XML SCHEMA FOR POWER QUALITY DATA

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Summary – The introduction of deregulation and competition in the energy market has forced utilities around the world to focus on the improvement of both efficiency and cost effectiveness of their operations. Central to this aim is the need to integrate large amount of real time and historical data in order to extract the knowledge so essential for better decision-making. This amalgamation of data originating from various technical and business systems is known as Enterprise Application Integration (EIA) and will in the future include Power Quality (PQ) data. However, this requires the organization of data in a way that is consistent with the overall aim. This paper discusses this aspect and presents an XML schema for power quality data.

INTRODUCTION

The making of good decisions is often dependant on the availability of information and knowledge to the decision maker. The typical functional organization in utilities is often a barrier to the flow of information between departments and thus prevents the exploitation of synergies. For example, asset management could be greatly improved if information contained in systems such as Geographical Information System (GIS), Maintenance Management Systems, Work Management Systems were merged with financial data [1].

The aim of EAI is to specifically break down these information barriers and to make it available wherever needed. This implies the interfacing of a large number of technical systems (SCADA, DMS, etc), commercial systems (SAP, Oracle, etc) as well as the usage of software suites that can process the data and progressively transform it into knowledge suitable for decision-making. Current effort to standardize this exchange of information [2] is also underway and this will simulate the development of standard off-the-shelf software suites for the power industry in the future.

While present usage of PQ data is generally limited to compliance reporting or for ad hoc investigations, EAI will permit the extraction of more of the information they contain. For example, the correlation of PQ data with SCADA, metering or network configuration data can provide insights to the causes of power quality degradation. This would enable improved network operation, planning and upgrade prioritization. Another proposed application is power quality predictive maintenance where the automatic monitoring of abnormality in current waveforms would provide early warning of component failures [3]. The application of data mining and artificial intelligence is also expected to reveal hidden relations among various sources of data [4]. One difficulty with the integration of PQ data with other sources is the volume of data generated by PQ analysers. The large number of instruments required for monitoring a distribution network compounds the problem. Furthermore, the type of information required by the various PQ data consumers may also greatly vary. This calls for a data organization that is layered according to the user’s needs and which is capable of accepting low and high level data. Important also is the need for easy navigation between these various levels as well the preservation of traceability.

This paper reviews first some of the trends that are shaping power quality monitoring and then presents a PQ framework developed at the University of Wollongong in Australia and finally the XML schema built around this framework. It is hoped that such a framework may contribute to future standardization of PQ data and allow its incorporation into larger databases.

SOME TRENDS IN POWER QUALITY MONITORING

The combination of technological progresses, regulatory changes and standardization has lead to the transformation of how PQ is monitored. Key trends in instrumentation, communication and EAI initiative are summarized.

Instrumentation. The last two decades have brought a lot of improvement in the functionality and ease of use of power quality instruments [5]. One of the major trends is the deployment of permanently installed instruments that are accessible any time through various communication media. Another major trend is the integration of power quality capability in protection relays, utility automation systems as well in smart meters [6,7]. Another trend is the present standardization effort in substation automation undertaken by the IEC TC 57 [8]. The aim of this project is to allow the seamless data integration across the utility enterprise using off-the-shelf international standards. In summary, the monitoring of PQ is slowly becoming an integral part of the distribution infrastructure and thus is leading to an increase in the availability of PQ data for EAI.

Communication. The introduction by utility of broadband networks [9] for their operational and administrative needs as well as the future availability of “last mile” broadband communication will permit the reaching of virtually any physical location in a distribution network. This availability will make presently uneconomical systems such AMR (Automatic Metering Reading) and DMS (Demand Side Management) viable, as well as the automatic network wide
PQ monitoring. Other present technologies such as mobile GSM telephony are commonly used in the deregulated electricity market in Australia and could easily have their functionality extended for PQ monitoring.

The creation of a multimedia framework standard MPEG 21 (Moving Pictures Expert Group) by a joint ISO/IEC group will also contribute to system wide PQ monitoring. The aim of this framework is to describe how multimedia elements relate to each other and to enable the transparent use multimedia resources across a wide range of networks and devices.

**EAI data for utility.** The integration of disparate applications running on a variety of new or legacy systems is not an easy task and can be greatly simplified by the adoption of standards defining the semantic of the inter-application messages. This is the aim of the WG 14 of IEC TC57 presently implementing such standards. This standardization is based on an architecture interface that will avoid the need for point-to-point connectivity. Figure 1 shows the various functional areas covered by the IEC 61968 [2] standard.

![Fig. 1 Functional areas of the IEC 61968 standard](image)

This standardization effort is essential for the exploitation of that information synergy and will certainly stimulate the development of the necessary software suites.

**FRAMEWORK FOR PQ DATA**

Power quality monitoring produces a large amount of data that can be time consuming to analysis and requires skilled technicians. Without automation the monitoring of a complete distribution network would be near impossible. Additionally, the extracted information must be tailored to the needs of the various consumers of PQ information. Three levels of PQ reporting have been identified as necessary [10]: site, network, and utility reporting. The respective aim and content of each level are given below:

- **Site:** Detailed information about a given monitoring site. The data are principally used for problems resolution or engineering analysis. Contains time series and / or histograms for each PQ disturbances.
- **Network:** Summarized information about a given site or group of sites. This information is used mainly for prioritization of mitigation measures, planning and system monitoring purposes.
- **Utility:** High level of summarized data typically used for the reporting of PQ compliance to a regulator. The data contain a single figure for each disturbance for various categories of sites (e.g. LV/MV, underground / overhead).

