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Abbreviations and Acronyms

AAM	Advanced asset management
ACM	Advanced control methods
AD	Advanced distribution
AM/FM	Automated mapping and facility management
AMI	Advanced Metering Infrastructure
BAH	Booz Allen Hamilton
BAU	Business as usual
BPL	Broadband over power line
CHP	Combined Heat and Power
CIS	Customer information system
CM	Configuration Management
CSP	Concentrated solar power
CSR	Customer service representative
CVR	Conservation voltage reduction
DA	Distribution automation
DER	Distributed energy resources
DG	Distributed generation
DMS	Distributed management system
DOE	Department of Energy
DR	Demand response
DUE	Distribution utility enterprise
EAC	Electricity Advisory Committee
EAM	Enterprise asset management
EIA	Energy Information Agency
EIS	Engineering information system
EMS	Energy management systems
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ESPA	Energy Sector Planning and Analysis
FACTS	Flexible AC Transmission System
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse gas
GIS	Geographic Information System
GPS	Global Positioning System
HAN	Home area network
ICT	Information and communication technologies
IHD	In-home displays
IIDS	Improved interfaces and decision support
IRP	Integrated resource plan
ISO	Independent system operator
IT	Information technology
KA	Key applications

KTA	Key Technology Area
NETL	National Energy Technology Laboratory
O&M	Operations and maintenance
PHEV	Plug-in hybrid electric vehicle
PMU	Phasor monitoring unit
PQ	Power quality
RCM	Reliability Centered Maintenance
RTO	Regional transmission organization/operator
SA	Substation automation
SCADA	Supervisory Control and Data Acquisition
SG	Smart Grid
SMES	Superconducting magnetic energy storage
SOA	Service-oriented architecture
SPS	Special protection systems
TCP	Transmission control protocol
T&D	Transmission and distribution
WAMS	Wide-area monitoring systems

Executive Summary

The optimization of power system assets has been a fundamental part of utility operations for many years. Utility business processes including planning, engineering, operations, maintenance and customer service are the primary means for asset optimization[1]. These processes—all of which are part of an asset management program—depend on the availability of key data and the capability of technologies to process that data. If these processes are integrated with one another, an asset management program can increase asset optimization.

This report examines the current state of utility asset optimization within the framework of a vertically integrated utility and presents evidence on why assets are not fully optimized today. It then discusses how Smart Grid processes, technologies, and applications could be leveraged to improve today's asset management programs enabling a significant improvement in the utilization of both system assets and human resources.

Utilities have worked hard over the years to develop asset management programs to optimize the use of their assets. An evaluation of asset management practices found the effectiveness of these programs has been limited because of a lack of sophistication in the processes, technologies, applications, data acquisition and communication systems on which these asset management programs depend.

The deployment of a Smart Grid is expected to deliver improvements in a number of areas including how assets are managed. For example, Information and Communication Technologies (ICT) will enable the integration of new information acquired by Smart Grid technologies with management processes that are currently limited. As additional technologies are implemented, they will likely lead to further improvements in utility asset management programs. These more sophisticated asset management programs have the potential to yield significant improvements in the utilization of both system assets and human resources.

This report identified identifies several areas where asset management programs could be improved including:

- Consumer systems that enable grid participation
- Advanced demand response to improve peak load management
- Integration of distributed energy resources, including renewables, that reduce system losses and give operators additional resources needed to support more efficient and environmentally friendly grid operations

[1] In general, optimization is the minimization (or maximization) of an objective function in the presence of constraints. Utility asset optimization consists of interrelated decisions on obtaining, operating, and maintaining physical and human resources for electricity generation, transmission, and distribution that minimize the cost of providing electric power to all classes of consumers, subject to engineering, market, and regulatory constraints.

- Distribution management systems (DMS) with advanced outage management tools to reduce the frequency, scope, and duration of outages
- Ubiquitous deployment of sensors that provide the operational and health status of all important assets
- Analytical tools and capabilities to better optimize system and human assets

These new technologies and applications, integrated enterprise-wide, are expected to also improve the planning, engineering, and customer service processes.

The Smart Grid transition is moving ahead rapidly in part to pursue these expected improvements in asset management programs and the associated processes, technologies, and applications. Improved asset utilization is the desired result. For example:

- Industry leaders are pursuing Smart Grid in the form of purchasing smart, communication enabled equipment and purchasing or upgrading their Supervisory Control and Data Acquisition (SCADA) systems;
- Pilots and demonstrations are ongoing, experimenting with Smart Grid technologies and applications (e.g., Smart Grid Investment Grant and Demonstration Projects); and
- Planning and operational tools are being developed and implemented to process information collected by Smart Grid technologies to improve asset utilization.

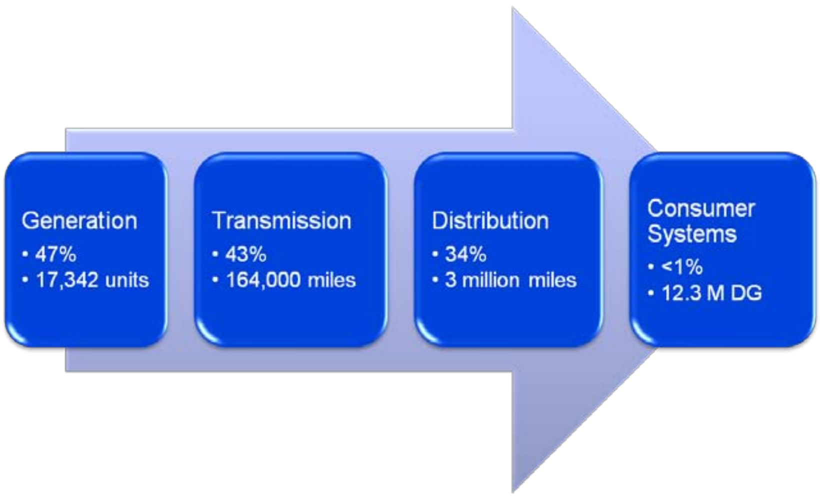
A number of initiatives are planned or underway and new opportunities for improving asset management programs and the utilization of assets are emerging. Some have not yet received an impartial evaluation regarding their need or effectiveness. Further research is recommended in three of these emerging areas:

- Microgrids — "*Can Microgrids Assist with Asset Utilization?*"
- Data Management —"*Leveraging the Value of Smart Grid Data*"
- Demand Dispatch — **"***The Feasibility and Value of Demand Dispatch in a Smart Grid Environment*"

1. Utility Asset Optimization Today

An analysis of utility generation, transmission, and distribution assets suggests opportunity exists to improve the efficiency of the grid and the utilization of its assets.

Exhibit 1-1 Asset Utilization in Today's Grid



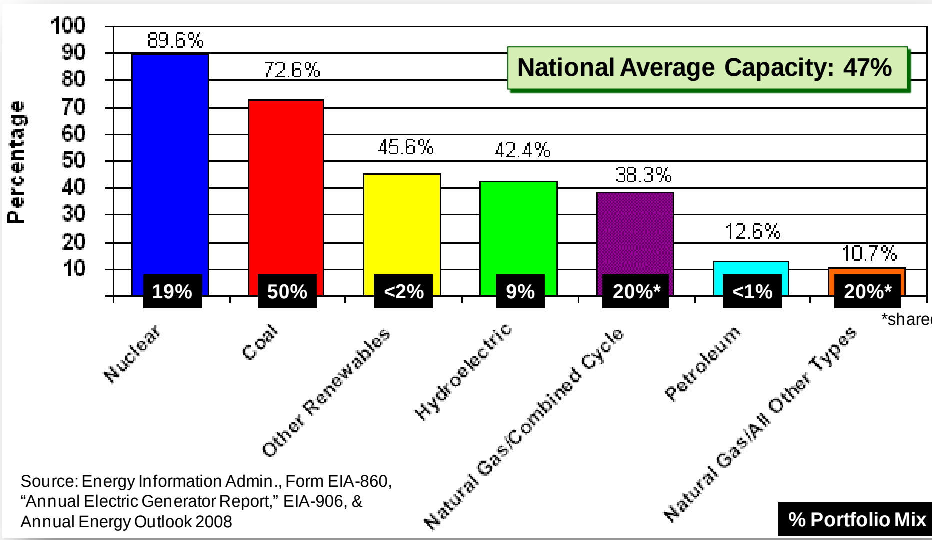
Source: Horizon Energy Group (2010)

Exhibit 1-1 above illustrates the current level of asset utilization in the four primary areas of grid operations in terms of average utilization as a percentage of capacity. The national capacity factor of the U.S. generation portfolio is approximately 47 percent, suggesting that additional capacity is available for production. Transmission lines are loaded to 43 percent on the average, while at specific times some line flows are limited due to congestion. Distribution asset utilization is 34 percent, again suggesting that opportunities might exist to better utilize existing resources rather than build new ones. Finally, one of the most under-utilized asset classes is consumer systems. Over 12 million distributed generation resources are located on consumer premises, yet the vast majority of them are not grid connected.

