PRESENT AND FUTURE FUNCTIONALITIES OF THE ENEL DISTRIBUZIONE POWER QUALITY DATA WAREHOUSE

Christian NOCE
ENEL Distribuzione – Italy
christian.noce@enel.com

Sergio SARTORE
ENEL Distribuzione – Italy
sergio.sartore@enel.com

ABSTRACT

In this paper, a general description of the innovative functionalities of the Enel Distribuzione (ED) power quality data warehouse (PQDW) is carried out; moreover, by means of an example, it will be described the synergy with the other ED network's management systems in the new smart grids perspective.

The PQDW is available through the Enel intranet, by means of an user-friendly web based interface, thus making exploitable the row data recorded by the power quality instruments (PQI), located in more of 500 installations.

In Italy, ED PQDW is the best practice of PQ management systems, combining research and operational issues.

INTRODUCTION

Power quality (PQ) is a critical issue for both the DSO and customers very sensitive to the quality of supply.

Disturbances are always well known in the grid and are mostly due to:

- networks failures and faults on customers installations (voltage dips and interruptions for the users connected to the network);
- rotating machines and transformers inrush currents (rapid voltage changes);
- rapidly changing loads and non linear loads (Harmonics, dips and swells, flicker, etc.).

In the last five years, also the spreading of the Distributed Generation units connected to the MV network can affect voltage regulation and provide abnormal voltage and frequency variations, such that it's important for the DSO to know the real impact of these new installations in term of PQ delivered to the customers.

For these reasons, ED believe that PQ monitoring is an important service that the utilities shall perform for both internal purposes and their customers.

In fact, today, the technology can be highly effective and can identify problem conditions. So, a modern PQ monitoring system should contain those analysis tools needed to organize and study the collected data.

The target is to find out the relation causes-effects for most of the medium voltage characteristics.

The PQ performances are not necessarily due to the utility power system management. In fact, many surveys have shown that the majority of problems are localized within customer facilities: so, PQ monitoring and analysis can be a key factor, for the DSO, to verify the quality of its "product" (i.e. the energy supply), thus improving the relationship with its customers.

For these reasons, ED, starting from the experience of the PQ survey promoted by the Italian Electricity Regulator (AEEG), has developed its own power quality data warehouse collecting the historical samples for a large number of installations, set in the MV distribution networks: 45 HV bus-bars and 360 MV bus-bars in the HV/MV substations and about 80 MV load premises, located in 14 industrial areas, named "clusters" .

This paper presents the actual functionalities of the ED PQDW and try to foresee its potential applications, thanks to the integration with the other enterprise management systems.

The paper also presents one of the most interesting present/future applications from the smart grids perspective.

ARCHITECTURAL DESCRIPTION

The figure 1 shows the complete web-based architecture of the ED PQDW.

The data stored in the PQI are collected by RSE (the Italian Research on the Electrical Systems) by means of a communication and control system, exploiting GSM/GPRS telecommunication network.

Using a simple web-based enterprise platform, ED can automatically download the row data coming from its own PQIs.

The PQ DB server is 24h connected, through the Enel SCADA network, to the other ED grid management systems, thus exploiting all the information and providing linkages between measures and operating data of the network.

The post-processing results are available on the Enel intranet web-site and can be monitored by all the ED network's control centres.

More information about the architecture of the PQDW can be found in [1].

MAIN FUNCTIONALITIES

According to the standard EN 50160, the followings characteristics are monitored:

- power frequency;
- supply slow voltage variations;
- rapid voltage changes;
- supply voltage dips;
- short interruptions of the supply voltage;
- long interruptions of the supply voltage;
- temporary power frequency overvoltage between live conductors and earth;

– transient overvoltage between live conductors and earth;
– supply voltage unbalance;
– harmonic voltage distortion (THD).

In the following sections, the main functionalities concerning the presentation modes of the analyzed data, will be described.

