An Internet Approach to Power System Monitoring And Control

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Abstract
The convergence of the Internet, PCs, client/server technology, and Internet-ready IEDs (Intelligent Electronic Devices) has allowed the creation of a new model for power system monitoring and control. With dedicated ASPs (Application Service Providers) offering the infrastructure for many customers with geographically diverse operations, the feasibility equation changes. Smaller sites that were previously unmonitored can now benefit from services previously available only for larger sites and organizations. This paper will review this Internet-based approach (ASP model) including the technology required for secure and continuous connection.

I. Introduction

Electric utilities, especially municipals and rural electric cooperatives, continually face the challenge of delivering reliable electric service at competitive rates to their customers. To remain competitive, utilities have to adopt new tools that redefine speed and agility, enhance productivity and enable collaboration. While traditional SCADA (Supervisory Control & Data Acquisition) systems are the main back-bone of today's electric utility system for remote monitoring and control, the Internet/Intranet provides an alternative *vehicle* for data communications and control for today's IEDs within the substation. The Internet is available 24/7 from anywhere (on site, home, office, on the road).

Most utilities are specifying and using the latest IEDs (protective relays, meters, RTUs, DFRs) throughout their distribution, transmission and generation system. Today's IEDs offer the capability of 10MBps or 100MBps Ethernet ports, which increase the bandwidth capability for information flow. IED manufacturers offer communication protocols over TCP/IP, such as Modbus RTU, DNP3.0 and UCA2.0. The ASP model for substation monitoring sees the supplier of the monitoring package taking responsibility of the IT issues, and hosting the service on the Internet based on a monthly service fee.

To successfully operate any enterprise, managers, engineers, operators, and maintenance personnel need timely & quick access to information. It is well accepted that computers and automation systems serve as excellent tools to this end. However, just as a machine operator does not need to know how to build a CNC Machine to machine a part, utility personnel do not need to know the inner workings of their automation system to make use of it. The ASP operates, maintains and upgrades the monitoring system leaving the utility to focus on their core competence, delivering power.

II. System Architecture

Internet-ready IEDs, such as protective relays, offer not only protection, but include extensive data recording, control logic and monitoring features. These IEDs will, and in some cases, have become the next generation RTU (Remote Terminal Unit). These IEDs can communicate via 10Mbps or 100Mps copper or fiber-optic Ethernet port(s) with IP, Subnet and Gateway addresses that are settable via the user. Installations exist where these IEDs are directly connected to the SCADA master via a high-speed Ethernet network.

The goal is to connect the IEDs at the substation or site to the Internet. Once they are resident on the Internet, they may be monitored by servers located anywhere on the Internet. These servers in turn log and classify data, generate alarms and format the information for viewing with a standard Internet browser. What this means is that the remote site may be viewed by anyone with Internet access and a login account.

There are 3 major components that create the system: the equipment at the substation, the ASP servers located on the Internet and, of course, the end user computers.

a. Substation Equipment and ISP Interfacing

The ASP Servers monitor digital and analog data from monitoring and control devices (these devices include protection relays, meters, RTUs, etc). The digital data may include electrical, process, security, and environmental alarms and status. The analog data may include metering of current, voltage, power, or any parameter with a transducer interface (temperature, level, pressure, flow, speed, counters, etc). The communication equipment required to connect the devices at the remote site to a local ISP (Internet Service Provider), is installed at the substation.

The following components are used by the ASP and packaged together in a weatherproof enclosure (see Figure 1):

- Internet-ready IED with CT inputs, VT inputs, contact inputs, contact outputs, or transducer inputs
- Multi-port Ethernet hub or switch
- Modem (Analog, DSL, Cable)
- Router (Firewall, VPN)
- Telephone line surge suppression
- DC-to-DC converter(s) to power Ethernet hub/switch, router and modem
- Un-interruptible power supply (necessary in AC control power applications)
- Serial-to-Ethernet converter(s)
- Heating or cooling arrangements (as required)

Figure 1
Typical Substation Equipment/ISP Interface

Serial-based IEDs exists at most substations or sites. Off-the-shelf serial-to-Ethernet converters allow utilities to create a "virtual" extension cord from the IED to a user's PC via an Ethernet network, likewise via the Internet. COM port re-director software is used to map a specific IP address to a given COM port. This enables the utility to access serial-based IEDs using the manufacturer's provided serial-based PC software. Figure 2 shows the possible connection.