How much can these utilization factors be increased and what will the impact be on the overall optimization of grid assets? Achieving full utilization (100%) of these assets is not possible without compromising cost, reliability, environmental and other performance goals. The optimal level depends on ever-changing system conditions and requires periodic analysis to ensure the system remains optimized around the desired criteria (cost, reliability, environmental, safety, etc.). Average utilization percentages are therefore not definitive in measuring asset optimization.

Exhibit 1-2 below illustrates the current utilization levels of the generation fleet. The primary requirements for operation are reliability and economics, i.e. to be dispatched each unit must clear those hurdles. Other issues affect the operation of the renewable resources such as the availability of water, wind, and sun.

Exhibit 1-2 Asset Utilization of the Generation Fleet



Source: EIA (2008)

One example of a successful asset optimization strategy is the nuclear power industry, which has dramatically improved its asset utilization over the past decade by reducing the duration of refueling outages, and with its low production costs has achieved a fleet capacity factor of almost 90 percent.

Utilization of coal-fired generation is over 70 percent but is perhaps threatened with higher fuel and operating costs in the future due to carbon concerns, and forced generation reductions due to variable renewable resource "must-take" requirements; whereas, the capacity factors of solar, wind, and hydro are a function of weather conditions.

Natural gas, combined cycle, and petroleum fired generation capacity factors are dependent on prices of other competitive fuels and system operational factors such as reliability when compared to other alternatives. Finally, capacity factors for natural gas/all other types are less than 11 percent primarily due to high fuel costs. These units typically remain idle except for peak periods and emergency use. While this may suggest a non-optimized situation, asset optimization requires addressing customer demand. The ability to alter consumer demand is one of the aspects smart grid technologies are expected to enhance, resulting in less peaking generation needed, and higher utilization of baseload generation.

A recent study completed by NETL (DOE/NETL, 2011) suggests that through the implementation of a Smart Grid and distributed generation technologies, including coal with Combined Heat and Power (CHP), the average utilization of coal power plants will likely increase as peak load is reduced. Thus, the fraction of load served by baseload plants becomes greater. Since utilization of nuclear plants is already above 90%, most of the increased utilization of baseload plants will be from coal and natural gas fired plants.

Section 1307 of Title XIII of the Energy and Independence Act of 2007 requests that states consider Smart Grid alternatives when presented with proposed investments in non-advanced grid technologies. This consideration should include whether a Smart Grid investment could eliminate, reduce in scope, or defer the construction of traditional peaking plants to meet peak demand.

Many factors influence how much time a given generating asset is used. This evidence, however, suggests that opportunities may exist for improving their utilization.

This paper focuses on the utility asset management processes that drive asset performance and how the introduction of smart grid technologies might contribute positively to these processes and further improve the optimization of all grid assets. Smart grid technologies are expected to directly influence several of the asset management processes described below, but perhaps not all. Indirect benefits are expected as well and both the direct and indirect benefits should be considered.

1.1 Utility Processes

Today's utility structures take many shapes, including:

- Vertically integrated utilities with generation, transmission, distribution, and retail customers;
- Regulated distribution companies interfacing directly with end-use customers or with retail energy suppliers;
- Deregulated generation companies;
- Municipally owned/operated organizations; and
- Cooperatives

To simplify, this report begins by examining the current state of asset management at a vertically integrated utility.

A vertically integrated utility is responsible for the entire power system supply chain, beginning at the customers' meters and including its distribution assets, transmission assets, generating plants, and fulfilling other supply contracts. The utility's objectives are to deliver electricity at the lowest cost, while satisfying reliability/safety standards and applicable environmental criteria. Optimizing the utilization of its system assets and the productivity of its human resources through effective and efficient business processes will minimize its costs, both operational and maintenance (O&M) and capital, while improving reliability and minimizing the impact to the environment. Effective asset management programs will support the accomplishment of these objectives.

A number of utility business processes make the integrated power system work. Collectively they also support the overall asset management program whose aim is to optimize system assets and human resources as the power system functions. The business processes that have the greatest impact, however, on asset optimization generally fall into the following five categories:

- Planning—Develops plans for both new and existing assets needed to meet projected increases in capacity and electric use, improve reliability, and support new interconnections. Planning is performed at the distribution, transmission, and generation levels. This includes new sources, lines, substations, line equipment, contracts etc.
- Engineering—Provides engineering, design, procurement, and construction of generation, distribution, and transmission facilities, including new customer connections, reconfigurations, and repairs.
- Operations—Monitors conditions, assesses impacts, and operates the distribution and transmission systems to ensure reliable and efficient results. Interfaces with regional transmission organizations (RTOs) at the transmission and generation dispatch levels, and dispatches crews and trouble men to assess, switch, and repair system problems.
- Maintenance—Develops and implements maintenance programs to reduce reactive maintenance. Performs preventive and predictive maintenance tasks and repairs on distribution and transmission equipment using in-house labor or vendors.
- Customer Service—Processes meter data into monthly bills, performs revenue management activities, and interacts with the customers to respond to their questions and complaints, educating them in the process.

These five processes are fundamental and have existed for many years at traditional, vertically integrated utilities. Over the years the processes have improved as new technologies have emerged (e.g., new load-flow applications for planning, electronic drafting technologies for engineering, Supervisory Control and Data Acquisition (SCADA) for operations, reliability centered techniques for maintenance, centralized call centers for customer service). Historically, many of the improvements were implemented separately in different utility departments, resulting in the creation of a number of "silos" for each process rather than a full integration at the enterprise level. Additionally, lack of information and control capabilities for the grid has further limited their optimization capabilities. The Smart Grid is expected to address each of these areas.

1.2 Current Limitations of Utility Processes

Understanding the existing status and limitations of these key utility business processes provides insights on how the Smart Grid could improve their effectiveness in optimizing assets. The Smart Grid has the potential to create both direct and indirect benefits for several of the processes described below. Section 2 describes the technologies and applications of a Smart Grid and the more direct influences they could have on asset optimization.

Planning

- Lack of complete time-stamped (Bennett 2009) load data to understand historical peak loads at various nodes impacts accuracy of load forecasting and often results in early builds of new capacity. This is a larger issue for distribution than transmission assets.
- Increasing growth of peak loads affecting transmission and distribution (T&D), and generation assets, requires a continuous build-out of peaking units and new capacity projects on the delivery system. These new projects are greatly under-utilized.
- Integration of planning processes among the T&D and Integrated Resource Planning (IP) departments is limited because of the siloed culture (Minikawa 2008; Gerber 2010). Analytical planning tools operate in a siloed domain (i.e., not integrated) resulting in sub-optimization at the enterprise level.
- Solutions to planning criteria violations (e.g., thermal, voltage, and stability) are typically standardized using traditional engineered solutions. Revision of these design standards takes time and effort to adapt to new Smart Grid technologies such as distributed generation and storage. Without new design standards, the application of traditional solutions that do not enable optimization as well will continue.
- System data regarding actual system responses to faults (e.g., fuses, reclosers, breakers) may be lacking, hampering the ability to verify the effectiveness of past coordination studies. Improvements in system coordination can improve reliability.

