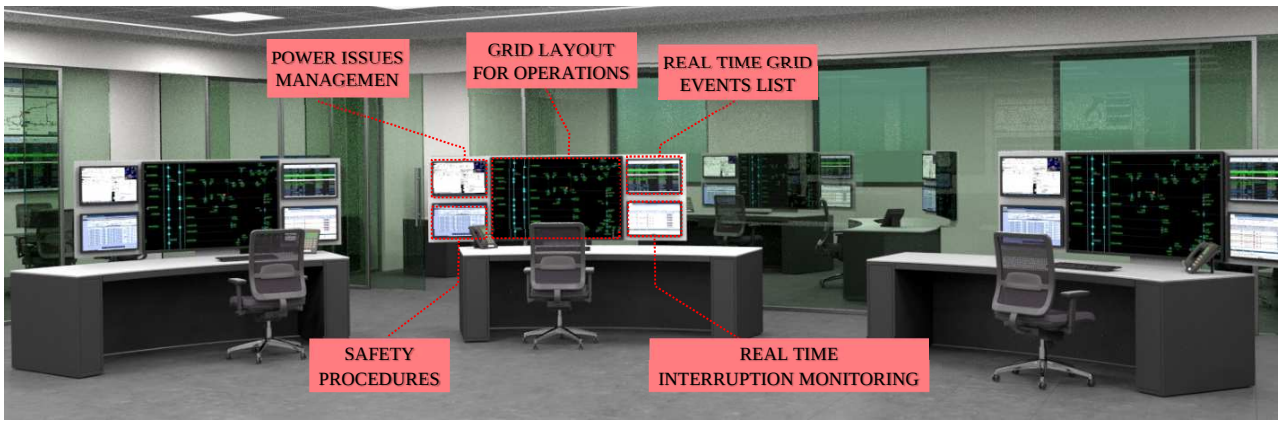

Fig. 7 Control Room with new HMI

The bottom right display [Fig. 8] shows an application called RETIM (Real Time Interruption Monitoring). It offers a synthesis of all the power cuts on the grid (both scheduled and accidental) allowing data aggregation for territorial area, for MV feeder or HV/MV station.

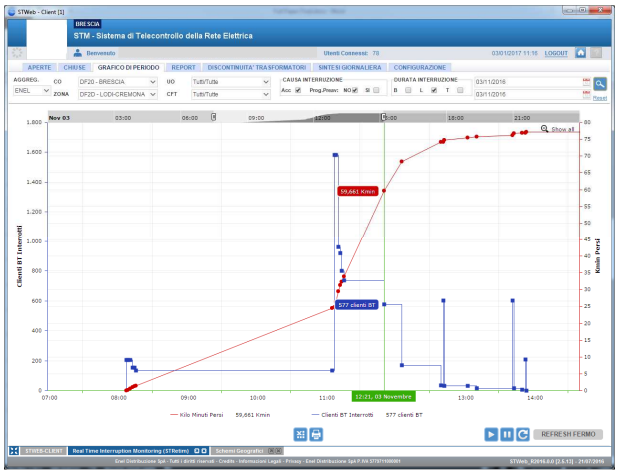

Fig. 8 Power cuts area aggregation

It also gives the opportunity to see the real time status of MV grid on a geographical map [Fig. 9] pointing out power cuts on feeders or substations with different colors.

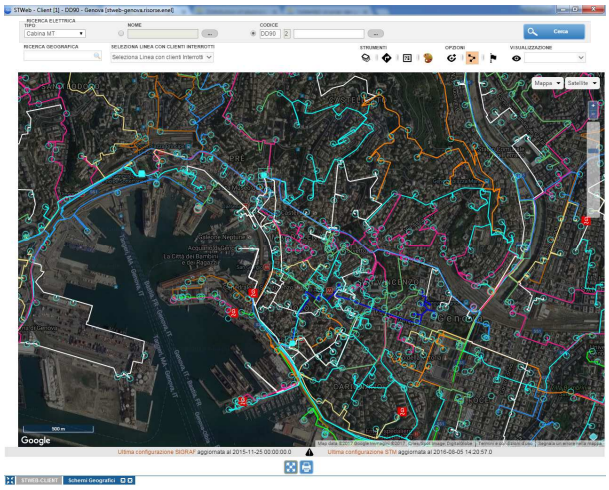

Fig. 9 Genoa's MV Grid

On the bottom left side there is an application to manage safety procedures for working activities on the grid.
On the top left an application to manage reported power issues from customers via telephone and alerting the nearest team for technical intervention. The application displays the position of reported issues and **e-distribuzione's** crews over a map.