Power Quality Management System – Batch Data Processing

This global standard defines the different types of batch data servers for the new set of ENEL's power quality central systems.

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ACRONYMS

- **PQ** Power Quality
- **PQI** Power Quality Instrument according to IEC 62586-1
- **PQMS** Power Quality Management System
- **REST** Representational State Transfer
- **JSON** JavaScript Object Notation
- **SCADA** Supervisory Control And Data Acquisition
- **HMI** Human Machine Interface
- **CREG** Commision of regulation of energy and gas (Colombia)

1 NORMATIVE REFERENCES AND BIBLIOGRAPHY

All the references are intended in the last revision or amendement.

1.1 For all countries

IEC 61000-4-30	Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods.
IEEE C37.111	IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems
IEEE 519	IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
IEEE 1159	IEEE Recommended Practice for Monitoring Electric Power Quality
ISO 8601:2004	Data elements and interchange formats – Information interchange – Representation of dates and times
ECMA-404	The JSON Data Interchange Format
RFC 4180	Common Format and MIME Type for Comma-Separated Values (CSV) Files
RFC 2138	Remote Authentication Dial In User Service (RADIUS)
RFC 2139	RADIUS Accounting
RFC 5280	Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile
RFC 791	Internet Protocol, Version 4 (IPv4)
RFC 2460	Internet Protocol, Version 6 (IPv6)
Appnote,1 APPNOTE.TXT	ZIP File Format Specification, PKWARE® Inc., September 2012
NMEA 0183	National Marine Electronics Association electrical signal requirements, data transmission protocol and time, and specific sentence formats for a 4800-baud serial data bus
ISO/IEC 7810	Identification cards - Physical characteristics
GSTQ001	Fixed installed indoor Power Quality Instrument
GSTQ002	Extended Power Quality Data Interchange Formats
GSTQ003	Power Quality Management System
GSTQ004	Power Quality Management System – Human Machine Interface

1.2 For EU countries

EN 50160	Voltage characteristics of electricity supplied by public distribution systems.

1.3 For Spain

R.D. 1955/2000	Real Decreto 1955/2000, de 1 de diciembre, por el que se regulan las actividades de transporte, distribución, comercialización, suministro y procedimientos de autorización de instalaciones de energía eléctrica.

1.4 For Italy

RSE 12004159	Specifiche tecnico-funzionali delle apparecchiature di monitoraggio della qualità della tensione per le reti MT.
[1]	R. Chiumeo, M. de Nigris, L. Garbero, C. Gandolfi, L. Tenti, E. Carpaneto, “Implementation of a New Method for an Improved Voltage Dips Evaluation by the Italian Power Quality Monitoring System in Presence of VT Saturation Effects”, International Conference on Renewable Energies and Power Quality (ICREPQ’10), Granada (Spain), 23rd to 25th March, 2010.
ARG/elt 198/11	Testo integrato della qualità dei servizi di distribuzione e misura dell’energia elettrica per il periodo di regolazione 2012-2015
646/2015/R/EEL	Testo integrato della regolazione output-based dei servizi di distribuzione e misura dell’energia elettrica per il periodo di regolazione 2016-2023

1.5 For Colombia

CREG 024/05	RESOLUCION N° 024 DE 2005. Por la cual se modifican las normas de calidad de la potencia eléctrica aplicables a los servicios de Distribución de Energía Eléctrica.
CREG 016/07	RESOLUCION N° 016 DE 2007. Por la cual se modifica parcialmente la Resolución CREG 024 de 2005 que establece las normas de calidad de la potencia eléctrica aplicables a la Distribución de Energía Eléctrica en el Sistema Interconectado Nacional.

1.6 For Argentina

ENRE 184/2000 ANEXO	Base Metodológica para el Control de la Calidad del Producto Técnico Etapa 2.

