Smart Grid Principal Characteristics

OPTIMIZES ASSET UTILIZATION AND OPERATES EFFICIENTLY

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EXECUTIVE SUMMARY

The Smart Grid is defined by its seven principal characteristics (PCs). One of those characteristics is "Optimizes Asset Utilization and Operates Efficiently." How this characteristic might be attained is the subject of this paper.

The Smart Grid will utilize the latest technologies to optimize the use of its assets over two different time horizons – the short term will focus on day-to-day operations and the longer term will focus on dramatically improved asset management processes.

Operation and asset management of the Grid will be fine-tuned to deliver the desired functionality at a minimum cost. Operationally, the Smart Grid will improve load factors, lower system losses, reduce environmental impact, and dramatically improve system reliability and outage management. Real time information from advanced sensors will give operators sophisticated risk assessment capabilities to better understand the state of the system. Planners and engineers will have the knowledge they need to build what is needed when it is needed, reduce transmission congestion, extend the life of assets, identify and repair unhealthy equipment before it fails unexpectedly, and more effectively manage the work force. Advances in technologies and materials will allow the "power density" of system assets to increase. Operational and maintenance improvements and the reduced cost for capital investments will yield "more bang for the buck" – resulting in downward pressure on increasing electricity prices.

This paper explores the dimensions of this principal characteristic and how it might be achieved. The following topics are addressed:

- The current state and proposed future state of the Smart Grid relative to this PC
- Requirements for implementation
- Implementation barriers
- Expected benefits
- Recommendations for moving forward

CURRENT AND FUTURE STATES

Before we discuss how the Smart Grid will optimize asset utilization and operate more efficiently, we need to understand this characteristic's current state and its future possibilities.

CURRENT STATE

Asset Utilization

In today's grid, the systems needed to understand and optimize real-time asset utilization are not typically available. This is particularly true of the distribution grid. Even with the needed information, the ability to adjust individual asset loadings is limited given the relatively low penetration of distribution automation and demand response into today's Grid. The utilization of transformers at distribution substations is currently about 40 percent. At transmission substations, utilization of transformers is around 50 percent.

Operating Tools

Advanced operating tools to help operators more efficiently manage the grid are limited, but work is underway to analyze and interpret the expected vast amount of new data in ways that will enable operators to rapidly comprehend the state of the grid. This "real-time" assessment of the state of the grid is needed to achieve maximum grid efficiency without sacrificing reliability. Grid operations would benefit greatly from these tools, but widespread availability and implementation has yet to occur.

System Losses

Today's U.S. grid suffers electrical losses in the range of 5–10 percent due to transformer and line losses associated with moving real and reactive power from generation sources to the point of consumption. Reducing these losses would result in a corresponding reduction in generation—making the grid more efficient, reducing costs and environmental emissions. Better information, control, and resource options are needed to effectively reduce these losses.

Another dimension to losses is the fact that today's outage management systems seldom minimize the time consumers are out of service. Outages represent a lost opportunity to deliver electricity as well as a large cost to consumers. Unexpected outages upset the planned delivery of electricity causing the re-dispatch of generating resources which can have both reliability and economic impact.

Asset Management

Asset management includes system planning, maintenance, engineering, and work management processes, among others. Each of these processes is limited in its effectiveness because the information on which they depend is limited.

System planners make decisions on capacity improvement projects using load forecasts with less than complete data—often leading to conservative decisions that are sometimes viewed after the fact as "overbuilding."

Maintenance engineers struggle with the implementation of condition-based maintenance (CBM) programs. They are hampered by a lack of the asset condition information needed for an optimal CBM program that can extend asset life and minimize reactive maintenance. Monitoring of equipment health in near real time is limited resulting in maintenance practices that are primarily time-based rather than condition-based. Reactive maintenance is common.

Today's engineering, design, and work force management processes also lack the operating information and communication capabilities needed to achieve a higher level of performance. Optimized capacity utilization, optimized asset health, and optimized operations will result in substantial cost reductions and performance improvements.

Improving asset efficiency and utilization is a priority today as increasing costs and environmental concerns take center stage. Much work is being done in the area of superconductivity, more efficient transformers, improved VAR support, and dynamic line ratings. The penetration of these technologies, however, is still limited due to their cost, stage of development, and lack of the appropriate support infrastructure.

