

ELECTRICALS/INSTRUMENTATION

Industrial power management: what plants need to know about the future electric system

Prepare for cost-control challenges and revenue-generating opportunities

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Over the next two decades the North American electric power grid will undergo significant modernization that will have tremendous impact on refinery operation and hydrocarbon processing in general. As both a major consumer and supplier of energy, the hydrocarbon processing industry (HPI) must prepare itself for the cost-control challenges and revenue-generating opportunities that grid modernization will present. For most, minimizing cost impact and taking advantage of the supply-side opportunities will be mostly a matter of leveraging the energy and automation infrastructure already in place.

Energy conservation itself is nothing new to the HPI. Process engineers usually design and operate systems with energy consumption and peak-pricing in mind, but interaction with the grid is typically passive; call it Industrial Power Management 1.0. With grid modernization, however, real-time response to energy prices and grid alerts becomes not only practical, but also essential. What is good for the grid is good for the refiner. We'll call this "Industrial Power Management 2.0."

What kinds of changes might occur? What strategies might companies plan for and implement to prepare for these future changes? How would these changes affect the information and control systems that are marketed in the industrial space? What products and systems should users adopt today to enable future adaptation?

Background. Roots of the North American electric power grid date back more than a century. It is one of the largest and most complex systems in the world; an interlinked network through which more than 10,000 plants deliver a terawatt of power to 130 million users.¹ About a third of the load is residential, a third commercial and a third industrial.* Handling peak demand with acceptable reliability requires maintaining an operating capacity margin of about 15%.*

Although North America's electric grid provides electrical energy that is cheap, stable and plentiful, the infrastructure is

aging and subject to cascade faults that can interrupt power over a large region. Periods of high demand can stress the system and increase the chance for failure. But the grid is still growing.

Some experts project need for a 25% increase in generation capacity over the next 20 years.¹ New central station and distributed generation capacity will help meet some of this, but demand management will be necessary to handle the shortfall. Much of that will have to come from smart metering and load management by all users, but the industrial sector can also provide new generating capacity, and profit significantly in the process. Realizing that profit will require HPI plants to rethink the way they consume, conserve and generate electricity and how they respond dynamically to grid events outside their own gates.

Peering into the future. When dealing with a system as huge and as complex as the North American electric grid, the best we can do is identify significant macro forces and patterns that drive the process. Following are the most significant forces that will likely play the greatest role in shaping tomorrow's electric energy grid:

1. The greenhouse effect—A consensus is building that we need to reduce CO₂ emissions and limit the country's carbon footprint. The search goes on for fuels that are inexpensive, clean and safe:

- Coal is inexpensive and plentiful, but even "clean coal" technologies do not fully overcome this fuel's high carbon footprint.
- Nuclear fuel has minimum carbon footprint, but safe, long-term storage of spent radioactive fuel remains a problem.
- Renewable energy sources such as wind, solar and geothermal have potential, but are not yet practical or cost-effective for large-scale electric generation.
- Hydraulic energy from dams can provide many megawatts, but location and construction of new dams are problematic in the developed world; tidal energy generation is still in early investigative stages.

* These are rough estimates only.

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2. Need for increased generation capacity—With such a large capital investment necessary, it is a good bet that electrical energy costs will escalate.

3. Need for energy independence—Political unrest and uncertainty is increasing in regions critical to world energy production.

4. Need for resilience and self-restoration—As one of the nation's critical infrastructure systems, the electric power grid must be capable of surviving disasters brought about by terrorism or natural acts.

Peering into the “fuzzy” crystal ball reveals the following likely scenarios:

- Energy demand will continue to grow faster than its supply.
- Electricity costs will probably fluctuate in “real time.”
- There will be many smaller sources of clean power.
- There will be a need to use power more intelligently.

Enter the smart grid. The electric grid is migrating from one that is highly centralized and passive to one that is distributed and active. Today's grid is largely a noninteractive system with only a loose relationship between generators and consumers. Most consumers don't currently track their hourly, daily or even weekly energy consumption and don't know how much electricity they've used until the bill comes in at the end of the month. But that's all about to change.

