

# Real Time Distribution Analysis for Electric Utilities

*Abstract*— Electric utilities are finding it increasingly necessary to better monitor, analyze and control their distribution systems. Planning and operation of the grid is increasing in complexity on one hand but subject to ever more binding constraints on the other. Real-time analysis is being seen as necessary to achieve acceptable operational efficiencies and quality of service.

Real-time analysis is the combination of computerized circuit analysis with measured real-time inputs (voltage and current into the grid) and outputs (customer consumption) to determine the actual and likely near-term voltages and power flows throughout the transmission and distribution grid. With appropriate analytical tools, display options, and control systems, real-time analysis will allow utilities to actively manage the grid to achieve better operating efficiencies and to anticipate and avoid service interruptions and other operating problems.

Most of the tools required for real-time analysis are already available. Computer load flow analysis has been used by transmission and distribution utilities for decades to simulate and analyze voltage, current, and real and reactive power flow for system planning and operations. SCADA has reached almost universal usage by transmission and distribution utilities of all sizes and makes it possible to monitor and control generators, transmission lines, substations, distribution lines, and in-line equipment and devices. Smart meters have, in the last decade, become an important and widely used tool not only for reading residential and commercial meters, but also for collecting data about the distribution system.

Challenges to real time analysis and active grid management include achieving full deployment of SCADA and smart meters, obtaining the necessary bandwidth and speed of data communications, integrating data from disparate brands and vintage of hardware and software, refining the computational methods, learning to utilize the results for grid planning and operation, and transforming the design of the distribution grid over time to maximize controllability.

In this paper we will:

- Discuss why real-time analysis is needed and useful;
- Define what real-time analysis is;
- Describe how real time analysis might be made to work for rural transmission and distribution utilities; and
- Outline a pilot project being planned at Owen Electric Cooperative in Kentucky.

*Index Terms*— Distribution Analysis, Distribution Automation, Distribution State Estimation, Load Flow Analysis, Real Time Distribution Feeder Analysis, Smart Grid, Active Grid Management

## I. INTRODUCTION – WHY REAL-TIME ANALYSIS?

### A. 19<sup>th</sup> Century Electric Utility Grid

An electric utility system today looks pretty much like it did more than a hundred years ago. And, for the most part, the same technologies are still being used for generation, transmission, distribution, and metering. Generation still involves using a fuel burning prime mover to turn a generator like it did when the first one went online in the late 1800's. Power from large, central station generation facilities is delivered to remote load centers via a bulk transmission grid. The power is delivered to customers through a local distribution grid. The only things that have changed significantly in transmission and distribution are the kinds of materials and styles of construction that are being used for poles, lines, insulators, and transformers. Two thirds of all electric meters are the same electromechanical registers that have been in use for a century. Utilities still rely primarily on their customers to let them know when their service is interrupted or service quality is substandard.

Electric utilities continue their traditional approach to reliability and quality of service by planning and constructing the grid with enough redundancy and extra capacity to accommodate anticipated changes in customer demand and recover from outages and other system disturbances. The only real option that utilities have to significantly reduce the likelihood and duration of service interruptions is to add new generation, transmission, and distribution capacity and redundancy. Once the system is constructed, there are few options to adjust operations to achieve system efficiencies or other goals.

Unfortunately, the business environment in which electric utilities operate has not remained similarly stable.

### B. Disruptive New Business Circumstances

Business circumstances have changed profoundly and will continue to do so.

- (1) **Declining reliability** – Declining generation reserves, growing customer demand, restructuring wholesale power markets, and an old, inadequate bulk transmission system have resulted in declining reliability with the worst kind of outages - system wide outages sometimes spanning several states that may last for many hours or even days at a time.

