About the Power Quality Data Interchange Format (PQDIF)

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Introduction

The need for a common power quality data interchange format has recently become increasingly important. Many utilities are monitoring the quality of the power they deliver to their customers, while some customers are installing their own instruments to measure the utility supply or to monitor their sensitive processes. Power quality software applications have been developed to provide database management and analysis, to run harmonic and transient simulations, to perform economic assessments, and to identify measurements using rules-based expert systems or artificial neural networks. Multiple vendors, each of whom has traditionally employed proprietary formats for data storage, produce such power quality monitoring systems and associated software applications. In order to maximize benefits that can be realized by integration of all of these systems, EPRI initiated the development of a common format for power quality measurement data formally known as the Power Quality Data Interchange Format (PQDIF).

One of the goals of defining PQDIF was to provide a platform-neutral means to interchange power quality data between software packages and monitoring instruments. An IEEE Power Engineering Society task force (TF 1159.3) is tasked with standardizing such a data interchange format. The EPRI PQDIF version 1.5 is being used as a starting point for this standardized format and is being evaluated by task force members at this time. This standard will differ from other interchange formats such as IEEE COMTRADE, which is sufficient for waveform data, but is not well suited for other types of power quality data such as rms voltage and current trends, harmonic spectra, probabilities, and indices.

This paper provides an overview of PQDIF, including basic design, record structure, and element structure. It also discusses the level of implementation in various software formats and monitoring platforms by different vendors. Finally, example translations of common power quality measurement data types are provided.

What Is PQDIF?

Power quality measuring instruments come in a variety of configurations with each offering recording features that are both similar and different. Depending upon the intended application and individual characteristics particular to the intended usage environment, one brand or instrument model may be more desirable than others. While some users of monitoring instruments have only one brand or model of monitor in use in their power system or within their facility, others may utilize instruments from several manufacturers. In addition to obvious differences such as number of monitored channels, sampling rates, and monitoring philosophy, these instruments can also differ in how they store and export collected data. Data formats vary from manufacturer to manufacturer and sometimes even from model to model. The various software formats give rise to different applications for setting up and polling the instruments and for analyzing the collected data. These various applications must individually be mastered if one is to use all of them in a monitoring program. This creates an imposing challenge to the power system engineer – manage and analyze data that is not produced in a standardized format.

A similar need to exchange multi-vendor data was determined several years ago by the IEEE relaying committee for the exchange of fault recorder data. This resulted in the IEEE COMTRADE format. This format provides specifications for an ASCII or binary file format for the interchange of transient data produced by fault recording devices. This format is quite useful for general time domain data interchange and is also in use within the power quality community. A number of vendors of monitoring instruments, simulation programs, and analysis programs have provided the means to read and write this format to facilitate the exchange of time domain data – be it measured or simulated. As useful as IEEE COMTRADE is, it was necessarily limited in applicability due to the scope of its originating committee. The principal limitation is its inability to deal with frequency domain and probability domain data.

PQDIF is a standard power quality data interchange format that was developed by Electrotek Concepts under contract from EPRI. It offers a solution to the problem of different power quality file formats. By offering a flexible, platform-neutral means of exchanging power quality data between instruments and data management and analysis software applications, PQDIF enables engineers and power quality specialists to work more efficiently with different families and models of monitoring instruments. Developed to serve as the primary data format for EPRI's PQDS, PQDIF offers a stable information format that works with all power quality data types, and is designed to be compatible with a wide variety of instrument models.

PQDIF Structure

PQDIF is a tagged, compressible binary file format using standard cross-platform basic data types. The format consists of a physical layer, which describes the physical structure of the file without regard to its content, and a logical layer, which describes the content of the file. This file structure is similar to that used by the Tagged Image File Format (TIFF), a common format used for storing images.

Tags in the logical layer include identification elements that tell us important information about the measurement. Typical elements that would be included are identified in Table 1.

