

Internet-Accessible Power Monitoring & Control Systems

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Introduction

Accessing electrical system information from any location allows the system manager to provide quicker command and control of intelligent devices. At the dawn of these devices, the manager could only access system parameters at the distribution location. As data communication techniques evolved, devices could be monitored anywhere within the building or within closely knit campus settings through proprietary protocols. Now, the Internet allows real-time access anywhere on the globe through open protocols.

Today, the following functions can be performed routinely and enhanced via the Internet:

Power Management

- Minimize downtime and reduce costly equipment damage
- Alarm and event management
- Improved predictive maintenance notification
- Increased safety by remote monitoring and device control
- Power quality and waveform capture

Energy Monitoring

- Utility billing auditing
- Demand management

The purpose of this article is to describe the available architectures that support these functions over the Internet: the hardware that allows the networking of intelligent electronic devices and the related software that manages the above functions.

Terminology

Ethernet: The industry-standard communication network used in local-area networks of PCs and now broadly called the Internet or the "Web."

Ethernet Gateway: Translates Modbus RTU to an Ethernet TCP/IP network.

HMI: The Human Machine Interface is the client software interface through which the user views metering information, configures IEDs and issues commands.

IEDs: Intelligent Electronic Devices are devices that control, protect and monitor the electric distribution systems:

- Electronic trip units on breakers
- Electronic power meters
- Protective relays
- Programmable logic control devices

Meter Configuration: This software is used to configure the meter for proper operation.

Modbus Concentrator: Translates vendor specific "legacy" protocols to Modbus RTU.

Modbus Remote Terminal Unit (RTU): An industry-standard, open protocol typically used in a close-knit network above the proprietary protocols.

PMCS: Power Management and Control System. The term will be used in the broadest context to include the hardware and software that enables a range of capabilities from simple power monitoring to a fully featured energy management and power quality system.

PMCS DDE Server: Power Management and Control System Dynamic Data Exchange server responds to requests from the Host PC to route data, to and from devices, by an identifying data tag. Often error detection and correction are performed at this layer.

Protocols: A generic term used to identify communication methods. It can be loosely described as the language of packaging binary data. Open protocols are available universally and are often the standard while closed protocols are proprietary and unique to each manufacture.

RS485: The network that communicates in the Modbus RTU protocol.

Server: Software that provides the centralized interface to connected devices issuing commands and requesting data. This is also called the host.

TCP/IP: Terminal Control Protocol over Internet Protocol. The industry-standard, open layered protocol that accesses the Internet where every node has a unique IP address. TCP/IP is buried in most operating systems including Unix, Mac OS X and current Windows versions. Note: TCP/IP is used here to generalize the suite of Internet protocols bearing different names.

Network Architecture

The purpose of PMCS is to exchange information and commands between IEDs and the system manager. The devices and Host PC must be able to interface with the data communications system, send and then reconstruct the original signal as accurately as possible in a particular protocol. The combination of IEDs, networks and protocols are numerous but easy to manage. IEEE 802.3 was the initiating standard for Internet communication now moving to the IEC 61850 standard specifically for substation automation.

Intelligent Electronic Devices

At the IED level, time-varying signals such as current, voltage, etc, are sampled and converted into a digital representation as a sequence of bits over conductors, modulated light or radio signals. The input/output transmitter presents these 1's and 0's as voltage shifts transmitted over the communication network in the appropriate protocol.

Protocols

For the purpose of this discussion, there are three protocols -- arranged from the earliest to present:

- Legacy Protocols – unique and closed for each PMCS manufacture (Comment, SEL, INCOM, PROFIBUS, etc)
- Modbus RTU (RS485 network)
- TCP/IP (Ethernet 10/100/1000Base-T network)