1.7 For Brazil

ANEEL PRODIST Módulo 8	Agência Nacional de Energia Elétrica – ANEEL Procedimentos de Distribuição de Energia Elétrica no Sistema Elétrico Nacional – PRODIST Módulo 8 – Qualidade da Energia Elétrica

1.8 For Peru

NTCSE D.S. 020-97-EM	Norma Técnica de Calidad de los Servicios Eléctricos
Resolución 616-2008-OS/CD	Base Metodológica para la aplicación de la Norma Técnica de Calidad de los Servicios Eléctricos – Urbana
Resolución 016-2008-EM/DGE	Norma Técnica de Calidad de los Servicios Eléctricos Rurales (NTCSER)
Resolución 046-2009-OS/CD	Base Metodológica para la aplicación de la Norma Técnica de Calidad de los Servicios Eléctricos Rurales – Resolución de Consejo Directivo OSINERGMIN

1.9 For Romania

Ord 11/2016	Standardului de performanţă pentru serviciul de distribuţie a energiei electrice.

1.10 For Chile

D.S. 327/1997	Reglamento de la ley general de servicios eléctricos.

2 APPLICATION FIELDS

The PQ monitoring architecture can be made by a central system and distributed power quality instruments (PQIs).

The PQI (according to GSTQ001 and GSTQ002) will be installed in any distribution grid for measuring any relevant PQ parameter. The relevant PQ parameters are defined in IEC 61000-4-30, IEC 62749 and EN 50160.

The installation will be a substation or another indoor premise in a country where one or more utilities are under Enel control.

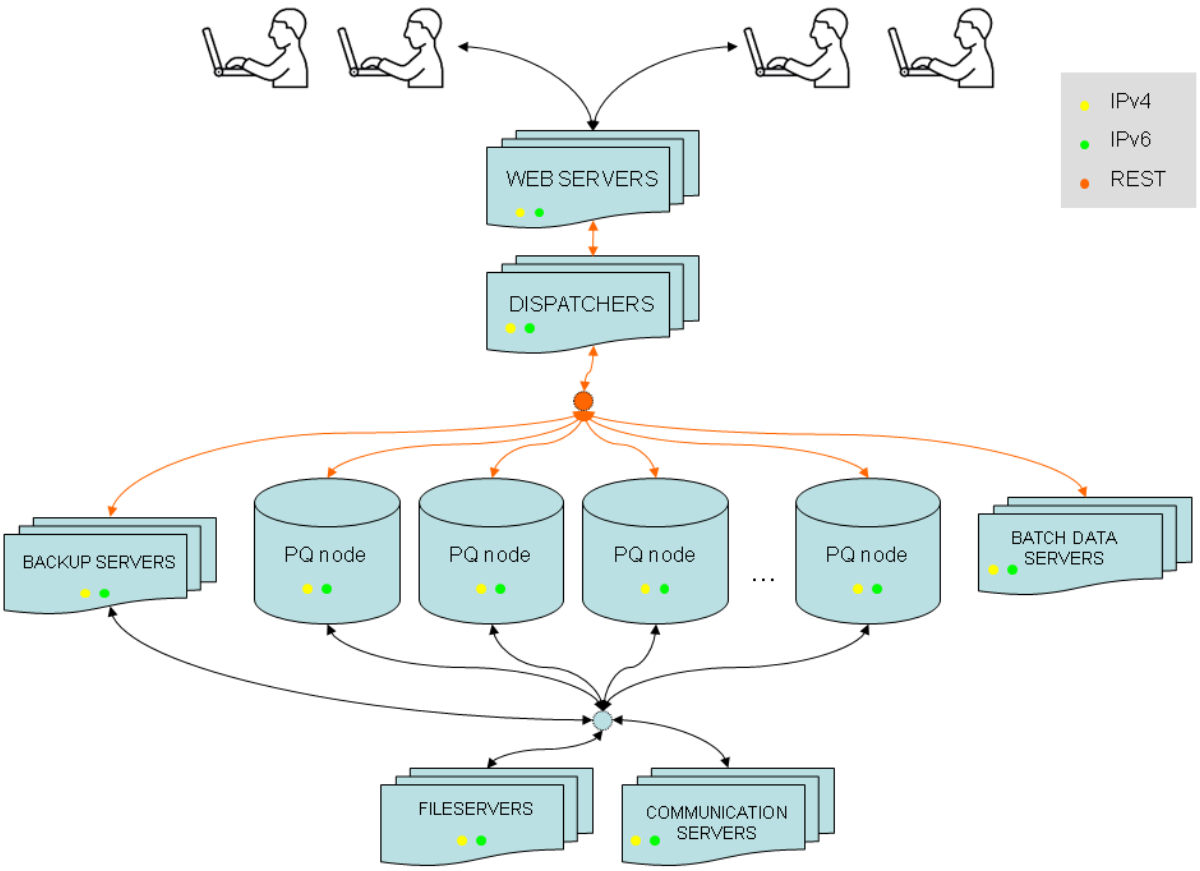
The PQMS is the Power Quality Management System (according to GSTQ003), including data acquisition from PQI, SCADA, weather stations and other relevant systems.