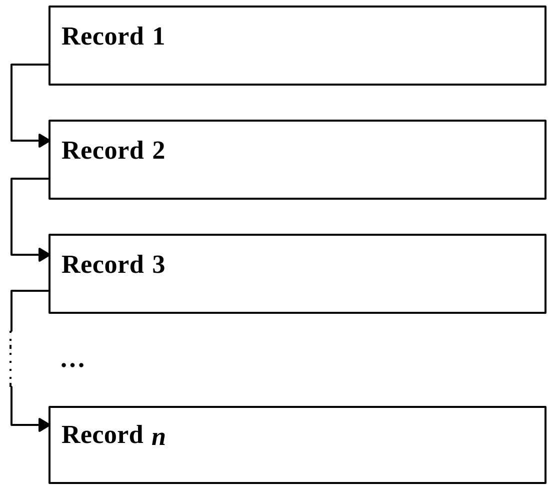
Table 1. Typical PQDIF Logical Layer Elements and Examples

Logical Layer Element	Examples
equipment manufacturer	Dranetz-BMI, PML, RPM, Square D, Sentry
equipment model	8010, 7100, Omega, ION, DL8000, 3P
phase or channel codes	V_a, V_{ca}, or I_b
IEEE Std. 1159-1995 disturbance categories	rms voltage variation, momentary interruption, oscillatory transient
high-level quantity type	waveform, min/avg/max rms envelope
series quantity units	timestamp, seconds, volts, amps
series value type	instantaneous voltage or current, min., avg., or max. rms voltage

The Physical Layer

A typical PQDIF file consists of a series of records arranged in a linked list. The links are provided by an absolute link in the header of the records, which allows new records to be inserted and old records to be deleted. This file format is flexible enough to enable the PQDIF records to be stored in a database or structured storage format, where the need for individual file management is eliminated. The order of the records shown in Figure 1 is Record 1, Record 2, Record 3 … Record n.

Figure 1. Standard record linkages



Each record has a standard header that contains a unique "signature" or identifier, record tag, size information for the records, and the absolute link to the next record. The body of the record consists of a set of elements that can be broken into three categories:

- Collection: An array of tags and relative links to other elements that allows a hierarchical structure to be created
- Scalar: A single value of a specific physical type
- Vector: A arbitrarily sized array of a specific physical type

A tag delineates each element, and the record body always starts with a collection element. This tag is actually a GUID (Globally Unique Identifier), which makes extending the list of tags virtually foolproof. A GUID is a 16-byte integer defined by a standard algorithm. Any computer in the world can generate a GUID and be reasonably assured that it is absolutely unique. The tagged element structure provides a great degree of flexibility and allows the contents to be defined logically independently of the actual physical definition.

The hierarchy of records allowed by the collection elements is the foundation of PQDIF's logical structure. This structure can change depending on the information compiled by the measuring instrument and the specifications of the user.

The PQDIF format is flexible enough that other structures besides the flat file can be used. For example, it would be possible to store individual PQDIF records in a database or a structured storage medium of some sort. In this case, some of the items in the header (the absolute link, for example) are not necessary and can be ignored. In some cases the header can be discarded entirely. Using PQDIF in this fashion is out of the scope of this paper, since the primary focus is the standard flat file used for interchanging data.

