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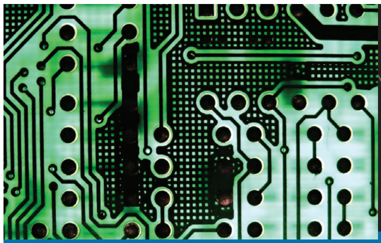

Opportunities and Challenges for Getting PQ Data from Intelligent Electronic Devices

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Contents

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EXECUTIVE SUMMARY

Intelligent electronic devices (IEDs) control and protect many parts of the electric power grid. As computer processing and storage have improved over the past decade, the microprocessors in these devices often have far more potential than is being used. Astute manufacturers can incorporate additional uses of this processing power—including power quality (PQ) monitoring—creating opportunities to attract new sales and new customers. Utilities can then take advantage of these additional opportunities for PQ monitoring to improve electricity delivery and grid operation.

One exciting opportunity may exist in using PQ data to assist with equipment condition assessment, such as for transformers, capacitor banks, and voltage regulators. Because most existing IEDs that have already been installed to meet required North American Electric Reliability Corporation standards for protection and control have incorporated power quality monitoring in their systems, adding this equipment assessment capability wouldn't need a huge investment in new monitors.

This *PQ TechWatch* explores the opportunities for gathering PQ information from these IEDs and discusses the potential challenges in integrating these devices into a power quality program.

About the EPRI Power Quality Knowledge program

The EPRI Power Quality Knowledge program provides a wealth of resources in well-designed, readable, and accessible formats. Paramount among these are documents covering a wide range of PQ topics, written not only for use by busy PQ professionals, but also to be shared with important end-use customers and internal utility management. The program's website, http://mypq.epri.com/, is the most comprehensive electronic PQ resource available, providing 24-7 access to proven expertise via the PQ Hotline, hundreds of PQ case studies, over 200 PQ technical documents, PQ standards references, indexes, conference presentations, and a wealth of other resources.

For more information, please visit http://mypq.epri.com/.

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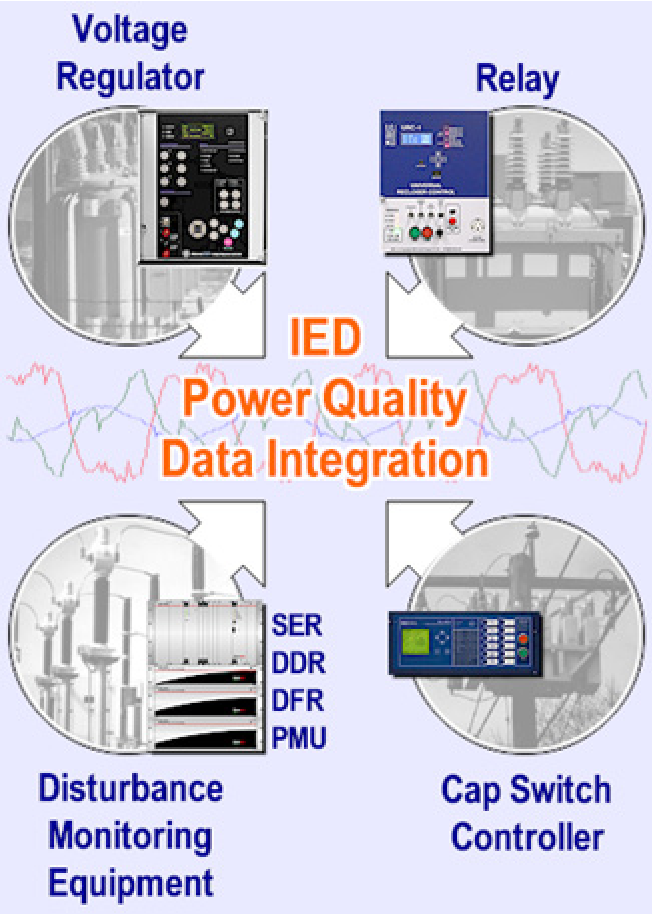
The most prevalent and most standardized IEDs are those required by the North American Electric Reliability Corporation.

INTRODUCTION

The electric power grid contains numerous microprocessor-based devices for control and protection. The electric power industry commonly refers to these devices as intelligent electronic devices (IEDs). With exponential improvements in computer processing and storage over the past decade, the computing potential for these devices far exceeds the requirements of their designed purpose. This leaves room for manufacturers to include improved or additional calculations and algorithms that can attract potential customers.

Integration of IED Power Quality Data



Power quality data are available in various distribution monitoring and protection equipment.

OVERVIEW OF TYPES OF IEDS ON THE GRID

The most prevalent and most standardized IEDs are those required by the North American Electric Reliability Corporation (NERC). NERC is the electric reliability organization certified by the Federal Energy Regulatory Commission to establish and enforce reliability standards for the bulk-power system. NERC standards PRC-018-1 (*Disturbance Monitoring Equipment Installation and Data Reporting*) and PRC-002-1 (*Define Regional Disturbance Monitoring and Reporting Requirements*) ensure that disturbance monitoring equipment (DME) are installed and that disturbance data are reported in accordance with regional requirements to facilitate analyses of events. These DME types include sequence of event recorders (SOEs/SERs), digital fault recorders (DFRs), and dynamic disturbance recorders (DDRs). Recent research and pilot projects supported by NERC are also looking at phasor measurement units (PMUs) for synchronizing phases for wide-area protection and control.

The next most-common IEDs are those used for control of protection and regulation devices. Although their main function is to control with discrete output states, they often are constructed with sensing for automated operations. Additionally, some are integrated with DME functions to help meet the NERC standards. These include voltage regulators, capacitor controllers, and digital protection relays (as in figure at left.)

Disturbance Monitoring Equipment

A sequence of events recorder is a system that monitors external inputs and records the time and sequence of the changes. SERs usually have a precision external time source such as a global positioning system (GPS) or radio clock. An SER enables rapid root-cause analysis after multiple events have occurred due to the recording of the events in the order of occurrence.