Figure 2
Serial-to-Ethernet Connectivity

Once the monitoring and control devices are connected, the Internet connection to the ISP completes the system. The connection to the Internet Service Provider (ISP) can be a traditional phone line/modem, a DSL, cable or wireless connection. Isolation provides immunity of ground potential rise to damage connected equipment.

Figure 3 details the system architecture of the substation equipment, ASP servers, security, Internet and User for the ASP model.

b. ASP Servers

The Application Service Provider (ASP) hosts the monitoring software on servers that are accessible through the Internet. Servers, maintained and supported by the ASPs maintain secure connection with the above packaged equipment. Data gathered is accessible anywhere, anytime through the Internet. The server monitors all substations/sites 24 hours a day, 7 days a week.

III. Security

As an application that utilizes the Internet infrastructure, security of data and information is a valid concern. In addition to password authentication on the substation equipment, data from the substation

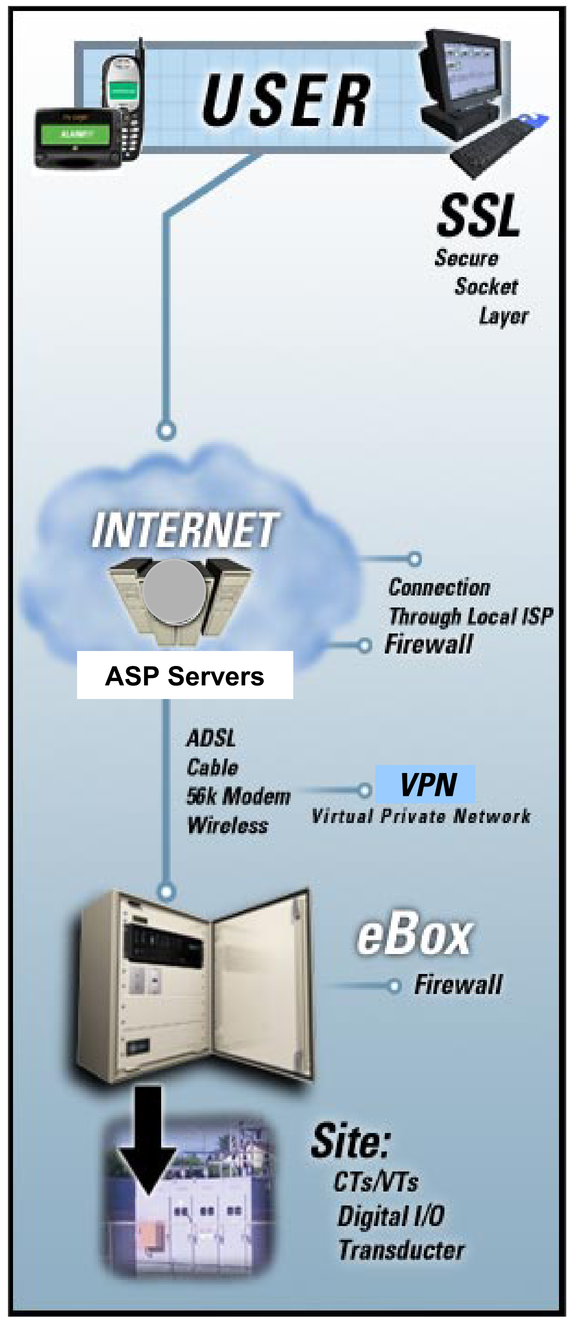

Figure 3
System Architecture – ASP Model

equipment to the ASP servers is protected within a Virtual Private Network (VPN). The VPN security appliance encrypts the data to create a “virtual tunnel” between the substation equipment and the ASP servers.

Firewall software is used and updated regularly by the ASP servers to prevent viruses and outside attacks on the data. This is similar to anti-virus software that is used for PCs and corporate networks.