The Logical Layer

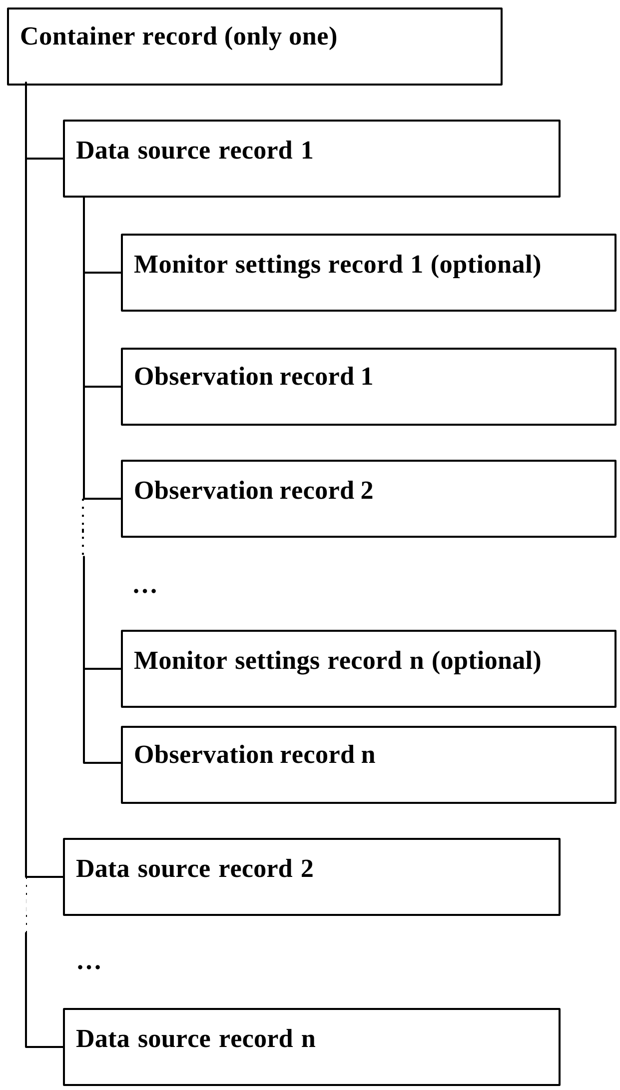
The basic structure is made up of a logical hierarchy of "records" – consisting of a single container, followed by one or more data sources, monitor settings, and observations. There can also be "extended" records by defining new tags.

The order of the records is defined by the absolute links in the header of each record. By following the list of records, a linear list of records is defined. This linear list has a logical hierarchy defined by Figure 2.

Note that several monitor setting records can appear in the middle of the observations for a particular data source. This allows the monitoring instrument setup to change. As a result, some parameters in the observations may depend on the information in the appropriate settings record. If multiple monitor settings records were not allowed, a totally new data source would have to be created if any settings changed.

The required and optional tags that define the PQDIF records constituting the logical structure are defined in the PQDIF Logical Structure document distributed with the Software Developer's Kit discussed below.

Figure 2. Example Record Header and Body



PQDIF Software Developer's Kit

Electrotek Concepts and EPRI developed a PQDIF Software Developer's Kit (SDK). The SDK is a collection of documents and sample code that facilitates the development of applications that can read or write PQDIF files – such as the PQView data translators discussed in the following section. To write these PQDIF-based applications, developers must know how to write Component Object Model (COM) Services and be familiar with the PQDcom4 component used in the translators. Included in the SDK are:

- Sample code for implementing a translator using Visual C++ version 4.2
- Documentation and sample code for PQDIF
- PQDcom4 documentation, source code, and samples
- TR-Test translator test application source code and setup files
- PQDIF utility source code and sample files
- A document on implementing PQDIF, describing how to use PQDIF to hold standard types of data

Since the IEEE 1159.3 Task Force is evaluating PQDIF for standardization, the SDK is available free of charge from the IEEE.

Software Currently Using PQDIF

PQDIF is the data format established for EPRI's Power Quality Diagnostic System (PQDS). One of the chief components of PQDS is PQView, which serves as the PQDS Measurement Module. To allow PQView and PQDS users to read data from a variety of power quality monitoring instruments, translators have been developed to allow users of several types of instruments to load power quality data. Some of these translators are PQDIF-based, where the proprietary instrument files are translated to PQDIF which are then imported into PQView. A flowchart of an example application is shown in Figure 3.

In addition to reading PQDIF files, PQView also writes PQDIF files through the PQView Disturbance Viewer. These files serve as the fundamental format used by the EPRI PQDS Event Identification Module, which uses artificial intelligence to identify power quality signatures.