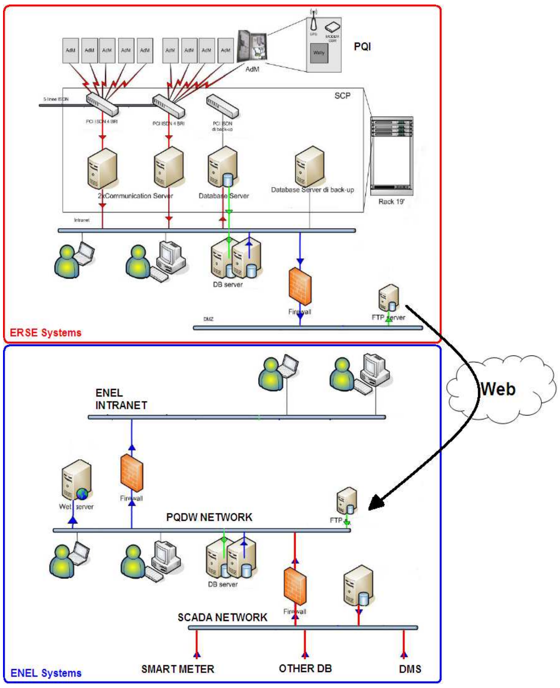

Fig. 1. Architectural design of ED PQDW

Available analysis for the continuous phenomena according to the EN50160

Every voltage characteristic can be monitored both at the single point of measure and in an "aggregated" way.

The typical example is the slow voltage variation: the system allows to represent the trend of maximum and minimum voltage values for a single installation both in numerical and in a graphical way (this is very import to verify if the transformer's tap charger and automatic voltage regulator have worked correctly).

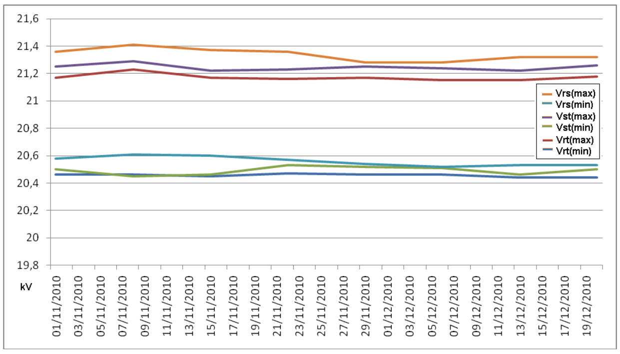

Fig. 2. Example of 3ph voltage profiles (max and min) in the 20 kV bus-bars of a HV/MV substation

The MV characteristics can be easily shown also for a set of points of measures in the same network.

Here below, there is a picture (figure 3) focusing on the 3ph RMS voltage variation measured in one MV cluster (i.e. area where a subset of customers premises, are supplied by the same HV/MV substation).

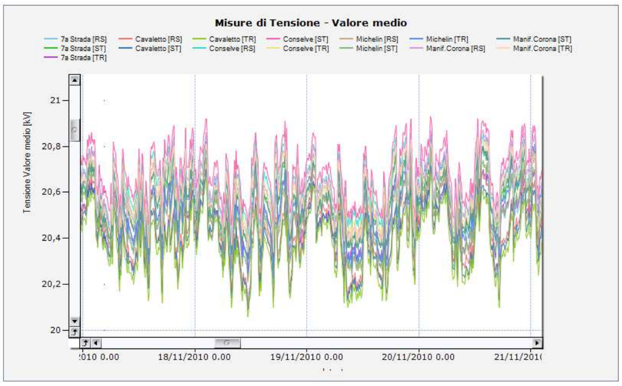

Fig. 3. Set of measures of the 3ph RMS voltage in the 20 kV network supplying an industrial area (PQDW visualization).

Similar analysis can be displayed for the other supply characteristics of EN 50160 standard (figure 4), such as THD, power frequency, voltage unbalance and current/power measures; at this aim, by means of the PQDW, voltage profile can be compared with current measures absorbed by the loads or it's possible to monitor the power frequency during the network's emergency conditions (i.e. loss of large power plants, or sudden high loads variation, etc..).