Sometimes primary data from PQIs needs to be processed into secondary sets of power quality variables, e.g. percentiles values. Those units in charge of this post-processing are called *batch data servers* (BDS) and belong to an upstream PQMS. The role of this global standard is to define different types of these servers.

The GSTQ003 is fundamental for the understanding of this document, generally also further GSs may complement this document.

3 BDS IN THE PQMS ARCHITECTURE

BDS are part of a modular architecture according to GSTQ003. The main blocks are depicted in the following picture:



- **WEB SERVER**, to store, process and deliver web pages to end-users.
- **PQ NODES**, consisting of any of the following elements:
  - **PQI**s in remote substation. These PQIs are connected by means of proper and reliable IP networks or any other communication way as in GSTQ002.
  - **PQ DATABASES**, comprising data from several PQIs, that may not have a strong, permanent and reliable IP connection. Aggregated and calculated indices (such as percentile values) could also be inserted in these databases.
  - **WEATHER DATABASES**, collecting data from external weather information services.
  - **GRID EVENTS DATABASES**: these units collect basic information about tripping of feeders, protections and other events or measures from SCADA. The aim is to be fast and standard regardless the SCADA database already used within the DSO.
  - **META DATABASES**: they keep information about the location of any set of data and important attributes (e.g. IP address, latitude, voltage ratio, alias, etc.).
- **COMMUNICATION SERVERS**: they behave as repositories where PQIs upload data or may initiate a connection to them and download specific sets of data.
- **FILE SERVERS**: they just provide shared file services to any server.
- **BATCH DATA SERVERS**: the perform specific calculations on raw data in order to get aggregated indices, such as percentiles or HV/MV origin of events. The results are stored in PQ databases.
- **DISPATCHERS**: they forward any request from the web server to the specific node.

- **BACKUP SERVERS**: they connect to remote PQIs and download specific sets of measurements. Typically they will consist of few 10-minute recordings and events list. Data is stored in a PQ DATABASE.

All these elements exchange information by means of a REST API and few other standard protocols.

Basically BDS collects data from specific nodes, make calculations and store the results in PQ DBs, that results may be laso accessible by the PQMS HMI.

At this moment two basic batch processes are defined, although it could be expanded in the future.

Common server features as stated in GSTQ003 sections 3.2, 3.2 and 3.4 apply.

4 TYPES OF BDS: PERCENTILE BATCH SERVER

The main goal is the assignment of percentile and time-over values according to GSTQ003 ANNEX 5 (Power quality percentile variables) and GSTQ003 ANNEX 6 (Power quality TIMEOVER variables). These weekly aggregated values will be stored in a PQ DB.

First the batch server will query its META DB and get a list of candidates from the PQSITE table. Within a configurable time scope (previously set by its web interface, e.g. 3 months), the server will check whether the weekly magnitudes have already been inserted in the PQ DB. If not, percentiles and time-over variables will be evaluated for the missing weeks taking as input the 10-minute voltages and any secondary measurement (i.e. harmonics, interharmonics, unbalance, flicker, zero-sequence and negative sequence). For the time-over values either the rated voltage or the top levels of the relevant Power Quality Standard shall be used (EN 50160, IEC TS 62749 or IEEE 519).

Starting timestamp for each device's weekly variables shall be delivered by the META DB.

Any parameter shall be configured by its web administration interface (see GSTQ003).