Secure Socket Layer (SSL) encryption and authentication is used between the ASP servers and the user’s browser to ensure that the data is secure. SSL is used by the on-line banking industry to insure secure transfer of data & information. A hard token with a rolling password provides an extra measure of security for critical applications with control.

Figure 3 details the security measures taken within the system architecture.

IV. Available Services

The below services are available from the Application Service Provider. Collectively, these services provide many of the functions of an enterprise management system. Standard web-browser interface and configuration tools, such as Microsoft Internet Explorer, are used by this Internet-based approach. (See Figure 4).

a. Annunciator & Reporting

Many companies are looking for report by exception systems that provide problem notification. A system annunciator display provides status and alarm information. As status and alarm conditions change within the Internet-ready IEDs, the monitoring system can provided automated notification. The digital information is gathered and classified by the ASP server as alarm or alert. Alarms and alerts may be tied to a phone and e-mail notification system providing automated 24-hour monitoring capability. (see Figure 5) Upon notification of a situation, staff can log on to the ASP from any location throughout the world and drill down to the source of the problem or log into the specific IED and download an oscillography file or event file via the Internet. By providing specific information about the exact location and device type of alarm, operators can dispatch appropriate personnel to resolve the problem. Messages could be sent to multiple operators to ensure action is taken.

b. Automated Collection of Reports

Raw data can be collected and stored in the server, enabling the user to create customized reports. Such reports might include audits, operation counters, inspection and maintenance, or regulatory. The advent of the wireless Personal Digital Assistant (PDA) devices enables mobile data entry. Maintenance staff can enter an inspection or trouble report on site by simply logging on to the system via the Internet. This allows easy access to existing reports as well as providing real-time data for new reports.

c. IED Real-Time Metering

Access to real-time analog values of current, voltage, watts, vars, power factor, frequency etc. are displayed by the system. This data is transmitted from the Internet-ready IEDs by Modbus RTU or DNP3.0 protocol over TCP/IP.

d. One-Line Diagram Display

Using web-based configuration tools, simple to complex single-line diagrams can be configured to display breaker positions, switch positions, analog values, etc. Links are used to access further details on a secondary page(s). Links can be established to web or Ethernet cameras located in the substation. After notification of an event, the user could log into the system and use

