TELECOMMUNICATION INFRASTRUCTURE FOR ENEL MV SMART GRIDS

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ABSTRACT

This paper introduces Enel Distribuzione's choices in terms of communication and network solutions to face the new challenging requirements of the Smart Grid projects on Enel Medium Voltage network. The deployment of this solutions is ongoing in several "pilot projects" that are based on new communication technologies (LTE and Wimax) and architectures.

INTRODUCTION

In the last three years Enel Distribuzione has designed and developed new "Smart Grid" solutions for the remote control and automation of its own electric grid.
One of the main target of the new developments is the management of Distributed Energy Resources (DER) in the Medium Voltage (MV) Grid, in order to enhance quality of service, increase grid hosting capacity with reference to DER, avoid undesired islanding conditions.
All the new automation and control functions, designed according to the new scenarios in the MV grid, are totally based on IEC 61850 service suite. Enel Distribuzione decided to adopt the IEC 61850 standard for any new development of IEDs and "Smart Grid" functions. The main functions are:

- a new fast fault detection algorithm;
- a real time DER shedding application (as anti-islanding approach)
- a voltage regulation, by the remote control of DER and Storage

All these functions introduce new telecommunication requirements who overcome the current communication solution in Enel MV grid, based on point-to-point (SCADA-RTUs) and GSM dial-up connections.. New communication solutions have to enable:

- new logical paths among substations
- real-time, and therefore always-on connections, everywhere.

4G MOBILE TELECOMM. CHOICE

Enel choice of 4G connectivity offered by TELCO Providerswas born to satisfy the strict latency and bandwidth requirements of the new Smart Grid applications in MV grid.
The advantage of this solution is to the use of communication solutions already in TELCO's portfolio, avoiding any approach based on dedicated communication infrastructure, however, we have to mention that the main Telcos are going to deploy 4G services in the largest Italian towns, instead Enel interest is often in rural area, where DER is particularly concentrated. This means significant investments by Enel in order to finance the provider 4G infrastructures in the areas .where "Pilot Smart Grid Projects" are deployed.

To the first strategic constraint (no proprietary communication infrastructures), Enel adds the compliance with IEC 61850 standard, not just inside a single substation but for each cluster of substations. We have to remark IEC 61850 standard was designed at first for the automation inside a "substation". It means that several services and applications, used in this 61850 "suite use "layer 2" protocols (ISO/OSI stack), in order to match real-time requirements. "GOOSE" is one of IEC 61850 protocols mapped on the "layer 2" but it's used in Enel WAN (not substation LAN!) to implement several Smart Grid functions.
With this assumption the most stringent latency requirement is associated with the new fast fault detection algorithm. It is based on a blocking tele-protection scheme and GOOSE messages ("blind" messages) are generated simultaneously by all the fault detectors along MV feeder upstream of the fault (Fig.1). "Blind" messages have to be exchanged among the relevant fault detectors in secondary substations, in a time window of about 100ms to successfully implement the algorithm. As is clear, this requirement is incompatible with 3G latencies.

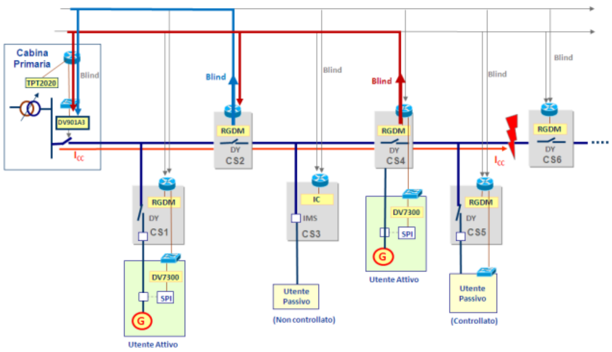

Fig.1: Example of blind messages exchange in case of fault

THE NETWORK ARCHITCTURE

The architecture solution has not just to offer real-time performances to the new Smart Grid functions, but it has to enable new communication flows between

substations and an always-on communication, overcoming the current GSM communication between SCADA system and RTUs in the Medium Voltage (MV) Grid. Furthermore the new network architecture has to face MPLS TELCOs network, who has in charge 4G coverage of Enel plants, satisfying scalability requirements. A "Hub and spoke" approach was adopted, where the HUB node, based in Enel MPLS corporate network is essential for the aggregation, commutation traffic and security. The HUB node should be well located to serve different areas, that can be geographically remote and to have an adequate Gigabit Ethernet connection with TELCO Providers and potentially it can extend in the future the number of spokes including new Smart Grid areas with their substations and it guarantees the interworking between different wireless communication technologies and different TELCO Providers (i.e. the wireless access network for substations belong to the same MV feeder could be different LTE/Wimax).
The secure transport of both level 2 (goose) and 3 (IP) messages to and from substations is guarantee through point-to-point tunnel IPSec connections with the HUB.
Instead Level 2 messages (goose) are transported in L2TPv3 tunnels before the encapsulation in IPSec tunnel. Accordingly the HUB node also has the role of terminations of both IPSec and L2TPv3 tunnels. In the picture below (Fig.2) an example of the communication network architecture adopted in Isernia Project.