Evaluation period may be upgraded to 1 month or 1 year when national or regional authorities request so.

Next table shows several examples of weekly aggregated variables:

Table 1 – BATCH SERVER – percentiles and time-over values

v_AB_p100	v_AB_p95	v_AB_harm_5_p95	v_AB_plt_p95	v_AB_t93
v_BC_p100	v_BC_p95	v_AB_harm_5_p95	v_BC_plt_p95	v_BC_t93
v_CA_p100	v_CA_p95		v_CA_plt_p95	v_CA_t93
v_AB_p00	v_AB_p05			v_AB_t107
v_BC_p00	v_BC_p05			v_BC_t107
v_CA_p00	v_CA_p05			v_CA_t107

5 TYPES OF BDS: EVENT ORIGIN SERVER

The main goal is the calculation of the HV or MV origin of any voltage dip according the algorithms and methods stated in countries regulations. These aggregated values will be stored in a PQ DB as new voltage dips with extra attributes and presented in the HMI.

Generally, first the batch server will query its META DB and get a list of candidates from the PQSITE table. Within a configurable time scope (previously set by its web interface, e.g. 6 months), the server will check whether the extra attributes have already been inserted in the PQ DB. If not, the server will download all the necessary events lists, perform any required calculation on them and will output another events list in JSON format with extra attributes according to GSTQ003 ANNEX 7 (Power Quality event codes). Each measurement location's unique id will be prefixed by a term, to avoid conflicts when using just one PQ DB for everything).

Any parameter shall be configured by its web administration interface.

5.1 Voltage dips analisys for Italy

Each measurement location's unique id will be prefixed by *"aeegsi198/"*.

For Italy, , each voltage dip is classified by means the application of an official method of classification called OR-2015. . In addition e-distribuzione applies a second method of calculation to classify each voltage dip, this criteria is called OR-ED. Both algorithms, which face the event origin challenge, utilize only the measurements of the voltage dips. In particular, the measured quantities are the residual voltages, the time of their occurrence, and their duration; correlation with external signals or SCADA events may be also adopted.

Both of the methods refer to PQ meters installed at the MV bus of real HV/MV stations that represent the point of common coupling between the two interconnected networks, i.e., the transmission system and the distribution system. A PQ meter is installed at each MV bus of the secondary of the transformer, and they are connected by the inductive voltage transformer (VT) that normally is used for energy measures.

In particular, most of the actual HV/MV substations in Enel perimeter were equipped with two transformers fed by the same HV busbar, but they were not connected in parallel during normal operating conditions. However it is possibile identify three more configurations:

a. two MV busbars for HV voltage level;
b. one MV busbar for HV voltage level;
c. more than two MV busbars for HV voltage level.

In 5.1.a, OR-2015 attributes the origin of all single voltage dips that occur only at one of the MV busses from the same HV busbar to the downstream system, i.e., the MV network. Then, for voltage dips that occur at all of the MV busbars, these voltage dips originate in the upstream system, i.e., the HV network, if all of the following conditions are met:

d. the residual voltages of the voltage dips differ by no more than 10%;
e. the voltage dips occur within 70 ms of each other;
f. the durations of the voltage dips are within 500 ms of each other.

For the MV multi bus bars is added a fourth condition to verify to classify a voltage dip, in fact, the system checks if the "bus-tie circuit breaker" (K) is open.

In 5.1.b, OR-2015 cannot provide results without correlation with external signals or SCADA events, so for all substation with one only MV busbar the OR-2015 consists in the application of OR-ED approach. In particular, for this type of HV/MV substations, the algoritm will check the presence of voltage dips on the

MV busbar of "twin substation"[1]. The list of "twin substation" is officially communicated by the Italian TSO.
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e-distribuzione applies the OR-ED for all substations, also for the those with more than one MV busbar.In 5.1.c, a combinatorial decomposition determine several couples of MV busbar where 5.1.a method is applicable; the voltage dip origin is "MV" only if 5.1.a approach results are "MV" for all the couples.