The PQDW provides also periodical reports giving the results in term of the EU standard compliance and statistical values.

Ampiezza della tensione

Settimana	Fase	Violazione EN50160	Percentuale entro il ±10% Un	Percentuale entro il ±15% Un	95° Percentile [kV]	Minimo assoluto Valore [kV]	Minimo assoluto Istante	Massimo assoluto Valore [kV]	Massimo assoluto Istante
Dal 30/08/2010 al 05/09/2010	RS	NO	100,0	100,0	20,78	20,46	01/09/2010 7.40	20,86	01/09/2010 1.50
	ST	NO	100,0	100,0	20,81	20,50	01/09/2010 7.40	20,90	01/09/2010 2.00
	TR	NO	100,0	100,0	20,79	20,46	01/09/2010 7.40	20,85	01/09/2010 2.00

Squilibrio della tensione

Settimana	Violazione EN50160	95° Percentile [%]	Minimo assoluto Valore [%]	Minimo assoluto Istante	Massimo assoluto Valore [%]	Massimo assoluto Istante
Dal 30/08/2010 al 05/09/2010	NO	0,18	0,06	05/09/2010 17.00	0,20	01/09/2010 0.40

Frequenza

Settimana	Violazione EN50160	95° Percentile [%]	Minimo assoluto Valore [Hz]	Minimo assoluto Istante	Massimo assoluto Valore [Hz]	Massimo assoluto Istante
Dal 30/08/2010 al 05/09/2010	NO	0,04	49,96	01/09/2010 23.10	50,10	30/08/2010 7.10

Flicker di tensione

Settimana	Fase	Violazione EN50160	Pst 95° Percentile	Plt 95° Percentile	Minimo assoluto Valore	Minimo assoluto Istante	Massimo assoluto Valore	Massimo assoluto Istante
Dal 30/08/2010 al 05/09/2010	RS	NO	0,40	0,40	0,14	30/08/2010 12.00	1,13	04/09/2010 1.40
	ST	NO	0,42	0,63	0,22	30/08/2010 12.00	1,12	04/09/2010 1.40
	TR	NO	0,37	0,61	0,11	30/08/2010 11.50	1,10	04/09/2010 3.00

Fig. 4. Example of the analysis reports for the EN50160 compliance evaluation, provided by ED PQDW.

Available analysis for the voltage events according to the EN50160

Voltage dips and supply interruptions are usually the critical issues for the most sensitive industrial processes, so it's very

important to detect them with accuracy and try to find out the potential or effective causes.
The principal tools of the PQDW provide a classification in term of depth and duration of the voltage dips detected by the PQIs. Looking, for instance, at the table 1 that is related to an HV/MV substation monitored for a 5 months period (02/08/2010 ÷ 02/01/2011), it's possible to confirm that the most of dips has the typical duration between 100 and 500 ms and depth up to 40% of the nominal voltage.

Tensione residua [% Vn]	Durata [ms]								
	20÷100ms	100÷500ms	0.5÷1s	1÷3s	3÷20s	20÷60s	60÷180s	>180s	Totale
85÷90	3	0	0	0	0	0	0	0	3
70÷85	2	5	0	0	0	0	0	0	7
40÷70	2	10	0	0	0	0	0	0	12
10÷40	0	3	0	0	0	0	0	0	3
<10	0	0	0	0	0	0	0	0	0
Totale	7	18	0	0	0	0	0	0	25

Table 1 - UNIPEDE voltage dips classification, in term of duration and depth related to the nominal voltage.

Moreover, it's also possible to draw data in the CBEMA and EN50160 curves and even to examine, in detail, the waveform of the single voltage event, as it is shown in figures 5 and 6.