- (2) **Rising costs** – Fuel costs have skyrocketed and are likely to continue to escalate. The costs of both raw materials and finished goods are exploding due to increasing global competition. Social and political issues related to aesthetic and environmental impacts are increasing administrative delays and costs.
- (3) **Increased risk** – Volatility is sharply up and growing in the availability and price of fuels, raw materials, finished goods, expert staff. New retail competitive schemes and customers' own energy management activities create unprecedented market risk. Operating an electric utility system in a post 9/11 world poses new risks of service outages and facilities damage heretofore largely limited to weather, natural disasters, and accidents. The longstanding practice of building large central station power plants far from load centers has concentrated the risk to the bulk power system from localized disasters (e.g., storms, earthquakes, accidents, equipment failures, vandals, terrorists).
- (4) **Financial constraints** – In the past 10 years, utilities' book values have declined, their return on investment has declined, and their bond / credit ratings have declined. Some have encountered severe, prolonged financial difficulties. Ready availability and low cost of capital are no longer a sure thing for many electric utilities. Increasing retail competition across the country places greater pressure than ever on utilities not to incur costs that result in higher prices.
- (5) **Environmental impact / climate change** – Electric utilities find more constraints than ever in building new facilities and operating and maintaining existing ones. Siting, design, and operations are all severely constrained by the need to reduce environmental impacts.
- (6) **No more cost-plus monopoly expansion** – The combination of items (1) through (5) above means that utilities can no longer as easily finance and build new facilities, incorporate their costs in rate base, and recover their investments with a good return anytime they need to. Utilities must perform better (reliability, safety, security, customer service, efficiency, environmental impact, etc.) with less (use existing facilities and fewer improvements and additions).
- (7) **New operating conditions** – Electric utilities face unprecedented operating conditions that exacerbate the challenges to reliability, security, and safety.

Wholesale power markets and retail competitive schemes are in turmoil. Regional transmission organizations (RTO's) and Independent System Operators (ISO's) regularly usurp utilities' control of their own generation and transmission facilities.

Many of the largest electric utilities, once vertically integrated, have split into independent generation, transmission, distribution, and retail sales companies.

Legislators and regulators are pressing utilities to provide customers with more sophisticated price signals and service options that account for the time dependent nature of utility costs as well as the long term costs of environmental impacts.

Residential, commercial, and industrial customers are increasingly choosing their own energy management and conservation schemes, competitive supply options, self generation resources, even living "off the grid" for better reliability, economy, or environmental sustainability.

Distributed conventional and renewable generation penetration is increasing, and will eventually cause profound changes in the longstanding T&D grid topology and operational schemes.

- (8) **New customer requirements** – Customers will not be content with limits on, or reductions in, service, power quality, reliability, safety, security, or economy. In fact, they will require new kinds of service options and better quality of service.

Customers expect electric utilities to offer the 24/7/365 convenience and personalized service that they have become accustomed to when doing business on the Internet.

Customers increasingly rely on advanced, mobile electronics, telecommunications, information technologies, all connected to the Internet, that in turn require increased reliability and flexibility of electric service.

As costs increase, customers demand options from their utilities that allow them to manage their energy costs as well as the environmental impacts of meeting their energy needs without undue erosion of reliability or service.

Customers have no understanding of, no interest in, and decreasing tolerance for the causes of declining electric service reliability and quality.

Consumer sentiment led Bob Galvin, formerly CEO of Motorola, to establish the Galvin Electricity Initiative.

*" . . . this landmark Initiative, which began in March 2005, seeks to define and achieve the Perfect Power System. That is, a consumer-focused electric energy system that never fails. The absolute quality of this system means that it meets, under all conditions, every consumer's expectations for service*

*confidence, convenience and choice. This will indeed result in the lowest cost system.”*

### C. Envisioning a Modern Grid

So how can electric utilities deal with these disruptive forces? By creating and operating a “smart grid.” The United States Department of Energy’s National Energy Technology Laboratory says in “A Vision for the Modern Grid,”:

***Self-heals*** – *Today’s grid responds to prevent further damage. Focus is on protection of assets following system faults. The Modern Grid automatically detects and responds to actual and emerging transmission and distribution problems. Focus is on prevention. Minimizes consumer impact.*

***Motivates & includes the consumer*** – *In today’s grid consumers are uninformed and non-participative with the power system whereas in the Modern Grid they are informed, involved and active consumers. Broad penetration of Demand Response.*