Engineering

- The integration of design processes, technologies, records, and data among the various engineering departments (e.g., new customer business, distribution, and transmission) is often incomplete and not shared with all departments that could benefit. The ability of all authorized users to access engineering drawings, maintenance records, and other pertinent data is not fully automated. Integration of these processes helps utility staff identify opportunities for improving asset utilization.
- The Design/Build process, which includes the engineering, procurement, and construction processes, is often not integrated with the work and resource management processes. This lack of integration prevents full optimization of how these resources are utilized.
- Many utility engineering processes are executed the “traditional way,” (e.g., without GIS and Automated Mapping/Facility Management [AM/FM] processes integrated with work management and Smart Grid technologies). Both GIS and AM/FM technologies provide opportunities to improve the utilization of both system assets and human resources.

- The lack of a single, common engineering model of the system accessible by all departments results in duplication of effort and introduces inaccuracies. Normally, the engineering organization is responsible for configuration management (CM) and, therefore, controls the configuration of the system. Other departments need that model—for example, planning needs it for load flow analysis; operations needs it for outage management diagnoses, switching operations, and dispatch of crews; and maintenance needs it for inspections and maintenance. In some cases, each department creates its own model. In the future, distribution management systems (DMS) will also need it. A common engineering model would greatly simplify all processes, increase accountability (since engineering is normally responsible for CM), and ensure all departments are working to the same, up-to-date model.
- Staffing levels within many engineering organizations provide very limited opportunities to explore new and creative (and Smart Grid-related) solutions. Changing traditional engineering and design standards requires time and effort, as many of these standards have been used for many years—a significant barrier to change. Some examples include dynamic ratings, use of distributed generation (DG) as engineered solutions, and new power electronics applications.
- Limited operational data are available to engineers that could help them improve future designs.

Operations

- Distribution operations are "starved" for system-state data for key assets (e.g., watts, vars, volts, amps), limiting the ability of operators to fully understand current conditions (lack of situational awareness), diagnose problems, and predict future conditions. Improvements in asset utilization depend on access to the fundamental data needed to perform analysis and take action.
- Lack of integration of other operationally related processes and technologies (e.g., outage management, weather forecasts, location and status of crews and trouble trucks, safety tagging, engineering drawings and records) affects the efficiency and effectiveness of distribution operations. For example, the duration of outages could be dramatically reduced by the integration of smart meters with loss of power detection capability and an advanced outage management system or DMS. This integration could reduce the detection and diagnosis part of the process dramatically. If integrated with work management, it could also deploy the appropriate crew to more rapidly remedy the problem.
- Operations processes have not yet advanced to the level needed to support the integrated operations of distributed energy resources, including electric vehicles. Current processes are based on the centralized generation model with power flowing "one-way" from the central plant through the delivery system to the customers' loads. Large numbers of Distributed Energy Resources (DER), particularly those operated at the consumers' discretion, and the possibility of "two-way" power flows create operational challenges not considered in current

operational processes. These processes will need to be upgraded to support the expected trend in the deployment of distributed resources; otherwise, the current level of asset utilization at the distribution level will be negatively impacted.

- Since distribution operations have traditionally been data "starved" for so long, advanced operational algorithms are underdeveloped. As more input data become available for these algorithms, there will be increasing impetus to develop them.
- Work and resource management processes for operational personnel are not normally fully integrated, resulting in a less efficient use of resources (e.g., new customer connects, meter reads, response to trouble, maintenance inspections, deployment of idle crews on new construction). Operations staff often support a diverse number of tasks and face competing priorities. Integrated work and resource management processes, particularly when integrated with Smart Grid technologies, can optimize the deployment of crews, trouble men, and other resources faced with multiple and changing priorities.
- The deployment of SCADA on distribution is limited, limiting the acquisition, analysis, and control of key components.
- The deployment of transmission SCADA is significantly broader, but the development of advanced algorithms to assist in understanding real-time situational awareness could be improved, particularly in the area of risk management and "what if" scenario planning.
- Deployment of phasor measurement units (PMUs) is occurring; however, how this new data set can be applied operationally is not yet well understood, particularly in how this new data can assist with asset utilization.
- Communication systems are needed to transmit and receive data among operations centers (both transmission and distribution). These systems were developed over the years by utility staff for their specific needs. An integrated communications system that satisfies the needs of all applications and users is needed. Utilities are reluctant to release control of the communication system to others. An integrated communications solution linking all the important assets—both system assets and human resources—would have a significantly positive effect on improving asset utilization.
- Operations are generally unaware of the health of system assets because that information is often not available and, when it is, may not be integrated with operational processes and technologies. Understanding asset health would give operators the opportunity to reduce loading and stress on degraded assets and schedule maintenance before failure.
- Use of dynamic, real-time ratings to maximize capacities is very limited. Dynamic ratings on transmission lines can significantly improve the loading levels on key transmission lines particularly during peak conditions.

- Ability to accurately measure outage statistics is poor (e.g., time outage starts, time outage ends, amount of load interrupted), resulting in inaccurate reporting of outage metrics. Inaccurate information can mislead asset optimization attempts.

Maintenance

- Automation of data collection processes for inspections (e.g., ground-line pole inspections, substations, lines) is limited. This makes the collection, analysis, and sharing of information among utility staff ineffective and inefficient.
- Deployment of real-time asset monitoring devices and associated communication systems is limited. Condition-based maintenance is just beginning to develop.
- Reliability Centered Maintenance (RCM) programs that identify and classify assets based on how critical they are to reliability and costs are limited. RCM uses these classifications as a basis for prescribing the level of maintenance to be applied for each. For example, the RCM process will identify some assets as "run to fail" with no maintenance prescribed. On the other hand, assets classified as "critical" will receive more attention. Without RCM, maintenance practices are sometimes applied unnecessarily on some assets and inadequately on others.
- Power quality diagnoses are difficult and time consuming since the installation of temporary instrumentation to trend suspected parameters is often necessary. Few sensors exist on the distribution system today inhibiting the ability to identify where PQ issues exist.
- Integration of asset health intelligence with operational decisions is limited (knowledge of assets in "stress").
- Online access to maintenance records and engineering documents is limited. These resources would simplify the maintenance process and make it more effective and efficient.

Customer Service

- Customer service representatives (CSRs) are limited in responding to customer questions because data sometimes is derived or comes from the operations or engineering processes (e.g., billing questions, estimated time for service restoration, cause of outage, status of construction on new services).
- Most existing customer information systems (CISs) have not advanced to the point that they can support interval metering at residential premises or varying time-based rates.
- Weak consumer education programs and less than compelling consumer incentives have limited the adoption of time-of-use rates. As a result, a lower-than-desired number of consumers are participating in demand response and energy efficiency programs.
- "Turn-on and turn-off" requests require a truck roll, labor costs, and delays in satisfying customer requests.

- Some states are deregulated, giving consumers choice in their electricity supplier. The introduction of a retail energy supplier complicates the interface between the utility and its customers.
- Most customers seem satisfied with the "status quo," and many are opposed to changes that will come with the Smart Grid. Some view the value proposition from their perspective as small when compared to the benefits promised by the utility. In some cases, the consumers have lost trust in their utility. More effective consumer education may be needed.
- Call centers are managed to keep customer wait times to a minimum. Lack of operational information slows down CSRs and can reduce their success rates at satisfying customers.

Crosscutting Limitations

- Processes and their enabling technologies are department-specific (siloed) and not shared among all departmental users (across the five processes). Information technology (IT) architecture is often not based on "Service Oriented Architecture" with an enterprise-wide data bus that would enable network sharing of data and information.
- Data are often entered multiple times in various "siloed" systems, leading to inefficient use of resources and the likelihood of introducing errors (i.e., lacks capability for "one time entry").
- Work and resource management processes are not integrated among departments nor linked with the engineering and operational process steps, leading to inefficient use of resources and lower production rates.