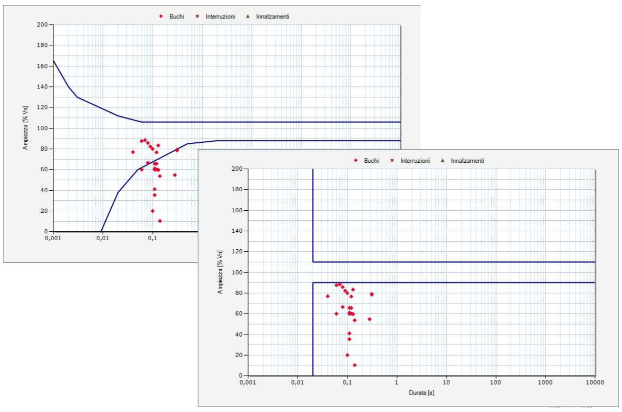

Fig. 5. CBEMA and EN 50160 curves.

Istante	Tipologia			Durata [s]	Tensione residua [kV]	Tensione residua [% Vn]
	RS	ST	TR			
07/11/2010 21:54:50,33	X	X		0,06	17,54	87,68

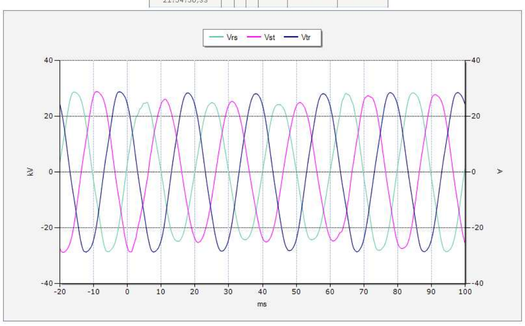

Fig. 6. Waveform during a voltage dip occurred into the MV network, displayed by the ED PQDW.

All of the above analysis and tools are very important because they could be used to support the manufacturers and help the DSO's customers to optimally design the equipment useful for their installation's power quality improvement (UPS, SVC, resonant transformers, etc.).

Integration with other DB

This application deals with an high potential sector for the modern PQ monitoring system development. The current integration between the PQDW and the other ED systems/database, implemented for the future smart grids scenarios, will provide an added value to the information managed by the DSO; in fact, it will be possible to match, to compare and post-process all data coming from the smart appliances (network automation and remote control, metering, demand management systems, PQ monitoring, etc.) integrated in the ED SCADA network.
Such integration will improve the understanding of the actual level of the MV supply characteristics, providing more data and information about the causes and the way of spreading of the PQ disturbances. The high number of the points of measure (PQI installed) will assure relevance to the statistical evaluations and profitable field-tests to develop the new functionalities.

AN EXAMPLE OF SMART APPLICATION

Nowadays, ED has about 1.700 HV/MV substations and almost 100.000 MV/LV substations remotely controlled and connected by the enterprise SCADA network.
Day-by-day, there is an huge amount of signals and commands the MV network can transmit and that can be displayed on the remote grid-operator's screen. All of these data give information on how the network operation is going, so they have been correlated with the supply voltage dips in order to analyze when and how many network events, such as the protection devices tripping, depend on the faults in the DSO networks (at this aim, further interesting results can be founded in [2], [3] and [4]).
The figure 7 below is only an example of the above correlation. Nine faults in the MV feeders supplied by the same HV/MV substation, occurred in the last two months of 2010 and detected by the relays tripping, caused a corresponding number of voltage dips in the network.
Experience has shown that it's possible to investigate on the real causes of the PQ events, in order to establish with accuracy if they come from the TSO's network, the DSO's network or the User's installations, thus providing further information to those players of the Electricity market (such as, customers, regulator and so on) interested in updating the EMC standardization and/or in drawing new kind of mutual agreements based on PQ issues ("Quality contracts").
Finally, since one of the most relevant advantages due to automation techniques set up in the MV network management is to reduce the number of the supply

interruptions, it's well clear that those tools concerning the "transient phenomena detection" shall be further improved, in order to optimize the enterprise PQDW towards a monitoring system fully dedicated to the PQ network performances.

