The Need for Speed

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ABSTRACT
Whereas the old adage is that, "speed kills", the opposite is becoming more apparent in today's rapidly changing global economy. Information is power, but its power is diminished if it doesn't arrive at the location(s) where it is needed when it is needed. This changing paradigm applies to power quality information, for both suppliers and consumers of electricity. Though deregulation may be capturing the news headlines, it is the underlying need to increase profitability by maximizing asset utilization and productivity on both sides of the electric meter that is driving the advances in power quality instrumentation and analysis software.

CHANGING INFORMATION PARADIGMS

Though it may have become a cliche already, the only thing that is constant today is change. The virtues of such could be debated, but the facts remain that the rate of technology-induced changes continues to escalate and have global economic impacts. One significant area of change has been in the area of information. It has been said that a child today in elementary school is exposed to more information in a day than a person in the middle ages would have encountered in a lifetime. How well the children are able to absorb and utilize all of this information is a different story.

Significant contributors to this process have been the information technology tools, such as personal computers and networks. "As the United States once moved from the agrarian age to industrialism, Wired magazine wrote recently, today it is involved in a new revolution -- one that is rooted in networked information: How to create it, move it, and manage it." [1] Computers and the software used in them help create the information that networks move about.

Much of the recent gains in the productivity of US workers have been attributed to the increased use of information technology tools. However, for the most part, the human still manages and analyzes the data and information. It is usually the human analyst who decides what to look for, where to look, when information is no longer needed and can be purged, and so on. "Providing information from (their) data remains a challenge, despite massive amounts of data and computer power. The key source in the process remains the analyst's time." [2] In this fast paced global economy, the time that it takes to do such has a negative impact on productivity, hence, on the profitability of a company.

"In a network economy, wealth comes not from perfecting the known, but from imperfectly seizing the unknown... The key attributes for identifying and cultivating the unknown are agility and speed." [1] Fast access to the information and answers derived from large amounts of data is a requirement in many industries. This has lead to a new set of tools with a variety of names, such as data mining, expert systems, and adaptive neuro-fuzzy systems. Several obstacles can get in the way of successful use of these tools. One problem is with extracting the knowledge from the expert and converting it into the programmable format that provides the proper inferences and conclusions. A wrong answer is often more detrimental than no answer. Trying to extract the information from incompatible databases and to move it across incompatible proprietary communication protocols can make it impossible.

CHANGING POWER QUALITY FIELD

Whether a consumer or provider of electricity, one can hardly escape the changes going on in the power industry, especially with regards to power quality. "A major factor contributing to the importance of the quality of power is the deregulation of the power industry. Customers will demand higher levels of power quality to ensure the proper and continued operation of sensitive equipment and processes." [3] Utilities that are burdened with high kilowatt hour costs will need to differentiate themselves by their services, including the quality of the power provided.

"What gets measured gets done," or "nothing can be managed until it is measured." If the proper data hasn't been gathered, extracting the information and answers needed from that data isn't feasible. Gathering the complete set of data that accurately represents an entire system can be an enormous data management task. This system-wide approach has been a part of the driving force in the growth of the power quality industry, particularly the recent increase in the number of permanently installed power quality monitoring systems. It is also seen in the substation automation movement. These changes are not without their drawbacks. "Utilities have struggled with the issue of efficiently processing the massive amounts of operating data generated from these devices (continuous monitors in substation). In other words, once you outfit your substation, you better have a system in place to properly manage and filter this newfound wealth of information or you will soon find yourself with a case of 'information overload.' " [4]

OVERCOMING THE PITFALLS

There are several areas of development that are underway to help minimize the pitfalls and maximize the gains. These will first be examined in the general sense, and then related to specific examples in the power quality industry.