***Resists attack*** – *Today’s grid is vulnerable to malicious acts of terror and natural disasters whereas the Modern Grid is resilient to attack and natural disasters with rapid restoration capabilities.*

***Provides power quality for 21<sup>st</sup> century needs*** – *Today’s grid is focused on outages rather than power quality problems. Slow response in resolving PQ issues whereas in the Modern Grid quality of power meets industry standards and consumer needs. PQ issues identified and resolved prior to manifestation. Various levels of PQ at various prices.*

***Accommodates all generation and storage options*** – *Today’s grid has a relatively small number of large generating plants. Numerous obstacles exist for interconnecting DER. The Modern Grid has very large numbers of diverse distributed generation and storage devices deployed to complement the large generating plants. “Plug-and-play” convenience. Significantly more focus on and access to renewables.*

***Enables markets*** – *Today’s grid has limited wholesale markets still working to find the best operating models. Not well integrated with each other. Transmission congestion separates buyers and sellers. The Modern Grid has mature wholesale market operations in place; well integrated nationwide and integrated with reliability coordinators. Retail markets flourishing where appropriate. Minimal transmission congestion and constraints.*

***Optimizes assets and operates efficiently*** – *Today’s grid has minimal integration of limited operational data with Asset Management processes and technologies. Siloed business processes. Time based maintenance. The Modern Grid has greatly expanded sensing and*

*measurement of grid conditions. Grid technologies deeply integrated with asset management processes to most effectively manage assets and costs. Condition based maintenance.*

## II. DEFINITION OF REAL-TIME ANALYSIS

This new approach, the Modern Utility, requires a new approach to electric utility distribution grid operations. It requires real-time analysis and active grid management.

### A. Real-Time Grid Analysis

Real-time grid analysis is the combination of computerized circuit modeling and analysis with measured real-time customer consumption and power source data to determining the voltages and power flows in all elements (lines, equipment, devices) on the grid. Analysis is done nearly continuously to determine the real-time characteristics of the grid.

The analysis is the means to an end - active grid management. The real-time data and computation results are utilized to facilitate generation dispatch, line switching, control of in-line equipment and devices, and customer load control to achieve operational goals.

Real-time analysis provides two major results:

- Calculated present and very near term future values for voltage and current for grid elements that are not measured and monitored in real time; and
- Report and display measured and calculated data in formats and on platforms that can be conveniently understood and used by system operators, analysts and management to actively manage the grid.

### B. Generation and Transmission Grid State Estimation

State estimation is widely used by transmission and generation control centers not only to calculate the real-time condition of the generation and transmission (G&T) grid, but also to estimate the condition of the grid in the immediate future. The ability to accurately extrapolate from the current state to the immediate future, combined with appropriate system design and controls, allows for pro-active management of controllable elements to achieve operational goals like economy, efficiency, reliability, environmental impact, etc.

While the analysis of G&T grids has its own set of complications and difficulties, it has a significant advantage over distribution systems. The G&T grid has a limited number of generators, transmission lines, and in-line equipment and devices, and so is technically and economically feasible to measure and communicate to a central computer all necessary data for all important nodes and elements on the G&T system. The number of

data points for a bulk power G&T grid is very small compared to a distribution system. The technical challenges and costs of reading and communicating data and modeling the G&T grid is insignificant compared to the technical challenges and costs of planning, constructing, operating and maintaining the G&T plant. Once billions of dollars have been invested to build the G&T grid, it is not unreasonable to spend millions of dollars to monitor and control it. In fact, such monitoring and control is essential to maintain reliability, efficiency, safety, and security.