Power quality measurements can be broken down into two primary categories: event data and steady-state data .

A digital fault recorder is a system that monitors and reports changes in the voltage and current waveforms during a fault event. Recordings are triggered by changes in waveforms, calculated envelope parameters, or external discrete signals. NERC standards require that the waveforms are recorded at a rate of at least 16 samples per cycle during an event. A DFR enables analysis of fault direction, amplitude, and often cause from waveform signature analysis.

A dynamic disturbance recorder is a system that is much like the DFR, except it continually records calculated parameters derived from waveform sampling, such as root-mean-square (RMS) values. NERC requires a sampling rate of at least 6 records per second.

A phasor measurement unit (PMU), or synchrophasor, is a monitoring device that takes the voltage and current waveform and converts to a mathematical vector form to give both an amplitude and angle of each phase. These vectors are compared to other units in different locations with a common time source, such as a GPS clock. This comparison of two time-synched phasors creates a synchrophasor measurement. Typical measurements are sampled at 30 times per second. PMUs can be stand-alone devices or can be a function integrated within some DFRs, DDRs, digital relays, or even GPS clocks.

A voltage regulator controller is a device that measures downstream voltage levels and controls that level by changing taps on a voltage regulator for that circuit. This typically can be done automatically based on statistical limits programmed in the controller or based on input signals fed from a central control system.

A capacitor bank controller is a device much like the voltage controller, except this device gathers real and reactive power to determine power factor. Based on those values, the controller decides when and how to switch in capacitors to move the system power factor closer to unity.

The digital protection relay (DPR) is a device that uses a microcontroller with user-configured advanced algorithms to detect if abnormal conditions exist on the system. The logic then determines if it needs to open a switch to protect the system. These IEDs typically require both voltage and current in addition to discrete inputs to determine a trip condition. The algorithms require the same sampling resolution as DFRs to perform precise calculations.

OVERVIEW OF POWER QUALITY DATA

Although standards like IEEE 1159 and IEC 61000 give detailed characterizations of power quality anomalies, for this report, power quality measurements can be simply broken down into two primary categories: event data and steady-state data.

Event Data

This PQ measurement type is collected by recording the actual waveform around a given triggered event, or an envelope measurement like RMS (see figure at top of following page). The trigger that records the event can be a momentary reduction or increase in voltage lasting several cycles, or can be a subcycle fast transient or notching in the waveform lasting only a few microseconds.

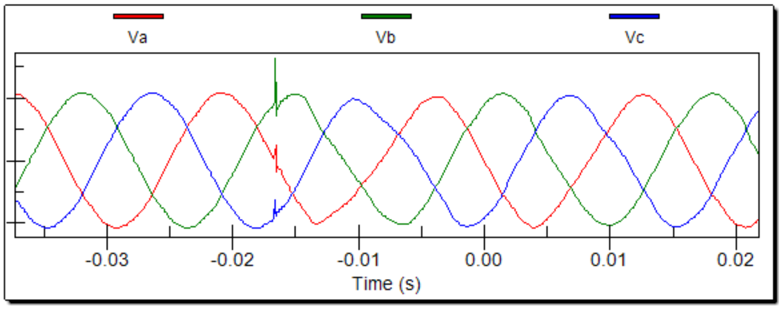
Transients

Transients are characterized by fast subcycle dV/dT changes that typically only require a cycle to be recorded; however, the resolution for that cycle requires high sampling to effectively analyze the characteristics of the event. Typical sample resolution needed can range from 256 to 1024 points per cycle.

Short-Duration Variations (Instantaneous/Momentary)

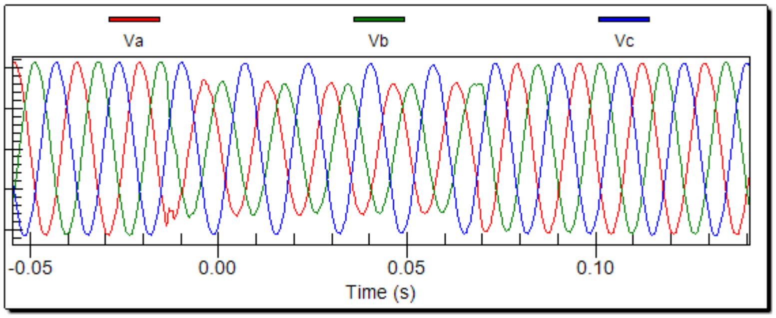
These events are characterized as changes in the waveform that occur in cycles (see second figure on the following page). Including pre-event and post-event data, the recordings for these events can range anywhere from 3 to 100s of cycles. Typical sampling is 128 points per cycle but can

Example Transient Waveform Event



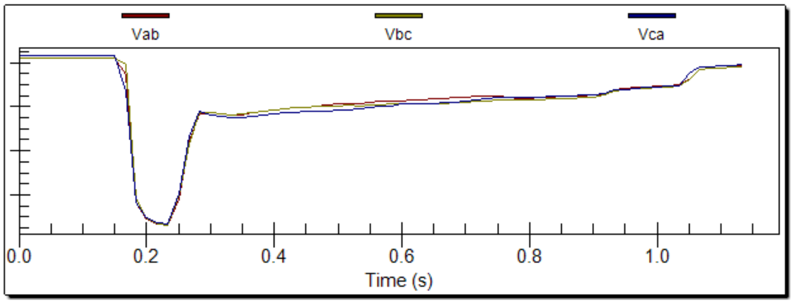
Transients are fast, subcycle events that require a high sampling rate.

Example Waveform Event for a Momentary Variation



Cyclic events such as voltage sags can be represented with low sampling rates.

Example RMS Trend of Longer Temporary Variation



Since waveforms require a large amount of memory, RMS trends can be used to interpret an event.

be characterized as low as 16 points per cycle. However, with low sampling resolution transients that can occur during these momentary events may be missed—for example, arcing transients during a voltage sag that can indicate a high-impedance fault from a down conductor.