STANDARDS

The development and use of standards hold one of the keys to overcoming the pitfalls. Often, proprietary systems cannot share data and information. "As a result of this lack of connectivity, manufacturers' options for creating automation solutions are significantly reduced, important data can be left locked in proprietary systems, and information cannot be easily distributed to those who need it to make important decisions." [5] Without standards, the user is seriously hampered when trying to develop a technically and financially efficient system. The choices become limited. "An 'open' system would be used where devices could be used independently or as part of a larger system and selected on the basis of functionality and performance rather than on compatibility with communication protocols or specific vendor architecture." [6]

Additional work in the area of power quality standards is being undertaken in the IEEE and IEC. Two of the existing power quality standards with the largest sphere of influence are IEEE 1159-1995 Recommended Practice for Power Quality Monitoring and the CENELEC EN50160 Voltage Characteristics of Electric Supply by Distribution Systems. There are a number of other standards in other countries that are similar to EN50160, such as the South African NRS 048:1996 Electricity Transmission and Distribution - Quality of Supply Standard, and the New Zealand NS5.1 Network Connection Requirements.

Three taskforces within the IEEE 1159 committee are working on providing standards for data acquisition, data characterization (particularly with sags), and the format for the transfer data from sources (such as power quality monitors) to sinks (such as analysis software programs). Just the task of providing a complete set of characteristics of sags is quite substantial.

Standards for communication are also being developed and refined. UCA-2 (Utility Communication Architecture) is an IEEE subcommittee that developed a protocol for communication of different devices within a substation. It is based on an EPRI sponsored project to adapt the MMS (Manufacturing Messaging System) and includes the addition of PQ Objects. There is a set of commands and responses required for compatible devices to "play together," just as different computers with different browsers can communicate with each other over the Internet. "When UCA-compliant devices are available, it will be able to communicate in MMS over Ethernet" [7]

TOOLS TO ACQUIRE DATA, COMMUNICATE, EXTRACT ANSWERS, AND FOR VISUALIZATION

Communication - The Internet

One of the fastest growing technology-based tools is the use of the Internet for near-instantaneous global visual communication. Though the Internet has been around for several decades, its use in the early days was primarily for academic and military purposes. The rapid growth in the business community is reflected in the graph of spending in Figure 1.

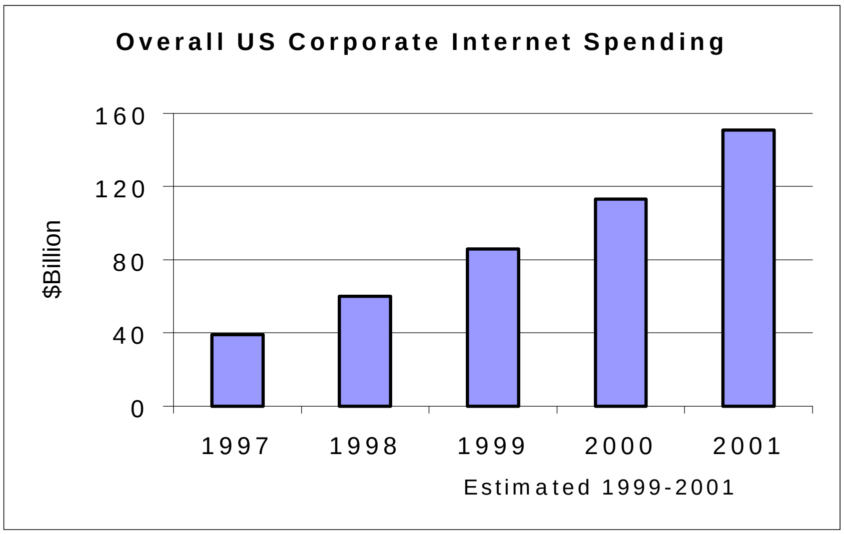

Figure 1. Overall Corporate Internet Spending [8]

The Internet can provide users located in virtually any part of the world with the right communication tools to have the capability to search for and display information from virtually any other part of the world. This can also be seen in the increase of corporate-wide monitoring of power quality across geographically distant facilities. Monitoring of lightning data provides early warning for data processing managers to switch computer rooms over to alternate power supplies before problems occur. PQ coordinators and customer service representatives of electric utilities can be proactive with their customers by sharing data and providing answers as events occur, rather than waiting for a customer's complaint. Facility managers in multi-story office buildings can have instant access to performance information about their systems without having to go back to their offices.