### C. *Distribution State Estimation*

Real-time distribution analysis is required for distribution state estimation, the process of predicting distribution system conditions in the very near term future. Because of the tremendous number of nodes and elements on any distribution system (e.g., hundreds or thousands of times more than for the corresponding G&T grid), it is technically impossible to continuously model the distribution grid in real time. Even if such modeling were technically feasible, it would be prohibitively expensive. The cost of continuously measuring and communicating data from every node and element is more significant in comparison to the cost of planning, building, operating, and maintaining them. So, real-time distribution analysis will be accomplished for the foreseeable future by calculating distribution grid conditions in the immediate past, (the previous day, the previous hour, or the previous fraction of an hour), and developing an estimate of the current and likely immediate future states.

## III. HOW CAN REAL-TIME ANALYSIS BE USED?

### A. *Actively Manage a Dynamic Distribution System*

Electrical distribution systems are dynamic, not static. That is, distribution grid conditions are continuously changing as a function of a variety of factors. Customer power demand and energy consumption varies continuously over time, sometimes with large, frequent changes in magnitude. G&T grid conditions can profoundly change the driving voltages and currents for the distribution grid. Temperature, wind, humidity, and precipitation affect distribution grid equipment characteristics. Changes can be caused by manual, automated and remotely controlled distribution grid equipment and devices or the aging, deterioration, or outright failure of same. Other system disturbances can result from accidents, natural disasters, and vandalism.

Some changes are infrequent and predictable such as those resulting from actions by utility employees (switching for construction and maintenance, connection of new customers, and disconnection of existing customers). Other more frequent and less predictable changes result from automated voltage regulation, current

limiting, reactive compensation, switching, and remote generation devices. The most frequent changes result from the continuous variation in the demand for power by customers.

While electric distributions systems are dynamic, without monitoring, analysis, and control based on real-time analysis, the system must be planned, constructed and operated as if they were static systems. Planning, construction and operation must be based upon predicted conditions for likely and emergency scenarios which are in turn based upon known past grid topology and loading conditions.

Today, utility planning and operating staff must make decisions about the construction and controllability of the distribution grid based on occasional system studies in which estimates of voltages and currents have been calculated for a small number of discrete peak load, off-peak load, and contingency scenarios. Operating decisions are made without the ability to accurately know or analyze existing distribution grid voltages and power flows, much less accurately predict impending conditions. So, decisions to switch lines, control equipment and devices, or manage customer loads must be based on static criteria chosen to allow ample margins of error for the unknown and changing nature of the system. The only way that this approach can work is for the distribution grid to be planned and constructed to have considerable redundancy and excess capacity.

Real-time analysis will allow engineers and operators to shift from static operations, based upon predicted scenarios, to active monitoring and control of the distribution grid. This shift will make it possible to make decisions and control equipment and devices based upon complete information from the system as it exists at the moment, or even shortly before, as well as upon the likely condition of the system a very short time in the future..This shift will further facilitate decision making and control responses that are informed by the immediate past and present status of the changing system. Operators, analysts, and management will know, with confidence, when unforeseen conditions develop.

Knowledge of the actual real-time characteristics of the electric system, along with immediate past history and predictions of immediate future conditions, allows the utility to switch lines, change taps on transformers, switch capacitors, manage controllable loads, dispatch distributed generation, and make other system tuning modifications to achieve operational goals related to economy, efficiency, reliability, environmental impact, customer service, security, and safety.

For example, a utility switches distribution lines to restore service that was interrupted because of a system disturbance, i.e., the loss of a substation transformer. Later, the switched feeder lines reach their loading limits and over current devices again interrupt service. Without

real-time analysis, the utility might not know that service was interrupted, or the extent of the outages, for some time after they occurred. Utilizing the traditional static prediction model and overly conservative safety factors, the utility may not promptly restore service to all customers after the first outage because of concerns about the potential for further overloads. This places the utility in the position of apologizing to customers for service interruptions after the fact. Real-time analysis would allow the utility to know, in detail what is occurring as it happens, and would allow the utility to take advanced corrective action through line switching and load controls. And, the utility would be able to keep its customers apprised of any adverse circumstances, maybe in advance!

The previously mentioned changes in the business environment are relevant here. In the previous example, suppose that one or more distributed generation facilities are operating on the affected lines, that one or more customers has special service reliability requirements, or that one or more customers has energy management capabilities or interruptible load, or that customer demand has grown beyond the capacity of the affected lines, but the utility is prevented by regulatory or other constraints from upgrading or expanding them. It is easy to see how real-time analysis will become increasingly important to utilities' planning and operations.