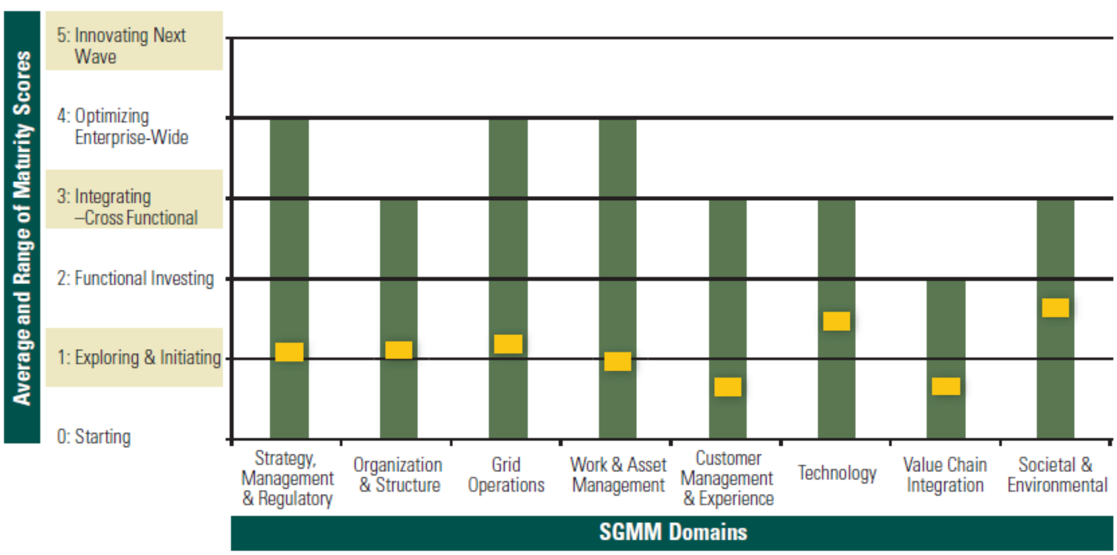
The integration of Smart Grid technologies and applications with these processes can address many of these limitations and improve the overall asset management program, thereby leading to substantial improvements in optimizing how assets are utilized. How the Smart Grid might support further improvements in asset optimization is discussed next.

2. How the Smart Grid Supports Asset Optimization

The Smart Grid has the potential to change how the industry approaches asset management with the adoption and integration of advanced communication systems, information collection and control devices, and software to economically deliver the optimal functionality.

Although the Smart Grid has great potential for improving asset management and grid efficiency, the utility industry is just getting started with its implementation. According to the Software Engineering Institute (SEI) at Carnegie Mellon University, the average level of Smart Grid maturity in the area of work and asset management (Exhibit 2-1) is about one on a scale of 0–5, suggesting that significant opportunity remains for leveraging the Smart Grid in these areas.

Exhibit 2-1 Average (yellow rectangle) and Range of Maturity Scores by Domain



Source: Carnegie Mellon University (2009)

SEI is the steward of the Smart Grid Maturity Model (SGMM). SGMM is a management tool that allows utilities to plan, quantifiably measure progress, and prioritize options as they move towards the realization of a Smart Grid. The model consists of eight domains of related capabilities and characteristics that an organization must address to reach Smart Grid maturity. Exhibit 2-1 depicts the results of surveys from 53 utilities who conducted self-assessments on their level of maturity in the eight domains shown

2.1 Smart Grid Vision – A System Perspective

The Smart Grid differs from today's grid in three fundamental ways:

Decentralized Supply and Control—Unlike today's grid, which is dominated by large central power stations providing electricity to consumers via a delivery system and dispatched via centralized command and control centers, the Smart Grid vision is to move to a more decentralized operating model. This model will increase the number of generating and storage resources dramatically—from thousands of centralized plants today to tens of millions of decentralized resources, including wind, solar, electric vehicles, combined heat and power units, and distributed energy storage devices. These decentralized resources will be owned by both utilities and non-utilities, including consumers. In addition, electrical loads will become subject to a control strategy that seeks to better match supply and demand in near-real time. Grid control will be delegated to the lowest (most decentralized) level capable of successfully performing the control functions. This substantial increase in the number of decentralized generation and storage assets will make grid operations more complex and represents a significant challenge to existing asset management programs.

Two-way Power Flow at the Distribution Level—Today's transmission system is a network, which supports power flow in two directions. Today's distribution system, which is primarily a radial design, does not. As decentralized sources are deployed at consumer premises and by utilities on their distribution circuits, power will begin to flow in both directions (e.g., from the consumer into the grid). Two-way power flow is a fundamental change to distribution system design and operation requiring a large investment in new relaying and control systems. New Smart Grid technologies and applications are needed to address this complication to operation and system protection as well as the opportunity it represents for improving the utilization of assets.

Two-way Information Flow—The level of deployment of measuring and control devices in today's transmission and distribution system varies. The ability to acquire data and act on it using SCADA at the transmission level is fairly comprehensive. At the distribution level, the deployment of SCADA and the number of points instrumented is very limited and what is available often employs only one-way communication. At the consumer level, essentially zero information is exchanged with the grid operator. The ubiquitous deployment of measuring and control devices, along with an integrated two-way communication system, will enable the Smart Grid to process vastly more information and exert control that is more sophisticated and granular.

These three fundamental differences are expected to provide the capability to significantly change and improve the five utility business processes, leading to improved asset utilization and more efficient operations.

The Smart Grid Vision is defined by its seven Principal Characteristics (DOE/NETL 2009). The Smart Grid will:

- Enable active participation by consumers;
- Accommodate all generation and storage options;
- Enable new products, services, and markets;
- Provide power quality for the digital economy;
- Optimize asset utilization and operate efficiently;

- Anticipate & respond to system disturbances (self-heal); and
- Operate resiliently against attack and natural disaster.

The fifth characteristic, "***Optimize asset utilization and operate efficiently***," is aimed directly at asset optimization by enabling the electric power system to generate, deliver, and consume electricity in the most efficient manner. This characteristic will affect today's system both directly and indirectly.

Direct impacts include ways the Smart Grid will reduce system peak loads that currently result in the inefficient use of generation resources. Direct impacts also include giving operators the ability to manage loads, reduce system losses, reduce transmission congestion, and reduce the duration and frequency of outages.

Indirect impacts include ways the Smart Grid can enable the various stakeholders to dramatically improve the efficiency of their processes. These opportunities to become more efficient exist at all levels. Security-constrained economic dispatch, reduction in transmission congestion, and regional transmission planning are examples at the RTO level. Utilizing Smart Grid intelligence and communication capabilities to increase productivity, reduce O&M costs, and defer otherwise required capital projects are examples at the utility level. Consumers, using Smart Grid intelligence and time-based price signals, can reduce their overall consumption of electricity (energy optimization) and reduce peak loads (capacity optimization).

The degree to which the Smart Grid addresses asset optimization can be measured in terms of reduced utility O&M and capital costs, keeping downward pressure on the future trend in electricity prices to consumers, improving reliability, meeting or exceeding environmental standards, and more efficiently managing the capacity factors of the central generation fleet. These improvements will be accomplished by optimizing both human resources and hard assets over the long term by integrating Smart Grid technologies and applications with the key processes described earlier.

2.2 Smart Grid Technologies

In today's grid, the technologies and applications needed to optimize real-time asset utilization are not widely deployed (DOE/NETL 2009). Some of the Smart Grid technologies and applications that are expected to support improved asset optimization in the future are described below.

Smart Grid technologies can generally be included in one or more of the following key technology areas:

Integrated Communications – High-speed, fully integrated, two-way communication technologies that make the grid dynamic and transactive for real-time information and power exchange. Open architecture will create a near plug-and-play environment.

Integrated communications are critical to enable the real-time, two-way exchange of data and information needed by the five operational processes. Today's communication systems do not support the bandwidth, latency, and reliability requirements of the Smart Grid or the next generation of asset optimization processes.

Sensing and Measurement – These technologies will enhance power system measurements and enable the transformation of data into information. They will evaluate equipment health, grid integrity, and grid congestion; support advanced protective relaying; eliminate meter estimations and prevent energy theft; and enable consumer choice and demand response (Faruqui 2010).

Many of the distribution assets are not currently instrumented today for key operational data such as watts, reactive volt-amperes (vars), volts, amperes, and operational status. Additionally, health -monitoring data such as number of device operations, temperature, and other indications of degraded conditions are generally not available. Smart Grid sensing and measurement technologies will provide this information to the O&M processes, giving them the information needed to reduce outages, address power quality issues, reduce losses, extend the life of assets, and reduce labor costs.

Extremely limited customer information is available today, and that is normally retrieved only on a monthly basis when the meters are read. Smart meters will provide near-real-time consumption data to operators and CSRs, thereby enhancing the operational and customer service processes from an asset optimization perspective.