Analysis Tools -- Getting Answers

Pressures to increase profits have driven businesses to "get more with less", including less people and in less time. This usually implies productivity increases through reduced personnel or adding more tasks to existing people. Coupled with attrition of key knowledgeable personnel through early retirement buy-outs, workers must work more efficiently, not just harder. Whereas computers have been traditionally used for repetitive processing of data (such as payroll, accounting, manufacturing scheduling, etc), computer programs are now being used to extract answers from massive amounts of "warehoused" data through use of artificial intelligence and data mining tools. These can provide new market trends, cost reduction opportunities, root cause analysis, and other analytical and insightful answers.

One of the keys to such tools is capturing the knowledge of the people who do such work. Much of the core knowledge of companies is not in electronic form. A recent survey conducted by the Boston consultancy KPMB Peat Marwick LLP on how knowledge is stored found that for methods and processes: 8% in somebody's head; 27% on paper; 26% electronic form but not to all; 31% electronically to all, and 8% unknown. When asked what happens "when key employees leave before their knowledge is tapped, 43 percent said a relationship with a key client or supplier was damage, half said knowledge of best practices was lost, and more than 10 percent said their enterprises lost significant income. That's just not acceptable in today's business climate." [9] Capturing this knowledge into electronic form is not a trivial task. "Answering questions involves imperfect data, assumptions, and knowledge of what is important; an element that is not easy to identify/quantitfy." [10]

There are a variety of useful tools to help generate answers:

- Case-based reasoning - provide a means to find records in a relational database similar to a specified record(s).
- Data Visualization - tools to quickly and easily view graphical displays of information from different perspectives.
- Fuzzy Query and Analysis - see results "close" to a stated criterion, allowing user to vary the 'closeness" of each criteria (non-crisp logic).
- Knowledge discovery - identify significant relationships that exist among variables. Use other tools to understand the nature of the relationships.
- Neural Networks - to discover and predict relationships in data. Models can be 'trained' to discover relationships that cannot be described with linear algebra. [11]

Visualization - Seeing Clearly and Quickly

Sharing this information and answers as well as the data among a diverse group people, both geographically and technically, requires a common user interface tool that is simple and intuitive to use. The web browser is just such a tool. "The computer browser may be the best tool ever given away." [12] Though legal issues may change such, browsers are readily available now as either part of the standard operating system software provided on most computers, or is downloadable free or for a nominal charge off the Internet.

The use of a limited set of recognizable buttons and hyperlinks that work the same way on different computers with different browsers is finally coming close to being truly user friendly. "The goal: making sophisticated software as readily available as flipping a light switch....Users can gather and update information from their applications via simple Web browsers. That means even those who have recoiled from complicated software can feel comfortable and be trained quickly." [13]. Vendors of equipment are making more functionality and features accessible through web browsers, and employees are able to easily and quickly post other information that needs to be shared, making intra- and inter-company communication much easier, efficient, and quicker.

PQ INDUSTRY - PARALLELS

Power quality monitoring is an industry that fits very well into the aforementioned description of needs and solutions. Power quality monitoring systems produce vast amounts of data that needs to be turned into information and answers by a proportionally smaller group of experts. "The proper diagnosis of power quality problems requires a high level of engineering expertise, and the required expert knowledge is not in any one area, but is rather in many areas of power knowledge. Despite the existence of numerous capabilities for recording PQ waveforms, there is a great shortage of qualified power systems engineers who can analyze the data and diagnose/solve the problems." [3] While some manufacturers of power quality monitors have been achieving some of those needs through trending, event time lines, and activity plots, the inclusion of web-based products that provide answers, not just data, on a system-wide, globally accessible basis is now gaining significant momentum.