Networks

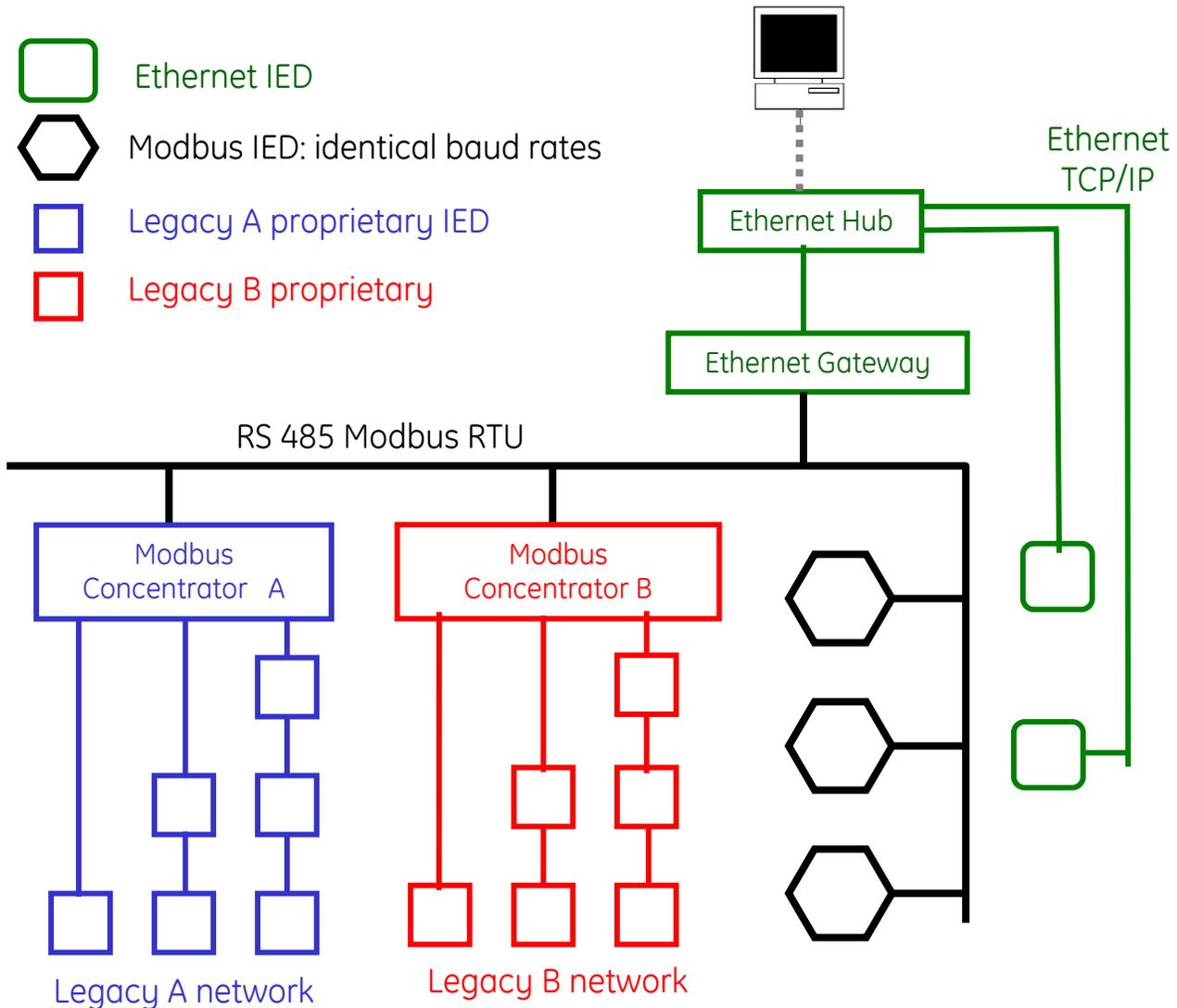
The physical network is primarily wire conductor based:

- Ethernet – LAN, Internet (TCP/IP protocol)
 - Media
 - X Base-T (twisted pair CAT 5)
 - X Base-FL (fiber optic)
 - X = Mbits/sec
- RS485 – Modbus RTU protocol
 - Media – two-wire twisted pair, shielded cable
- Legacy –Proprietary protocol
 - Media – two-wire twisted pair, shielded cable

Networks can also be radio, microwave or satellite based. The only difference is the methods of sampling, modulation (coding) and demodulation (encoding) signals.