Short-Duration Variations (Temporary)

These events are characterized as changes that occur in seconds (see figure at bottom left). Although some monitors will record waveforms for seconds, most will only give you waveforms for the first few cycles going into the event and then a few cycles as it returns to nominal. This is done to reserve memory for additional events. Also, most monitors record an RMS of the event to give an indication of what occurred between the beginning and ending of the event. Instead of numerous points per cycle, this recording will only require one point per half cycle at most.

Steady-State Data

This power quality measurement is made of numerous calculations derived from the voltage and/or current waveforms. Commonly the data is collected as a continuous trend; however, to analyze deviations between data intervals, a minimum-maximum-average periodic measurement or set of cumulative percentiles is required. Typical trends vary from 1 second to 15 minute intervals. The following values are examples of typical power quality trend parameters.

Amplitude and Time-Derived Parameters

The following amplitude and time-derived values contribute to steady-state calculations (see figure on the following page):

- Voltage RMS, peak, etc.
- Current RMS, peak, etc.
- Frequency
- Unbalance/imbalance
- Phase angle
- Phase sequence
- Flicker

EPRI is currently conducting research in using PQ data to assist with equipment condition assessment.

Distortion Parameters

The following are common measures of distortion:

- Individual harmonics levels
- Total harmonic distortion (THD)
- Interharmonics and total interharmonic distortion (TID)
- Harmonic phase angles
- Crest factor
- K factor

Power and Demand

These are the values used for power and demand:

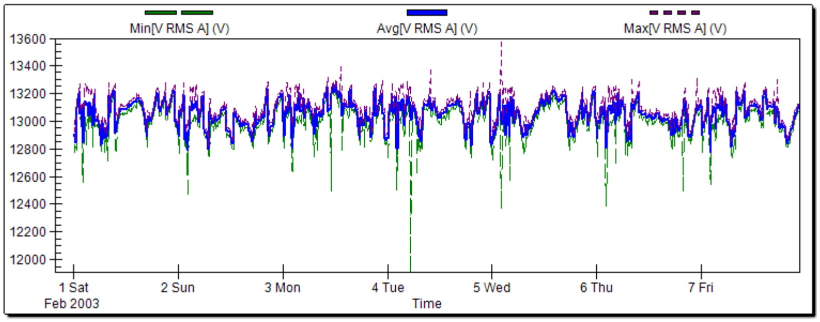
Real (watt)

Reactive (VAR)

Apparent (VA)

Power factor

Example of Steady-State Data



Because trend data is collected continuously and over a spread time period, statistical representation of the data is often required to interpret data.

Energy

Energy is measured with the following variables:

Watt-hours

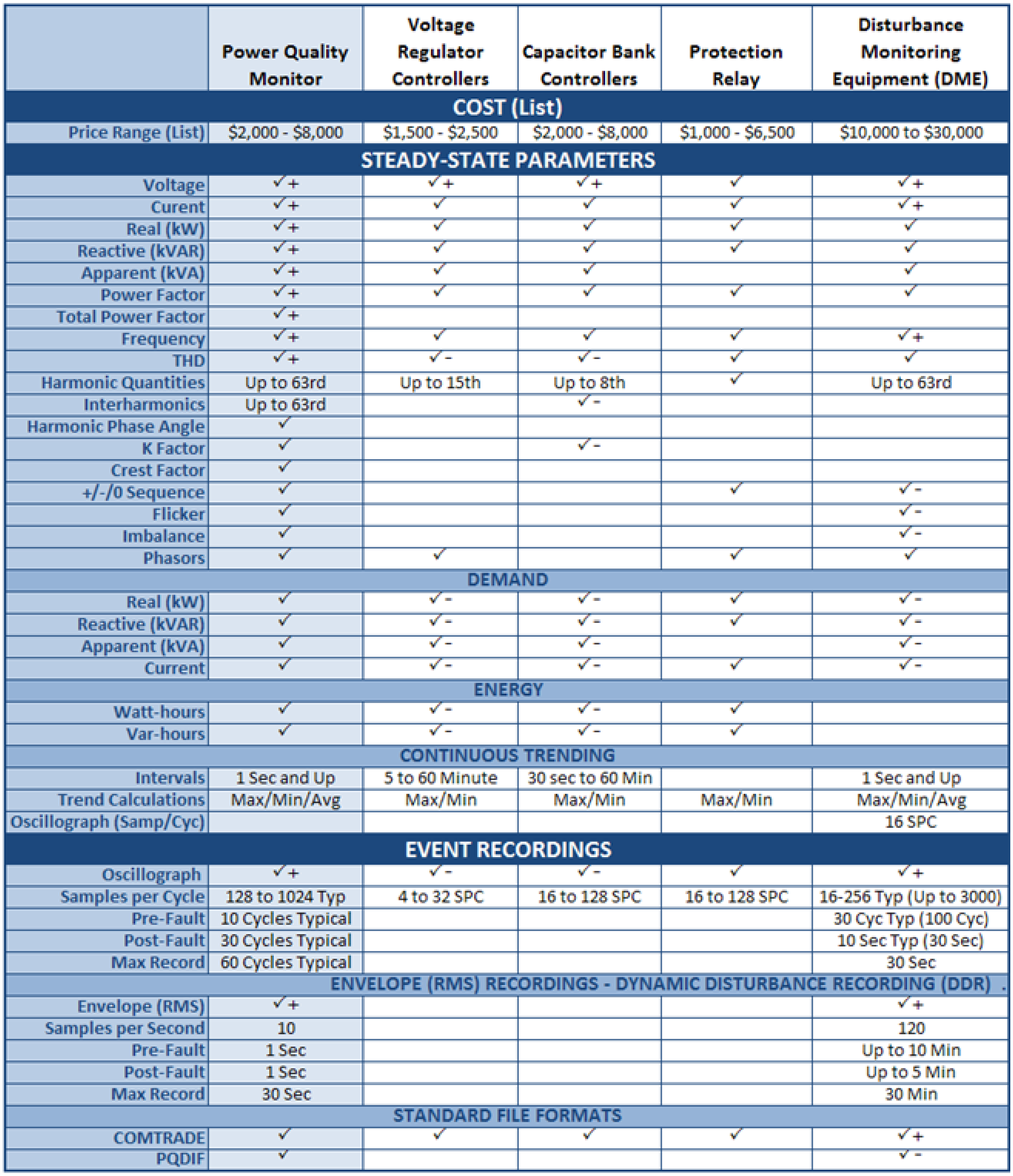
VAR-hours

OPPORTUNITIES

Types of PQ Parameters Available with IEDs

Traditionally, power quality monitoring has been associated with assuring the end-use customer is receiving good quality power. The closer to end-use equipment, the higher the levels of distortion, imbalance, and increased events such as voltage sags. Still, PQ data can be of value to the entire grid at the distribution level. In addition to having a broader monitoring coverage for the customers, signatures from event data can assist with fault location. EPRI is currently conducting research in using PQ data to assist with equipment condition assessment such as transformers, capacitor banks, and voltage regulators. To start taking advantage of this capability, does not necessarily require investing in new PQ monitors and installation. Most existing IEDs required for NERC standards or protection and control have incorporated power quality in their systems. The table on the following page lists some of the predominate features with power quality monitoring and compares them to what is available in other IEDs. A check-plus is a feature that is included in most standard equipment; a check symbolizes availability in some; while a check-minus is available in a few.

PQ Monitoring Features in IEDs



	Power Quality Monitor	Voltage Regulator Controllers	Capacitor Bank Controllers	Protection Relay	Disturbance Monitoring Equipment (DME)
COST (List)					
Price Range (List)	$2,000 - $8,000	$1,500 - $2,500	$2,000 - $8,000	$1,000 - $6,500	$10,000 to $30,000
STEADY-STATE PARAMETERS					
Voltage	✓+	✓+	✓+	✓	✓+
Curent	✓+	✓	✓	✓	✓+
Real (kW)	✓+	✓	✓	✓	✓
Reactive (kVAR)	✓+	✓	✓	✓	✓
Apparent (kVA)	✓+	✓	✓		✓
Power Factor	✓+	✓	✓	✓	✓
Total Power Factor	✓+				
Frequency	✓+	✓	✓	✓	✓+
THD	✓+	✓-	✓-	✓	✓
Harmonic Quantities	Up to 63rd	Up to 15th	Up to 8th	✓	Up to 63rd
Interharmonics	Up to 63rd		✓-		
Harmonic Phase Angle	✓				
K Factor	✓		✓-		
Crest Factor	✓				
+/-/0 Sequence	✓			✓	✓-
Flicker	✓				✓-
Imbalance	✓				✓-
Phasors	✓	✓		✓	✓
DEMAND					
Real (kW)	✓	✓-	✓-	✓	✓-
Reactive (kVAR)	✓	✓-	✓-	✓	✓-
Apparent (kVA)	✓	✓-	✓-		✓-
Current	✓	✓-	✓-	✓	✓-
ENERGY					
Watt-hours	✓	✓-	✓-	✓	
Var-hours	✓	✓-	✓-	✓	
CONTINUOUS TRENDING					
Intervals	1 Sec and Up	5 to 60 Minute	30 sec to 60 Min		1 Sec and Up
Trend Calculations	Max/Min/Avg	Max/Min	Max/Min	Max/Min	Max/Min/Avg
Oscillograph (Samp/Cyc)					16 SPC
EVENT RECORDINGS					
Oscillograph	✓+	✓-	✓-	✓	✓+
Samples per Cycle	128 to 1024 Typ	4 to 32 SPC	16 to 128 SPC	16 to 128 SPC	16-256 Typ (Up to 3000)
Pre-Fault	10 Cycles Typical				30 Cyc Typ (100 Cyc)
Post-Fault	30 Cycles Typical				10 Sec Typ (30 Sec)
Max Record	60 Cycles Typical				30 Sec
ENVELOPE (RMS) RECORDINGS - DYNAMIC DISTURBANCE RECORDING (DDR) .					
Envelope (RMS)	✓+				✓+
Samples per Second	10				120
Pre-Fault	1 Sec				Up to 10 Min
Post-Fault	1 Sec				Up to 5 Min
Max Record	30 Sec				30 Min
STANDARD FILE FORMATS					
COMTRADE	✓	✓	✓	✓	✓+
PQDIF	✓				✓-

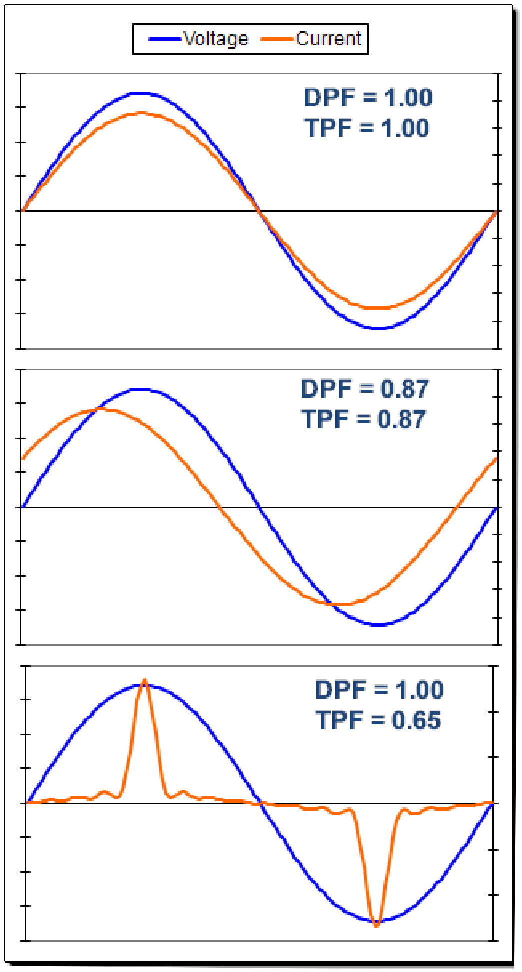
NOTE: Assessment of capabilities is based on average from research; however, check with manufacturers as some features left unchecked may be available for some devices.

