Development of Meter Specifications

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REPORT SUMMARY

This report describes the progress of the Power Quality Revenue Meter Project, which is targeted at developing a functional description and specifications for a new-generation measurement device—a power quality revenue meter for industrial and commercial use. The competition engendered by deregulation is pushing electric utilities to monitor the quality of the electricity they sell to enhance customer satisfaction. Currently, measurements of power demand and power quality are treated separately, and most companies make meters for recording one or the other. Because both measurements require sampling of voltage and current, it makes sense to assess the feasibility of utilizing a single device to record and quantify the two together at a potential reduction in cost compared to having two separate meters. Ideally, such a meter would be priced low enough to use widely throughout a distribution system ($500 for a base system).

Among the many types of electrical disturbances, this report identifies transients, voltage sags, voltage swells, voltage notches, harmonics, and voltage fluctuations as the greatest concerns to commercial and industrial customers. To measure these disturbances, the meter could be equipped with all the necessary hardware, which can then be activated on a feature-by-feature basis. This would afford the meter a great flexibility, enabling meter users to tailor functionality to meet their specific needs. The only additional hardware required would be a communications module, the type of which would depend upon the available mode of communication, such as modem, Ethernet, or cellular.

EPRI PEAC Corporation conducted two surveys: one for utilities and one for manufacturers of revenue meters. A survey of power quality meters was also planned, but informal discussions with several power quality meter manufacturers determined that their lack of interest in the project warranted no issuance of a formal survey.

Utilities indicated that the measurement of voltage sags was the highest priority, with the measurement of other electrical disturbances following (see Figure ES-1). Meter personnel tended to rate power quality features low, whereas power quality professionals rated them high. Most (75%) supported the idea of specifying a single meter with “soft” upgrades to avoid expensive hardware change-outs. Half of the respondents indicated that the meter would have to be a “socket” type.

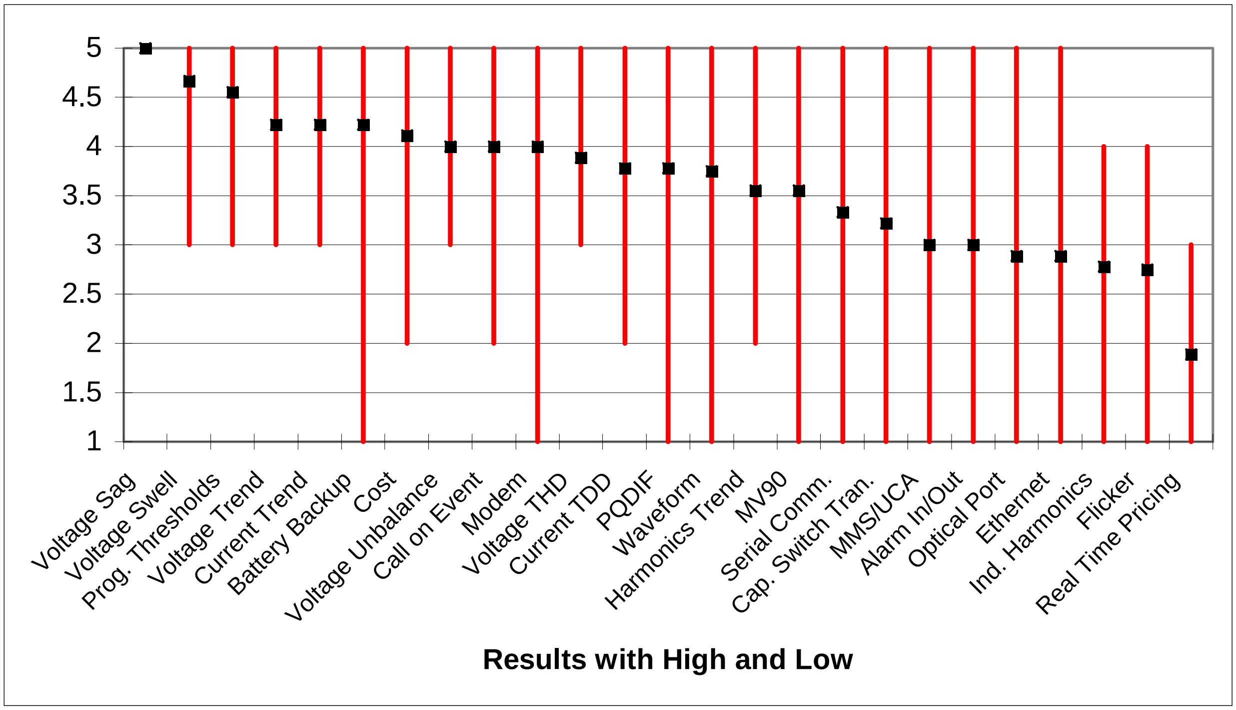


Figure ES-1. Ranking of the importance of electrical disturbances by electric utilities (higher numbers mean more importance).

Manufacturers of revenue meters indicated that they were concerned about the increased production costs of adding power quality measurement features. For example, the calculation of flicker would require expensive hardware that would increase the cost of the meter beyond the target price, and the capture of waveforms would require increasing the amount of memory. Power supplies were another concern of the revenue-meter manufacturers, who predicted an additional cost of between $30 and $60 for an adequate power supply for the various hardware features.

A cost/benefit analysis yielded specifications for a revenue meter that would measure steady-state voltage, voltage sags, voltage swells, voltage unbalance, transients, and distortion. The meter would also be able to capture waveforms. The cost of the base unit is estimated to be around $500, and the cost of the fully featured unit would be around $1,500.

Although some existing revenue meters include the power quality capabilities specified in this report, they are not as flexible via software and firmware control. Therefore, this report recommends that EPRI proceed with the development of a flexible power quality revenue meter, which should enjoy a welcoming market.

CONTENTS

1
INTRODUCTION

Although some power quality instruments have minimal revenue metering capabilities and some revenue meters can attempt power quality measurements, until now the two technologies have been fundamentally different. Foreseeing an invaluable role for power quality revenue meters in a deregulated electricity market, electric utilities have joined to garner a better understanding of the requirements for a revenue meter that also functions as a power quality monitor. The Power Quality Revenue Meter Project is targeted at developing a functional description and specifications for a new-generation measurement device—a power quality revenue meter for industrial and commercial use. Appendix A contains the Tailored Collaboration offering to commercialize this meter.

The project will bring together utility and industry experts to coordinate and guide the conceptual design. The deliverable will be a realistic and cost-effective specification for a power quality revenue meter based on knowledge of existing revenue meters and power quality measuring equipment. Input and feedback from experts within both revenue and power-monitoring fields will be consolidated to inform a detailed cost/benefit analysis. This report describes the progress of the project to date.

The Primary Stakeholders

Many companies manufacture power quality monitors. Likewise, many companies manufacture revenue meters. Manufacturers of revenue meters know that they need to begin adding some functions of power quality monitoring to their products to meet the impending demand for such products. However, although they know how to measure billing quantities very accurately, they do not have much experience with measuring electrical disturbances. Manufacturers of power quality meters understand how to accurately recognize and record electrical disturbances, but are not experienced in the requirements for measuring billing quantities. To date, these two types of manufacturers have not successfully collaborated on a design for a power quality revenue meter.

One barrier to a successful union of metering and monitoring is the different ways that the two manufacturers measure electrical parameters. Revenue meters generate pulses whose frequency depends upon the electrical parameter being measured (usually limited to power and voltage). The meter counts the number of pulses over a fixed interval to determine quantity. On the other hand, power quality meters directly measure electricity in engineering quantities, such as volts and amps.

Software is often another barrier to a successful union. The software associated with revenue meters is often very difficult to use. It is meant to serve as a translator of interval data. Included with revenue meters that are endowed with power quality monitoring, the monitoring features of the software are often poorly integrated, appearing “tacked on,” an afterthought that may require a second software application to access and present data.

The Role of Deregulation

Pressures to innovate efficiencies, compete in a deregulated electricity market, and improve customer satisfaction are increasing the demand for meters with advanced functions. Automated meter reading (AMR) is one way to gather pragmatic data from commercial and industrial customers. In fact, many U.S. electric utilities are outfitting their entire commercial and industrial customer bases with AMR meters.

The decreasing cost of revenue meters enables widespread application of AMR. Besides using AMR to gather near-real-time data on customer loads, it can be used by distribution or “wires” companies to monitor adherence to service-quality specifications. In most models of a deregulation market, wires companies remain regulated. Most public utility commissions are including reliability requirements in the rate structure for the wires companies. Along with reliability requirements, some commissions include power quality requirements, mostly in the form of voltage-sag indices. Wires companies need some way to measure their performance because better performance means higher rates for electricity, and therefore higher profits. The reliability and power quality indices shown in Tables 1-1 and 1-2 are ways to calculate performance from measured electrical parameters.

Table 1-1. Reliability indices.

Index	*Full Name*	*Formula*
SAIFI	System Average Interruption Frequency Index	$\frac{\text{number of customer interruptions}}{\text{total customers in system}}$
CAIFI	Customer Average Interruption Frequency Index	$\frac{\text{number of customer interruptions}}{\text{\# of customers with 1+ interruptions}}$
SAIDI	System Average Interruption Duration Index	$\frac{\Sigma \text{ of all customer interruption durations}}{\text{total customers in system}}$
MAIFI	Momentary Average Interruption Frequency Index	$\frac{\text{\# of customer momentary interruptions}}{\text{total customers in system}}$
ASAIA	Average Service Availability Index	$\frac{\text{customer hours service availability}}{\text{customer hours service demand}}$

Table 1-2. Power quality indices.