FUTURE STATE

The deep penetration of intelligent electronic sensors, the ability to control essentially all assets – including the smart loads of willing consumers, the integration of communication systems that connect them and the advanced algorithms that analyze and diagnose asset condition will enable this Smart Grid characteristic to be achieved. Much of this functionality will be provided by the technologies and processes that support the other principal characteristics of the Smart Grid. Sharing of this information allows operators, planners, and engineers to greatly improve operational and asset management processes for a relatively small incremental cost.

Asset utilization will improve—Advanced Distribution Management Systems (DMS) and enhanced transmission monitoring and control will give grid operators the tools needed to adjust system flows and increase the loading of under-utilized assets. Loading of stressed assets will be reduced, lowering their probability of failure and extending their lives. Improved power quality will further extend equipment life as damaging surges and harmonics are reduced. And, improved load factors will allow more energy to be delivered per unit of installed capacity.

System losses and congestion will be reduced—Widespread deployment of distributed generation, electric vehicles, demand response, and particularly energy storage will give grid operators additional resources to reduce losses. Two-way power flow capability and the participation of willing consumers who offer their resources to the market will allow the distribution system to become an asset to Regional Transmission Organizations (RTO's), giving them additional tools for managing transmission congestion and improving their economic dispatch process. In addition, improved reactive power management will allow transmission lines to operate near unity power factor, thereby reducing losses associated with reactive power flow.

Capacity planning processes will improve—Detailed and accurate load forecasts, including more accurate details and forecasts of consumer loads and resources will enable system planners to better predict asset loading. Complete, historical, time-stamped information will be available at all planning nodes, also leading to a more accurate projection of future peak loads. Future overloads and voltage constraints will be more accurately identified, leading to more effective solutions and a more accurate timeframe on when the solution is needed. In addition, the use of distributed resources (generation, storage, and demand response) represents a new set of tools for system planners. This additional information and new resource options will allow planners to more accurately determine what needs to be built and when it needs to be built.

Maintenance programs will move from reactive to predictive—Utilizing asset condition information for all critical assets, maintenance programs will predict when failures can be expected to occur. Armed with this understanding, equipment can be taken out of service for repair or replacement before failure. The lifetimes of critical assets will be extended, and the costs, dangers, and inconveniences of failures and the associated reactive maintenance will be reduced. CBM will also provide the capability to extend the lifetime of existing assets by predicting when assets should be relocated to a less stressful electrical environment. The result will be lower maintenance costs, safer maintenance practices and fewer equipment failures.

Advanced Outage Management Systems (OMS) will greatly reduce outage duration—Extended outages are inconvenient and costly to consumers and represent a loss of revenue to generators and delivery companies. Advanced OMS will significantly reduce the time to detect, locate, and diagnose outages allowing system dispatchers to focus on getting the needed resources in the field more quickly to correct the problem and restore service. And, Advanced Distribution Management Systems will complement OMS by dynamically reconfiguring system feeders and branches and by utilizing available distributed resources, to reduce the number of customers affected by an outage.

Engineering, customer service, and work management processes will also benefit —The availability of operating and asset condition information gives engineers the ability to improve their design standards and gives customer service staff the information they need to better satisfy customers. Access to the distribution communication system and its interface with existing Geographical Information Systems (GIS) will also enable a more efficient mobile work force management program.

Modeling and simulation tools will enable operators to better manage operating risk—The availability of operating and asset condition information, coupled with modeling and simulation tools, will allow both distribution and transmission operators to improve their risk management capabilities. Understanding how the Grid might be affected as conditions on it change, and the corresponding corrective actions are implemented, can improve grid efficiency and prevent unexpected disturbances. New monitoring tools such as wide area monitoring systems (WAMS) using phasor measurements will allow transmission operators to anticipate emerging problems and take corrective actions.

The "power density" of assets will increase—Advanced materials will allow higher capacity ratings on new assets and new intelligent electronic sensors and communication methods will support accurate dynamic ratings for transmission lines and other assets.

REQUIREMENTS

Achievement of this principal characteristic will impose a number of new requirements on the Smart Grid including the deployment of new applications and technologies at various levels.