Most DME and PQ devices will allow down to 1 second of measurement resolution, while other IEDs typically calculate and store only 15-minute values.

Steady-State from IEDs

For the most part, basic parameters such as voltage/current RMS, frequency, and power are available in each IED; however, compared to PQ monitors, most IEDs are lacking in higher level harmonics and distortion type parameters. This could be due to the limitation in waveform sampling from which these parameters are derived, or simply because distortion has historically not been a concern at the distribution level. This is also evident in the fact that most IEDs other than PQ monitors do not include distortion in their power factor measurements. Two types of power factor measurements are common: displacement power factor (DPF) and total power factor (TPF). As shown in the figure below, the displacement power factor calculation only considers the time displacement of the current in relation to the voltage. Total power factor takes both displacement and distortion into consideration. So for the distorted example, the current is aligned with the voltage, but the current distortion produces a low power factor. In this case, an IED—which doesn't distinguish a difference and simply reports a power factor (PF)—could produce a misleading value.

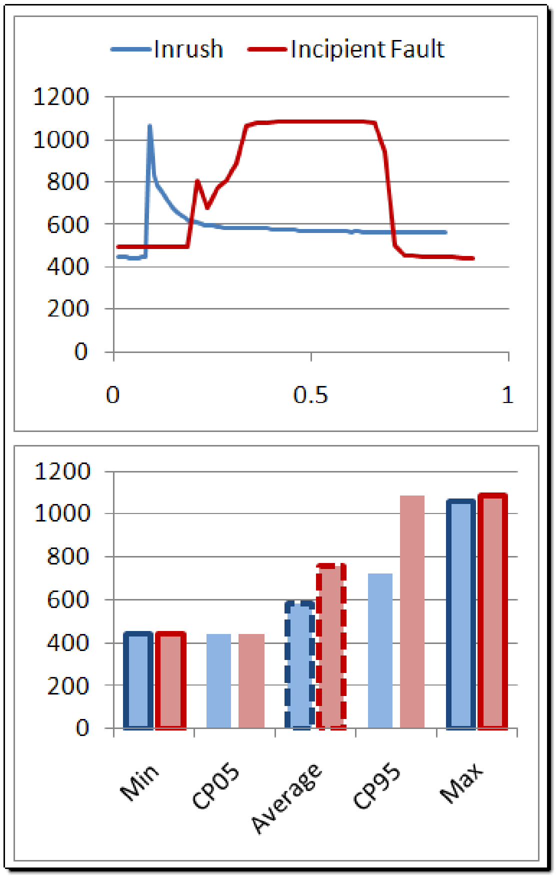
Illustration of Displacement Power Factor and Total Power Factor Calculations



By not considering both displacement and distortion (used to calculate total power factor), the displacement power factor results from an IED could be misleading.

Another important distinction between IEDs is the interval and the statistical values they apply to the interval measurements. Most DME and PQ devices will allow down to 1 second of measurement resolution, while other IEDs typically calculate and store 15 minute values. Depending on the resolution of change in the parameter, 15 minutes may be too long. For example, a multiple reclose operation would only indicate one change in a 15-minute period, while it actually may have had three or four changes. Also, other IEDs only collect minimum and maximum statistical values, while DME and PQ devices collect average and even cumulative percentile (CP) values. Minimum and maximum values can be deceiving due to outliers in various parameters, especially if they're being calculated over a long period of time. For example, a measurement from inrush current would show the peak current for that period and would not distinguish between steady or momentary overcurrent. As shown in the figure on the following page, if all we had was maximum and minimum values, we would not be able to distinguish an inrush caused by a momentary current increase from an incipient fault. Both values are approximately the same. Adding an average or CP value would help translate the duration of the overcurrent and perhaps the type of event.

Sample Statistical Measurements from Inrush and Incipient Fault



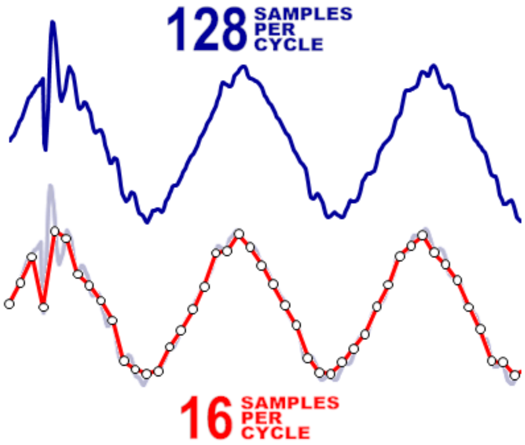
Relying on minimal statistical data may lead to misinterpreting an event.

Event Waveform Recordings

Although most power quality monitors don't sample below 128 samples/cycle, all other IEDs vary widely on sampling. For early-model DME and IEDs, most manufacturers followed the limitations written in the NERC PRC standards. The latest standards list the minimum sampling rate at 16 samples/cycle. Newer models of IEDs are now sampling similar to PQ monitors up to 128 samples/cycle. Some new DFRs are giving the capability to even exceed most PQ monitors, with 3000 samples/cycle.

Although 16 samples/cycle is enough resolution to interpret most system events, consideration should be given to subcycle transient events or whether postanalysis is to be conducted for high-frequency harmonics. For example, in the figure below, a capacitor switching transient is shown at both 128 and 16 samples/cycle. The anomaly in the 16 samples/cycle recording could be mistaken for a voltage notch caused by a subcycle fault, such as a tree limb momentarily touching a conductor. The higher sampling, however, clearly shows the oscillation signature and decay of a typical capacitor switching transient.