SARFI	System Average RMS (Variation) Frequency Index	$SARFI_x = \frac{\sum N_i}{N_T}$
SIARFI	System Instantaneous Average RMS (Variation) Frequency Index	$SIARFI_x = \frac{\sum NI_i}{N_T}$
STARFI	System Temporary Average RMS (Variation) Frequency Index	$STARFI_x = \frac{\sum NT_i}{N_T}$
SMARFI	System Momentary Average RMS (Variation) Frequency Index	$SMARFI_x = \frac{\sum NM_i}{N_T}$
ARDI	Average RMS (Variation) Duration Index	$ARDI_x = \frac{\sum N_i T_i}{\sum N_i}$

X = RMS voltage threshold, usually 70% of nominal.
N_i = Number of customers experiencing voltage deviations with magnitudes above *X%* for $X>100$ or below *X%* for $X<100$ due to measurement event *i.*
N_T = Number of customers served from the part of the system being assessed.
NI_i = Number of customers experiencing instantaneous voltage deviations with magnitudes above *X%* for $X>100$ or below *X%* for $X<100$ due to measurement event *i.*
NM_i = Number of customers experiencing momentary voltage deviations with magnitudes above *X%* for $X>100$ or below *X%* for $X<100$ due to measurement event *i.*
NT_i = Number of customers experiencing temporary voltage deviations with magnitudes above *X%* for $X>100$ or below *X%* for $X<100$ due to measurement event *i.*
T_i = Duration of measurement event *i.*

2
OVERVIEW OF ELECTRICAL DISTURBANCES

Also known as power quality events or power quality phenomena, electrical disturbances, as used in this report, are any aberration of a voltage waveform, current waveform, RMS voltage level, or RMS current level that has the *potential* to upset or damage equipment or wiring. The term “disturbance” as it is used in “electrical disturbance” refers more to the condition of the electricity than to the condition of equipment that uses the electricity or wiring that carries it. For example, an electrical disturbance, such as a voltage sag, may upset one piece of equipment but leave another unharmed. Because the response of equipment to electrical disturbances varies widely, it is the *potential* to upset or damage—and not the actual effect on equipment—that power quality meters are designed to detect and flag.

Not all aberrations are worthy of flagging. For example, a power quality meter does not need to flag voltage levels at a service entrance that are above or below nominal as long as the levels are within a predetermined maximum and minimum voltage. Most state regulating bodies adopt ANSI C84.1, *Electric Power Systems and Equipment - Voltage Ratings (60 Hertz)*, as their standard for service voltage. For low-voltage delivery (120 V to 600 V), ANSI C84.1 requires a voltage between ±5% of nominal.

In any event, any effective discourse between manufacturers of power quality meters, revenue meters, and electric utilities requires a common language. To that end, the following sections discuss the electrical disturbances that power quality revenue meters may be designed to flag. All descriptions derive from the IEEE Standard P1159. Figure 2-1 shows typical graphical representations of the electrical disturbances discussed in this report.

Categories			Typical Duration
Transients	Impulsive	Nanosecond	> 50 Nanoseconds
		Microsecond	50 Nanoseconds to 1 Millisecond
		Millisecond	> 1 Millisecond
	Oscillatory	Low-Frequency	0.3 Milliseconds to 50 Milliseconds
		Medium-Frequency	20 Microseconds
		High-Frequency	5 Microseconds
Short-Duration Disturbances	Instantaneous	Sag	0.5 Cycles to 30 Cycles
		Swell	0.5 Cycles to 30 Cycles
	Momentary	Sag	30 Cycles to 3 Seconds
		Swell	30 Cycles to 3 Seconds
	Temporary	Sag	3 Seconds to 1 Minute
		Swell	3 Seconds to 1 Minute
Waveform Distortion	Notching		Steady-State
	Harmonic Distortion		Steady-State
Voltage Fluctuations	Voltage Fluctuations (Flicker)		Periodic/Intermittent

Figure 2-1. Graphical representations of applicable electrical disturbances.

Oscillatory Transient

Description

Oscillatory transients are distortions of electricity caused by lightning, large motors starting, capacitor switching, and other appliances. As opposed to an impulsive transient, an oscillatory transient has two directions (both positive and negative).

Reason for Flagging

These electrical disturbances can damage the components of electronic equipment, cause process controls and adjustable-speed drives to trip, upset computer processes, and corrupt data.

Impulsive Transient

Description

Impulsive transients are distortions of electricity caused by nearby lightning strikes and the opening of an inductive circuit. As opposed to an oscillatory transient, an impulsive transient has only one direction (positive or negative).

Reason for Flagging

These electrical disturbances can damage the components of electronic equipment, cause process controls and adjustable-speed drives to trip, upset computer processes, and corrupt data.

Voltage Sag

Description

A voltage sag is a brief decrease in the normal voltage level. Sags can be caused by motors starting and remote faults in the power system.

Reason for Flagging

In an industrial environment, voltage sags are notorious for causing process equipment to shut down. Equipment such as adjustable-speed drives, programmable logic controllers, relays, and motor contactors may be particularly sensitive to sags. In a commercial environment, sags can cause computers to restart or lock up, as well as cause other appliances to lose memory.

Voltage Swell

Description

Not nearly as common as a voltage sag, a voltage swell is a brief increase in the normal voltage level. Swells can be caused by switching off large loads, remote faults in the power system, and capacitor switching.

Reason for Flagging

Swells can cause industrial equipment to shut down, components to overheat, and fuses to blow.

Voltage Notches

Description

Voltage notching is a periodic voltage disturbance caused by the normal operation of power electronic equipment as current is commutated from one phase to another. During commutation, two phases of a three-phase voltage nearly short-circuit, causing notches in the phase-to-phase voltage.

Reason for Flagging

Voltage notches, while not a threat to equipment components, can cause microprocessor-based control systems and computer equipment to shut down or lock up.

Harmonic Distortion

Description

Harmonic distortion is the presence of frequencies in the voltage or current other than the fundamental power frequency, which is 60 Hz in North America. Harmonic distortion is most often caused by system resonance or nonlinear loads, such as adjustable-speed drives.

Reason for Flagging

Harmonic distortion can cause overheating of electrical equipment and wiring.

Voltage Fluctuations (Flicker)

Description

Voltage fluctuations are either periodic or intermittent variations in voltage amplitude. Periodic fluctuations can be caused by the operation of high-current equipment with known periods of operation, such as spot welders. Intermittent fluctuations can be caused by the operation of equipment with unknown periods of operation, such as rock crushers.

Reason for Flagging

Generally, voltage fluctuations do not damage or upset equipment. However, they can cause lights to flicker in industrial and commercial facilities, as well as in residences.

3
GENERAL DESCRIPTION OF A POWER QUALITY REVENUE METER

The idealized power quality revenue meter presented in this report is intended for three-phase service entrances, typically limited to industrial and commercial customers. The idea behind this meter is to include all of the hardware to perform all of the desired functions in the basic meter. The meter would be software-upgradeable to perform the higher-end functions. The exception is the need for additional hardware (in the form of a plug-in module) for communications options. Another possible exception is the provision to add additional memory.

Functions

The meter would function as a basic revenue meter out of the box. Advanced functions, the cost of which would be added to the price of the basic unit, would be activated by using the interface software. This flexibility would enable equipment users to tailor the functionality of the device to meet their needs or their customers' needs. It also enables the addition of new features in the future by upgrading software, rather than upgrading hardware. Therefore, the signal-processing and data-processing subsystems would need to be state-of-the-art to allow for the addition of new features in the future. A modular power quality revenue meter would have three main functions: revenue metering, power quality monitoring, and communication.

Revenue Metering

Revenue metering is the most important function of a power quality revenue meter. A power quality revenue meter must be able to measure the quantities required for billing under the various tariffs in effect. The continuing interest in distributed generation makes four-quadrant metering important. The meter should be able to measure power flow into and out of customer facilities. Specifically, the "high-end" revenue functions should include:

- Four quadrant metering
- Multichannel recording
- Fixed and sliding demand intervals
- Pulse input and output
- Transformer loss compensation

Power Quality Monitoring

The meter should measure the most common electrical disturbances that cause problems with process equipment and commercial operations. A meter that measures all disturbances is too costly. Therefore, capabilities must be chosen with cost/benefit in mind. The meter needs to have an overall cost that does not impede its widespread installation in a distribution system. It should measure and monitor the most notoriously problematic events, such as voltage sags, swells, overvoltages, undervoltages, voltage and current unbalance, voltage and current distortion, and momentary voltage interruptions.

Communication

The envisioned power quality revenue meter will have an interchangeable module for advanced communication options. These options will enable the meter to be used for data transmission to the electric utility or wires company. Plug-and-play options include modem, Ethernet, and cellular communication.

Uses

Electric utilities have expressed four main reasons for valuing a power quality revenue meter:

1. They provide power quality data on the “wires” system.

2. They provide power quality data on the customer for conformance to IEEE Std. 519, a specification for harmonic distortion.

3. They provide advanced revenue metering functions such as remote communication, four-quadrant metering, transformer-loss compensation, and load trending.

4. They help utilities avoid multiple service trips to install temporary power quality monitoring equipment. For example, for one complaint, the utility may have to make several trips to download data from the monitor. With a power quality-enhanced revenue meter, much of the monitoring data will be readily available at all times through remote communication, enabling utilities to be proactive rather than reactive.

4

POTENTIAL MARKET FOR POWER QUALITY REVENUE METERS

In recent years—and especially in the current throes of deregulation—electric utilities have come to value information about the energy they purvey. Beyond how much electricity a customer uses, utilities must garner other information to maintain current customer bases and enhance their competitive edge. For example, how electricity is used; the condition of the electricity at the customer service entrance; short-term and long-term trends; duration, magnitude, and frequency of electrical disturbances; the type and amount of emissions that the customer is contributing to the system.

Armed with a bounty of such data, electric utilities can also identify potential customers of power quality services based upon specific customer needs. Utilities can also offer a host of services to their industrial customers—including power quality monitoring, power quality data analysis, and efficiency analysis—to increase the value of electricity in a competitive energy market. Moreover, with fast remote access to monitoring data, utilities can offer information—such as customized energy-use information—to their industrial and commercial customers via the Internet. Other possible services include online usage history, real-time pricing, and special billing initiatives.

According to *Electrical World* (August 1988, page 9), the worldwide market for electricity-tariff meters was valued at $1.82 billion (U.S. 1997 dollars) in 1997. Of that market, the U.S. represented about 15 percent. In the August 2000 issue of *Utility Automation,* Frost and Sullivan predict that the U.S. utility meter market will grow at about 3 percent per year.

