ABSTRACT
This paper describes the application of Advanced Meter Infrastructure (AMI) and Smart Metering based tools for network optimization purposes – situation in Enel Distribuzione, Dec. 2008.

INTRODUCTION
Advanced Meter Infrastructure (AMI) and Smart Metering enable a variety of utility applications that can deliver substantial efficiencies in network distribution operations. The document describes Smart Metering based applications, relevant features and outputs, aimed to optimize the use of the low voltage (LV) networks. Presently, Enel Smart Metering System covers more than 97% of Enel LV network – Dec. 2008.

ADVANCED METERING INFRASTRUCTURE
Advanced Metering Infrastructure (AMI) refers to a system that measure, collect and analyse energy usage, from advanced devices such as electricity smart meters, through various communication media, on request or the basis of pre-defined schedule.
Starting since 2001 Enel has put in place such a comprehensive, integrated collection of devices, networks, computer systems made by 31,8 M customer premises electronic meters, 350 k data concentrators and some thousand of meters in selected MV/LV substations fully dedicated to energy service applications.
The basic components of Enel AMI infrastructure (named Telegestore) are, by the way, the smart meters installed on each supply node (POD, i.e. point of delivery). They are enrolled by the AMI system through data concentrators internal procedures (named “commissioning”) needing for this activity a basic knowledge of the network structure (i.e. association between smart meters and data concentrator to whom are connected) and remotely managed. Smart meters provide not only with the consumption data but also with the load profile of the customer and the voltage quality data of the POD associated. AMI enables the automatic massive gathering of customer and network data with a secure, reliable fashion and at low cost.
The data, conveniently converted into information, enable to support a variety of utility applications as for instance, the direct measurement of network components loading, the substation energy balance finalized to losses determination (technical/commercial), the voltage quality assessment of the LV network. These features drive a substantial change in the way DSO’s are used to plan and operate the network, making possible to hugely enhance the classical tools based on statistics or deterministic models with real network data, at marginal costs.

NETWORK USAGE APPLICATIONS
With this term (i.e. network usage apps) we refer to all the applications useful to measure directly the load placed on network components (transformers, power lines). This knowledge is very useful to achieve higher level of efficiency in the Distribution.
In the following paragraphs we’ll refer to DTU (Distribution Transformers utilization) and PLDU (power line loading and degree of unbalancing) as specific applications.

Distribution transformers utilization (DTU)
Distribution transformer application practices are often more an art than rigorously based on direct measures of actual loads placed on transformers. This though the effective management of distribution transformers is critical enough for the utility’s financial success.
Reference [1] has shown that conventional practices that evaluate the load of a transformer solely in terms of peak load demand/kVA rating tends to be too conservative since overload factors are normally high and the aging of the transformers depends also on the shape of the load profile (i.e. on the load factor of such profile) and on the ambient temperature at which it operates. AMI allows to have this information in cost-effective and real time way.
To evaluate the load on distribution transformers it would be necessary to install a polyphase indirectly smart meter (EBM) and relevant CT’s connected to low voltage bus bars in the MV/LV substation, as shown in the figure below:
Fig. 1 – Actual load measurement on LV components

Once an optimum saturation of the POD’s with meters is reached, it is possible to obtain the transformer load curve (T), with a sufficient approximation (network losses are not computed), simply summarizing the single load curve of each customer meter (P) without the need to install an additional meter in the substation. An application built on AMI, DTU, enables to acquire from remote the active and reactive load profile data of each customer meter connected to the transformer and to perform the sum of such single load profiles. The result of this mathematical operation yields the active and reactive load profiles on the transformer and combining the two profiles to obtain the electrical apparent load profile.

Then it is possible to evaluate the loading state of the transformer not only in term of capacity to satisfy the peak load demand but also in term of capacity to withstand with its load factor. The following chart shows the extent of the analysis enabled on a transformer load:

![Transformer apparent load vs. Rating (15’ daily samples)](image)

Such knowledge is valuable for the utility since it is possible to optimize the investment on the network basing the decisions over actual data.

Finally, the application combining the active and the apparent profile enable to determine the power factor (PF) profile of the load on the transformer and to evaluate the economic opportunity of MV/LV substation PF correction:

![Power factor of load (15’ samples)](image)

Moreover DTU enables to map the distribution transformers fleet in the domain “peak demand/ kVA rating – Load factor” to evaluate precisely the level of loading of such a fleet (see Fig. 4):

![Utility transformers fleet positioning in the domain Peak load/Rating-Load factor (fleet map)](image)

The fleet map can be used effectively by the utility to guide the investment action plans on the fleet itself in the best way leveraging on actual data.

Power lines loading and degree of unbalancing (PLDU)

In distribution systems, four-wire distribution feeders are made up of three-phase and single-phase sections. Customers are supplied three-phase or single-phase, either from the primary feeder of from a spur. As a consequence, the currents in the three-phase sections are never completely balanced and, in many cases, can be significantly out of balance. It is not uncommon to have as much as 50% difference in magnitude between the highest and lowest loaded phases. Balancing is normally accomplished by selecting the phase of the supply for each load so that the total load is distributed as evenly as possible between the phases for each section of feeder.