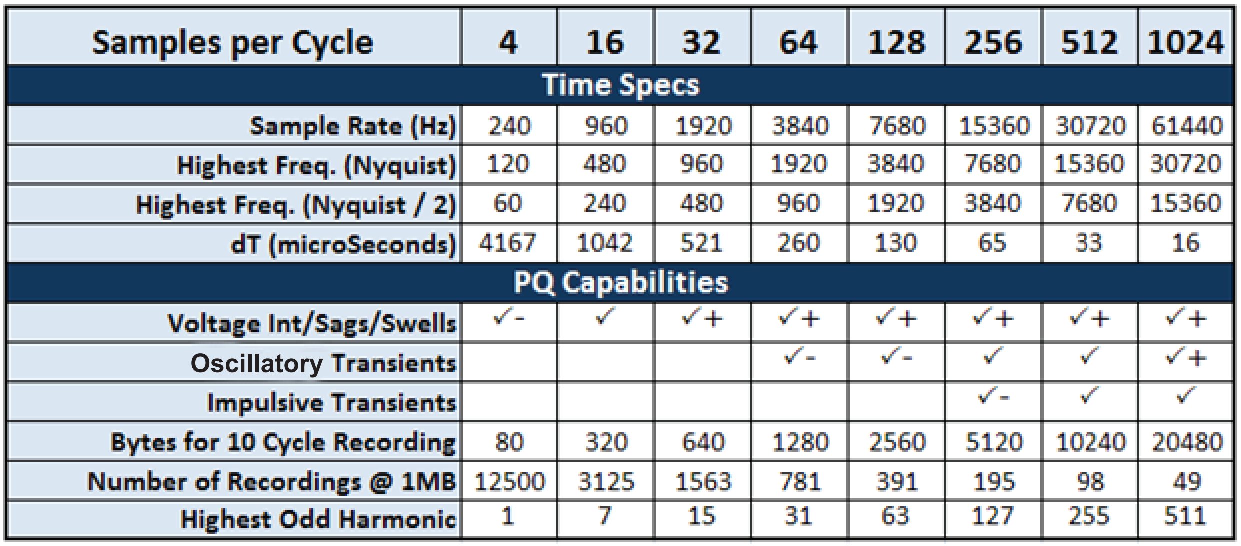
Measurement Data Showing Capacitor Switching Transient



While the transient shows up at both sampling resolutions, the data from the higher sampling rate allows a more conclusive categorization of the event.

The table on the following page lists performance that can be expected from different sample rates. Although the Nyquist frequency determines bandwidth, often more samples are needed to recognize anomaly signatures, therefore making the bandwidth smaller as listed for the highest frequency (Nyquist/2). Further, the level of harmonics is also affected by the sampling and bandwidth; however, most harmonics of concern are usually below the 15th harmonic.

PQ Performance from Different Sample Rates



Samples per Cycle	4	16	32	64	128	256	512	1024
Time Specs								
Sample Rate (Hz)	240	960	1920	3840	7680	15360	30720	61440
Highest Freq. (Nyquist)	120	480	960	1920	3840	7680	15360	30720
Highest Freq. (Nyquist / 2)	60	240	480	960	1920	3840	7680	15360
dT (microSeconds)	4167	1042	521	260	130	65	33	16
PQ Capabilities								
Voltage Int/Sags/Swells	✓-	✓	✓+	✓+	✓+	✓+	✓+	✓+
Oscillatory Transients				✓-	✓-	✓	✓	✓+
Impulsive Transients						✓-	✓	✓
Bytes for 10 Cycle Recording	80	320	640	1280	2560	5120	10240	20480
Number of Recordings @ 1MB	12500	3125	1563	781	391	195	98	49
Highest Odd Harmonic	1	7	15	31	63	127	255	511

When monitoring power quality with an IED, understanding the frequency response of the instrument transformers (or sensors) supplying the measurement signals to the IED is important.

Some IEDs such as digital fault recorders offer dual sampling rates for waveform recording. Triggers are set up depending on what events need high or low sampling rates. The sampling can be low for cyclic events, but can record for long periods to capture pre- and postfault performance, such as system current inrush after voltage is restored. For subcycle events, a higher sampling rate will capture detailed waveform signatures such as the capacitor switching transient in the figure on the previous page, but don't need a great deal of pre- and postcycle recordings.

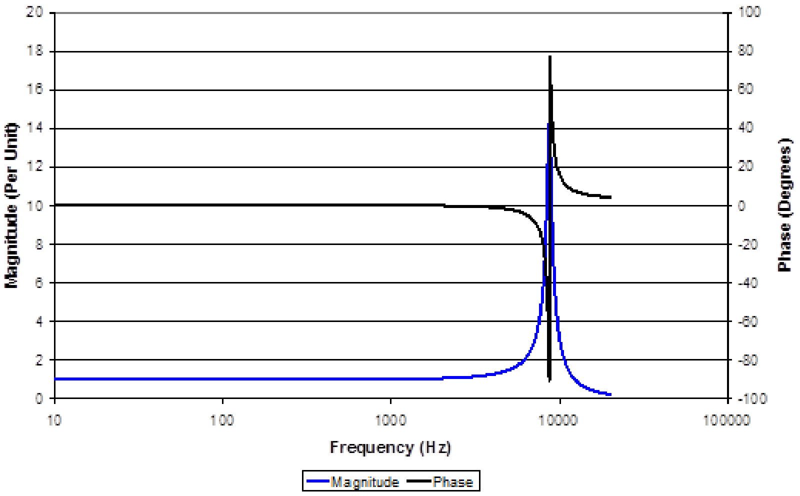
Early generations of digital relays only provided sampling at 4 samples/cycle. Later generations of relays could sample at 16 samples/cycle, but during file extraction, a manual selection of 4 or 16 samples/cycle had to be selected. The latest generation of relays is capable of sampling at 128 samples/cycle or higher. Some of these relays can also be used alongside a data concentrator to provide DME monitoring capability. Future sampling rates are expected to continue on this trend as processing power continues to grow, component costs come down in price, and components shrink in size, thereby meeting heat dissipation requirements for "substation-hardened" equipment.