Below, Figure 1 is an illustration of the various networks discussed combined to allow all IEDs accessibility over the Internet:

Figure 1. Multi-Protocol Architecture



The red and blue networks represent two different proprietary protocols where each signal is translated into Modbus RTU by the Concentrators. The baud rates of every Modbus IED and both manufactures' Modbus to Ethernet Concentrators must be identical. The Modbus protocol is then translated to TCP/IP at the Ethernet Gateway. All the Ethernet TCP/IP devices are gathered at the Ethernet Hub and present to the Internet by one of many providers.

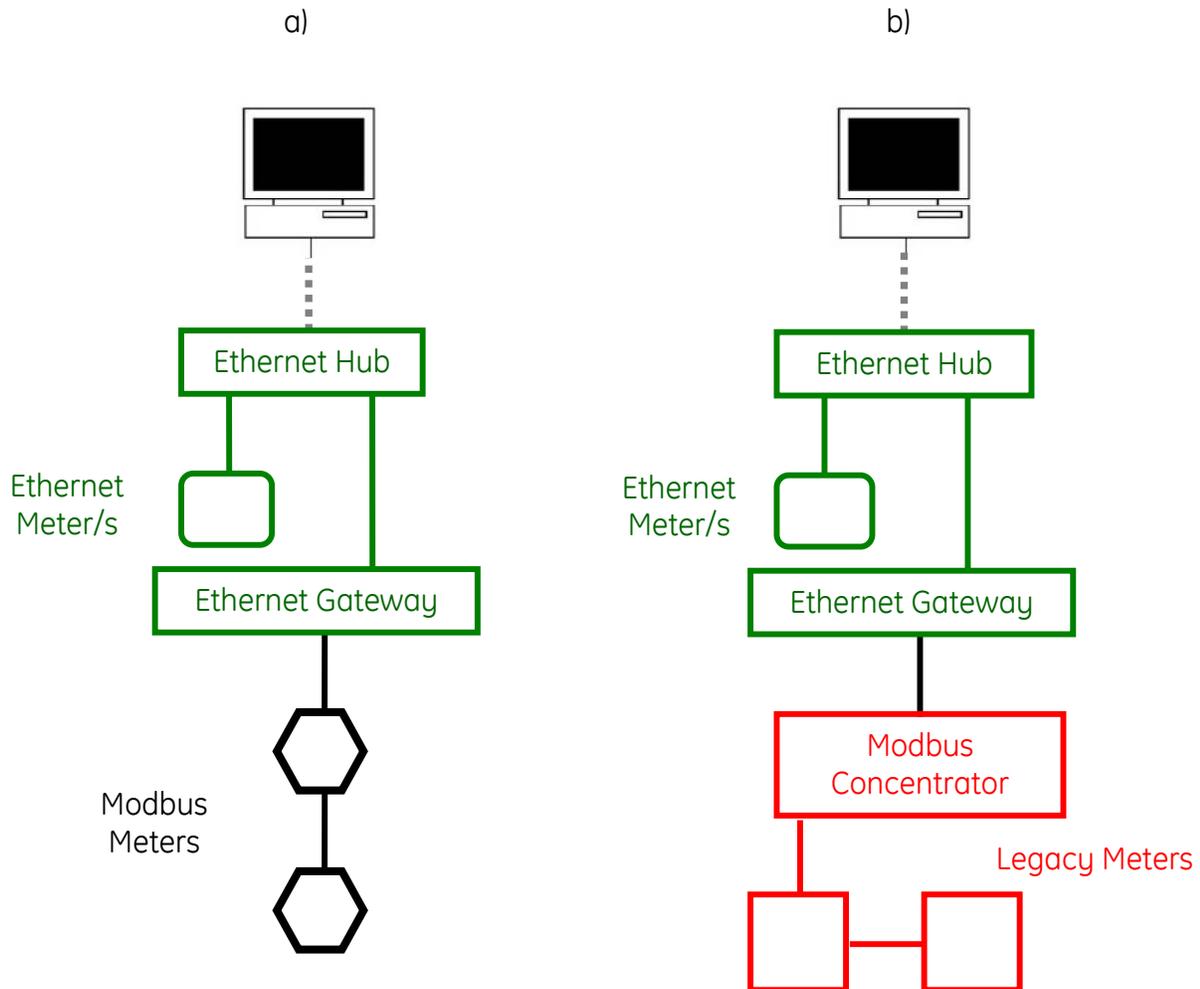
Host PC

The host PC above connects to the Ethernet hub via the Internet (shown as a gray dashed-line). The host PC is equipped with an Ethernet Card for Internet communications. The PC location is unrestricted, provided an Internet connection is available and also assuming IT security regulations allow access from outside of the