Dynamic, real-time line-rating technologies, another important item in the sensing and measurement area, measure the capacity of a transmission line in real time rather than basing allowable line loadings on earlier system studies that do not consider actual ambient conditions (i.e., static ratings). Thus, a line would not experience the overload-induced excess sag, which leads to tree contacts, nor would it be loaded too lightly, which results in potential lost wholesale opportunities. Dynamic ratings can increase the utilization of both transmission and generation assets.

Advancements in sensing and measurement technologies are improving grid operations at both the transmission and distribution levels. For example, wide-area monitoring systems (WAMS) employ a GPS-based phasor-monitoring unit (PMU) that measures the instantaneous magnitude of voltage or current at a selected grid location to provide a global and dynamic view of the power system, and automatically checks to ensure predefined operating limits are not violated.

Advanced Components – Advanced components play an active role in determining the grid's behavior. The next generation of these power system devices will apply the latest research in materials, superconductivity, energy storage, power electronics such as flexible alternating current transmission system (FACTS) devices, and microelectronics, producing higher power densities, greater reliability and power quality, enhanced efficiency, and provide environmental gains. They can be either applied in stand-alone applications or connected together to create complex systems such as microgrids, which are local energy networks.

The shift to a more decentralized operating model in the future will lead to the deployment of possibly tens of millions of distributed energy resources, including distributed generation, storage, and electric vehicles whose owners have chosen to engage them with grid operations in exchange for a payment. This decentralized model would give the operations process many new options for optimizing assets at the distribution, transmission, and central generation levels. However, asset optimization in this context does not translate to an increase in the utilization of all assets. Depending on the optimization criteria, there may be winners and losers. Some assets will be less utilized and others utilized more as the overall system is optimized.

Advanced components support the operational process by giving new tools to both distribution and transmission operators for controlling conditions on the grid, including the ability to better optimize the central generation fleet.

Advanced Control Methods – Advanced control methods (ACM) technologies are the devices and algorithms that predict conditions on the grid, take appropriate corrective actions to eliminate or mitigate outages and power quality disturbances, and optimize grid operations (Smart Grid News 2009). These methods will provide control and protection at the transmission, distribution, and consumer levels, and will manage both real and reactive power flows. These technologies will perform the following functions:

- Diagnose and solve – The availability of real-time data processed by powerful high-speed computers will enable expert diagnostics to identify solutions for existing, emerging, and potential problems at the system, subsystem, and component levels.
- Take autonomous action when appropriate – The Smart Grid will include significant advances in system protection and control by incorporating high-speed digital communication systems with advanced analytical technologies. Special protection systems (SPS) will allow power transfers across the grid that would not otherwise comply with standard contingency criteria. Upon a change of status (e.g., a loss of generation and/or loss of a transmission line), a pre-programmed set of actions will be instantly initiated (e.g., wide area load-shed, generator re-dispatch, separation of interties, islanding) to maintain acceptable reliability margins while optimizing the affected assets.
- Perform "what-if" predictions of future operating conditions and risks – fast simulation and modeling applications are examples of this.

The Smart Grid will rely on local intelligence, automation, and decentralized control for selected applications, particularly those with primarily local impact. Centralized ACM will be utilized in other applications that involve a broader and more integrated impact. One of the overall objectives of ACM is to perform system and asset level analyses over multiple time horizons and take timely action to continuously optimize the overall operation of the system.

Improved Interfaces and Decision Support (IIDS) – Operation of the grid has become more complex and integrated since FERC orders 888 and 889 opened the U.S. energy market to competition. As a result, the time available for operators to make decisions has shortened from hours to seconds. Thus, the Smart Grid will require wide, seamless, real-time use of applications and tools that enable grid operators and managers to make decisions quickly. IIDS technologies will convert complex power-system data into information that can be understood by human operators at a glance.

Decision support tools will enhance skills and human decision making at all levels of the grid. Effective decision-making creates the ability to take advantage of optimization opportunities when they arise.

The integration of these key technology areas across all five utility processes will enable these existing processes to take full advantage of this new grid information, intelligence, and control capability for optimizing assets. This integration is provided by the Smart Grid key application areas.

2.3 Smart Grid Applications

Key applications emerge as logical sets of key technologies that enable the principal characteristics of the Smart Grid. The eight key Smart Grid applications discussed below constitute a significant transformation of the nation’s grid from a passively managed infrastructure to one that is more actively managed and better optimizes its assets.

Advanced Metering Infrastructure (AMI) – AMI is the integration of smart meters, an integrated 2-way communications system, and utility consumer processes, and it serves as the primary consumer interface to the electric system. From the utility’s perspective, AMI represents the “edge of the network.” This edge is where most of the innovation is taking place today. In theory, AMI will provide a path not only for utilities to remotely monitor the energy usage at a very granular level, but also for consumers to receive necessary alerts and price signals for their conservation objectives and/or demand response programs. AMI and the information it provides to the customer service and operations processes will help reduce peak loads, improve the detection, diagnosis, and restoration from outages, and reduce the number of calls and resulting truck rolls required today. It also simplifies the meter reading process and substantially reduces the number of labor hours required by the metering process. Integration of AMI with the other utility processes will also improve their ability to optimize assets.

Consumer Systems (CS) – CS includes “behind the meter” technologies that enable customers to fully participate with the Smart Grid. The consumer is changing, is becoming more technologically informed, and more interested in self-determination related to information, energy, and interaction with service organizations. Such CS technologies as home area networks that communicate with smart meters (AMI), smart appliances that respond to price signals or system operational parameters, home energy management systems, and others empower consumers to conserve energy, participate in demand response programs and offer their customer owned resources (distributed generation, storage, electric vehicles, etc.) to the energy market via the Smart Grid. All of these actions are supportive of operating more efficiently and optimizing assets beyond what can be done today.

The consumer will greatly influence the electrification of transportation. As an application, the plug-in hybrid electric vehicle (PHEV) fleet has the potential to contribute positively or negatively to the nation’s electric system, depending upon how intelligent the electric system becomes over the next decade. With AMI and CS applications, the nation will be able to collaborate with the consumer to charge the PHEV fleet at times when prices are lowest and most advantageous to utilities for efficiency and asset optimization.

Distribution Management System (DMS) – The DMS platform represents the primary utility enterprise application for managing the complex and dynamic aspects of distribution operations. Additionally, DMS can serve as the integration mechanism for linking new Smart Grid applications with existing and future asset optimization applications. The key applications integrated within the DMS suite include:

- Common enterprise network electrical connectivity model – configuration controlled by the engineering design process and integrated with all other enterprise applications that require an up-to-date model to operate (e.g., planning analysis tools, safety tagging, maintenance programs, crew dispatch).
- Geographic information system (GIS) – provides the locational dimension of assets and land base information for all users.
- Supervisory control and data acquisition (SCADA) – provides primary monitoring of distribution assets and control signal infrastructure.
- Customer Information System (CIS) – application that contains customer-specific information.
- Engineering Information System (EIS) – contains engineering data, drawings, and records.
- Advanced Metering Infrastructure (AMI) – provides consumer usage information, power detection, and remote switching capability.
- Outage management system (OMS) – primary application for understanding the extent of outages and supporting the stabilization and recovery of the system from an outage.
- Distribution automation (DA) – analysis and control application that monitors grid operational issues and dispatches controls to operate line-sectionalizing equipment to minimize impact of degraded conditions or actual outages.
- Conservation Voltage Reduction (CVR) – monitors and maintains feeder voltages closer to minimum levels by dynamically adjusting regulators and capacitor banks thereby reducing energy consumption and losses.
- Maintenance applications and programs such as condition-based maintenance, asset health monitoring, and maintenance data and records.
- Workforce Management System – provides work status, location of field personnel, and work related information.

- Distribution planning tools – analysis applications that perform load flow analysis to identify strengths and weaknesses in the distribution system (e.g., predicted future low voltage and overload conditions).
- Advanced Network Applications – provides functions that achieve optimum network utilization.

The great value of DMS is its capability to display multiple overlays from other applications to give operators and other users a complete context of various parameters that have been historically separated by utility department processes and technologies (silos).