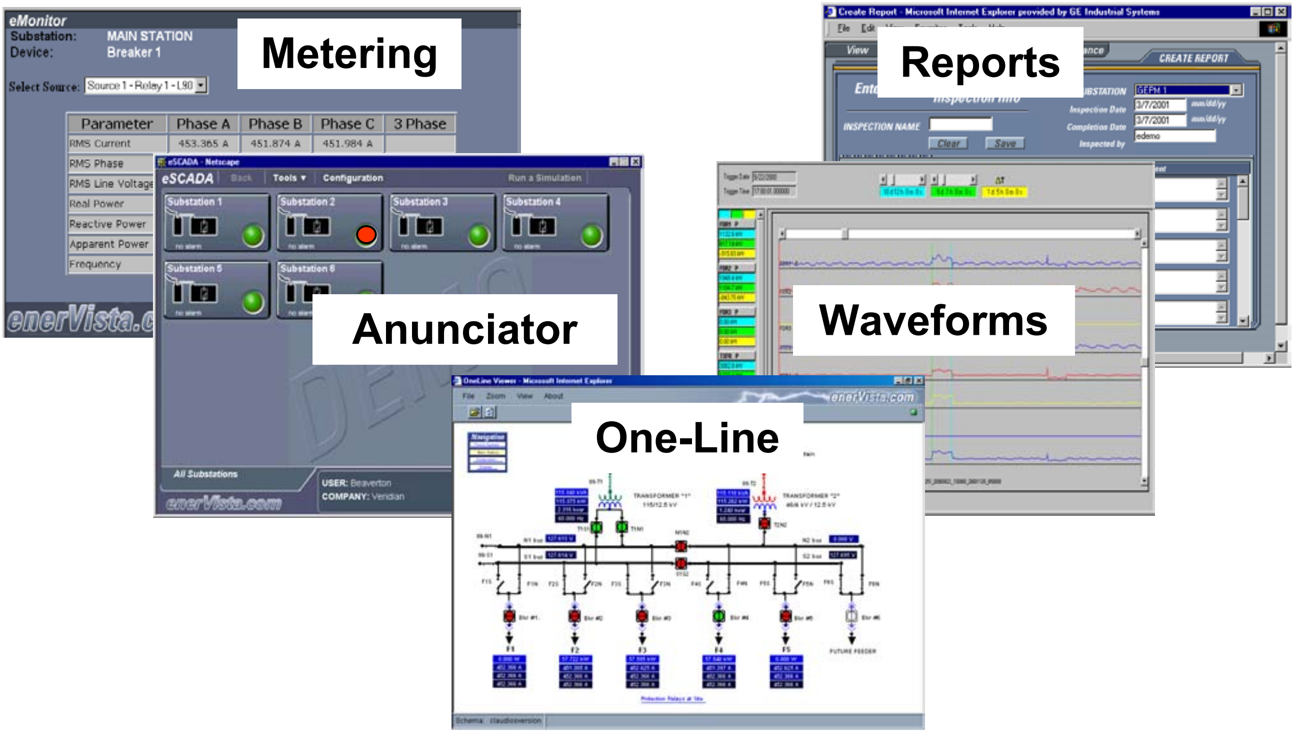

Figure 4
Available Services by ASP

the web camera to investigate the problem further.

e. Electronic Documentation Storage
Quick access to critical data anytime, anywhere enables the user to be more efficient. Server storage space can act as a repository of information that could include:

- Operating procedures
- Manufacturer's data and instruction manuals
- Connection diagrams of equipment
- Design drawings
- Breaker switching procedures
- IED setting files
- Troubleshooting guides
- Contact lists
- Web-site links
- Equipment serial numbers

Documents are best to be stored in Portable Document Format (PDF). Much of the data will be Public data, while each user's specific data is stored in a Private folder requiring password access for retrieval.

f. Control Capabilities
By directly communicating to the Internet-ready IED(s) at the site, control of output contacts or function blocking can be accomplished. Security is achieved through the Virtual Private Network and usage of the IED control password(s).

V. Comparison Between "Traditional" SCADA Systems

Traditional SCADA systems are typically a large undertaking requiring significant capital investment. The ASP model is a naturally scaleable service that does not require a minimum number of sites to become feasible. A SCADA system

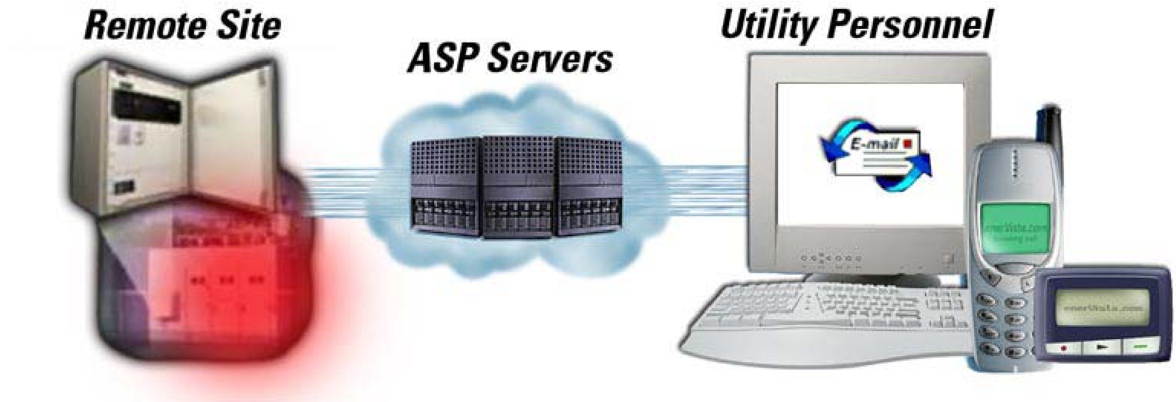

Figure 5
Automated Alarm Notification

requires a significant resource commitment in time, training, and IT. A remote site may be made visible in 4-6 weeks with an Internet-based system as compared to 6-24 months for SCADA. Within a half-day or less, a person could become very proficient with an Internet-based substation monitoring system. Training can be minimized when using such web-based tools. With servers maintained by the ASP on the Internet, IT resources required are minimal.