These levels of reporting encapsulate two key requirements for a PQ data framework, namely time compression and space compression. The former is concerned with the reduction of long time series of a specific measurement into a single number while the later is the reduction of the same measurement taken for several locations into a single number to characterize an area. Another important requirement is the easy navigation between the various reporting levels so as preserve the tractability of all data to the original measurements as well as allowing further detailed analysis when required. The complete PQ data framework [11], also named PQ data triangle, is shown in Figure 2.

![Fig. 2 Power quality triangle](image)
triangle represents time compression and includes nine steps while the upper part with its four levels describes space compression. The various levels are summarized below (numbers relate to diagram):

1 Data input.
This first lowest level represents the raw sampled voltage or current waveforms.

2 Continuous disturbances.
The continuous disturbances (voltage, unbalance, harmonics, flicker) are extracted from the waveforms according to IEC standards [12-14]. The output is a number for each disturbance every 10 minutes.

3,4,5 Discrete disturbances.
The discrete disturbances (sag, swell, interruption and transients) are identified and characterized according to the standard IEC 61000-4-30. However, characterization of transients is still an area requiring clarification. The output is a time record of the occurrences and a severity index which is a number indicating the relative effect of the disturbance [15].

6 Site disturbance indices.
The cumulative probability value over a duration ranging from one week to one year is computed in order to determine the 95% recommended by EN 50160 [16]. The topic of a single index for discrete disturbances is still a debated topic.

7 Normalization (disturbance severity).
Each disturbance index is divided by the maximum level allowed. A value of 0 represents the absence of disturbance while 1 indicates the maximum allowed level. For discrete events there are no accepted indices at the present time and further work is required to develop maximum acceptable levels for them.

8 Combine indices.
With one index for each harmonic and the THD it is necessary to reduce them into a single index representing the gravity of the harmonic level. For this the worst index is chosen. For example in the case of the flicker the worse normalized index (Pst or Pst) is used as the combined flicker index.

9 Site index.
The various indices are now combined to create a single overall PQ index [17]. Other indices are preserved.

10 Feeder Index
In this first stage of space compression, the PQ indices from several sites are reduced into a single set of indices representing the various feeders. If a given feeder contains several measuring points a similar process reduces these indices to a single set. This requires a choice of weighting such as load KVA supplied.

11 Substation PQ indices.
For each substation, a new set of indices can be computed from the indices of the various feeders originating in that substation.

12 District PQ indices.
The above process is repeated for the various districts of the utility.

13 Utility PQ indices.
The last level that provides a single set of numbers representing the PQ levels within a utility.

XML SCHEMA FOR PQ DATA
The schema closely follows the power triangle that is presumed to be a component of one of the functional areas of the future IEC 61968 standard. At this present stage it is not known which of functional areas will contain power quality data. Due to limited space, only the skeleton and the low levels of the time compression will be presented. Space compression will be presented in a future paper.

Skeleton of the schema. Figure 3 shows the layers mentioned in the previous section. The links existing between them allow the navigation between layers as well as the maintenance of traceability. The number of leaves in each layer depends on the size and configuration of the distribution network. It should be mentioned here, that physical locations of the data contained in each layer are not necessarily identical. This provides for the possibility for the handling of PQ data by different organizations. For example, metering data agency (in Australia) would be well positioned to collect PQ data and process the lower levels layers before they are passed to the consumers of that information.

Time compression of PQ data. With the aim of producing just a few numbers from continuous waveforms, the time compression is mainly concerned with the extraction of power quality indices. Figure 5 shows some of the details at the waveform level, while Figure 4 shows how the raw data are reorganized once processed according to IEC 61000-4-30 [12]. At the next level of processing is the transformation of these disturbances into indices. In summary, the schema is nothing more than a progressive transformation of the waveforms into information.

Starting from the lower level shown in Figure 5, any waveform captured at a given measurement point is first combined with “housekeeping” information such as: type (voltage, current, phase), the location of the point of measure, as well as the instrument configuration. The waveform itself is most likely made up of several time series captured at different intervals. Thus a time stamp is added to each record of raw data.
The next levels up, shown in Figure 4, the transformed waveforms are now organized into a structure designed around disturbances classification. First they are separated into their respective class (continuous or discrete) then combined with their associated information which is not shown in the diagram. In addition to the disturbances, general information is also included: measurement class (A or B), flagging [12] as well as a link to the original waveforms shown in Figure 5.

Finally all disturbances are converted into a single number in the last two stages of the time compression. The 95% cumulative probability is computed as outlined in the EN-50160 standard [16]. The discrete disturbances are also given a single number. All these numbers are normalized as described in the last section before being combined into a site index that summarizes a monitored site. Since data are linked, it is always possible to “drill down” and investigate the reasons of a given site’s poor index.
CONCLUSIONS

This paper presented a possible framework that is suitable for the data resulting from large scale PQ monitoring. Without a framework, it will be nearly impossible to obtain useful overall results or insights from the large amount of data generated by the growing number of PQ instruments deployed in distribution networks. It is also the key for the automation of the analysis of PQ data and its integration into EAI that permits the conversion of these data into knowledge necessary for improved decision-making.

The usage of XML also brings several benefits to this framework. Mainly the ease of data sharing through text files makes these data independent of computing platforms and thus prevents rapid obsolescence. Since XML is also used in other relevant standards, the integration of the PQ framework into other schemes will be simplified.

It is acknowledged that this framework is still embryonic and that an industry-working group would be best suited for the task of a detailed implementation.

REFERENCES


[16] EN 50160, 2000, Voltage characteristics of electricity supplied by public distribution systems”, CENELEC, Brussels, Belgium