For example, as the engineering process designs and builds new assets and connects new customers to the grid, the configuration of the connectivity model is updated. The model is then imported into DMS so that all applications needing the model use the same and most current version. When an outage occurs, DMS detects from AMI and SCADA where the problem is located and then analyzes the most likely failed asset. Linking to the work management system and using GPS information, DMS can determine the most effective crew to dispatch to the problem area based on the crew's location, skill level, type of equipment being operated, overtime limitations, etc. This integration capability of DMS makes it an extraordinarily powerful optimization tool that benefits not only operators but also all other utility process users. It is rapidly becoming the primary enterprise tool for ensuring network security, reliability, and stability because of its reach to all the intelligence devices in the network as well as the various enterprise applications that affect day-to-day operations. Because of this key operational position, DMS must operate with secure data and protect the privacy of the consumer data it uses.

Development of a fully integrated DMS has begun, but a complete understanding of how this platform can harness the new Smart Grid information, intelligence, and operational capability and leverage existing asset management processes is not yet fully understood.

Information and Communication Technology (ICT) – Integration of all Smart Grid applications is needed to fully leverage their functionality for asset optimization purposes. As noted earlier, existing technologies were often developed in "silos" and the corresponding information technology architectures were similarly designed. ICT applications address this weakness by deploying service-oriented architecture with an enterprise-wide information bus that allows all related applications and communications technologies to interoperate (i.e., "plug and play") so that users have access to processes that are fully integrated. Key to this functionality is a well-integrated data warehouse for managing and housing the large volumes of data originating from numerous sources. ICT is a critical enabler of DMS that relies on the integration of its key applications and is foundational for asset management programs.

Demand Response (DR) – The fundamental goal of DR is to reduce the peak load. The peak load occurs at certain times of the day in certain regions and lasts from minutes to hours. The peak is characterized by a rapidly increasing load in real-time and requires quick response from generating resources that are more expensive to operate. According to the Federal Energy Regulatory Commission (FERC), the peak load of the nation could be reduced by 150 GW over the next ten years with an aggressive DR program. For reference, the peak demand without any demand response is estimated to grow at an annual average growth rate of 1.7 percent, reaching approximately 950 GW by 2019 (FERC, 2009)

Demand response programs include:

- Dynamic pricing without enabling technology – consumers respond manually to high prices at peak demand.
- Dynamic pricing with enabling technology – consumers respond via automated devices to high prices at peak demand.
- Direct load control – energy-intensive consumer devices are directly controlled by the utility during peak demand.
- Interruptible tariffs – consumers agree to reduce demand to predetermined levels when called upon by the utility, in exchange for some incentive or rebate.
- Other programs generally available to larger business consumers, such as capacity bidding, demand bidding, and aggregator DR services.

AMI and CS applications are expected to greatly enhance the effectiveness of demand response on reducing peak load. Reducing load during peak load periods is a key tool for optimizing system assets. The Smart Grid will enable DR to be applied more broadly across the system, but to achieve the desired levels of peak demand reduction, many policy, technology, education, and market information objectives must be implemented in states and regions.

DER Operation and Microgrids – There is a large existing fleet of distributed energy resources (DER) and the Smart Grid is expected to encourage the deployment of a much greater number in the future. DER provides a significant opportunity for optimizing assets as they are called upon to contribute to the generation mix, support demand response to reduce peak load and improve reliability when the grid needs their support.

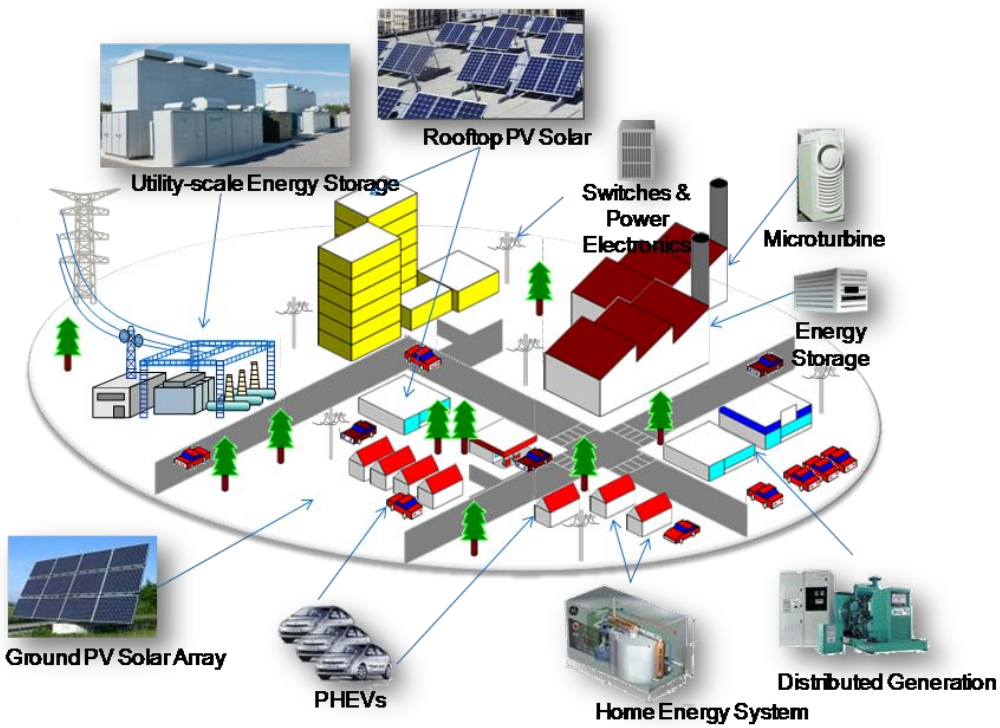
The challenge will be to efficiently and effectively operate this large number of distributed and diverse resources. DER operation is expected to be accomplished through two processes – DMS and utility microgrids. Both are expected to assist grid operators integrate DER operations to improve asset optimization of grid assets and operate more efficiently.

The DOE (DOE/OE, 2010) offers the following description of microgrids:

> "A microgrid, a local energy network, offers integration of DER with local electric loads, which can operate in parallel with the grid or in an intentional island mode to provide a customized level of high reliability and resilience to grid disturbances. This advanced, integrated distribution system addresses the need for application in locations with electric supply and/or delivery constraints, in remote sites, and for protection of critical loads and economically sensitive development."

Along with utility microgrids, a new Consumer System-type application has recently emerged – the community microgrid. Community microgrids represent a new level of intelligence and control methodology aimed at creating small control areas that optimize the local assets around the objectives of the community. Exhibit 2-2 illustrates the complexity of the community microgrid.

Exhibit 2-2 Community Microgrids



Source: Horizon Energy Group (2010)

As the local infrastructure complexity grows, the microgrid provides the intelligent applications necessary to meet the local objectives. Microgrids operate in conjunction with the main distribution network the majority of the time, and only on occasion transition into an island operation. This occurs seamlessly when the community objectives are challenged in such a way that the intelligence in the microgrid determines that the community would be better served economically, reliably, or environmentally as an island. When the challenge passes, the microgrid seamlessly transitions back to grid-connected operations. The community microgrid continuously seeks the optimal solutions for meeting its objectives.

Microgrids operating in a cellular structure can simplify the operation of these new resources and enable them to be optimized around the objectives most important to the local consumers. Multiple microgrids integrated with DMS can simplify and optimize the operation of the distribution system and provide another method for improving its efficiency.

RTO/ISO Applications – Regional transmission organizations (RTOs) and independent system operators (ISOs) provide overall bulk power movement authority in roughly 60 percent of the nation. Their role is to optimize transmission and generation assets from both reliability and economic perspectives for the large transmission system footprint they operate. They economically dispatch the generators located in their footprint, monitor and analyze reliability on a near-real-time basis, and provide the market mechanisms that will ultimately encourage consumers to participate in the electricity markets. Integration of Smart Grid applications at the distribution level with these applications would enable the transmission system to utilize the distribution system as an asset to further optimize transmission and generation assets and their operation.