CERA (Cambridge Energy Research Associates) projects that electric meter installations will grow between 10 and 17 percent annually, depending on the advances in lower-cost communication options (*Electric Light and Power,* April 2000, vol. 78, issue 4). CERA anticipates that between one-fourth and two-thirds of U.S. electric meters will be communications-equipped by 2015.

Chartwell Research found that 75 percent of energy providers that responded to their survey (*The Chartwell AMR Report 2000)* are either using or piloting automated meter reading (AMR) (*Utility Automation,* August 2000, vol. 6, issue 6). Energy providers are targeting AMR toward commercial and industrial customers. Thirty-two percent of the survey respondents plan to use AMR for all of their commercial and industrial customers.

See Appendix B for a functional assessment of existing power quality monitoring and revenue metering products.

5
SURVEYING THE STAKEHOLDERS

To characterize the expectations of the electric utilities involved in this project, as well as the disposition of the meter manufacturers, EPRI PEAC Corporation conducted two surveys.

Survey of Electric Utilities

Description

The survey given to the supporting electric utilities was designed to determine which advanced functions of power quality revenue meters that utilities value for current and future use. Survey recipients were informed that the “standard” meter functions—such as kWh, kVA demand, and kVAR—would be assumed functions of any proposed power quality revenue meter.

See Appendix C for the complete survey and comprehensive results.

Summary of Results

Voltage sags are the number one electrical disturbance in terms of frequency of occurrence and number of customer complaints. Therefore, it was no surprise that the collection of sag data was the number one requirement of utilities. The rest of the electrical disturbances were ranked in importance roughly according to the frequency of their occurrence in the distribution and transmission system. Figure 5-1 shows how the respondents ranked electrical disturbances by importance.

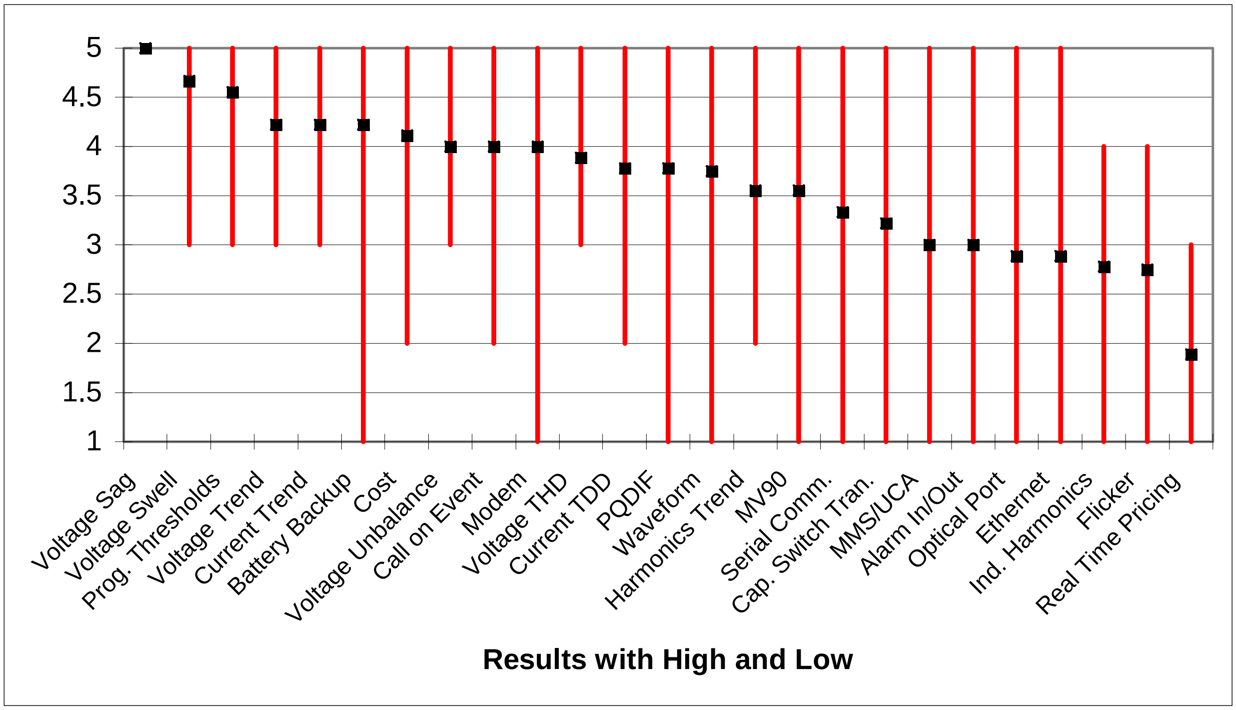


Figure 5-1. Ranking of the importance of electrical disturbances by electric utilities (higher numbers mean more importance).

Each of the meter features listed in the survey had at least one "high" and one "low" vote on its importance. To some extent, this can be explained by the fact that some of the surveys were completed by meter personnel. Meter personnel tended to rate many of the power quality features as low while rating the meter functions as high. The converse is true for the responses from power quality professionals.

The majority of the respondents (75%) supported the idea of specifying a single meter with "soft" upgrades. This makes sense because it allows for changes in the function of a meter without hardware change-out, which can be costly in terms of labor. Half of the respondents answered that the type of meter necessary was "socket." Many utilities are considering standardizing on socket-type meters, which can be done by making use of adaptors when A-Base or panel-type installations are required.

Survey of Manufacturers of Revenue Meters

Description

The survey designed for the manufacturers of revenue meters (see Appendix D) was rather open-ended. Therefore, survey data lends itself better to qualitative description rather than quantitative analysis.

Summary of Results

The target of the Power Quality Revenue Meter Project is to produce a meter that costs approximately $500 (U.S.) in a basic revenue meter configuration and $1500 (U.S.) when equipped with all of the power quality and revenue features in the specifications in this document. These prices do not reflect the additional cost of communication options such as modem or Ethernet. The basic meter would have all of the hardware necessary, with the exception of communication, to perform all of the specified functions. The functions would be activated with software. Each option that is activated would include a cost.

Respondents to the survey indicated that they were most concerned about features that increase the cost of production, specifically flicker measurement and waveform capture on event. Calculation of flicker (IEEE P1453) requires expensive hardware that would increase the cost of the meter beyond the target price. Waveform capture on event greatly increases the amount of required memory.

Respondents also expressed concern about the increased power supply requirements to meet the specifications for 128 samples per cycle, additional memory, and faster processor to perform the advanced calculations such as individual harmonics, four-quadrant metering, and waveform capture. The additional cost to the power supply for these options could be anywhere from 30 to 60 dollars each.

According to the respondents, battery backup for 1 minute could cost as much as $50. It could also require the use of an external battery. The battery backup for memory could be handled by using a battery or Flash memory.

Manufacturers of Power Quality Meters

The two manufacturers of power quality meters with the largest market share were informally contacted about their participation in a survey. Neither manufacturer demonstrated interest in the survey or the Power Quality Revenue Meter Project. Therefore, no survey instrument was designed for or distributed to manufacturers of power quality meters.

6
APPLICABLE STANDARDS

Table 6-1 lists all of the applicable standards for power quality revenue meters. Appendix E lists complete references for these standards.

Table 6-1. Applicable standards.

Standard	*Application*
ANSI C12.1	Basic accuracy, performance, and safety for meters and metering equipment.
ANSI C12.7	Watt-hour meter sockets.
ANSI C12.10	Accuracy, configuration, and performance of electromechanical watt-hour meters.
ANSI C12.13	Accuracy and performance of time-of-use (TOU) registers.
ANSI C12.16	Accuracy, configuration, and performance of solid-state electricity meters.
ANSI C12.18	Protocol specification for ANSI Type 2 optical port.
ANSI C12.19	Specifications for utility industry end devices.
ANSI C12.20	0.2% and 0.5% accuracy class electricity meters.
ANSI C37.90.1	Surge-withstand capability test.
ANSI C62.41	Surge voltages.
CAN3-C17-M84	AC electricity metering.
CAN/CSA-Z234.5	Date and time format.
FCC Part 15	Radio frequency (RF) interference.
FCC Part 68	REN (Ring Equivalent Number)
IEC 60687	Active energy Class 0.2.
IEC 61000-4-2	Electrostatic discharge.
IEC 61000-4-4	Electrical fast transients (EFTs).
IEC 61036	Active energy classes 1 and 2.
IEC 61268	Reactive energy classes 1 and 2.
UL 1950	Electric safety.

7

FUNCTIONAL SPECIFICATIONS FOR AN IDEALIZED POWER QUALITY REVENUE METER

The idealized power quality revenue meter presented in this section is a compromise between the requirements of the surveyed electric utilities and the cost of production indicated by the surveyed manufacturers. The specifications for the idealized meter are listed below.