This is occurring through two very significant changes: distributed generation and demand response. These affect the future sourcing and sinking of electrical power on what is often referred to as the “smart grid.” This smart grid represents both a challenge and an opportunity for refineries and other HPI plants.

Distributed generation. Distributed generation embraces the concept that instead of only building a few large generation facilities, a viable alternative would be to augment bulk power generation with large numbers of smaller generators. These generators would leverage renewable energy sources such as the wind, waves and geothermal, just to name a few. Less than 5% of current capacity is generated by distributed energy sources so there's plenty of room for growth.¹

The downside of these distributed energy sources is that they are usually dynamic and easily influenced by external forces. This causes them to be unreliable and in some cases unpredictable. Such behavior is in stark contrast to the high reliability that the electric grid demands.

Captive power plants in industrial manufacturing facilities such as HPI plants represent a very valuable distributed generation asset for the emerging smart grid, and one that is potentially more reliable than some of the other alternatives. A Berkeley National Lab report indicated that in 2001, refining industry self-generation provided only 26% of the 50 terawatt-hours (tWh) of electrical energy consumed.² This load is quite significant and represents over 1% of the 3.7 terawatt kWh total electricity consumption in the US.³ Expanding these captive industrial power plants by adding clean carbon and renewable capacity, and exporting more power onto the grid, could represent a significant and highly profitable investment. Several factors reinforce this opportunity as many HPI plants already:

- Have the needed electrical infrastructure to support power export

- Are located in areas that would be conducive to expanding alternative power generation capacity such as solar and wind farms

- Have sophisticated distributed control and automation systems that can be easily expanded

- Utilize advanced energy management and optimization systems.

Demand response. Demand response is the basic concept that electrical loads can respond to grid events by reducing consumption without need to shed the entire load as occurs during a rolling blackout. These “smart” loads can reduce electrical consumption by up to 30% or more while still providing power to critical subsystems. Aggregated over a large number of loads, this amounts to a very significant decrease in power consumption during critical periods. The ability to automatically respond to these critical events provides the grid with an adaptability and robustness that it does not possess. No longer is electrical service a “Boolean” process that is either on or off. It now can take on many shades of gray. In the industrial world, this is very similar to replacing a solenoid valve with a control valve. In fact, it's starting to look a lot like a very large, multilayered, multivariable control loop!

The ability to rapidly respond to external grid events in a closed-loop manner will become an important capability for tomorrow's HPI plants.

Device asset management. Interconnecting the distributed generators with the intelligent loads is a transmission and distribution network containing devices that provide enhanced real-time data and health information as well as the ability to diagnose faults and predict failure. This distributed asset management network will expand upon the supervisory control and data acquisition systems used to monitor and control remote substations. These infrastructure systems, which include high-speed phaser monitoring (i.e., the angular difference between current and voltage on a transmission system), are a focal point of current industry initiatives because they will provide the core foundation needed to improve visibility and conditional awareness of the transmission system. Enhanced fault detection will benefit the power system by reducing service restoration times and helping to enable a more decentralized network of distributed generation and demand response technologies.

Industry initiatives. Two key smart grid initiatives are the Gridwise Alliance⁴ and Intelligrid.⁵ In addition to these, there are many other coalitions, alliances and consortia that are focused on smart grid activities. Adding to this are regional and state-legislated mandates such as the California smart meter initiative which is mainly focused on residential heating/cooling. All of these activities reinforce the drive toward the smart grid. But there are many regulatory and technical roadblocks that lie ahead. Well-thought-out economic incentives need to be put into place along with just the right amount of legislation. Moving on to technical issues, four required characteristics of the smart grid that stand out are interoperability, security, reliability and scalability. These are not mutually exclusive. Secure, reliable and scalable solutions are typically proprietary. Interoperability often decreases security unless it's explicitly addressed. Reliability that scales and is interoperable is difficult. But the grid needs all four, and much more. As a way to address these issues and

others, DOE created the GridWise Architecture Council⁶ whose mission it is to:

“... establish broad industry consensus in support of the technical principles that enable the vast scale of interoperability necessary to transform electric power operations into a system that integrates markets and technology to enhance our socio-economic well-being and security. The scope of the GridWise Architecture Council spans intelligent interactions across the component elements of the electric system, embracing distributed energy resources (end-use systems, distributed generation and storage) with distribution, transmission and bulk power generation.”⁷

As a key step in this direction, the Architecture Council has developed the “GridWise Interoperability Framework.” This document categorizes the many facets of interoperability and describes what is required for systems to achieve interoperability. The train is on the track and rolling.

But what does this mean for manufacturing and industrial automation? Why should industry care? Besides, energy conservation is not new. It’s been around a long time. Let’s consider the following:

- Industrial manufacturing consumes about 30% of the grid’s power.
- Some larger industrial manufacturing sites already have self-generation capacity and can act as either net producers or net consumers. Many, however, are still grid-dependent. An opportunity will exist to re-evaluate the economics of energy self-generation and possibly enter the energy export business.
- Energy conservation is an important design criterion during plant construction and maintenance, but is often of secondary concern to process operations and management. Most of the major HPI companies have already made very significant investments targeted at energy conservation in general. These are very important but are often passive. There is a large body of knowledge surrounding energy conservation that will be very applicable to active electrical energy management.
- Energy cost will increase and change dynamically over time and industrial sites will need to respond to events that occur on the grid in near-real time. This will require more intelligent plant equipment utilization and control.

Manufacturing plants as ‘electrical control valves.’

Energy-intensive industries such as hydrocarbon and chemical processing will be impacted the most and will need to react intelligently to events that occur on the grid. This will add another dimension to operation’s management in industrial facilities.

Let’s take a closer look at an industrial plant as an electrical control valve for the grid. A typical oil refinery consumes a very large amount of electricity. Many contain their own coke-fired cogeneration power plants that produce many megawatts of electricity along with high-pressure steam to operate refinery process equipment. In these scenarios, the refinery can either operate off-grid or as a net producer of power on the grid during “favorable” economic conditions or in response to grid events. These facilities provide a very important function on the grid but are somewhat insulated from grid dynamics. In addition to these, many plants do not have internal generation capacity. Within this scenario, these plants will need to be good grid citizens and provide demand response in the form of real-time, active electri-

cal power management. The good news is that active control of refining processes is not new.

How might the smart grid affect an oil refinery? The rules of engagement within a typical refinery are:

Rule 1: Operations is king.

Rule 2: See rule 1.

Historically, information and systems integration was focused on maximizing process production and vertically integrating information and control for the purpose of optimizing manufacturing operations. This is clearly the primary business objective of a process plant. Maintenance was considered a cost to be minimized. This is changing. Maintenance and asset management are receiving capital investment and becoming integrated with day-to-day plant operations.

It’s widely understood that maintenance and asset performance can have a very significant impact on operations. From reducing exchanger fouling to extending process unit runtimes, asset performance monitoring and failure prediction are becoming first-class citizens. Organizations such as the Machinery Information Management Open Systems Alliance (MIMOSA) are actively involved in integration and interoperability of operations and maintenance systems. Energy management systems, however, are often considered ancillary and nice to have, but not core.

As the smart grid emerges, electrical energy will become an increasing percentage of product cost and be viewed as a first-class raw material. Energy management will follow asset management and transition from a secondary function to one that is actively integrated and managed. This is a key concept. “Active electrical energy management and control” will become an important part of daily operations. Based upon dynamic energy costs and grid events, it will become economically justifiable to prioritize energy consumption and actively control energy usage on a real-time, closed-loop basis. Today’s open-loop, manual energy control will evolve toward tomorrow’s automatic closed-loop control. This is at the core of Industrial Power Management 2.0 and is what differentiates it from today’s industrial energy conservation.