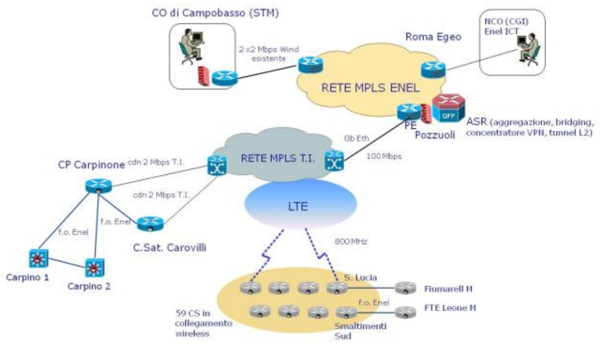

Fig.2: The network architecture in "Isernia Project"

In Isernia Project the secondary substations access to the LTE network through a Customer Premises Equipment (CPE) provided by the TELCO operator in order to easily manage the connectivity, while the primary substations have a wired connection with the TELCO network. All the substation are equipped with a "Smart Grid router", according to Enel's specifications, for the routing of traffic generated by IED's to HUB node and viceversa and for switching of traffic inside the substation, closing and managing all the necessary tunnelling functions and security issues.

Overview about network sizing

The throughput sizing, for every access to the network, is strongly dependent by the latency time, the network topology and other issues. Several factors were considered because of their conditioning the appropriate band, both uplink and downlink sizing; they are:

- Electric network topology in term of maximum number of IED detecting simultaneously the fault on the MV feeder
- 100 ms latency and the traffic dynamics (simultaneous events and goose ramp generation)
- Messages size with overhead (due to the different tunneling methods)
- Probabilistic assessment of any other kind of traffic (i.e. MMS)

For the bandwidth size, the analysis should consider the worst case and led to the following table (Tab.1):

Banda minima richiesta [Mb/s] m=2							
n*_max	Delay						
	30ms	40ms	50ms	55ms	60ms	65ms	70ms
1	0,2	0,3	0,3	0,3	0,4	0,4	0,5
2	0,3	0,4	0,5	0,5	0,6	0,7	0,8
3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
4	0,5	0,6	0,7	0,8	0,9	1,1	1,2
5	0,6	0,7	0,9	1,0	1,1	1,3	1,5
6	0,7	0,9	1,0	1,1	1,3	1,5	1,7
7	0,8	1,0	1,2	1,3	1,5	1,7	2,0

Tab.1: Minimum access bandwidth in secondary substation

Summarizing, considering 5 (*n*_max*) IED detecting simultaneously the fault and generating "blind" messages ramp, at least 2 "blind" replicas (*m*) received by the fault detector in secondary substation and 70 ms delay, the minimum bandwidth requested in:

- secondary substation is 1,5Mb/s.
- primary substation is 1,6 Mb/s
- HUB 8≤bandwidth Mb/s≤21

These values impact another aspect of the network architecture design, described above, with the setting-up of bridge domain at HUB level including the primary substation and all the secondary substations of MV feeders involved and vlan segregation in the substations nodes. These actions allow to confine the goose traffic and to limit the number of connections required avoiding the transmission of goose messages to substations not interested in receiving them and avoiding network congestions too.

CONCLUSIONS

The always on remote control of secondary substation in POI-P3 project is already a reality thanks to the implementation of this network solution.
At the same time a network performance monitoring on POI-P3 network is ongoing through a dedicated client-

server platform installed in the main node of Smart Grid network. First results over some random sites highlight that the latency (100ms) and bandwidth (1,5Mb/s) between secondary substations are respected.
As a confirmation, first measurements between secondary substations connected by LTE (using ICMP packets of 400byte size as goose messages) revealed an average Round Trip Time (RTT) about 55 ms in a temporal window of a week (Fig.3)

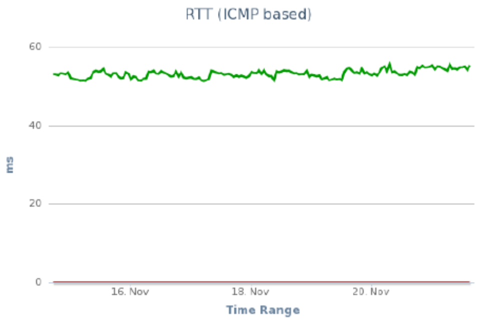

Fig.3- Average RTT between two LTE secondary substations

These early results are really promising for the successful use of Smart Grid functions by adopting the Enel's network architecture solution