Some of the services provided by RTOs/ISOs include:

- Security-constrained economic dispatch (SCED);
- Locational marginal pricing (LMP) markets;
- Day ahead forecasting and scheduling;
- Ancillary services – regulation services, reserves, DR, capacity bidding, etc;
- Wide area monitoring systems (WAMS) – the North American SynchroPhasor Initiative (NASPI) is a project to provide real-time monitoring of the nation's bulk power system;
- Wide area situational awareness (WASA) – new visualization tools to improve grid management automation and situational awareness thus improving reliability and efficiency; and
- New system analysis tools – applications that support short-term and long-term planning, what-if analyses, and other analytical tools needed to support optimal transmission operations.

RTOs/ISOs have learned a lot as they started up their reliability and economic dispatch programs. Integration of their experiences, processes, and technologies with Smart Grid technologies and applications on the distribution system could lead to further opportunities to optimize both transmission and distribution assets.

Substation Automation (SA) – For decades one of the key locations for adding intelligence into the network was the substation (ABB, Selinc, Siemens), primarily at the transmission level. After a decade of pilot projects that demonstrate the value of pushing intelligence out to substations, utilities are typically establishing long-term transformation plans for their fleet of substations. This suite of intelligence usually includes:

- Incorporation of intelligent electronic devices – digital relays, controllers, multi-function meters, etc.;
- Substation Local Area Network and host processor;

- Data concentrators and warehousing of real-time and event data;
- Connectivity models and device attributes;
- Communications to integrate substation level intelligence with grid operations and RTO applications;
- User interface (remote and local); and
- Condition monitoring sensors.

SA provides critical transmission level information to support analysis and optimization of transmission assets.

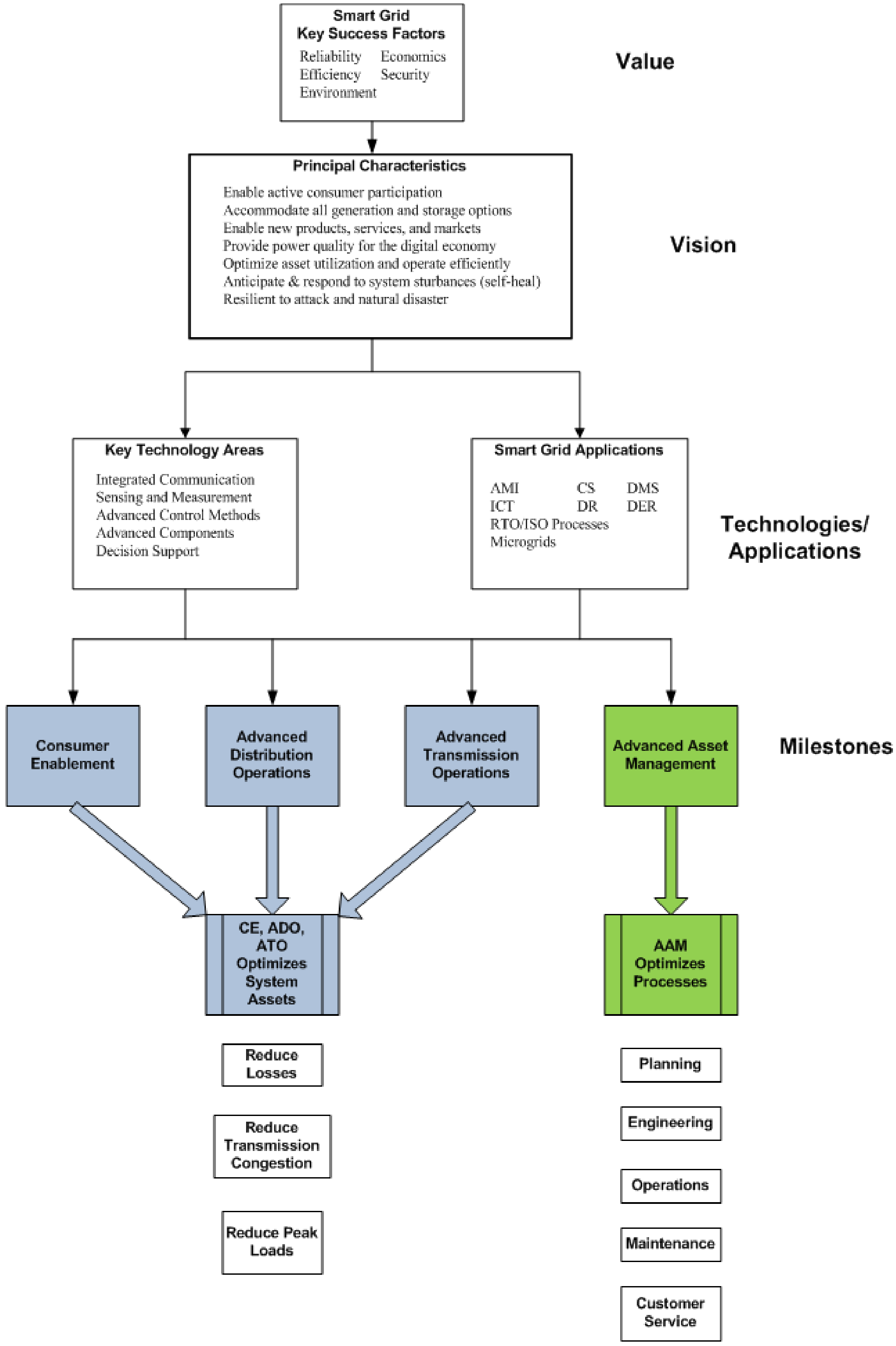
2.4 Smart Grid Summary

Exhibit 2-3 below illustrates the linkages between the Smart Grid vision, key technologies and applications, and how system assets and utility processes can be optimized.

The Smart Grid key success factors (KSFs) define where value will be created by the Smart Grid as its Principal Characteristics (PCs) are achieved. These KSF value areas include expected improvements in reliability, economics, efficiency, security, environmental friendliness, and safety. The PCs will be achieved through the deployment of the Smart Grid key technologies and applications in four milestone areas: Consumer Enablement (CE), Advanced Distribution Operations (ADO), Advanced Transmission Operations (ATO), and the one of prime interest, Advanced Asset Management (AAM).

The first three milestones directly influence asset optimization of the hard assets and the Advanced Asset Management milestone integrates grid intelligence to leverage the performance of the key utility business processes that influence asset management over the longer term.

Exhibit 2-3 Smart Grid Linkages to Asset Optimization



Source: Horizon Energy Group (2010)

3. Conclusions

Utilities have made slow but steady progress over the years in optimizing their business processes and assets. The level of grid intelligence available, the limited granularity of control, and the lack of integration of key processes that drive improvements in asset management have restrained progress.

Smart Grid technologies and applications create new opportunities for taking asset optimization to the next level. The electric power industry is just beginning its journey to become Smart Grid enabled, as envisioned in the "Systems View of the Modern Grid" (DOE/NETL 2007). Industry is moving forward with many asset optimization initiatives as the emphasis on achieving the Smart Grid vision has increased. It is noted that:

- Industry leaders are pursuing Smart Grid in the form of purchasing smart, communication enabled equipment and purchasing or upgrading their SCADA systems;
- Equipment manufacturers are responding by producing smart, communication-enabled equipment;
- Pilots and demonstrations are ongoing, experimenting with Smart Grid technologies and applications (e.g., Smart Grid Investment Grant and Demonstration Projects);
- Planning and management tools are being developed to utilize information collected by Smart Grid to improve asset management;
- Interoperability of systems is being examined by NIST; and
- Security questions are being investigated by NERC.

As systems and equipment become available, industry leaders are employing them to collect previously unavailable data. These data, combined with new management tools, are used to better understand their assets. This new understanding is leading to the identification of new concepts on how to better manage and optimize them.

Regulatory policy has generally been supportive of asset optimization. Assets are expected to be "least cost" when compared to other investment options and must be "used and useful" before the utility is entitled to receive any cost recovery for the investment. The collective impact of external influences such as political, regulatory, environmental, and consumer preferences, however, will challenge the pace at which asset management improving processes and technologies are deployed.

The Smart Grid presents a number of opportunities for further optimizing distribution, transmission, and generation assets. Some of these opportunities are being addressed by industry, and are moving forward. Some examples include:

Distribution Management Systems—DMS has been commercialized, although it will undoubtedly be improved over time as deployments increase and lessons learned and best practices are incorporated to continuously improve its contribution to asset optimization.