Example PQ Measurement Data Translation

As previously noted, the primary application of PQDIF thus far has been for the development of PQView data translators. Translation of power quality data of any format requires that the following information be gleaned from the native file format and translated to PQDIF:

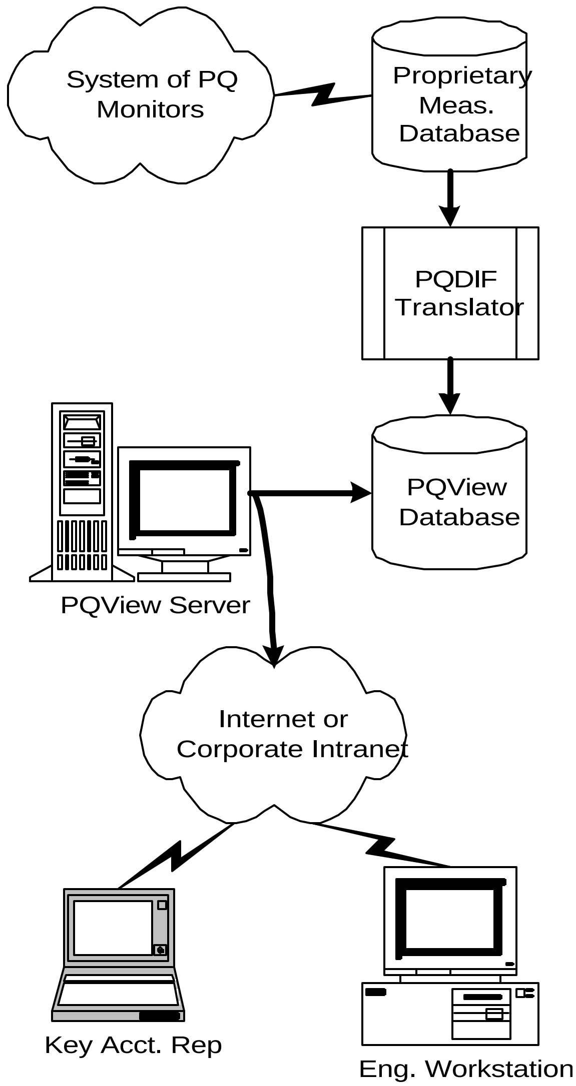
1. Monitor information – general site information such as site name, installation information, calibration information, etc. This is information is written to the Monitor Settings record of the PQDIF logical structure. The extent of monitor information that needs to be translated to PQDIF is dependent on the final application that will use the PQDIF files as an input.
2. Measured data type – description of what is represented by the actual quantitative measurement data. This information associated with a given numeric measurement data set is often referred to as the data channel definition and is written to the Data Source record of the PQDIF logical structure.
3. Measured data values – actual quantitative measurement data associated with a defined data channel. The measurement values are written to Observation records of the PQDIF logical structure

The following sections discuss the PQDIF 1.5 element tags that must be populated to relate the three pieces of information listed.

Data Source Record (Channel) Specification

Before the individual measurements can be translated to the PQDIF 1.5 file format, individual channels must be defined in the PQDIF file that relate what the measured data represents. A channel is a unique combination of quantity, characteristic, and phase. PQDIF 1.5 requires several data fields to completely describe the quantity, characteristic, and phase which define each channel. Table 2 lists the required element tags that must be assigned values for each channel. Table 2 shows two series definitions. Note that a channel may consist of only one series, but most channels consist of two or more. Also, it should be noted that the tags listed in Table 2 are only the required tags. There are many other optional tags that may be assigned values.

Figure 3. Example PQDIF-Based Application



Each of the required element tags listed in Table 2 has an associated set of acceptable values. The "Example Value" column of Table 2 shows the values that should be assigned to define the channel which records phase A-neutral instantaneous voltage waveforms. See the PQDIF SDK document "PQDIF 1.5 Logical Structure" for the list of acceptable values for each of the element tags defined in Table 2.

Table 2. Required channel element tags that must be populated for PQDIF 1.5.