As an analogy, a similar transition has already occurred on the Internet. Users migrated from a role as primarily passive, “read-mostly” participants in Web 1.0 to active, “read-write” contributors of content in Web 2.0. This active content is bringing with it many benefits such as vastly improved human interactivity and collaboration.

Possible refinery interoperation scenarios. In the future, the contracts that individual refineries or petrochemical complexes enter into with the local grid operators are likely to be much more complex than today’s relatively simple tiered rate schedules.

A hypothetical example of a negotiated contract between an HPI plant and the local grid operator could read:

“The refinery must reduce power consumption by 3% within 10 minutes when triggered by a power warning event and 5% within 5 minutes upon receiving an emergency event. In either case, an energy penalty will be invoked, if unable to comply.”

Horizontal control integration and interoperability. Refinery control engineers work with operations to identify the lowest-priority processes that can temporarily be safely and economi-

cally throttled back or shut down on short notice. Processes with marginal steady-state economics are also targeted. Even though the economics are very context sensitive and must be evaluated on a plant-by-plant basis, one can assume that the cat cracker is probably not on this list. A small petrochemical satellite facility may not fare as well. After identification, the plan is to prioritize the required actions and automate an orderly feedstock or power reduction sequence using appropriate control logic. The problem is that these targeted energy consumers will most likely be sparsely located throughout the plant site and may cut through several isolated control systems from several vendors. If these processes were operated independently, then interoperability may never have been a concern. All of a sudden, the low-hanging fruit is no longer low-hanging. But, for this exercise, let's say that these systems are integrated and straight-forward process automation can reduce power by 2%. Now what? We still need to reduce the power consumption by another 3%.

Vertical information integration and interoperability.

Depending upon current process and equipment conditions, operating targets may need to be affected in an effort to further reduce power. These cutbacks should be economically evaluated and prioritized on a dynamic basis. As a rough guideline, the Berkeley Lab report lists fluid catalytic crackers, hydrotreaters and hydrocrackers as the highest electricity users among refining process units.² Safeguards and limits need to be developed so that process starvation does not occur. The idea is to control energy consumption with minimal and acceptable disruption to ongoing production while meeting the terms of the contract in an economically viable manner. In most cases, the impact of this reduction can be minimized if spread out or load-leveled throughout the refinery. In this way, any given process unit is only required to make small adjustments. Because these operating adjustments may interact, they should be coordinated and synchronized. The more automated this process, the easier and faster a response can be. Highly capable, flexible and interoperable automation and enterprise business systems will be key enablers. The ability to integrate day-to-day economics with distributed control system logic in a robust way will be instrumental to the plant being able to adapt to the changing energy environment within which it operates.

And in some cases this can represent quite a challenge. Refinery economics, for example, hinge upon the margin between the market cost of a barrel of crude oil and the market price of the products produced such as fuel oil and gasoline. But once the refining process commences, the math starts getting interesting. That barrel of crude turns into a spectrum of hydrocarbon components flowing around an array of streams. Identifying intermediate stream "values" or "shadow prices" requires a refinery model with substantial resolution coupled to accurate and timely yield reconciliation and complex inventory management. This is a topic worth volumes but is an important ingredient for real-time economic decision-making within continuous manufacturing processes.

Industrial interoperability. An important ingredient required for achieving the integration level required for Industrial Power Management 2.0 is systems-level interoperability, both within an enterprise as well as between enterprises. The "GridWise Interoperability Framework" explores this complex issue (Fig. 1).

Within the industrial space, a very critical harmonization is starting to occur. Key standards organizations that were once only focused on solving specific points-of-integration problems have realized that interoperability is larger than any one organization. This has resulted in a concerted effort by the following organizations to participate in the Open O&M Initiative:

- Instrumentation, Systems and Automation Society (ISA)
- MIMOSA
- Open Applications Group
- OPC Foundation
- Fieldbus Foundation
- HART Communication Foundation
- Profibus (PI International)
- FDT Group (Field Device Tool)

This initiative is attempting to identify and resolve the many model and transaction conflicts that exist within the collection of standards that are involved in manufacturing integration. But it's not easy. Very strong forces oppose change. The concept that interoperability will expand opportunities is often lost as organizations try to prevent short-term perturbations to business. As an example, one has only to look at the handfull of standardized technologies that have enabled the Internet to explode into immense business value. The HPI industry can greatly benefit from interoperability and needs to increase its active involvement in the standards efforts, as well as leverage its immense purchasing power, to help drive these standards and this critical convergence forward.