The largest PQ monitoring project in the United States at the distribution substation level was the EPRI Distribution Power Quality, or DPQ, project.
The DPQ project "presents the most thorough and recently performed study describing existing power quality levels on utility distribution systems in the United States." [14] 50 gigabytes of power quality data from 300 sites from 24 utilities through the US was collected from June 1993 to September 1995. This data included steady state and disturbances recorded on three points of a distribution feeder: substation, mid-point, end. There were over 6 million steady-state measurements alone over 27 months. Processing this data to determine baseline levels of the various power quality phenomena was a massive task.

Baseline information can help determine if the quality of the power is getting better or worse, what some of the effects of deregulation on it are, and where solutions applied actually improve or make the situation worse. Such systems are not limited to power quality applications. Energy reduction strategies can be employed on the same data by analyzing consumption, power factor, and demand at service entrance, distribution system and individual loads. The user can also check for efficiency changes, time of use, peak demands, etc. to help control costs.

The complexity of the data is apparent in the multitude of characteristics that need to be considered depending on the type of phenomena, including (but not limited to): loss of energy, peak magnitude, primary frequency, time of occurance, rate of rise, rate of decay, RMS magnitude, duration, phase angle between voltage and current, phase shift, rate of change of phase shift, missing voltage, point-on-wave of initiation, point on wave of recovery, distortion level, harmonic and interharmonic spectrum, unbalance (three phase symmetry), andfrequency of occurance, [15]

There is clearly a need to classify events, diagnosis possible causes, and recommend possible solutions. "Large amounts of data, fuzziness of that data, and endless variations of system configuration are all factors contributing to the complexity of power quality analysis and diagnosis and the applicability of AI techniques...AI techniques suit PQ applications for the following reasons:

- Scarceness of PQ experts in the electric power industry
- Knowledge about PQ is dispersed and fragmented
- Endless number of system configurations, making each PQ problem unique in its characteristics and diagnosis
- Large domain of PQ in the variety of equipment, standards, and methodologies
- Distributed PQ monitoring systems that gather a huge amount of data, which is infeasible for a human expert to handle.
- Large amount of data that requires not only intelligent analysis but also intelligent data management
- Serious imprecision of data, making conventional programs fail to identify any PQ problem
- Lack of synchronization between monitors, which adds to the dispersion of the data.
- With the lack of PQ knowledge resources, the explanation facility of an ES becomes an invaluable asset.
- PQ diagnosis requires expertise in a wide variety of power topics. AI tools combine multiple knowledge domains as well." [3]

Besides being used to establish normal operating characteristics, expert systems can learn equipment behavior through on-line experiences and teach themselves to recognize deviations from normal operating characteristics. As long as the process is running normally and there is no degradation observed, then the information overload problem can be reined in. "The expert system would eliminate the flood of data by only alerting utility personnel to potential problems (i.e. on an exception basis). If no change is detect by the system, no message is generated." [4]

The use of standard Internet communication protocols, such as TCP/IP, along with HTML-based visualization of data and information for post-processed data is used in several power quality monitoring systems.

- The Dranetz-BMI Signature System includes an embedded web-server so that data and information is instantly available to multiple users simultaneously without custom software loaded onto a PC, just like web sites on the Internet from devices that communicate via UCA-2. It also provides answers, such as the identification of transients caused by power factor capacitor switching and the direction (upstream or downstream) from the monitoring point. See Figures 2-4.

- Electrotek Concepts hosts several Internet-based power quality sites for customers through www.pqmonitoring.com, including sites in Fairfax County, Virginia and the Glassgow Electric Plant Board in Scotland.

- The University of Wollongong has a site at their Educational Delivery Technologies Laboratory to demonstrate automatic power quality Monitoring of a Remote Load.

- Idaho Power monitors their circuit breakers, transformers, batteries, chargers and bushings using an expert system to look for trends that fall outside operating parameters, which then alerts maintenance personnel before catastrophic failures occur.

- Dayton Power and Light uses a condition-based maintenance optimization program, which identifies the optimum time to perform maintenance, rather than spending money on periodic maintenance that may not be needed.

- EPRI has a Xvisor expert system for monitoring condition of power transformers.