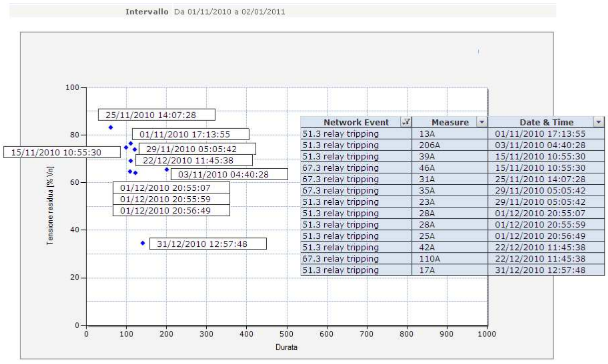

Fig. 7. Correlation diagram between voltage dips and the MV network events (the blue spots are the voltage dips which presented the full correlation with the network events).

In the above chart, voltage dips are displayed in term of their characteristics (duration and residual voltage respect to the nominal value).

CONCLUSIONS

This paper has described the innovative web-based power quality monitoring system of Enel Distribuzione focusing on its functionalities.

ED planned important investments to improve the continuity of supply in its networks, according to the recommendations and disposals of the Italian Regulator (AEEG); the achieved results have confirmed the efforts sustained (figure 8).

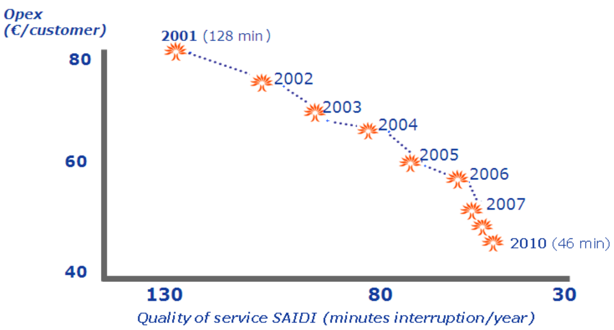

Fig. 8. Continuous improvement of the cumulative interruption time to the customers over the years.

Following the same approach in the "power quality" field, ED has developed its power quality data warehouse, with own tools completely customized and independent from the ones realized for national researching issues, in the other systems: "Queen", by RSE and "Monique", by TERNA S.p.A[1].

The first release of PQDW has a set of functionalities made available by means of a quick but secure access module in the enterprise intranet, protected by password and firewalls, thus allowing to analyze the medium voltage characteristics and checking their compliance with EN 50160 limits; moreover, the integrations with other ED DB systems make exploitable the correlation between the above analysis and the network operational events (for example, the circuit breakers and protections tripping).

This integration process has already started and it is still in progress: so, in the next future, it could be possible to manage within the same web-platform all data coming from the smart appliances remotely controlled by ED.

The principal advantages are:

– to monitor the actual level of the medium voltage characteristics, helping DSO's operators to take duly into account the PQ issues, in the network control and management processes;
– to provide more data and information about the causes and the way of spreading of the disturbances, thus helping ED customers to optimize their investments and installations and to become more insensitive from the voltage dips or the other voltage characteristics, set in EN 50160 standard.

REFERENCES

[1] C. Noce, S. Sartore, 2010, "The new Enel Distribuzione power quality data warehouse and its applications for smart grids", *Proceedings of ICHQP 2010.*

[2] Valtorta, Di Marino, Cerretti, Allegranza, De Berardinis, "Preliminary results of the power quality survey in progress on the MV ENEL network", *Proceedings of CIRED 2007, paper 0654.*

[3] Valtorta, Cerretti, Sartore, De Berardinis, Cugini, "Power quality analysis of MV networks supplying industrial areas in Italy", *Proceedings of CIRED 2007, paper 0647.*

[4] Valtorta, D'Orazio, Sartore, De Berardinis, "Power quality survey in progress on the MV ENEL network: analysis of gathered data", *Proceedings of CIRED 2009, paper 0363.*

[5] Valtorta, D'Orazio, Sartore, De Berardinis, "Power quality survey in progress on the MV ENEL network: analysis of gathered data", *Proceedings of CIRED 2009, paper 0363.*

[1] TERNA S.p.A. is the Italian Transmission System Operator. It has developed an owned PQ monitoring system of the HV network characteristics (called "MONIQUE").