Characteristics of future automation systems.

Traditionally, large-scale plant information and control systems have been commissioned for the primary purpose of supporting the automation of core operations. More recently, these systems have been installed or expanded to support plant operational excellence and asset management. In the future these systems will also need to support active electrical energy management.

Interoperability categories

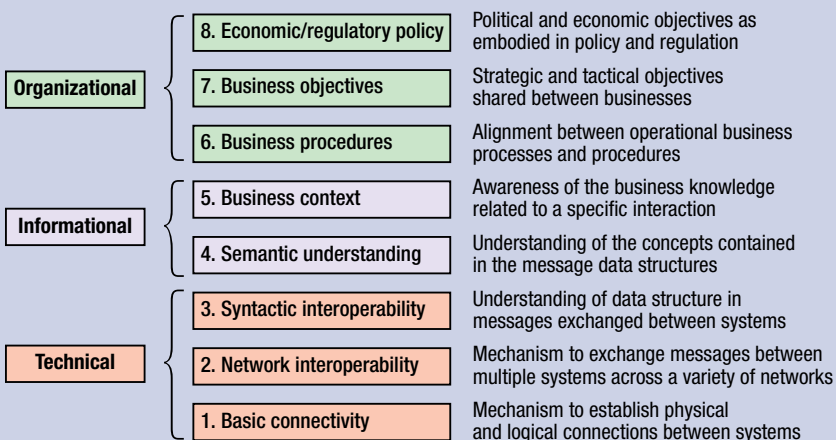


FIG. 1 An important ingredient for achieving the integration level required for Industrial Energy Management 2.0 is systems-level interoperability.

Many modern distributed process control systems grew up providing regulatory closed-loop control attached to simple instrumentation. These systems are being adapted for asset management by leveraging a new breed of smart, networked, field instrumentation that provides rich health information and the ability to percolate that information vertically through the automation system as conditions change. More recently, the concepts of process control have been extended to enterprise control, a powerful concept that refers to the capability to actually close the loop on business control by measuring business performance in near-real time, manipulating appropriate variables to achieve business “setpoints” and adapting the setpoints as business requirements change.

Active electrical energy management will leverage this capability but will require even more dexterity. Integrating systems so that they can react intelligently to real-time grid events will require the ability to easily add or modify integration and control logic. This logic will need to be context sensitive and integrated with production management. Changes to production schedules will have a direct impact on priorities relative to energy savings.

Control systems that can support new control algorithms and logic, provide for incremental upgrades and modifications and implement high-performance, industry-standard open interfaces will be the best hedge against these probable future changes.

A new species of control system will emerge as existing systems evolve. These systems will provide indigenous interoperability with external systems while maintaining a high degree of security and reliability. They will essentially be “systems of systems” stitched together into a modern open standards-based “service-oriented architecture” or SOA. The OPC Foundation’s Unified Architecture extends SOA into the realm of manufacturing automation by enhancing performance, reliability and interoperability. These systems will provide flexible, hybrid functionality while still being able to complete their primary mission of safe and economic control of process operations. This hybrid functionality will include the capability to perform

functions beyond those originally specified and to implement new and flexible control algorithms online with minimal impact to operations.

Manufacturing industries should monitor and understand the impact of the emerging smart grid on their day-to-day operations. They may just become a component within a very large multivariable, closed-loop control system. Prudent companies will start planning and implementing integrated operations information and control systems with architectures that will be able to adapt to this “brave new world.” Operations management, asset management and energy management are converging. Plant systems should reflect this convergence and be implemented with enhanced functionality and interoperability as part of an integrated asset and energy management strategy. With change comes opportunity. **HP**

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