Instrumentation Transformers

When monitoring power quality with an IED, understanding the frequency response of the instrument transformers (or sensors) supplying the measurement signals to the IED is important. The figures on the following page show the frequency responses of a typical potential transformer (PT) and a typical current transformer (CT). Both devices were rated for application at medium voltage. Both the magnitude (normalized to the rated ratio of the device) and phase angle (difference between input and output phase angles) are shown. Both quantities can result in measurement errors.

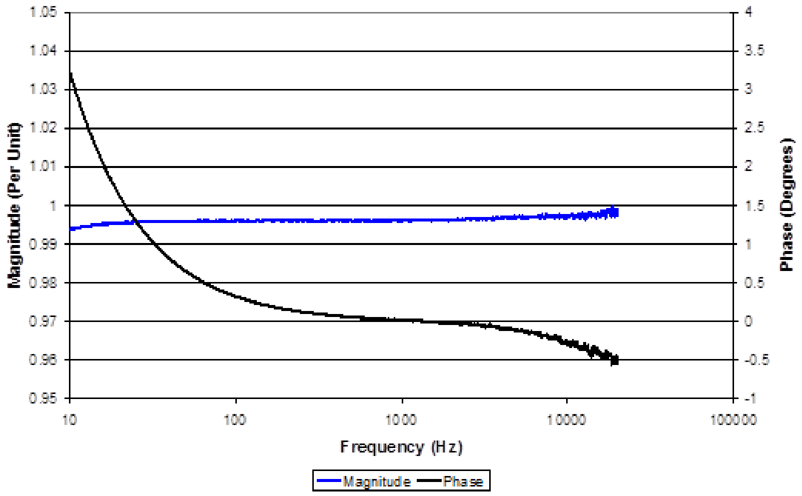
In this case, the PT has a resonance at approximately 9 kHz. The resonance frequency for a given PT depends on the length of the secondary conductor and the input impedance of the measuring device. With this setup, any measurement at frequencies over approximately 8 kHz would be suspect.

Frequency Response of Typical Potential Transformer



The CT has a fairly flat response for both magnitude and phase angle from 60 Hz to 20 kHz. This is commonly the case with traditional magnetic CTs. This CT exhibits reasonable accuracy for power quality measurements up to 20 kHz (or possibly higher). Having a CT provide adequate accuracy up to 30 or 40 kHz is not uncommon.

Frequency Response of Typical Current Transformer



Other types of voltage and current sensors are also in use in the power systems. The capacitor coupled voltage transformer is commonly used at voltages of 69 kV and up. These devices are tuned for accuracy and operation at 60 Hz and exhibit very poor response at almost any other frequency. They are generally not suited for power quality measurements. The use of line-post sensors on medium-voltage systems is gaining popularity due to decreased material and installation costs. Each make and model of these sensors exhibits a different frequency response. The frequency response of one model of voltage sensor is shown in the figure on the following page. As can be seen, the sensor is only accurate at frequencies relatively close to 60 Hz.

Understanding the frequency response of the instrument transformers, or sensors, supplying measurement signals to IEDs is important. Without this knowledge, any analysis of the resulting measurements may be flawed.

UPGRADING

Instead of replacing inferior equipment with completely new ones, some manufacturers present opportunities to save cost by upgrading existing equipment.

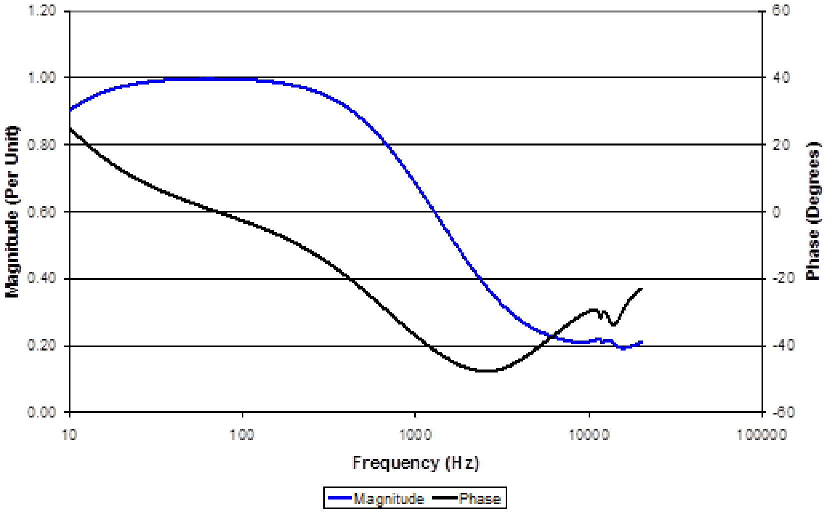
Panel Meters to PQ Meters

PQ meters are being challenged by traditionally non-PQ substation and supervisory control and data acquisition (SCADA) panel meters or revenue meters that are being upgraded with PQ functionality. Utilities may upgrade revenue or SCADA meters to include PQ functionality for only a few hundred dollars more in some cases.

Upgrading to DME Without Changing Field Wiring

Older DFRs can be upgraded to meet current DME requirements as defined by NERC PRC standards. During these upgrades, the chassis and field wiring can typically be left in place

Frequency Response of a Line-Post Voltage Sensor



Various connectivity options that are selected may also come with increased scrutiny from security and compliance groups due to various regulations and cyber-security concerns.

while the central processing unit and analog-to-digital processing boards are upgraded. Often, these upgrades can provide older IEDs with the capability of more modern PQ or PMU monitoring.

CHALLENGES WITH IMPLEMENTATION

Access and Regulations

Along with the opportunities that improved communication provides, various connectivity options that are selected may also come with increased scrutiny from security and compliance groups due to various regulations and cyber-security concerns. The levels and impacts can vary greatly depending on the connectivity used (dial-up, Ethernet, or serial).

While NERC Critical Infrastructure Protection (CIP) regulations do not apply to lower-voltage distribution circuits, distribution substations with shared generation or transmission facilities may fall under NERC CIP and have the effect of possible restricted access at these more critical sites. Locations that are classified as "critical assets" under NERC CIP have increased requirements for protection of data and access to the IEDs that provide that data. These restrictions often involve restrictions on access points through firewalls, which may impact the ease or ability to extract "nonoperational" data such as power quality information.