- Baltimore Gas & Electric's SCIP system's application/database will also monitor and determine when maintenance is required on equipment (condition based maintenance) rather than performing interval-based maintenance. This change in maintenance planning will enhance reliability-centered maintenance techniques presently used for substation equipment. The data is available to planning, maintenance, customer reliability management, system protection engineering, and strategic accounts.

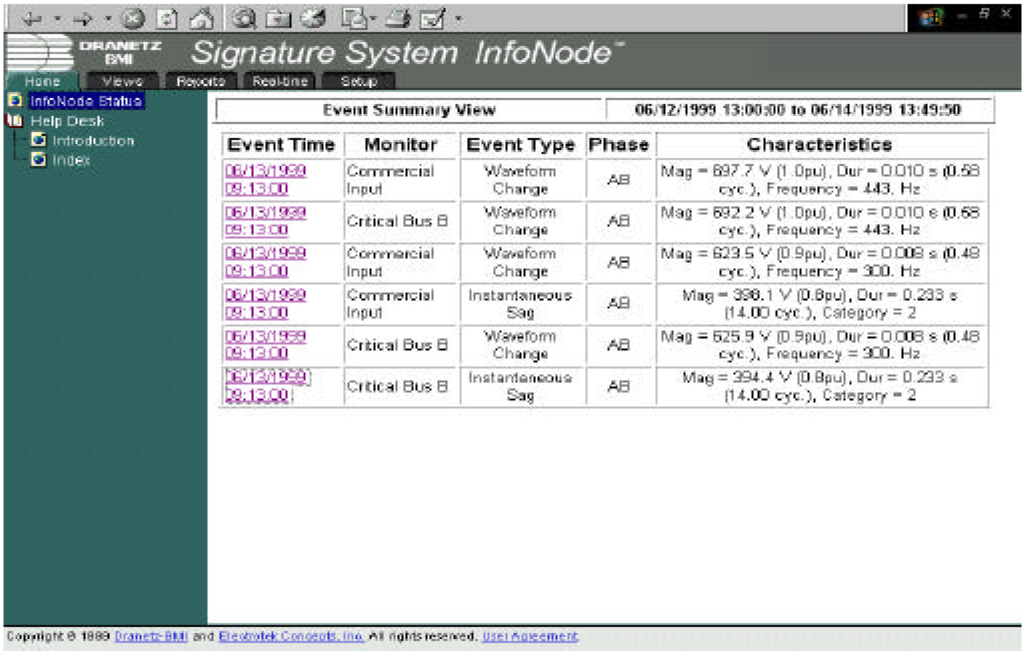

Figure 2. Event List of Disturbance.