OR-ED is based on the following steps:

g. all the MV busbars are clusterized for the relative HV voltage level;
h. the geographical area (i. e. distribution area) is divided in several sub-area by according to the connectivity of the the HV network;
i. in each sub-area and for each HV voltage level, the voltage dips are clusterized by checking the contemporaneously (within a Δt) of the starting and ending times;
j. final validations.

OR-ED is developed as geographical method to account for the following conditions:

k. the propagation of the voltage dips can be very wide;
l. the affected areas of the nodes at higher voltage level can involve a broad portion of the lower voltage network, including both busses of the same HV/MV stations and busses of different HV/MV stations;
m. the same fault can cause voltage dips characterized by residual voltages that range over a wide interval;
n. the transformers of the same HV/MV stations are equipped with on-load tap changers that can operate at different positions so that the difference of the residual voltages can exceed the 10% limit imposed by OR-2015, in case of HV voltage dips with high residual voltage (close to 90%) the effect of the tap changers may erase only one voltage dip;
o. the Italian distribution network has high penetration of DER, which makes the transformers' power flow unpredictable and variable.

The OR-ED origin determination algorithm is described in a e-distribuzione technical specification.

[1] The twin substation is the closest one electrically HV plant of the same Network Operator, connected in standard scheme to the examined HV/MV substation.

6 TYPES OF BDS: AGGREGATED EVENTS BATCH SERVER

The main goal is the calculation of total number of events over standard periods for faster data retrieval. These aggregated values will be stored in a PQ DB. Total number of any event type can be calculated over a wide (e.g. a week -604800 seconds-) or short (e.g. 10 minutes -600 seconds-) period and stored as an independent variables. Variables names are constructed as follows:

- Preffix “n_”
- Plus event type according to *GSTQ003 ANNEX 7 “Power Quality event codes”* (e.g. *interruption, dip, swell*, etc.).
- Plus a string with self-defining information about limits (e.g. time and value).

Next table shows a practical example for voltage interruptions, dips and swells[2].

Table 2 – PQ DB: aggregated events variables

variable	description	typical agregation [s]
n_interruption_u0_u1_t0_t60	interruptions shorter than 1 min (0%<=voltage<=1%)	604800
n_interruption_u0_u10_t0_t60	interruptions shorter than 1 min (0%<=voltage<=10%)	604800
n_dip_u1_u90_t0_t60	voltage dips shorter than 1 min (1%<=voltage<=90%)	604800
n_dip_u10_u90_t0_t60	voltage dips shorter than 1 min (10%<=voltage<=90%)	604800
n_swell_u110_uinf_t0_t60	voltage swells shorter than 1 min (110%<=voltage)	604800
n_dip_u1_u95_t0_t60	voltage dips shorter than 1 min (1%<=voltage<=95%)	604800
n_dip_u10_u95_t0_t60	voltage dips shorter than 1 min (10%<=voltage<=95%)	604800
n_swell_u105_uinf_t0_t60	voltage swells shorter than 1 min (105%<=voltage)	604800
n_interruption_u0_u1_t60_tinf	interruptions longer than 1 min (0%<=voltage<=1%)	604800
n_interruption_u0_u10_t60_tinf	interruptions longer than 1 min (0%<=voltage<=10%)	604800
n_dip_u1_u90_t60_tinf	voltage dips longer than 1 min (1%<=voltage<=90%)	604800
n_dip_u10_u90_t60_tinf	voltage dips longer than 1 min (10%<=voltage<=90%)	604800
n_swell_u110_uinf_t60_tinf	voltage swells longer than 1 min (110%<=voltage)	604800
n_dip_u1_u95_t60_tinf	voltage dips longer than 1 min (1%<=voltage<=95%)	604800
n_dip_u10_u95_t60_tinf	voltage dips longer than 1 min (10%<=voltage<=95%)	604800
n_swell_u105_uinf_t60_tinf	voltage swells longer than 1 min (105%<=voltage)	604800

Starting timestamp and evaluation period for each device’s aggregated variable shall be delivered by the META DB. Any parameter shall be configured by its web administration interface (see GSTQ003).

[2] For Colombia the typical aggregation time would be 10 minutes (600 seconds).