Hardware Specifications

Revenue Functions

- 0.2% accuracy on kWh and kW
- Standard meter functions such as demand kW and kWh (delivered and received)
- Four-quadrant metering
- Four-channel recording
- Multi-level password protection
- Alpha display
- Battery-backed operation (15 seconds for the meter, 35 days for the data)
- Compliance with MV90
- Compensated metering (transformer loss)
- Alarm inputs and outputs (minimum of four, selectable for input or output)
- Real-time pricing capability
- A-base, socket, and panel models available

Power Quality Metering Functions

- Logging of voltage sags in table form (magnitude and duration with 0.5-cycle resolution, time stamp)
- Logging of voltage swells in table form (magnitude and duration with 0.5-cycle resolution, time stamp)
- Programmable thresholds for voltage limits
- Waveform capture on event (voltage and current at 128 samples per cycle)

- Voltage unbalance measurement
- Voltage trending (minimum, average, and maximum during the billing interval)
- Current trending (minimum, average, and maximum during the billing interval)
- Capture of capacitor-switching transients (300 to 900 Hz)
- Call home on event
- Logging of voltage THD events with programmable threshold
- PQDIF data export from the interface software (see Appendix F for more information on PQDIF)
- Alarm inputs and outputs (minimum of four, selectable for input or output)
- Logging of current TDD events with programmable threshold (total demand distortion as defined by IEEE Std. 519-1992)
- Harmonic tending (V_{THD} and I_{TDD})
- Individual harmonic trending

Communication Functions

- Serial communication
- Modem and Ethernet communication
- Standard optical port
- MMS/UCA
- DNP3

Communications

- Standard optical port and serial (RS232) communications port
- Optional modem, Ethernet, and RS485 ports
- MMS/UCA, Modbus, and DNP3 as options

Interface Software Specifications

- PQDIF data export option (see Appendix F for more information about PQDIF)
- Compliance with MV90
- Compliance with Open Database Connectivity, or ODBC (see Appendix G for more information on ODBC)
- Compatible with Windows 95/98, NT4.0, and 2000
- Includes a full version for translation and a version for data access and programming

- Automated polling of meters via telephone or Ethernet

In addition to hardware, communications, and software considerations, firmware for data compression must also be considered. Wavelet data compression shows great promise for this application. It reduces the memory requirements for storing captured waveforms. A recent paper by Santoso, Powers, and Grady indicates a compression ratio of five to one can be achieved using this technique (see Santoso, S., Powers, E.J., and Grady, W.M. “Power Quality Disturbance Data Compression Using Wavelet Transform Methods.” *IEEE Transactions on Power Delivery*, vol. 12, no. 3, July 1997.).

8
COST/BENEFIT ANALYSIS

Cost

Because of the keen competition in the meter industry, obtaining adequate and trustworthy cost data is an almost insurmountable complication for a meaningful cost/benefit analysis. Since EPRI's foray into the revenue meter market with its SE-240, manufacturers in this industry view EPRI as a potential competitor and are therefore even more reluctant to assist in the design of a power quality revenue meter.

The following costs are based on the engineering analysis of EPRI PEAC with modest information garnered from informal conversations with the power quality meter industry and the survey results presented in Chapter 5 of this report. The personal knowledge of the principal investigator about existing products also aided in the analysis.

The basic meter, with all of the hardware to provide the advanced features spelled out in the functional specifications, will cost approximately $500 with volume production. In its basic configuration, the meter will simply provide kWh and kW demand, both received and delivered. Additional features will be enabled using software, which will incur additional costs. Table 8-1 shows the analysis of these costs as a percentage of the cost of the standard meter. A fully featured meter, less the advanced communications hardware such as a modem, would cost approximately $1,500.

Table 8-1. Costs of meter features.

Configuration/Feature	*Cost (% of Basic)*
Basic Meter	100%
Four-Quadrant Metering (with kVar, kVA, etc.)	20%
Multichannel Recording	20%
Compensated Metering	10%
Event Logging (Voltage Sag, Swell, Vthd, Itdd)	30%
Voltage and Current Trending	30%
Waveform Capture of Capacitor Transients	40%
Alarm I/O	10%
Harmonic Trending (Vthd, Ithd)	20%
Individual Harmonic Trending (of Selected Harmonics)	20%
Fully Featured Meter (Total)	300%

The hardware requirements in IEEE 1453 makes the endowment of flicker measurement an expensive proposition. The additional cost to provide flicker measurement is estimated to be $1,000.

Benefits

With a base cost of approx $500, it would be feasible to install this meter at many, if not all, sites of commercial and industrial customers. The power quality and advanced revenue features can then be added on to those customers who warrant the additional expense or those that have a power quality complaint. The majority of power quality events affecting customers are voltage sags. The proposed meter could cost-effectively monitor voltage sags on an entire system.

9
CONCLUSIONS AND RECOMMENDATIONS

In this report, we have endeavored to produce a set of realistic specifications for a multi-function revenue meter with power quality capabilities. The intent is for the meter to be priced such that it can be widely implemented in a utility, while being flexible enough to meet most of the power quality monitoring needs of the utility.

The changes taking place in the utility industry indicate a need for a flexible revenue meter. The data from such a meter will provide not only the normal data used for billing, but also information that can be used to tailor new products for customers. The data will also be useful for power aggregators as they try to predict short-term demands.

Increasingly, state utility commissions are setting quality and reliability standards for electric power distributors, known as the "wires companies." A flexible, cost-effective revenue meter with power quality functions can provide the utility with the information needed to help influence the standards set by the commissions. Once limits are set, the same meters can provide the information necessary to measure the performance relative to the standards. In many cases, a utility that can prove that it is exceeding the requirements may be compensated with higher rates and/or profits.

Some existing meters have some, or all, of the functions specified. A few meters even have more features. However, a meter with the flexibility and functionality put forth in this report does not exist. It is our recommendation that EPRI proceed with the development of such a flexible power quality revenue meter, which should enjoy a welcoming market.

A

TAILORED COLLABORATION OFFERING FOR POWER QUALITY REVENUE METER DEVELOPMENT

Tailored Collaboration Opportunity
EPRI Power Quality Target October 2000
Power Quality Revenue Meter Development
Evaluates Power Quality Performance

Background

Premium power services can be the key to attracting and retaining industrial and commercial customers in today's competitive energy market. But before you can implement these services, you need to be able to define your existing power quality levels. To do this, many energy service providers are installing systems that monitor, report, and analyze changes in power quality at key points in the transmission and distribution system. Power quality is second only to price in the minds of industrial and commercial customers as they choose their energy service providers. To preserve a strong market position, you must be able to respond coherently, quickly, and effectively to power quality situations at customer facilities.

Existing power quality monitors are useful for this evaluation, but is also fairly expensive at this time and adds to the hardware investment for a given circuit or customer. A need exists for a way to not only bring this cost down, but also to bring more flexibility and functionality to the meter. This can be accomplished by combining the hardware that monitors revenue (power flow) and power quality into one piece of equipment. Combining the revenue meter with the power quality meter at a competitive price enables utilities to leverage an existing need with a future need through a single cost-effective investment. By participating in the EPRI Power Quality Revenue Meter Project, utilities can be on the input-specification stage for the design of this next-generation meter, thereby ensuring that required power quality parameters are implemented in the design, while leveraging resources from an EPRI matching fund.

Project Summary

This project is a follow-on activity related to the "PQ Revenue Meter Functional Requirements" project completed by EPRI in September, 2000. Utilizing the functional specifications developed in that project, utilities will be able to participate in the actual design stages of the first-generation PQ revenue meter. Meter manufacturers will be invited to participate as designers of the meter and work closely with the project sponsors to ensure that all necessary compatibility requirements, specifications, and functions are implemented in the design. As the design progresses, beta testing will be conducted at EPRI's Power Quality Test Facility to ensure both survivability and specification compliance. Each participating utility will receive four of the meters for evaluation as part of the deliverables of this project.

Deliverables

- Final report on functional specifications and test results/validation
- Four first-run PQ revenue meters
- On-site technical assistance in specifying and installing monitoring instruments
- Monthly and quarterly status reports
- Customized final report of findings

Benefits

By participating in this project, you can improve your business practices, more effectively allocate resources, and speed up your response to power quality problems. The use of a cost-effective, integrated monitoring system to characterize power quality for your substations and customer facilities enables you to identify your base power quality levels.

Such information is a prerequisite to offering premium power services, which can enhance customer relationships, increase revenue opportunities, and build customer loyalty. On-site training and support allow you to maximize the benefits of project participation. They help your marketing and account executives, transmission and distribution engineers, and power quality staff build a team to better serve key customers and can potentially assist in defining or benchmarking the distribution system for possible future regulator expectations.

Demonstrated Value

Only EPRI has the diverse resources necessary to position your company to win customer loyalty in today's increasingly competitive energy services market. EPRI’s broad knowledge of energy customers, changing markets, and international developments can help you anticipate and shape the changes that are transforming the energy industry along with the needs of your customers. EPRI has long been at the leading edge of market insights and technology development, delivering a wide range of products, support, and services. EPRI has created an unparalleled network of technical experts, research allies, manufacturers, industry representatives, and marketing specialists from around the world. As an objective source, EPRI can seek the best technology, vendor, and fit for your particular needs.

Price of Participation

An investment of 20,000 dollars is required to participate in this Tailored Collaboration project.

Project Status and Schedule

This project is open to participation and will begin as soon as funding is secured. The total length of the project is estimated to be 12 months beyond securing funds necessary to conduct the work.

Who Should Join

This Tailored Collaboration opportunity is available to all funders of EPRI Power Quality activities.

Contact Information

For more information, contact the EPRI Customer Assistance Center at 800-313-3774 or askepri@epri.com.

EPRI 3412 Hillview Avenue, Palo Alto, California 94304 PO Box 10412, Palo Alto, California 94303 USA 800.313.3774 650.855.2121 askepri@epri.com www.epri.com Printed on recycled paper in the United States of America TO-111960

B

FUNCTIONAL ASSESSMENT OF EXISTING PRODUCTS

Table B-1. Manufacturers of electronic revenue-quality meters.

Manufacturer	*Power Quality Capabilities?*
ABB	YES
Arbiter Systems	YES
Computerized Meter Manufacturing Corp.	NO
E-Mon	NO
Ekstrom	UNKNOWN
Electro Industries	YES
GE	YES
Meter Technology Corp.	YES
Ohm Tech Labs	NO
Power Measurements LTD	YES
Rochester Instruments	YES
Schlumberger	YES
Scientific Columbus (Rochester)	NO
Siemens	YES
Transdata	YES
EDMI (Australia)	YES
PRI (UK)	NO
Total Metering (NZ, AU)	YES

Table B-2. Manufacturers of electronic revenue-quality meters with power quality capabilities.

Manufacturer	*Sags/Swells/Outages*	*Harmonics*	*Transients*
ABB	YES	YES	YES
Arbiter Systems [1]	YES	YES	NO
Electro Industries	YES	YES	YES
GE	YES	YES	NO
Meter Technology Corp.	YES	NO	NO
Power Measurements LTD	YES	YES	YES
Rochester Instruments[2]	YES	No	No
Schlumberger	YES	YES	NO
Siemens	YES	UNKNOWN	NO
Transdata	YES	YES[3]	NO
EDMI (Australia)	YES	YES [4]	NO
Total Metering (NZ, AU)	YES	NO	NO

1. Also measures flicker.
2. Three-cycle minimum duration for sags and swells.
3. Distortion alarm.
4. Captures a single snapshot of 5 cycles. This can be evaluated using the manufacturers software for harmonic spectra.

C
SURVEY FOR ELECTRIC UTILITIES AND DETAILED RESULTS

Survey Data for
Power Quality Revenue Meter Functional Specification

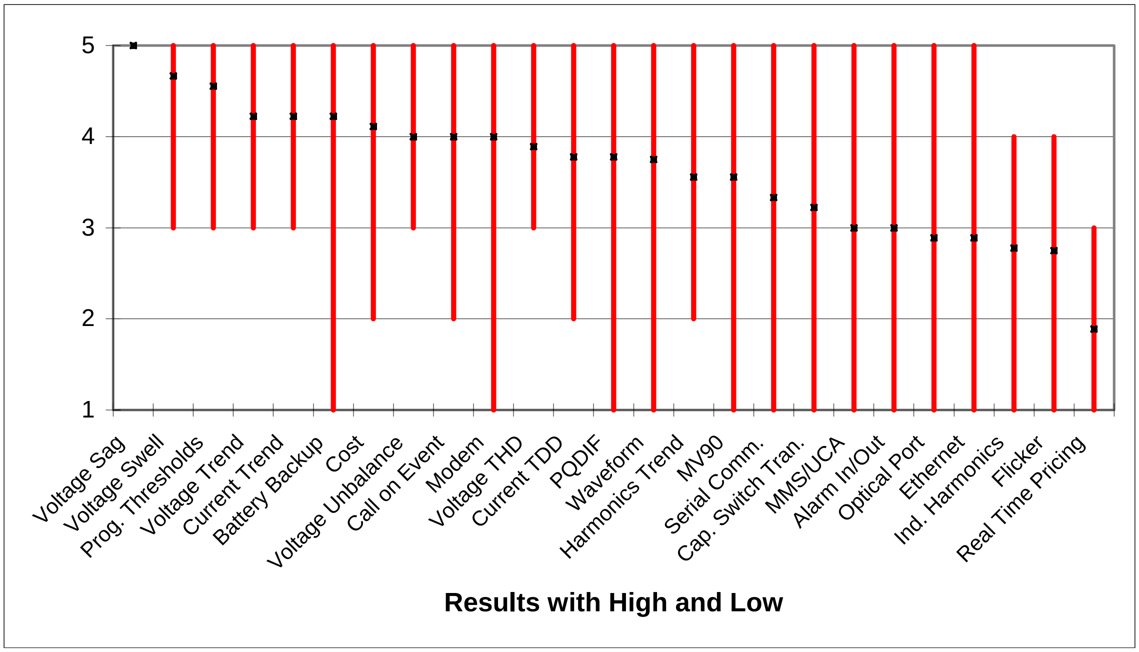
Target 7: Power Quality Measurements and Testing
Power Quality Revenue Meter Functional Specifications

This survey is designed to obtain feedback from members of Target 7 regarding the desired features in a revenue meter with advanced power quality and communication functions.

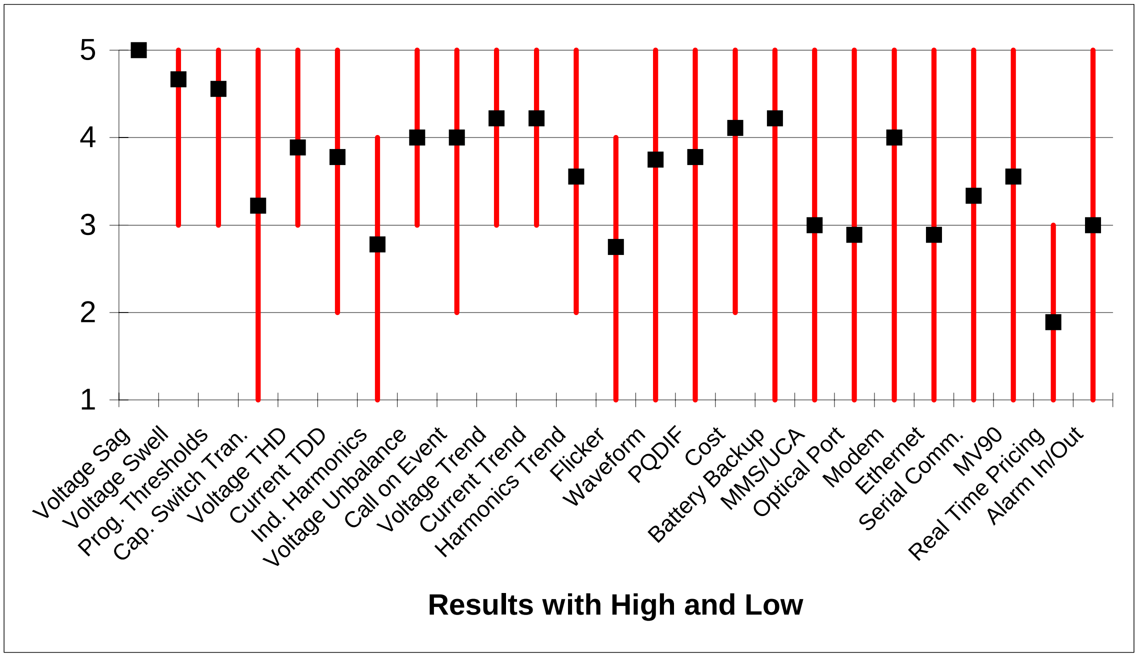
There were a total of 9 respondents to this survey. Because not all of the respondents answered every question, the number of respondents is shown in parenthesis following each question. The results are shown as a *percentage of respondents*.

If you have any questions regarding this survey, please call Charles Perry at (865) 218-8034 or email him at chperry@epri-peac.com.

Below is a summary of the results of question 1. Shown is the average value for each question as well as the minimum and maximum value. The results are sorted from most important to least important as rated by survey respondents.

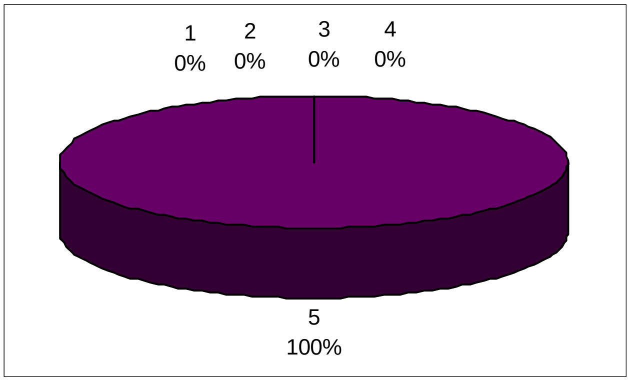

5
4
3
2
1
Voltage Sag
Voltage Swell
Prog. Thresholds
Voltage Trend
Current Trend
Battery Backup
Cost
Voltage Unbalance
Call on Event
Modem
Voltage THD
Current TDD
PQDIF
Waveform
Harmonics Trend
MV90
Serial Comm.
Cap. Switch Tran.
MMS/UCA
Alarm In/Out
Optical Port
Ethernet
Ind. Harmonics
Flicker
Real Time Pricing
Results with High and Low

Below is a summary of the results of question 1. Shown is the average value for each question as well as the minimum and maximum value.



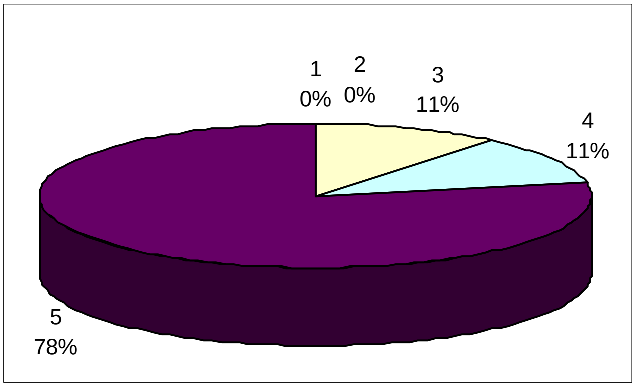
1a. Rate the importance of Voltage Sag Capture (9).

1 Low
2
3
4
5 High



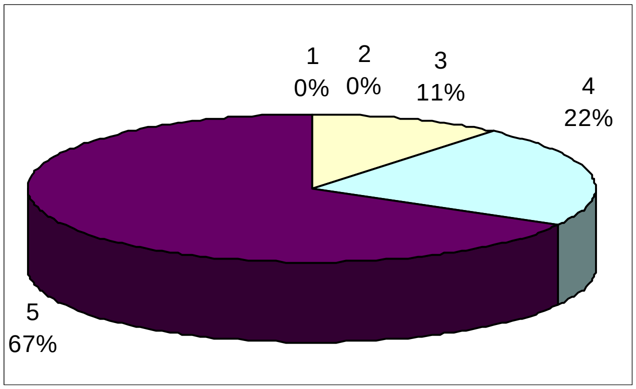
1b. Rate the importance of Voltage Swell Capture (9).

1 Low
2
3
4
5 High



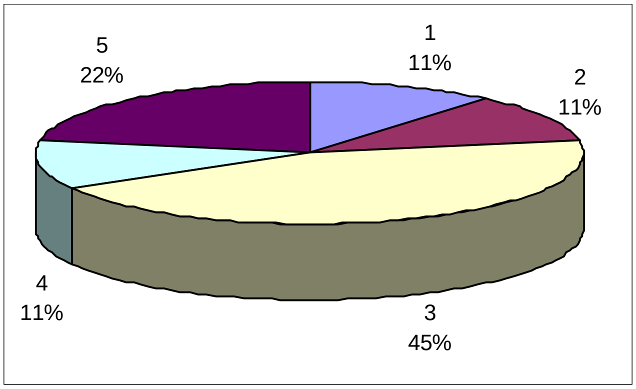
1c. Rate the importance of Programmable Thresholds(9).

1 Low
2
3
4
5 High



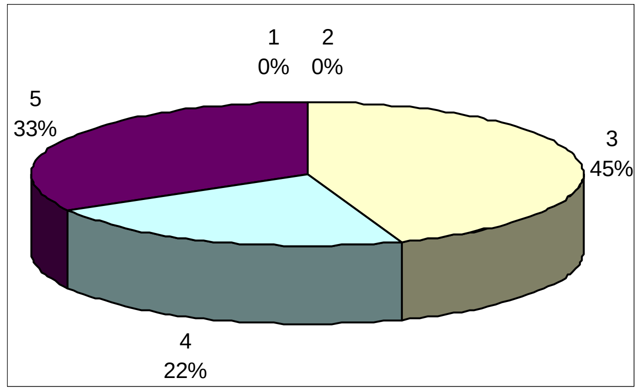
1d. Rate the importance of Capacitor Switching Transient Capture (9).

1 Low
2
3
4
5 High



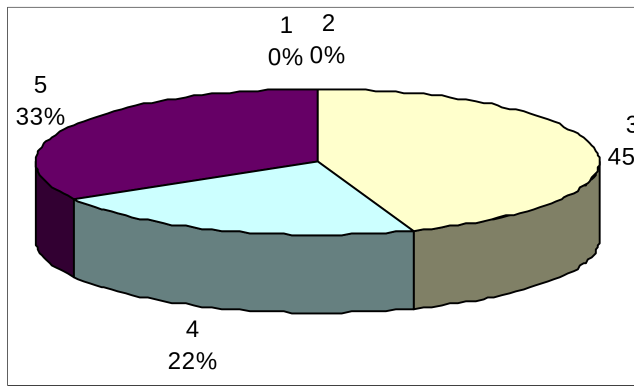
1e. Rate the importance of Voltage THD Measurement (9).

1 Low
2
3
4
5 High



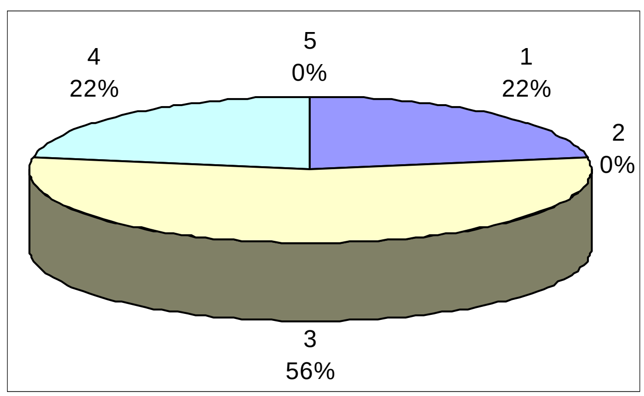
1f. Rate the importance of Current TDD Measurement (9)

1 Low
2
3
4
5 High



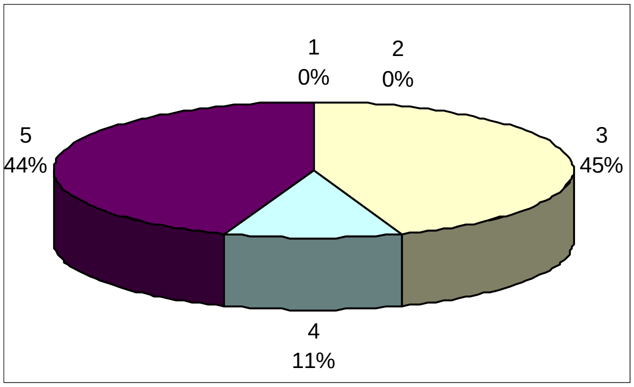
1g. Rate the importance of Individual Harmonics Measurement (9)

1 Low
2
3
4
5 High



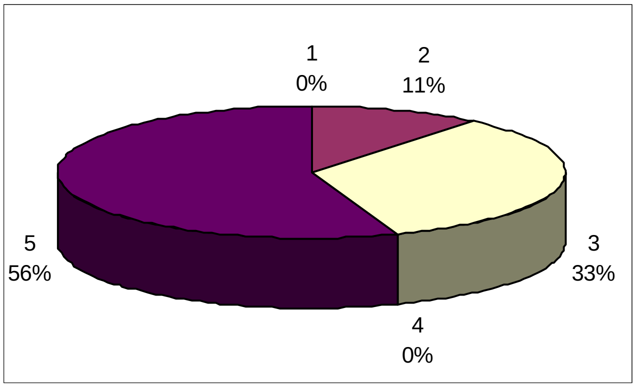
1h. Rate the importance of Voltage Unbalance Measurement (9)

1 Low
2
3
4
5 High



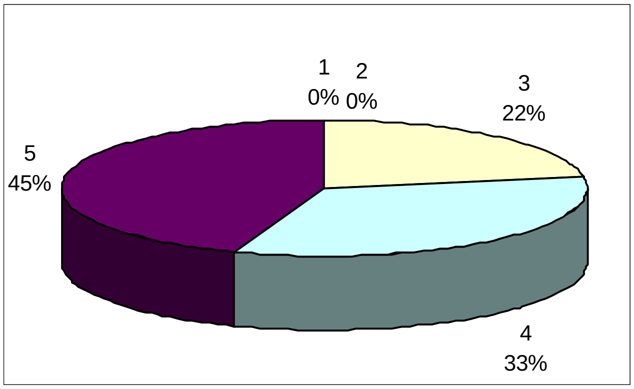
1i. Rate the importance of Call on Event (9)

1 Low
2
3
4
5 High



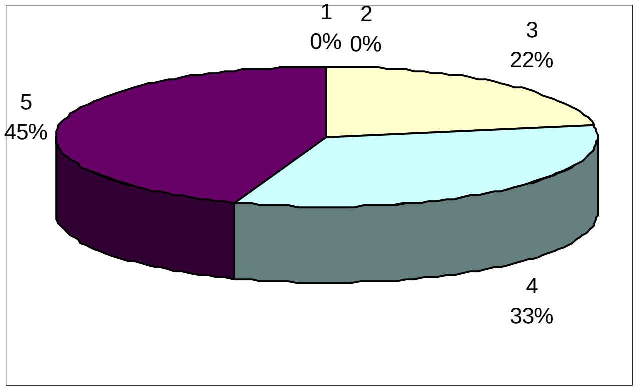
1j. Rate the importance of Voltage Trending (min/max/avg) (9)

1 Low
2
3
4
5 High



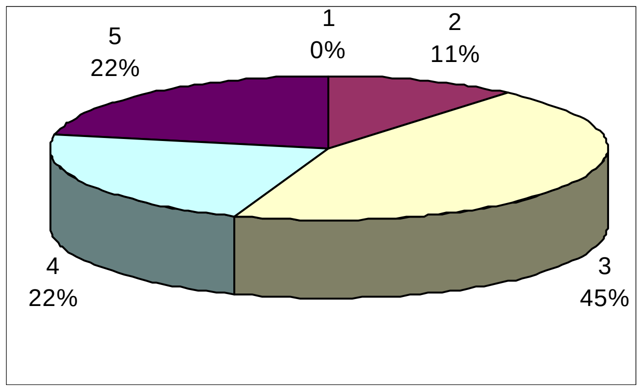
1k. Rate the importance of Current Trending (min/max/avg) (9)

1 Low
2
3
4
5 High



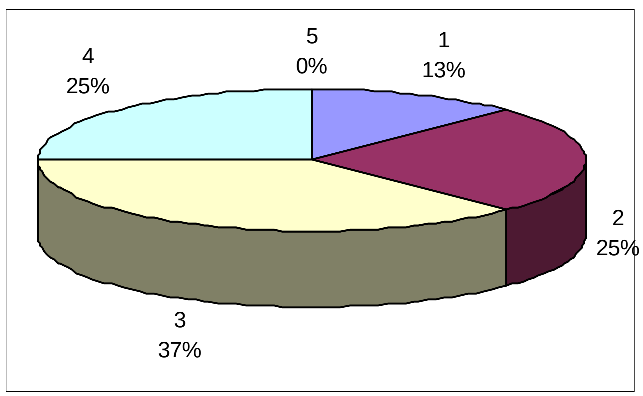
1l. Rate the importance of Harmonics Trending (min/max/avg) (9)

1 Low
2
3
4
5 High



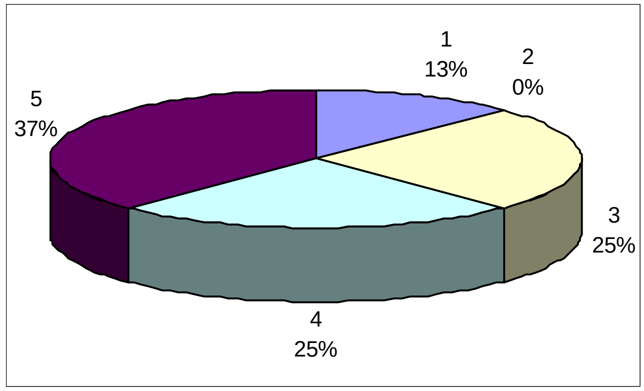
1m. Rate the importance of Flicker Measurement (8)

1 Low
2
3
4
5 High



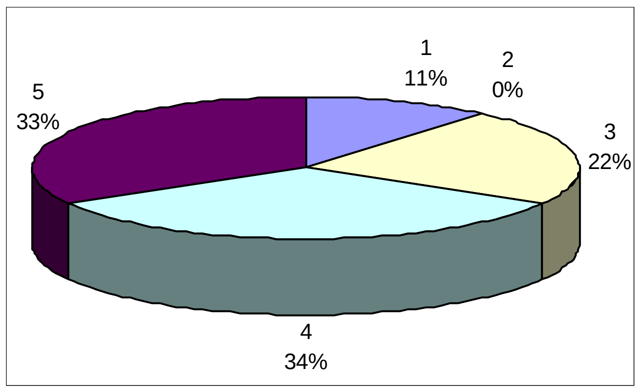
1n. Rate the importance of Waveform Capture on Event (8)

1 Low
2
3
4
5 High



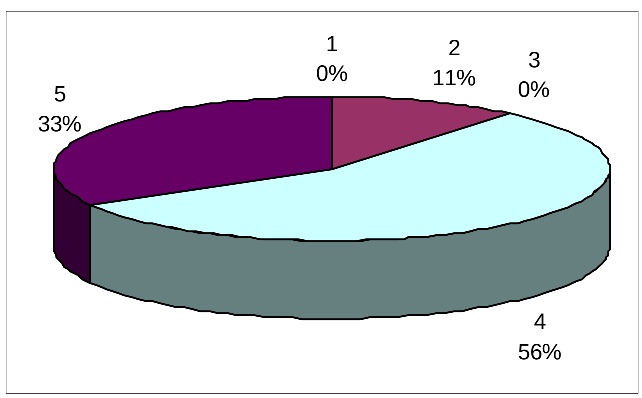
1o. Rate the importance of PQDIF Data Export (9)

1 Low
2
3
4
5 High



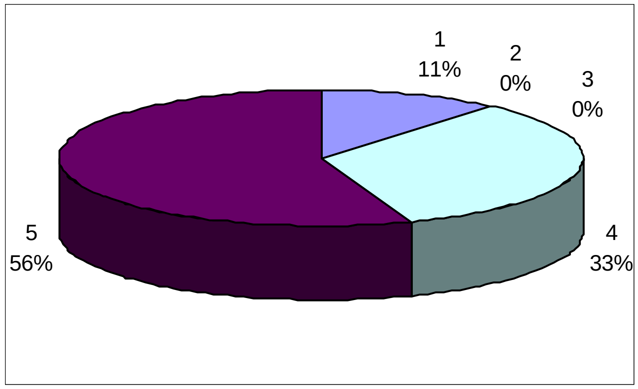
1p. Rate the importance of Cost (9)

1 Low
2
3
4
5 High



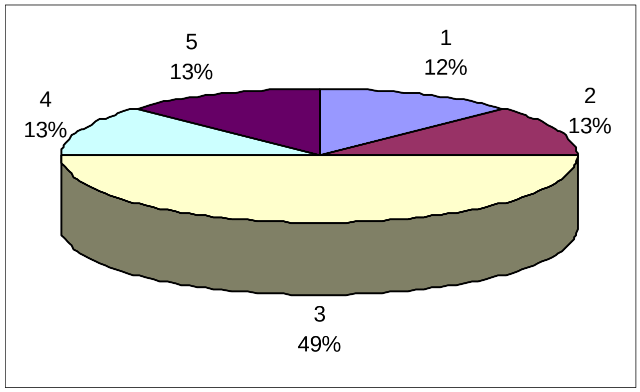
1q. Rate the importance of Batter Backed Operation (9)

1 Low
2
3
4
5 High



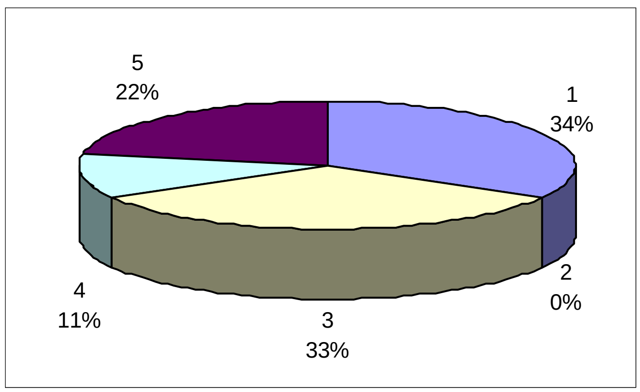
1r. Rate the importance of MMS/UCA Compliant Communications (8)

1 Low
2
3
4
5 High



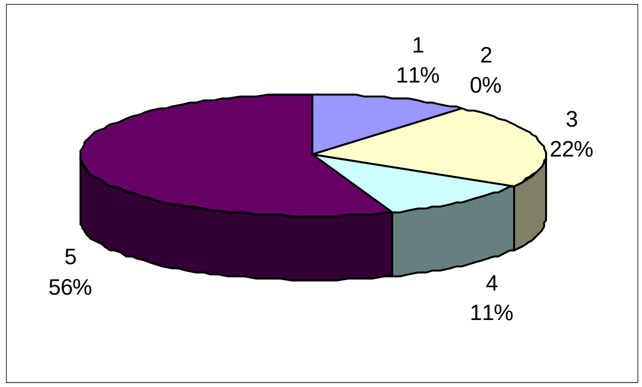
1s. Rate the importance of Standard Optical Port (9)

1 Low
2
3
4
5 High



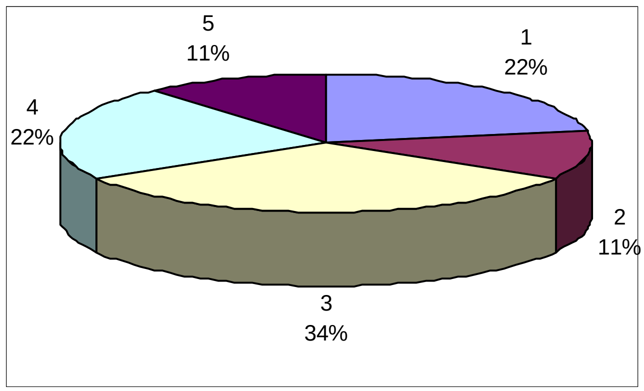
1t. Rate the importance of Modem (9)

1 Low
2
3
4
5 High



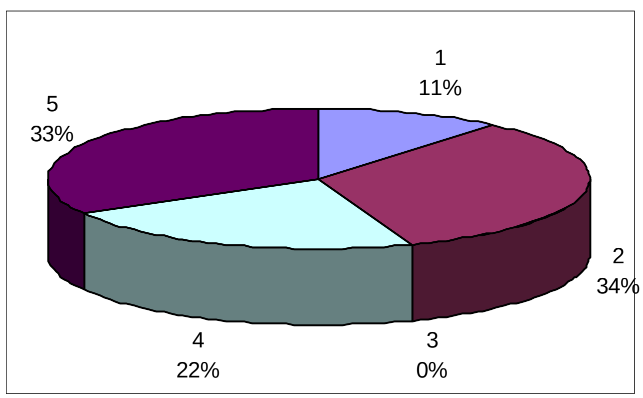
1u. Rate the importance of Ethernet Communications (9)

1 Low
2
3
4
5 High



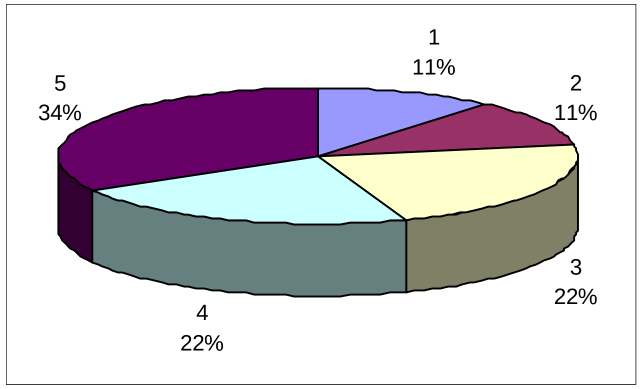
1v. Rate the importance of Serial Communication Port (9)

1 Low
2
3
4
5 High



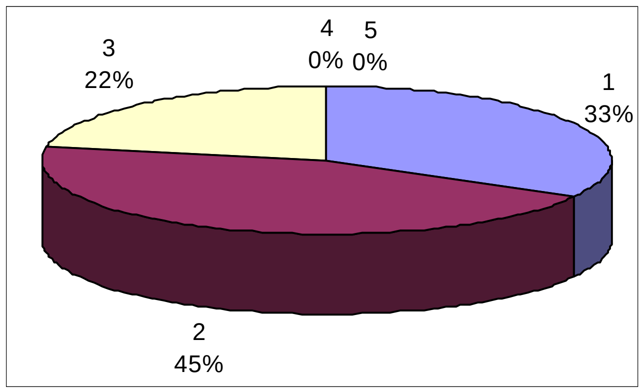
1w. Rate the importance of MV90 Compatibility (9)

1 Low
2
3
4
5 High



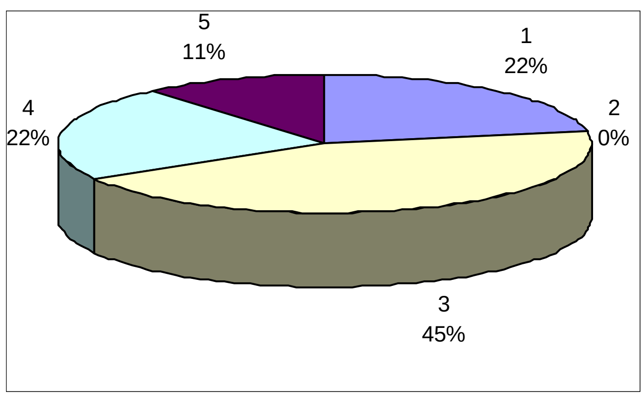
1x. Rate the importance of Real Time Pricing (9)

1 Low
2
3
4
5 High



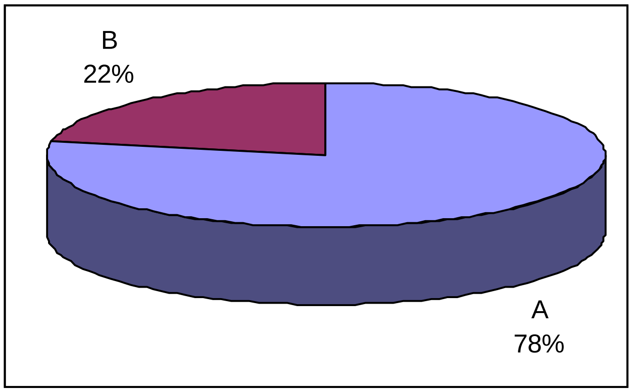
1y. Rate the importance of Alarm Inputs and Outputs (9)

1 Low
2
3
4
5 High



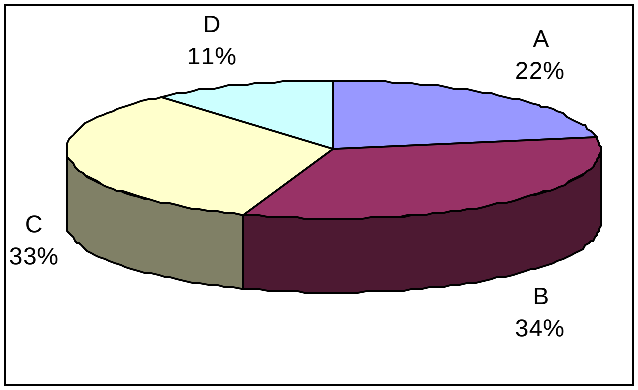
2. Do you want a Standard Alpha Display or a Graphic Capable Display? (9)

A Alpha
B Graphic



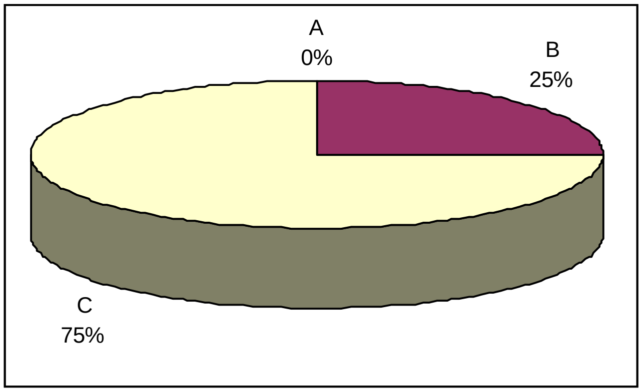
3. What sampling rate do you think is necessary? (9)

A 2kHz
B 7.2 kHz
C 15.3 kHz
D 100 kHz



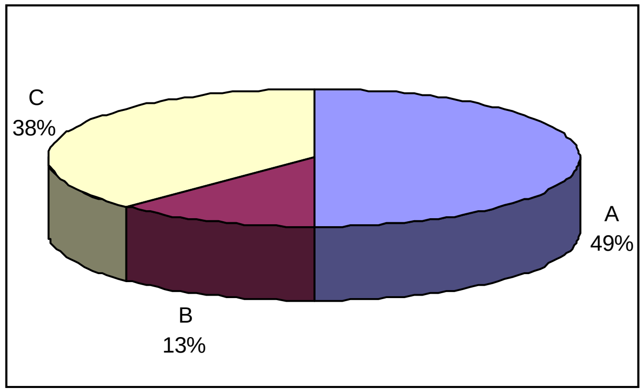
4. Do you want to specify a single high end meter, two meters (one low end and one high end), or a single meter that is upgradeable from low end to high end? (8)

A High End Meter
B Both High End and Low End
C Single Meter with Soft Upgrades



5. Do you want to standardize on one type (socket, DIN, etc) or have all types available? (8)

A Socket
B Socket and Panel
C All Types



6. What will be the benefit of a meter with the capabilities that you have indicated? How will the data be used? Is there a business case for such a meter?

Primary benefit is the ability to verify events and time stamp which allows for causal analysis and mitigation strategies. The business case is in selling the information to the customer.

If the device cost is low enough, applications for high end customers may appear.

Data and information will be used in troubleshooting activities and for proactive system operation.

The business case for such a meter will start to occur naturally as questions of system reliability become more critical.

To meet customers' billing and "basic to intermediate" power quality needs. To permit customer and utility to simultaneously access meter data.

Such a product becomes an excellent product offering. It can be sold to the customer as outage/event notification as well as load/facility monitoring. Additional electric system PQ monitoring at the PCC is the key benefit.

This meter could allow our utility to start a cost effective pro-active power quality program.

Provide easy access to both power consumption and power quality data at the PCC.

D
SURVEY FOR MANUFACTURERS OF REVENUE METERS

Power Quality Revenue Meter Questionnaire

EPRI PEAC Corp. is currently working on a project to develop the functional specifications for a power quality capable revenue meter. Below is a list of features that utilities want in a revenue meter with power quality monitoring capabilities according to a survey that was recently performed by EPRI PEAC Corp. Now that we know what utilities want, we need to find out what features are practical given economic constraints. Your estimates will NOT be construed as being bid prices for production or sale. I am only interested in your insight and opinions. The results of the survey will be provided only as a group. No individual results will be published. The source of all data will be kept confidential.

For the following questions use the following assumptions:

- Reasonable volume – We are not interested, at this point, in the cost of the first meter, rather the cost of the Nth meter.
- Standard revenue features – There is no reason for me to list such things as kVA demand as a required feature. Assume the revenue features available in a “standard” electronic revenue meter are implied.

Assume the target price for this meter is $1000 (in volume). After reviewing the list of desired features, do you think a meter could be built for this price? If not, how much would it cost? Which options would have to be removed to get the meter to the $1000 price. The features will be listed from most important to least important. For the features that you would remove, what is the cost associated with adding each one. I understand that the total cost of the individual components may not add up to the total cost of the meter.

If you have any questions, don’t hesitate to call me at 865 218 8034 or email at cperry@epri-peac.com.

Features in order of importance (assume “standard” revenue features are present and the meter is to be socket based):

- 4 quadrant metering
- 4 channel recording

- Multi-level password protection
- Alpha display
- Voltage sag capture in table form (magnitude, duration, time stamp)
- Voltage swell capture in table form
- Programmable thresholds for voltage limits
- Battery backed operation (1 minute for meter, 35 days for data)
- Waveform capture on event (voltage and current at 128 samples per cycle)
- Voltage Unbalance measurement
- Voltage trending (min/avg/max over billing interval)
- Current trending (min/avg/max over billing interval)
- Serial communication
- MV90 compliant
- Capacitor switching transient capture (300 to 900 Hz)
- Call home on event
- Voltage THD event logging with programmable threshold
- PQDIF data export (from the interface software)
- Modem and Ethernet communication
- Compensated metering (transformer loss)
- Alarm inputs and outputs (min of 4: selectable for in or out)
- Current TDD event logging with programmable threshold (Total Demand Distortion as defined by IEEE 519-1992)
- Standard optical port
- Harmonic (V THD and I TDD) Trending
- Individual harmonic trending (ie. 3rd harmonic)
- Flicker
- MMS/UCA
- DNP 3
- Real time pricing capability

Don't assume that only the features at the bottom of the list need to be considered when trying to lower the cost. For example, the modem and Ethernet communications features could be separately priced options.

I would also like you to identify the few “big ticket” features that you believe add the most cost to the proposed meter. What is the relative cost of these features?

Again, feel free to call me if you would like clarification of the questionnaire or the project associated with it.

Please return responses to Charles Perry at the following:

Fax 865 218 8001

Email cperry@epri-peac.com

E
REFERENCES TO APPLICABLE STANDARDS

ANSI C12.1-1995, *American National Standard for Electric Meters—Code for Electricity Metering Revision and Redesignation of ANSI/IEEE C12.1-1988.*

ANSI C12.7-1993, *American National Standard Requirements for Watthour Meter Sockets.*

ANSI C12.10-1997, *American National Standard for Electromechanical Watthour Meters.*

ANSI C12.13-1991, *American National Standard for Electronic Time-of-Use Registers for Electricity Meters.*

ANSI C12.16-1991, *American National Standard for Solid-State Electricity Meters.*

ANSI C12.18-1996, *Protocol Specification for ANSI Type 2 Optical Port.*

ANSI C12.19-1997, *Utility Industry End Device Data Tables.*

ANSI C12.20-1998, *Electricity Meters 0.2 and 0.5 Accuracy Classes.*

ANSI C37.90.1-1989, *IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.*

ANSI C62.41.1991, *IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits.*

FCC Part 15, 47 CFR 15, *Radio Frequency Devices.*

FCC Part 68, 47 CFR 68, *Connection of Terminal Equipment to the Telephone Network.*

UL 1950-1997, *Information Technology Equipment Including Electrical Business Equipment* (revision of ANSI/UL 1950-1994).

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F

PQDIF—POWER QUALITY DATA INTERCHANGE FORMAT

Power quality measuring instruments may store and export captured data in different ways. The format of the data may also vary from instrument to instrument. To facilitate to use of data from these instruments, the Institute of Electronics and Electrical Engineers (IEEE) drafted a recommended practice for standardizing the transfer of power quality data. IEEE P1159.3, *Recommended Practice for the Transfer of Power Quality Data,* was in its fourth draft as of July 2000.

The new recommended practice specifies a Power Quality Data Interchange Format, or PQDIF, which enables the interchange of data between various power quality instruments, computer platforms, and software. Data in this format is compressed and structured in a way similar to the Tagged Image File Format, or TIFF. The compression is “non-lossy,” which means that the file size is reduced without degrading the data in any way. The tags in such a data file include information about the equipment used to collect the data, how the data was collected (phase-to-phase, phase-to-neutral, and so on), the category of the collected electrical disturbance according to IEEE 1159, and information about the electrical disturbance itself, such as amplitude, time domain (waveform or RMS), and date-time of occurrence.

For more information about PQDIF, visit the site of the Standards Coordinating Committee 22 (Power Quality) of IEEE:

http://grouper.ieee.org/groups/1159/3/

G
OPEN DATABASE CONNECTIVITY

Open Database Connectivity, or ODBC, is a standard interface for access to most database management systems (DBMSs). An ODBC-compliant database is one that has an ODBC interface, typically an application programming interface based on Structured Query Language (SQL). With an ODBC interface, users can connect to a variety of data sources. The goal of ODBC is to make it possible to access any data from any application, regardless of which DBMS is handling the data. ODBC manages this by inserting a middle layer, called a database driver, between an application and the DBMS. The purpose of this layer is to translate queries sent by an application into commands that the DBMS understands. For this to work, both the application and the DBMS must be ODBC-compliant—that is, the application must be capable of issuing ODBC commands and the DBMS must be capable of responding to them.

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