facility. However, with proper password and “firewall” protection, the system can be made secure while providing the system manager with the overwhelming advantage of having instant access to devices from any location.

A simplified option is available when remote monitoring of meters is the objective, especially significant for L.E.E.D. certification (Figure 2). The Ethernet hub accepts the connections from one or multiple Ethernet meters and gateways. Additional Modbus meters may be daisy-chained to the Ethernet gateway (Figure 2a) or a proprietary network through a concentrator and gateway (Figure 2b). This architecture minimizes both hardware and software requirements when only meters need to be accessed. The Ethernet meter may also contain an embedded web server, in which case the meter acts as the host and the PC uses a web browser as the HMI without PMCS software.

Figure 2. Metering Only Architectures



Software

The PMCS software at the operator level is the heart of the system. It functions as the HMI at the highest layer, but also performs many tasks (DDE server functions) in the background related to orchestrating the gathering and distribution of information.

While numerous options and accessories for PMCS software are available, the market generally offers a range of basic through premium software products. The basic PMCS software is intended for smaller networks of IED's. This software costs less but does not offer high-end features such as energy management and limits the number of clients connected to the host. The premium PMCS package will provide the full range of monitoring, control, energy management and power quality features. It is intended for larger numbers of IEDs and will allow many more clients to access the system. The difference in cost between the basic and premium PMCS products is significant enough to warrant a careful review of the requirements of the project.

The PMCS HMI is the graphical user interface that provides the operator with a portfolio of features that makes complex tasks manageable. These include:

- IED management

 - Initial connection to, and set-up of, networked IEDs

 - Adjust parameters as the electrical environment changes

- Monitoring of metered data through pre-configured screens

 - Voltage, current, power, energy, power factor, frequency, etc

- Viewing of power quality events

 - Captured waveforms, total harmonic distortion, trending, etc

 - Time-stamped events

- Monitoring system status

 - Editing and viewing of single-line diagrams

 - Breaker positions

 - Alarm settings and annunciation

 - Predictive maintenance

 - Report generation

- Management of energy usage

 - Energy and demand data

 - Cost allocation

 - Reducing peak demand through load shedding

The HMI software is installed on each computer that will view the data. The PC that "hosts" the network of IEDs is the PMCS server. It is possible to have one computer to act as both a client and a host. When the host and client are on separate computers; the client does not have direct connections to the IEDs -- information is sent to the client by the host.

If the requirement is to integrate PMCS data into higher-level monitoring, automation, or control systems, then products exist to make PMCS data available to other non-PMCS applications. An example of this requirement would be to incorporate electrical distribution events into a facility-wide data logger. An integrating software using OLE (Object Linked Embedding) for Process Control or OPC for short will fill this need. OPC server software can be purchased as an option to a basic PMCS software package or may be integral to the premium versions.

Conclusion

From simple daisy-chained electronic meters to advanced PMCS with energy management and power quality features, the system designer needs to tightly define the requirements of the project and allow for future expansion. Clearly, specify all metered functions, any throw-over or load-shedding schemes and identify any requirement to interface with an existing PMCS. Also, indicate which feeders and other downstream equipment requiring monitoring and control.

The software will allow for ease of set-up and provide future users a simple platform to operate and monitor the system. Most software products provide a “plug-and-play” capability so field changes are easily performed. Along with clearly specifying the IEDs and functions, care must be taken to select the proper level of software capabilities.

Therefore, IEDs that operate on a variety of protocols may be combined into an Ethernet network using readily available components. With the proper coordination of architectures and software selection, diverse systems can be managed from any location connected to the Internet.

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