Deep penetration of intelligent electronic sensors that measure both operating and asset condition parameters is needed. These sensors must be capable of monitoring at the consumer level (e.g., smart meters), distribution level, and transmission level (e.g., phasor measurement units).

Deployment of automated switching devices and systems controlled by grid operators and, where appropriate, by autonomous software agents are also needed. Grid management systems need to give operators the ability to switch distribution and transmission assets as needed. Intelligent controls that enable automatic grid reconfiguration and microgrid operation are also needed to address rapidly-changing events.

An integrated communication system to communicate the needed information to the users and systems responsible for optimizing the operation and management of the assets is needed. This communication system should also be interoperable with other enterprise-wide processes such as GIS, mobile work force management, engineering, and records management.

Process integration among all applicable users and systems is needed so that the operating and asset condition information can be leveraged and shared. In particular, an interface with the RTO is needed to ensure the optimization of operations and asset management is not limited to just the distribution system.

Advanced applications and algorithms are needed to take advantage of the vast amount of new information and control options. Real time dynamic rating applications, condition-based maintenance applications, advanced protection and control systems, and more sophisticated modeling and simulation tools are examples that can greatly enhance efficiency and reduce operating risks. New visualization methods are also needed to convert the huge amount of new data to information so that system operators can comprehend grid status “at a glance.” Situational awareness enabling a rapid conversion of information to action will be greatly improved.

BARRIERS

The following fundamental elements are needed to create a Smart Grid that meets this characteristic. Barriers to achieving each of them are presented.

Measurement of operating and asset condition data—advances are needed to greatly simplify these sensing devices so they are small, low in cost, easy to install, interoperable, and communicating.

Integrated communications systems—communications that enable "plug and play" convenience with the above sensors are not yet widely deployed at the needed penetration levels – consumer, distribution system, and transmission system. Also, the interoperability of these communication systems should allow integration with existing enterprise-wide technologies and processes. Standards are the key to this interoperability. And, since communications provides the foundation of the smart grid, the totality of applications needs to be considered when designing the communications platform.

Applications and analysis tools—applications designed around the expected higher level of information provided by a smart grid are needed. Development should be done now so that when the needed information is available the applications can be immediately deployed.

Methods to increase the power density of assets—new materials, manufacturing processes, and designs are needed that increase the capacity per unit volume of assets. Two examples are high temperature superconductivity and new energy storage technologies. Also, new approaches for calculating dynamic ratings of lines and other assets using advanced sensors are needed.

Effective change management processes—change is hard. The change process in utility organizations is often difficult to execute since traditional utility processes have been in place for many years. Changes to regulatory policy are also needed and will require substantial effort to achieve. The recent American Recovery and Reinvestment Act of 2009 provides financial motivation to support many of the changes needed to transition to the Smart Grid. Additionally, extensive work has been done by the Department of Energy and Smart Grid stakeholders to develop metrics for monitoring progress on building the smart Grid.

Asset transition process—a strategy is needed that supports a timely and low cost upgrading of existing assets so they can integrate with new Smart Grid technologies and processes. Changes to regulatory policy may be needed to allow replacement of partially depreciated equipment that is not compatible with the newer Smart Grid technologies.

Smart Grid implementation plans and business cases—A consistent approach for defining region-specific Smart Grid implementation plans and complete business cases is needed. The Modern Grid Strategy team is currently working to provide some guidance in this area.

BENEFITS

Overall the benefits of this characteristic come at a relatively low cost in that much of the information, communications, and control technologies that are needed to achieve the other six principal characteristics enable this one. These benefits can be viewed in the context of the Smart Grid's key success factors:

Improved reliability—the improved utilization of assets and the understanding of asset health will reduce reactive maintenance and, hence, improve reliability.

Improved security—a more robust grid is a more secure grid. This PC increases grid robustness by operating in the most efficient and reliable manner. Improved monitoring capabilities can also provide video surveillance for critical assets.

Improved economics—improving the efficiency of the grid will put downward pressure on electricity prices. The knowledge to build what is needed, when it is needed will result in the deferral of large capital investments.