Conservation Voltage Reduction—CVR is the deliberate reduction in line voltage, closer to the lower limit allowed by regulation, to reduce energy consumption and losses. CVR has been deployed at a number of utilities and the concept is well understood. PNNL addressed CVR in its January 2010 study, *The Smart Grid: an Estimation of the Energy and* CO_2 *Benefits.*

New Asset Optimization and Operational Tools for Distribution—many of these tools will be developed as part of DMS maturation. The DMS vendors and utility operators will most likely drive their development. Some examples include fast stimulation and modeling of the distribution (and transmission) system.

Corrective, Preventive, and Predictive Maintenance—condition-based maintenance and reliability centered maintenance opportunities are hot topics today in the Smart Grid community. Utilities and vendors are working this space to commercialize technologies that can be leveraged by the Smart Grid.

Dynamic rating technologies—promising new technologies are available and have the potential to improve the capacity of key transmission lines, reduce transmission congestion, and provide new options for transmission-constrained generators. Regional planning at RTOs is expected to further drive this opportunity.

On the other hand, a number of opportunities are just now emerging or have not yet received an impartial evaluation regarding their need or effectiveness. Some key examples include:

- Microgrids — "*Can Microgrids Assist with Asset Optimization?*"
- Data Management —"*Leveraging the Value of Smart Grid Data*"
- Demand Dispatch — **"***The Feasibility and Value of Demand Dispatch in a Smart Grid Environment*"

These topics are discussed in detail in the next section.

4. Recommended Next Steps

Additional effort is needed to fully understand and communicate how these emerging opportunities might contribute to further asset optimization.

4.1 Can Microgrids Assist with Asset Optimization?

The general concept of microgrids is well known; however, how that concept could be applied in a Smart Grid environment to address asset optimization is not well understood. Varying opinions exist on their true value. Utilities generally view them as a threat if not owned or controlled by them. An objective evaluation is needed to fully understand all the pros, cons, and value propositions of the various microgrid architectures.

Additional research is suggested in the area of microgrids and how their deployment and operation can address the key value areas of the Smart Grid vision (i.e., improved reliability, economics, efficiency, environmental friendliness, security, and safety). Microgrids might be one of the Smart Grid technologies/applications that can leverage asset optimization and create value in these areas.

Discussion

Microgrids are often described as a vital part in the overall implementation of a Smart Grid and a major tool for increasing the optimization of electric utilities' generation, transmission, and distribution assets. Much has been promised and from a variety of sources. For example:

- CERTS (Consortium for Electric Reliability Technology Solutions) says that its "Microgrid Concept is an advanced approach for enabling integration of, in principle, an unlimited quantity of DER (e.g., distributed generation (DG), energy storage, etc.) into the electric utility grid. A key feature of a microgrid is its ability to separate and isolate itself from the utility system, during a utility grid disturbance." (CERTS 2010)
- The Galvin Initiative, a well-known supporter of the smart grid vision, says that microgrids will "achieve specific local goals such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction (Galvin, 2010).
- *Power Magazine* seems to sum up all the promises of the microgrid with the following statements: "Thanks to recent technology developments, large U.S. electricity customers soon could be improving their power quality and lowering their cost of energy through the use of microgrids. Industry analysts view microgrid development as a major transition in the way electricity is generated, delivered, and controlled. The deployment of microgrids could shift electricity supply away from today's highly centralized universal service model toward a more dispersed system." (Neville 2008)

Some debate the value of microgrids, suggesting that they may introduce unintended consequences and perhaps may not be a cost-effective solution for optimizing around reliability, economics, and environmental opportunities. Further objective research is needed to evaluate and validate these claims and concerns for both utility-owned and consumer/community-owned microgrids.

A number of questions remain to be answered with respect to microgrids:

- What is a utility microgrid?
- What is a community microgrid?
- What is the current state of microgrids in the United States and internationally?
- What are the best architectures (e.g. residential, commercial/industrial, community, utility)?
- How would each operate in a Smart Grid environment?
- Can microgrids deliver as claimed (improved reliability, improved economics, and improved environmental impact)?
- What issues (technical and business related) do microgrids create for utilities and how might those issues be addressed?
- What is the value proposition for the various microgrid architectures?
- What are the challenges and barriers that must be overcome to realize the deployment of meaningful numbers of microgrids?
- What role do state regulators play in the deployment of each of the microgrid architectures?
- How do non-utility microgrids integrate with utility operators and the market?

4.2 Leveraging the Value of Smart Grid Data

The Smart Grid will generate huge volumes of data, however, how this data will be "handled" is not well defined.

Advanced Asset Management depends on data and access to it. ICT applications will ensure that all users, processes, and technologies can access information, but what data is needed and how will it be retrieved and managed remains a question. Further work is needed to identify a data management process that ensures Smart Grid data is effectively utilized by the utility business processes.

Discussion

New Smart Grid sensing and measuring technologies will have the capability to acquire and store vast amounts of data. These data will include both operational parameters (e.g., watts, vars, volts, amperes) and asset health parameters (e.g., temperature, pressure, power quality) and that data may be collected on a near-real-time basis.

New Smart Grid advanced control methods and analytical tools will process these data into information for use by operators and other authorized users. Additionally, these data and information may be further processed for yet-to-be defined uses by other applications in the future.

How data and information will be acquired, stored, processed, protected, analyzed, and acted upon has not been well defined. Further work is needed in this area to explore how the use of this data can be optimized leading to improvements in the five utility business processes.

A number of questions remain to be answered with respect to data management:

- What is the current thinking regarding how Smart Grid data will be managed?
- What data do the asset management processes need?
- What data are required as inputs to the Smart Grid advanced control method technologies and analytical tools?
- How does local vs. central data management and control affect the data requirements?
- What Smart Grid technologies and applications will acquire this data?
- At what frequency do the various data sets need to be collected?
- How will the needed data be acquired and managed and where will they reside (e.g., data warehousing)?
- How will data be validated for quality?
- What are the communication and storage requirements?
- How will the data be protected?
- How do other industries manage their data (e.g., telecommunications)
- What data management process is needed to support asset management?

4.3 The Feasibility and Value of Demand Dispatch in a Smart Grid Environment

Demand Dispatch (DD) is a relatively new operating concept and represents a different approach to balancing generation and load. Unlike traditional Demand Response, DD is active and deployed all the time, not just during peak times—it aggregates and precisely controls individual loads on command. Rather than generation following load, DD capitalizes on flexible loads and dispatches that load to follow generation. Resources like EVs and PHEVs, which can actually adjust the load they represent to the grid while charging, could vary their charging rates to follow the variations in intermittent resources (e.g., wind, solar). Large numbers of EVs operating in this mode could be a valuable asset for optimizing the integration of renewables. Other consumer loads could also be used to support DD.

Further research in this area is needed to clearly develop this concept and to estimate its contribution to the overall benefits of the Smart Grid.

A number of questions remain to be answered/clarified with respect to DD:

- What is Demand Dispatch?
- What is its current state of development in the United States and internationally?
- How might it be enabled in a Smart Grid environment?
- What loads and configurations might be used to support DD?
- What level of capacity do these loads reasonably represent?
- Is DD a feasible concept?
- What is the value proposition for DD (i.e., in terms of integration of renewables, reducing peak load, wholesale prices of electricity, incentives)?

5. Summary

Asset management at utilities is not new and many efficiencies have been accomplished over the years. Progress, however, has been restrained due to the limited data and control capability that has historically been available. Smart Grid technologies and applications and the data acquired by them, effectively integrated with the utility business processes, provide a major opportunity for accomplishing the fifth Principal Characteristic of the Smart Grid, ***"Optimize asset utilization and operate efficiently."***

The authors recognize the significant asset optimization and smart grid efforts underway by the power industry today. A number of solutions for leveraging asset optimization have been developed, commercialized, and are now being deployed. A few areas are just now emerging as potential opportunities. It is important for the industry to continue to reach out and search for lessons learned, best practices, new technologies and applications that could further improve asset utilization and enable more efficient grid operation.

The Smart Grid transformation is a huge undertaking and represents a significant change management challenge. Utilities will need to break from tradition in a number of areas to create the momentum needed to better optimize the utilization of its assets. Continued research is also needed to identify new opportunities for moving forward. This paper identifies some of these promising new areas of research.

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