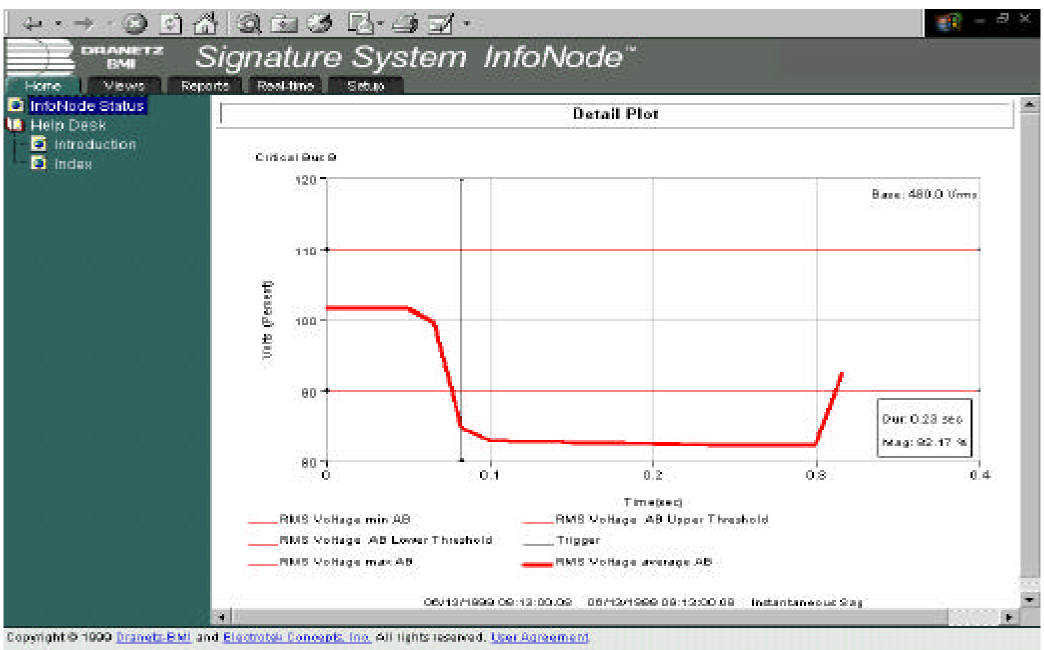

Figure 3. RMS Timeplot of Instantaneous Sag

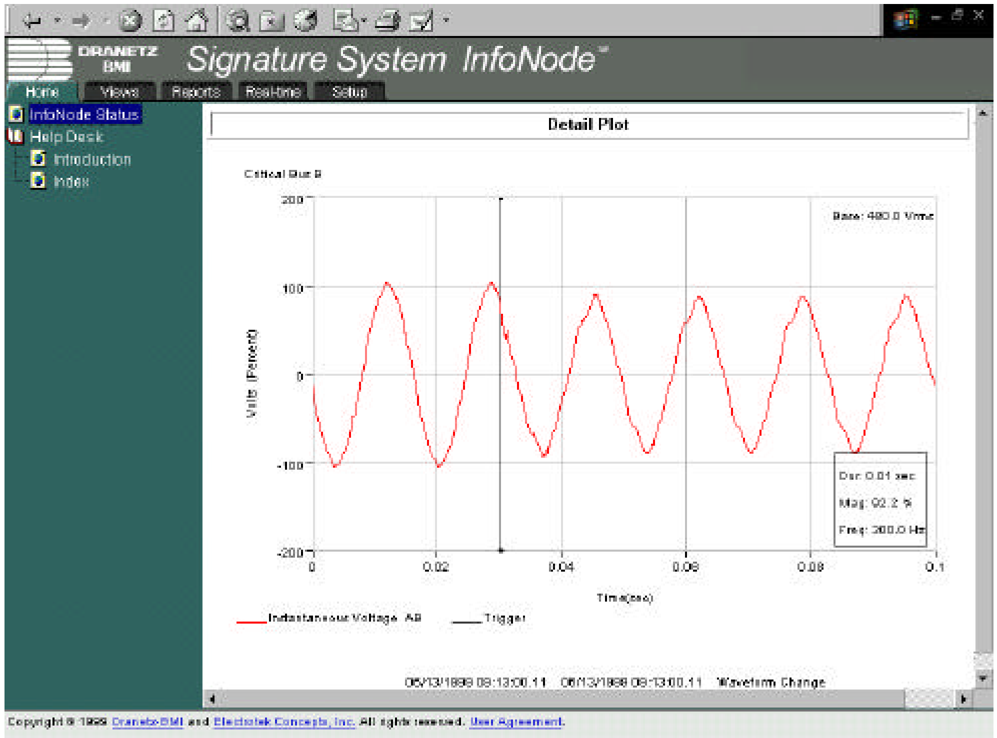

Figure 4. Waveform of Instantaneous Sag

CONCLUSION

Though there are those in the power quality field that may think of the problems that they face as unique, there is a great deal of commonality with the challenges faced in other industries, such as increased profit demands with decrease resources. Quick access to more information and answers out of vast amounts of both are requirements. Technology tools, such as standard protocols, Internet-based communication and visualization techniques, and artificial intelligence and data mining tools, make this possible. "Implementing an expert-based substation operations and maintenance system is no longer a matter of choice. If utilities are to survive in a competitive industry with lean staffing levels, these systems will be adopted. Utilities that aggressively pursue adopting this technology will benefit from a more efficient workforce, a more reliable system, and better service to the customer." [4]

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