PLDU is the application AMI based designed to measure the load on LV lines and relevant degree of unbalance. At the end of the enrolment phase, AMI normally acquires the information of the phase of supply of each single-phase meter. Such information, together with the basic knowledge of the network (i.e. association between meters and lines), is used by PLDU to determine the load placed on each power line and, given a line, the load per phase and the degree of unbalance of the line itself.

Such knowledge is very useful for the utility operations since it is possible to have available from remote the situation of the actual load on the lines and their degree of unbalance. That aimed to take the right actions and achieve a better balancing of the load.

Poor balancing of power lines is one of the primary causes of voltage magnitude variations and interruptions on LV networks.
LOW VOLTAGE NETWORK ENERGY BALANCE (LVEB)

Energy Balance refers to an application AMI based (LVEB) that enable to determine precisely the difference between the total active energy withdrawn by all the customers connected to a distribution transformer and the total active energy fed by the MV/LV transformer, in the same interval of time. To perform the energy balance operations it is necessary to have all the POD measured (i.e. with meter installed), to rely on the complete reachability of the meters and to have the energy balance meter installed in the MV/LV substation (see Fig. 1).

The LVEB application is able to acquire the daily active energy data supplied to customers and to calculate the delta with the total active energy fed by the transformer. This delta, expressed in terms of percentage of the total energy fed, can represent a field of inquiry for revenue protection purposes as it yields additional information useful to pursue frauds.

LOW VOLTAGE QUALITY ASSESSMENT (AQT)

The 292/06 resolution of Italian Regulatory Authority for Electricity and Gas [2] established an obligatory requirement on all DSO operating on Italian territory to install electronic electricity meters for all low-voltage users, including residential ones.

The resolution stated, among other features, that electronic meters have to be able to detect the slow voltage variations according to quality standard fixed in CEI EN 50160 standard.

Meter features

Enel meter is able to detect the violations of the slow voltage variations standard stated by CEI EN 50160 best practice. It counts the number of voltage samples that are within the tolerance range (Vn-10%; Vn+10%) during a week time (current period and previous period). The current period is the period between 00:00 of the previous Monday and the instant of inquiry; the previous period is week before the current week.

The meter stores in its registers the following data:

- Instantaneous voltage value (Vrms average on 10 seconds);
- Number of voltage samples (Vrms averaged on 10 minutes) in the current period within the range (Vn-10% - Vn+10%);
- Number of voltage samples (Vrms averaged on 10 minutes) in the previous period (7 days) within the range (Vn-10% - Vn+10%);
- Max and min voltage value in the current period Vrms averaged on 10 seconds;
- Max and min voltage value in the previous period (7 days) Vrms averaged on 10 seconds;

The total number of samples in a period (current or previous) is 1,008, equal to 24 hours x 7 days x 6 samples per day.

Automatic application program features

AQT is an AMI based application able to acquire and manage the power quality (PQ) information described in the previous paragraph recorded in the meter:

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Fig. 5 – AQT application architecture
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The application named AQT allows to select the set of POD to be investigated for PQ purposes. The selection can be performed either at single POD level or at massive level covering an entire area. Acquired data are stored in a database available for analysis and elaboration.

Examples of data output

AQT yields outputs that allow to verify the compliance of the supply points to the standard. Below is shown a basic output of AQT:

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Tab. 1 – Basic AQT output
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The output contains the following information:

- MV/LV substation ID
- Customer ID
- Meter ID
- Vrms averaged on 10” instantaneous (instant of the acquisition)
- Vrms averaged on 10’ max in the previous period
- Vrms averaged on 10’ min in the previous period
- Vok number of Vrms samples averaged on 10’ within the range (Vn-10% - Vn+10%);
- Vok number of V rms samples averaged on 10’ not within the range (Vn-10% - Vn+10%);
% of $V_{rms}$ samples averaged on 10' within the range ($V_{n-10\%} - V_{n+10\%}$);

CONCLUSIONS

This paper shows how it is possible to leverage on an automatic metering infrastructure to achieve a competitive edge in the distribution asset management activities (network optimization). The complete availability at low cost of information about the utilization of the LV network components enable a dramatical improvement of the distribution practices conventionally based on estimated factors (i.e. contemporaneity/ utilization coefficients). Such factors are in fact often variable for seasonality reasons and typology of LV loads connected. Moreover, the availability of such information enable to completely answer the challenge that utilities face nowadays to be faster and efficient in the response to customer connections requests and to rise of available power supplied. Nevertheless the possibility to rely on the availability of a complete map of the load placed on the LV components is the key to address in the best way the investment decisions on the LV level and to allocate them at managerial level instead of at operative level.

REFERENCES

For a Conference citation:
