OFFICIAL PROCEEDINGS
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POWER QUALITY 2000

Presented at

POWERSYSTEMS WORLD® 2000
CONFERENCE & EXHIBIT

OCTOBER 3–5, 2000
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Integrating Permanent Power Quality Monitoring into a Critical Operations Center

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Abstract

This paper covers the important reasons for considering power quality when installing a building metering and monitoring system. At this site, hundreds of PC workstations, dozens of servers as well as a variety of banking and e-commerce business tools are installed as part of a redundant corporate operations center. The subject system is comprised of a 17 point metering network utilizing meters from Power Measurement Ltd. Software consists of the PML Pegasys package running under Windows NT4. The author describes why these products were utilized, how they are connected and what should be considered when integrating the components with an existing building's operations.

The customization of the system is described; detailing the requirements for determining power quality alarm notification to the operators. Reporting extensions utilizing standard software components are described and critiqued. These components can be very useful to the operators, however the metrics must be carefully evaluated and analyzed. One such metric -- the ITIC curve -- better known as the CBEMA curve, is examined and found to be of little significance for building service entrance analysis.

Some usage data from the site is presented and management issues after a full year of operation are presented for consideration. The reliability and accuracy of the system are highlighted with some anecdotal monitoring incidents obtained from the first year of monitoring. Internet based extensions for data presentation are also discussed briefly.

The Need

The field of power quality diagnostics and monitoring has matured dramatically in the past 20 years. The most fundamental transition has occurred in the way power quality is perceived in commercial facilities. Where once facility managers and technical personnel viewed power quality in a reactive fashion, new lower-cost monitoring systems can integrate standard electrical energy monitoring information with high-speed power quality data capture to provide proactive electrical system information.

Proactive, or more correctly; predictive power quality monitoring, is still in its infancy in terms of the software tools available to alert electrical system personnel. These tools and systems are being built in response to those in data intensive environments who require real-time power system information. The introduction, concentration and networking of small computer systems in commercial facilities since the early 1980s requires increased awareness of the electrical system resource. These needs have been amply demonstrated in many other papers presented both at this forum and other technical conferences. The data intensive environments of today feature concentrations of high-speed network workstations and clusters of "server farms". The rapidity of acquisition and deployment of these systems along with the expectation of high mobility and near 100% up-time often catches facility managers off-guard. From an electrical power standpoint one way to increase system up-time is to monitor electrical system parameters, leading to preventative actions that will avert equipment failure. These systems have only become "ready for prime time" in the past 4 to 5 years.

Site Description

The site in question is located in a multi-story office tower. The top four floors of the building have been designated as a "Business Recovery Center"(BRC) by one of Canada's largest financial institutions. The function of the center is to provide backup, mirror or support services for any of the company's business units. If a natural or operational disaster occurred in credit card transaction processing, currency trading, stock transactions or automated banking many of the functions could be temporarily routed to this center. As a result, the BRC contains a significant concentration of computing resources that need to be available at any time. In addition, staffing at the center could swell from 10 to 500 people in the matter of a few days. Workstation computing requirements are based on the actual working systems used by line personnel. Theoretically, a trader could move from their normal workstation to the BRC workstation and provide identical service.

Disaster and recovery planning must allow for unforeseen events. Even the best disaster planner will realize that some events contain the seeds for others; some problems are cascading in nature and this requires adaptability on the part of the recovery center. At this location, electrical capacity has been designed to allow for increased loading from extra workstations and servers that may be brought to the site subsequent to the on-set of a recovery situation and added to the existing complement of business equipment. This could result in system over-loading at some points in the distribution network. In the modern context of loading, harmonic currents need special attention, thus a real time monitoring system was requested to provide harmonic and true loading of the center's distribution grid.

As was pointed out to the BRC personnel and engineering staff; for only a small additional cost a total power quality monitoring system could be installed that would provide building envelope information along with distribution point data within the envelope. The BRC utilizes a 600 V base building distribution system.[1] BRC business equipment transformers are fed from one of two bus risers, while mechanical equipment is fed from a separate 600 V bus duct. In the event of a total loss of utility power these bus ducts can be fed by two diesel generators that have an extended operating capability.

Site Considerations and Requirements

The following elements were critical in developing a workable electric monitoring system for this site:

Staff Technical Expertise

While there are many experienced computer and networking personnel at site, they are not involved with the day to management of the building. In addition, building managers and base-building technicians – adept at dealing with the usual building control systems (ie: alarms, HVAC, fire etc.) – are not electricity monitoring experts. There exist therefore, a gap between the two groups both in terms of expertise and responsibility for the electricity resource. Realizing this dilemma, the building superintendent sought a system that was easy to operate while providing timely alarms and monthly reports.

Building Operations

Movement of loads by BRC computer staff are not always coordinated with building managers; ie: they are "tenants" and the building managers provide building services. It is possible that due to business process requirements concentration of loads may develop in particular operational areas of the building without regard to the harmonic loading requirements of the source transformer.

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[1] 600 VAC, 3 phase, 60 Hz distribution systems are standard throughout most commercial and industrial buildings in Canada.

Integrating With Other Building Monitoring Components

The system had to be capable of interfacing with the existing building management system. Data from system had to be portable to allow interchange between departments and corporate programs.

The Monitoring System

System Selection Criteria

The following requirements were developed both from BRC requests and expert input from the various stakeholders:

- Each dry-type transformer in the BRC was to be monitored
  Reason: To provide current and harmonic loading, current and voltage distortion, voltage unbalance, neutral current readings in real-time.
- A low cost per point for transformer monitors
- Reduced form factor required because of retrofit space requirements
- Power quality meters to provide transient, sag/swell and waveform deviation graphs and statistics
- Power quality thresholds must be programmable and accessible
- Reporting of power quality data and energy data must be a "low click", easily reproducible exercise requiring little training
- Energy monitoring must provide an aggregated table of consumption criteria with graphs on a monthly basis
- All meters must be fully networked utilizing open standards networking architectures and protocols
- Software must be Windows NT 4 compatible
- All data must be ODBC compliant for export/query purposes

The Selected System

The system of meters chosen to perform the monitoring was comprised of:

- 15 PML 7300 Meters on each of 14 dry-type distribution transformers and one on the BRC mechanical bus
- 2 PML 7700 Meters on each of the BRC business equipment busses
- All meters were interconnected by RS-485 multi-drop network; one 7700 at each end
- Each 7700 acts as a gateway from the RS485 to Ethernet that leads to the host computer (one is the active gateway, one is a hot standby)
- Host computer is a Windows NT4 server running PML Pegasys power management software

Configuring and Installing

The system is connected as shown in Figure 1. The host server runs 4 basic software modules or servers. These are the communications server, log server, virtual ION processor and the

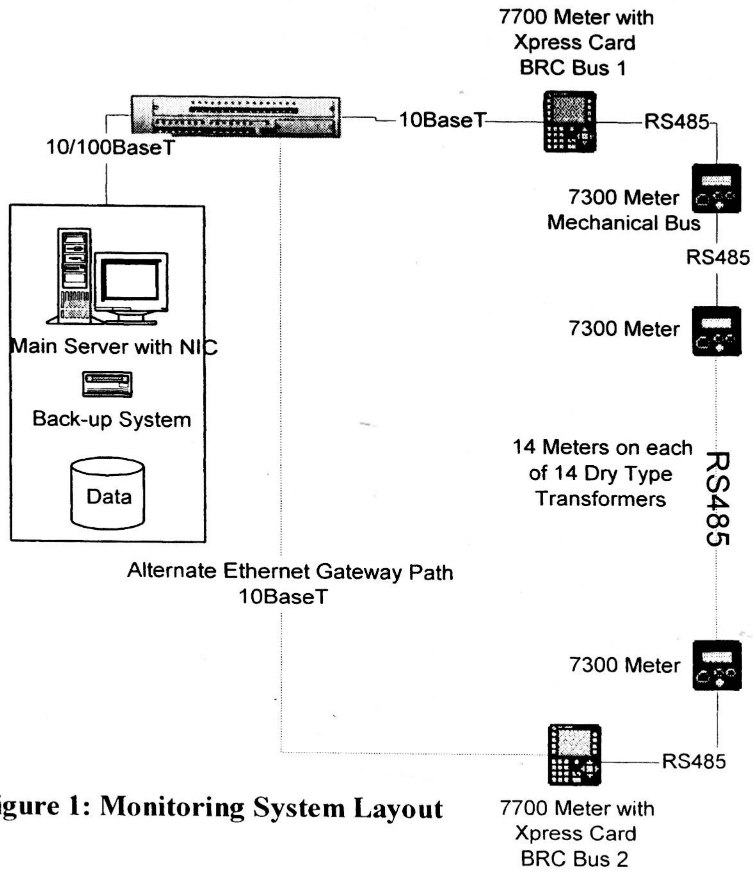

Figure 1: Monitoring System Layout

display/analysis component. Data is logged to a Structured Query Language (SQL) database; a license for Sybase SQL Anywhere is included with the Pegasys Software.

Database Tracking for Quality Control and Commissioning

The system requires the advance collection of electrical distribution information and metering data. This is easily tracked in a basic database for later project and operator access. The basic items collected, noted by field name are in Table 1. Also maintained in this database are a series of checklists for project quality control. These include items like register initialization for nominal voltage, CT Ratios and communications parameters; as well as hardware setup items like per point cable termination acceptance and parts installation. Use of this type of checking enables the network to be brought up in a very rapid manner. For example, at this site the network did not operate beyond the 7700 gateways when first fired up. A scan of the checklist showed that RS485 terminating resistors had not been installed on the ends of the RS485 network. Installation of these resistors led to an immediate initiation of communications and the network was ready for commissioning.

Table 1: Field Names of Items Tracked for Installation and Commissioning

ID
Generic_Name
Source
Location
Primary_Feeder
Secondary_Feeder
Amps_Per_Phase
Meter_Type
Sec_Voltage
Transformer_Size
Other_Data
CT_Ratio
Meter_SerialNo
Unit_ID
RS485_Speed
Meter_DeviceName

Not a "Plug and Play" Exercise

There are two basic components to meter installation; hardware installation and system integration. The clear network orientation of the metering system requires a mix of computer networking skills along with electrical power system knowledge. This is a scarce combination of skills and is a key element in determining the ease with which a metering installation will proceed.

Key points to note from the installation of hardware are as follows:

- The metering CT ratios at each point must be cross-checked by the electrician
- The electrician must install the correct serial number of meter at the designated point. Serial numbers are a fundamental component of establishing the network communications scheme through equipment ID's.

Use of Networking Standards

Network set-up is aided by the use of a rational ID scheme and the use of standard TCP/IP network protocols. The use of IP addressing allows for routing in more advanced networking environments and means that the meter can be hooked directly to a Virtual Private Network on the Internet. The non-proprietary networking scheme also means that standard networking cables, hubs and switches can be employed. It also implies the use of alternative physical media like fiber optic cables if these are desired.

Customizing the System

The basic metering screens and power quality screens that PML ships with Pegasys were adequate for BRC staff look-ups but the central operator screen was built from scratch. The basic operating screen shows each of the 17 meters arranged in a stylized one-line diagram by floor and by load (ie: the designated transformer or bus they are monitoring). Each meter indicates on the screen at all times:

- the highest present phase current
- the V_{thd},
- the present KVA load at the monitoring point and its acceptable maximum

K-13 rated transformers, where they are installed, can carry 100% of the design KVA, while each of the non-K rated transformers in the BRC have been de-rated using the simple CBEMA de-rate calculation (where the de-rated capacity of the transformer if the majority of the loads are single phase switchmode power supplies is the ratio of the average RMS phase currents to the average peak phase currents). If the monitoring point reaches 80% of either of these maximums then the on-screen meter icon for that location turns yellow indicating increased loading. Monitoring points turn red when any of the screen parameters exceeds the rated maximum for that point.

PML's software technology is dubbed the "ION" system. ION utilizes a distributed processing model that can be confusing for a new user. Each meter has processing functionality that allows for the calculation of certain electrical monitoring parameters. For instance, a meter may have the ability to capture and display individual odd and even harmonics and then totalize these values to provide summary harmonic distortion data. Other meters may have the ability to capture these individual harmonics but not to prepare summarized totals. In cases like this the data from a meter can be further processed by another ION module either on a more capable meter or in a virtual ION processor running at the host server. The system invites a sharing of data and processing across the network that can increase the efficiency of data presentation, but that may also slow down network operation and lead to data clutter. ION processing decisions must be well designed to overcome network latency and the trend to providing too much information to an operator. Some ION/Pegasys data systems viewed by this author have poor presentation and usage models; the designers have succumbed to the notion that being able to do something means that it should be done.

Reporting: Data to Information

While the on-screen operator interface is the key component of real-time interaction with BRC staff, it is the ad hoc reporting element that provides the BRC with data about energy usage and power quality. Reports are built utilizing a PML written custom software component that presents a check-list of SQL queries from the database. This component then passes the data from the queries to a Visual Basic for Applications Macro that runs in Microsoft Excel. This is an open system that allows for some level of customization, however an excellent knowledge of both the database structure and of Visual Basic are required. The BRC utilizes an energy report that aggregates power consumption from each of the 2 business equipment busses. This information is used for intra-company energy billing and replaces a monthly manual meter reading exercise that took half a day.

Building envelope power quality is summarized in a report that captures sag/swell, transient and waveform data from each of the data logs of the 7700 meters. This information represents instantaneous incidents regarding phenomenon like load switching or utility feeder faults. Steady state harmonic and loading information is available through the operator screens. While the power quality reports provided by the PML technology have been helpful, the basic metric for determining incident severity is flawed, since it utilizes the 1996 ITIC curve; better known as the CBEMA curve. The CBEMA curve has become a tonic for numerous power quality event characterizations. As has been described elsewhere[2], the CBEMA curve is a poor predictor of equipment upset since its thresholds are arbitrary, universal and ignorant of current surge characteristics in a load. The curve definition can be replaced by alternative envelopes but this process is not easily carried out with the PML software.

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[2] Gibson, Brad. Five Things to Forget about Power Quality. Presented to the 1999 Electricity Forum on Power Quality and Harmonics, Toronto. Also available on the www.openpowerquality.com web site.
Note too, that one of the developers of the original CBEMA curve, Alex McEachern, has referred publicly to this curve as the "BOGSAT" Curve ("Bunch of Guys Sitting Around Talking"). As he related in his talk to the attendees at the 2000 Electricity Forum on Power Quality and Harmonics in Toronto, he noted that the curve was never developed to be a comprehensive guideline for all types of distribution systems and electrical loads.

A better metric for report generation would be a query set based on the definitions for power quality outlined in IEEE Std 1159. This would allow one to analyze the data in distinct subsets from shortest duration to longest duration and by class of disturbance. The 7700 meter samples at 7680 Hz or 128 samples per 60 Hz cycle. This allows transient detection to no less than 260 μs in duration, but the meter can actually over-sample during high speed trigger to allow resolution down to 130 μs. The practical meaning of this is that the unit has a capability to only monitor transients in parts of Categories 1.1.2 and 1.2.2 and in Categories 1.1.3 and 1.2.1 and as defined by IEEE Std. 1159-1995. A reporting tool that summarized the waveform deviations in terms of Transients, Short Duration Variations and Long Duration Variations and then allowed screening by threshold voltages or currents would be far more helpful in terms of rapidly finding events of interest to the power quality engineer. At the present time we have constructed a number of queries utilizing SQL and run these against the database on an ad hoc basis to generate custom power quality reporting data. For instance a simple query of data from March to December 1999 revealed that 128 separate transient events were recorded on BRC Bus 1. Many of these transients were oscillatory in nature and therefore registered multiple transient hits in the 7700 detection circuitry. Filtering these using the timestamp and duration data it was revealed that the largest transient impacting the bus was 304 V on August 24 1999, during a lightning storm. The maximum duration of the transients was of 15.6 ms and the minimum detected was 130 μs, the limit of the device.

The Monitoring System in Use

After over one year in operation at the site, data has been collected that exceeds an 80 MB file size. This is a small, manageable database by modern standards and indicates there are many years of growth available for the data file given the multi-gigabyte hard drive available. Back-up functionality is performed via a daily tape storage routine, while one annual database tuning and off-site capture has been carried out. An additional meter was added to the system in the summer of 2000 in order to accommodate additional mechanical load. The longer term requirements for this system are a more functional power quality reporting tool that will integrate with a messaging host off-site. The host will be enabled to determine the severity of a power quality disturbance from within the parameters of the Std. 1195 categories and past historical data, it will then notify key personnel through a combination of email, paging or PCS messaging depending on severity.

Notes from the Field...

The high accuracy of the meters was put to the test during a Y2K drill in October of 1999. At that time every load in the facility was powered up in order to stress the distribution system. Bus voltage drop was found to be the range of 5% on one riser; checks with hand-held meters revealed voltage drops of only 3%. However a survey of the meter specifications and technology for each of the meter types showed that the 2% difference could be accounted for and that the 7700 meters were delivering the more accurate measurement. One of the key decisions that has been made at this site on the basis of data viewed from the power quality component of the meters has been with regard to Uninterruptible Power Supplies (UPS). Two issues have arisen that have lead to great cost savings. The first of these concerned the need for a large on-site UPS system which was advocated by some. While servers require the ride-through of the UPS, management has determined that the impact of transfer switching, while annoying for some is acceptable and that most workstations do not need the protection of 0.5 – 2 s of ride through afforded by the UPS. Data from monthly generator tests revealed however that transfer switch wave shape anomalies were impacting the servers leading to some network anomalies. The UPS's in use at the site were of a hybrid type that allowed transient and switching noise to pass through the UPS. UPS's have also been subject to excessive battery wear. Based on waveform data captured during testing a decision was made to switch to an on-line UPS design and to institute a networked UPS management system. The UPS's are being introduced to the site for all servers and key workstation functions.