Integration

Data integration still remains a challenge, as disparate systems have a need for some of the same data, yet these systems are not capable of exchanging data with each other, even when using COMTRADE (Common format for Transient Data Exchange) or PQDIF (Power Quality Data Interchange Format). An example would be the use of a revenue meter that has PQ features. Some utilities may allow a single download for all of the data from the meter, and both the billing and PQ groups can then access the data that each one needs. Other utilities may allow each group to download the data that each needs into separate databases. This approach ties up the connection to the meter for longer periods of time (with potential connection conflicts when accessing the meter) and this does not promote effective data management. And still a third utility may choose to deploy one meter for revenue uses and a separate meter (it could even be the same model) for PQ use only. This approach requires the expense and effort of installing and maintaining two separate meters as well as separate communication lines; however, each group would maintain "full ownership" over their own meter and only the pieces of data required by each group would be retrieved.

When attempting to perform data integration using "redundant" event data captured from multiple IEDs such as meters, relays, and DFRs, note that while the full data set from PQ meters may be polled daily, events from relays, DFRs, and other IEDs are only polled when an obvious event occurs. More minor events such as subcycle faults may not be identified with this process, and opportunities to identify

Subcycle faults can be viewed and analyzed, and if caught soon enough, these can be valuable precursor events to a failure.

The use of Ethernet and universal serial bus front port connections are opening up numerous opportunities to connect to these IEDs and poll the data from a variety of sources.

these precursor events may be missed unless all data are retrieved from all IEDs on a regular basis. Vendor proprietary as well as third party applications that support automated polling are beneficial for this application.

PQ tools such as PQView can be used to analyze fault records directly from relays, sometimes in their native formats, and always in COMTRADE. Conversion may sometimes be required from the native proprietary format. Subcycle faults can also be viewed and analyzed, and if caught soon enough, these can be valuable precursor events to a failure. Being able to locate these precursor events before customers experience an outage or assets are damaged would be very beneficial in improving the System Average Interruption Duration Index and System Average Interruption Frequency Index of a utility.

Data Format and Conversion

Many IED vendors store their data in their own vendor proprietary format even though COMTRADE is usually an available output. Conversion to COMTRADE is not always an automated process. However, just because COMTRADE is used does not necessarily make it universal. Various vendors have implemented COMTRADE-1991 or -1999 (official version) and sometimes use different formats to represent their data within the files, making a conversion step mandatory before files can be interchanged for data integration. PQDIF is also not yet widely adopted by nonmeter IEDs.

Storage

For meters, onboard storage has been increasing from no onboard memory to 128MB in currently available products in the marketplace. 0MB of onboard memory is typically sufficient for SCADA meters, which provide data only when polled, while 64kB, 128kB, 256kB, and 512kB can be good for short-term storage, or when polling rates are longer or bandwidth may be constrained or fluctuating. Within the past few years, memory options of 1MB, 2MB, 4MB, 8MB, and 16MB provide for short-term storage at higher sampling rates, or longer storage at lower sample rates. The newest meters may have up to 128MB of onboard memory. One vendor is currently advertising options for 32MB, 64MB, and 128MB depending on the model selected. The 128MB model could allow for months or years of high-sample-rate data collection, including continuous capturing of triggered events, internal events, and revenue data; event logs for 500 events; and support for more than 10,000 records in the logs. The number of triggers, how many logs, and sampling rate are all factors in how much can get stored and the length of time until those records are erased in a first-in, first-out pattern.

Communications

Communication options to IEDs have traditionally included dial-up modems and RS-232 and RS-485 serial connections. The use of Ethernet (copper or fiber connection) and universal serial bus front port connections are gaining more widespread adoption, opening up numerous opportunities to connect to these IEDs and poll the data from a variety of sources. In addition, remote access becomes available for updating the configuration, upgrading firmware, and retrieving device records.

Protocol options on IEDs are continuing to expand to include more product capabilities. Protocols such as Simple Mail Transfer Protocol (SMTP), Simple Network Time Protocol (SNTP), DNP 3.0 (Ethernet and serial), Modbus (Ethernet and serial), IEC 61850 (power quality enhancements for 61850 are being developed within the standard), and sometimes a vendor proprietary protocol are common among IEDs. Power quality information can sometimes be sent over these SCADA protocols; other times, data or file extraction must occur over a separate communication path such as File Transfer Protocol (FTP) or vendor proprietary formats. SMTP can be used to send e-mail alerts based on triggered PQ events, and Hyper Text Transfer Protocol (HTTP) can be used to view various PQ events on a web page generated by an onboard web server on the IED itself.

Some equipment may require a simple upgrade or component replacement that can be made with minimal cost.

SCADA systems are limited to the number of points that can be brought into the EMS. These limitations may be due to bandwidth of communication lines, frequency of polling, or an intention to keep the number of points coming into the SCADA system limited to just "operational" data. An example of minimizing SCADA points is the practice of monitoring A-phase current on one line for one analog point, B-phase current on a second line into a second analog point, and C-phase current on a third line into a third analog point.

If the full set of power quality data points are desired to be extracted, a separate "nonoperational" data path must be available. As sampling rate increases and file size subsequently increases, the bandwidth, cost, and architecture required to retrieve these data and files become a more substantial consideration.

CONCLUSION

With improvements in computer processing and storage over the past decade alone, IED manufacturers are constantly adding extra capabilities to devices traditionally intended for one function. Power quality measurements are one of the features electric utilities can take advantage of to not only improve the quality of electricity delivered to their customers, but improve the quality of operating the grid as well. Start by looking at existing IED equipment and assess if any barriers like communications or integration are restricting the equipment's full potential, and whether they can be overcome. Some equipment may require a simple upgrade or component replacement that can be made with minimal cost. As we move toward a smarter grid, data access and integration are a pinnacle step, and the work that's been done in power quality can add great benefit.

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