Improved efficiency—optimizing asset utilization and more efficient grid operation will lead to an increase in the value of each dollar spent on the grid – creating "more bang for the buck." Use of advanced grid components such as power flow devices, distributed generation, storage, and others will enable the realization of these efficiency improvements. Advanced materials and the use of dynamic ratings will enable power densities to increase.

Less environmental impact—reduced losses will enable a reduction in generation for a given load thereby reducing environmental emissions that would otherwise have occurred. Improved maintenance practices and the reduction in reactive maintenance reduce the potential for accidental spills and emissions from grid assets.

Improved safety—optimizing maintenance results in the performance of less reactive maintenance which reduces the exposure of workers to hazards.

Table 1 summarizes how this PC positively impacts the six Smart Grid key success factors.

Key Success Factors	Benefit Drivers
Improved Reliability	Advanced sensors and control devices will: ■ Increase situational awareness ■ Reduce stress on assets and balance loads by enabling grid configuration changes ■ Support rapid diagnosis of problems thereby reducing outage duration.
Improved Security	■ Surveillance monitoring of critical assets. ■ Increased awareness of asset status and health. ■ More widely distributed generation.
Improved Economics	■ Deferral of large capital projects. ■ More efficient operation that reduces demand on system generation, putting downward pressure on prices to consumers. ■ Improved utility processes that reduce costs.
Improved Efficiency	■ Dynamic ratings and new materials that increase the energy transfer through assets. ■ Increased reliability of equipment at a lower maintenance cost. ■ Reduction in losses leading to overall system efficiency improvements.
Less Environmental Impact	■ Reduction in electrical losses reducing the demand on system generation and corresponding emissions. ■ Reduction in equipment failures further reducing the potential for accidental spills.
Improved Safety	■ Reduced exposure of workers to accident through improved maintenance practices.

Table 1: Positive impacts on the smart Grid key success factors

RECOMMENDATIONS

What are some of the steps that need to be taken to achieve this characteristic?

Align around a clear vision—the seven principal characteristics of the Smart Grid have been widely communicated, but more work is needed to share this vision with stakeholders, particularly those that are still uninformed. More work is needed to help residential consumers better understand the value of the Smart Grid to them and society in general.

Develop Smart Grid deployment plans—the seven principal characteristics form a common vision for the Smart Grid; however, the applications, technologies, and processes needed to achieve can vary depending on many factors – clearly one size does not fit all. The next step is to develop region-specific implementation plans and business cases to determine the value propositions for all stakeholders. Specific Smart Grid deployment plans that consider the entire vision should be developed to ensure the benefits of this characteristic are achieved in the most efficient way.

Conduct demonstration programs—regional demonstrations should include integrated solutions for optimizing grid assets as described by this PC. Metrics that monitor the incremental value that Smart Grid technologies add to improving operating efficiencies and asset management programs should be included. Best practices from these programs should be identified and communicated to all stakeholders. The American Recovery and Reinvestment Act of 2009 provides substantial opportunities in this area.

Increase R&D—additional research and development is needed to accomplish the items cited in the *Requirements* section. The American Recovery and Reinvestment Act of 2009 provides substantial opportunities in this area as well.

SUMMARY

The ability to optimize the use of grid assets and operate more efficiently is essential to realizing the full promise of the Smart Grid.

This PC is a beneficiary of the other six PCs. It requires data and information and the capability to fine-tune Grid assets, all of which are provided by these other PCs. Successful integration with operational and asset management processes are essential to the full achievement of this PC.

This PC supports real-time operations as well as longer term functions including capacity planning, maintenance, engineering, work management and even mobile workforce management. Effectively leveraging the capabilities of the other PCs will maximize the value of this one. Keeping "the end in mind" when developing Smart Grid implementation plans will ensure the benefits of this PC are realized.

Barriers may slow our progress, but despite the challenges, there is now a clear path forward.

The Modern Grid Strategy (MGS) is working with a wide range of stakeholders. The MGS will continue its outreach efforts to communicate and educate stakeholders on various Smart Grid concepts and to assist in better defining the Smart Grid value proposition.

For more information

This document is part of a collection of documents prepared by the Modern Grid Strategy team. Documents are available for free download from the Modern Grid website.

The Modern Grid Strategy

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