Level	Element Tag	Example Value
0	tagRecDataSource	--NA--
1	tagChannelDfns	--NA--
2	tagOneChannelDfn	--NA--
3	tagPhaseID	*ID_Phase_AN*
3	tagQuantityTypeID	*ID_QT_Waveform*
3	tagQuantityMeasuredID	*ID_QM_Voltage*
3	tagSeriesDfns	--NA--
4	tagOneSeriesDfn	--NA--
5	tagValueTypeID	*ID_Series_Value_Type_Time*
5	tagQuantityUnitsID	*ID_QU_Seconds*
5	tagQuantityCharacteristicID	*ID_QC_None*
5	tagStorageMethodID	*ID_Series_Method_Values*
4	tagOneSeriesDfn	--NA--
5	tagValueTypeID	*ID_Series_Value_Type_Val*
5	tagQuantityUnitsID	*ID_QU_Volts*
5	tagQuantityCharacteristicID	*ID_QC_Instantaneous*
5	tagStorageMethodID	*ID_Series_Method_Values*
5	tagSeriesNominalQuantity	13800.00 (real value of base)

Observation Record Specification

Assignment of the observation element tags is primarily a matter of listing the measurement values in a way that coordinates with the manner in which the associated channel has been specified. Note that a single PQDIF 1.5 observation may consist of many different measurements that are associated with the same trigger. For example, a single voltage sag might trigger both waveform and rms measurements. Although the data recorded due to this single sag is associated with many different channels, it is more efficient to store all of the data associated with a single trigger in a single observation. This also allows for proper association of data channels in the final application using the PQDIF files.

Table 3 lists the required element tags that define a given observation. As with the channel specification, there are other optional tags that can be assigned as well. Permissible values for each element tag listed in Table 3 are provided in PQDIF logical structure document. The "Example Value" column of Table 3 lists possible values for a phase A voltage waveform associated with the channel specified in Table 2. Note that the tagChannelDefnIdx value of 57 in Table 3 is arbitrary. This value is a sequential index to the channel definitions in the associated data source record. The value of 57 means that this observation data is for the 58th channel defined in the data source record.

Monitor Settings Record Specification

The monitor settings tags provide site information. The monitor settings record is not required. If information such as the trigger values for a given channel is critical to the data being translated, it is recommended that the monitor settings record be created. Most of the defined tags are optional and are to be populated only if the data exists and would be useful to other applications. Table 4 lists the required monitor settings tags and example values for the example channel defined in Table 2. Note that only one channel is included in Table 4, but monitor setting tag values should be specified for each defined channel.

Table 3. Required observation element tags that must be populated for PQDIF 1.5.

Level	Element Tag	Example Value
0	TagRecObservation	--NA--
1	TagObservationName	*Phase A Voltage Waveform*
1	TagTimeCreate	*12/9/1998 11:42:24.453813818*
1	TagTimeStart	*2/13/1998 23:17:44.086079597*
1	TagTriggerMethodID	*ID_Trigger_Meth_Channel*
1	(tagTimeTriggered)**	*2/13/1998 23:17:44.086079597*
1	TagChannelInstances	--NA--
2	TagOneChannelInst	--NA--
3	TagChannelDefnIdx	57
3	TagSeriesInstances	--NA--
4	TagOneSeriesInstance	--NA--
5	TagSeriesValues	0,0.00013,0.00026, . . .
4	TagOneSeriesInstance	--NA--
5	TagSeriesValues	-4607.4621, -5030.9689, -5428.9193, . . .

Table 4. Required observation element tags that must be populated for PQDIF 1.5.

Level	Element Tag	Example Value
0	TagRecMonitorSettings	--NA--
1	TagEffective	Date at which settings were implemented.
1	TagTimeInstalled	Date monitored installed
1	TagNominalFrequency	60.00
2	TagOneChannelSetting	--NA--
3	TagChannelDefnIdx	57
3	TagTriggerTypeID	--NA--

In Conclusion

PQDIF standardizes power quality data into a format that is easily managed and analyzed. It allows easy integration of data from different instrument models or brands, making it ideal for engineers using different instruments in a power quality measurement system. PQDIF has already been successfully utilized to develop applications for reading and writing proprietary file formats that otherwise would not have been obtainable. It is currently under adoption by EPRI as the standard file format for power quality data and is under consideration by IEEE as its standard file format. Its flexible structure allows for individual file management or storage in a database, and its offers powerful file compression that protects data integrity.

References

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