The Internet-based system offers multiple users access to site management information over secure Internet connections using a standard Web browser. SCADA systems traditionally allow limited access through dedicated channels via proprietary software.

Using alternative communications paths, with a virtual control room anywhere there is Internet access, the ASP model may also serve as a backup system for disaster recovery. For utilities with a SCADA system, the ASP model can make smaller sites visible where the SCADA value equation simply would not add up.

The ASP model allows utilities to fund the services from their O&M budget rather than a large capital expenditure of a SCADA system.

Greater bandwidth capability (as high as 1.5MBps) is achievable by the ASP model when using a DSL or cable connection. Data transfer is limited by the SCADA systems due to baud rates in the neighborhood of 1200 to 9600 baud.

VI. Industry Applications

Besides substation applications, this web-based monitoring & control system could be applied to other equipment & facilities, such as fuel cells, oil platforms, industrial facilities or dispersed generation.

This same model being used for monitoring substations via the Internet will likely find wide acceptance in the field of distributed generation. As utilities and end-users will invest in distributed generation technology as a means to enhance reliability and hedge against the cost of energy, cost effective control of generation (via the web) will be a critical component. Distributed generation, as with many other functions within a utility, can become part of the new Internet–based utility enterprise.

VII. Future Technology Trends

The model of monitoring substations via the Internet is a commercially available option today. The future promises to make the model even more attractive as technology evolves.

a. Connectivity

Digital cellular broadband connections are becoming available in urban areas. This simplifies connectivity and eliminates the need for GPR (ground potential rise) isolation. Compared to the slower analog cellular modems, service rates are more reasonable as billing is metered on data, not airtime. In addition to more bandwidth, satellite ISP services have all the benefits of digital cellular connections with the added bonus that they have blanket coverage throughout North America. As these services come online, the ASP, simplifying the model for the end-user, may offer them (Figure 6).

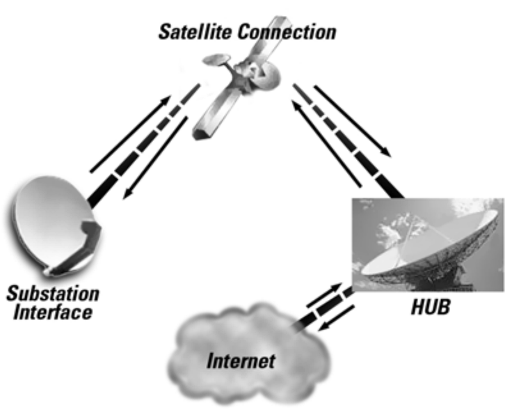

Figure 6
Future Satellite Connectivity

b. Portability

As tablet computers and PDAs (personal digital assistants) become more mature, the portability of an Internet-based monitoring system becomes even more compelling. It can give personnel access to all sites from anywhere at anytime. This is especially useful for field operations and troubleshooting.

VIII. Conclusions

Companies seek simple, quick, cost effective methods of obtaining data to various departments. Using the Internet infrastructure and today's Internet-ready IEDs, a new level of system accessibility is obtained. Not only is the substation monitoring automated; it is now available to *all* utility personnel who need it, when they need it. At the substation, in the control room, during meetings, while troubleshooting, while commissioning, or after an outage, information is as accessible as the Internet. The ASP model, made practical through the Internet, levels the playing field for small and large utilities alike. With overheads assumed by the ASP, investment and risk is low, while deployment is extremely fast. For some companies, the ASP model has enabled them to manage a neighboring utility.

AUTHORS:

Craig Wester received a B.S. in Electrical Engineering with a strong emphasis on power systems from the University of Wisconsin-Madison in 1989. Craig joined General Electric in 1989 as a utility transmission & distribution application engineer. Mr. Wester is currently an employee of GE Power Management as Regional Sales Manager. Mr. Wester's role consists of providing sales management, power system protection application and support to the investor-owned utilities, rural electric cooperatives, electric municipals, consultants, and OEMs throughout the southern US for GE relaying equipment. Mr. Wester is a member of the IEEE.

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