#### B. Greatly Improve System Planning

The ability to determine and document system loading and voltage conditions nearly continuously will provide substantially better data to use in planning for system growth. System planning will no longer be limited to forecasting future conditions based upon a handful of historical loading scenarios. A broad range of loading configurations, for any number of time periods, could be saved for each feeder or substation service area and readily accessed for review and analysis when planning for the future.

Even more importantly, real-time analysis and active grid management will equip a utility to plan for the future with more accuracy and flexibility. Rather than using brute force redundancy and excess capacity, the utility will be able to plan with much greater accuracy and flexibility. Improved efficiency, reliability, service quality, and reduced environmental impact can be achieved with less capital investment and O&M costs.

The ability to observe the actual performance of each system area would make it possible to regularly review planned system improvement projects and delay or accelerate them as needed. The utility will have the benefit of an ongoing system analysis instead of an analysis performed once every few years.

#### C. Provide the Ability to Respond to New Customer Service Requirements

For decades, there has been little change to basic criteria for planning and operating the distribution system. System load changed in density and magnitude, and equipment capacity and efficiency improved, but the basics of planning and operations remain the same.

In the last few years, a variety of customer issues have emerged that are likely to dramatically affect planning and operating the electric grid. These issues include:

- Power quality monitoring and control (harmonics, flicker, momentary interruptions, voltage regulation, grounding, etc.);
- Service reliability (zero outage service);
- Service flexibility (ability to change service options 24/7/365);
- Real time pricing (providing time variable price signals to customers along with the monitoring and automation tools to take advantage of them);
- Retail competition (providing options to customers to purchase their energy requirements from multiple competing suppliers along with the data and monitoring and automation tools to do so);
- Environmental impact scheduling (providing data to customers to allow them to manage their energy consumption to minimize environmental impact along with the monitoring and automation tools to take advantage of them);
- Renewable energy offerings (providing options to customers to purchase a part or all of their energy requirements from "green" resources along with the pricing, monitoring and automation tools to take advantage of them);
- Distributed generation facilities (solar, wind, fuel cell, conventional CT or engine) installed by customers for economy, reliability, or environmental impact;
- Distributed generation facilities installed on customer premises by electric utilities (in lieu of T&D construction, to reduce losses, to regulate voltage, to increase reliability, to take advantage of renewable fuels, etc.); and
- Distributed storage facilities used by customers (hybrid electric vehicles, advanced technology batteries, electric powered heat/cool storage).

While it is not a certainty that any of these will become controlling issues, it is likely these and other changes will occur more frequently and with greater cumulative impact. Real-time analysis is the only comprehensive and manageable way that will allow utilities to accommodate and take advantage of these things.

#### IV. WHAT IS REQUIRED FOR REAL-TIME ANALYSIS?

Real-time distribution analysis is not possible today. The closest thing to real-time analysis is automated outage

management based upon a detailed electric circuit model that accommodates input from SCADA and AMR. In order to move from active grid management during occasional outage management events to continuous active grid management, several things are required.

#### A. *Detailed Circuit Model:*

Computer load flow analysis has been used by transmission and distribution utilities for decades to simulate and analyze voltage, current, and real and reactive power flow for system planning and operations. The computational methods are comprehensive and mature.

An accurate and detailed circuit model is the foundation of real-time analysis. While other measured variables are necessary to achieve accurate real-time analysis, detail and accuracy in the circuit connectivity and impedance model are also essential. This requires detailed and accurate representation by phase of the connectivity and impedance of elements (lines, equipment, devices) all the way to the customer meter. Without this representation, it will not be possible to estimate the state of the distribution system with enough accuracy to form the basis for planning or operations.

Utilities have been able to generate this level of detail and accuracy in circuit models for outage management system (OMS) databases. In most cases, existing GIS, CIS, physical asset data files and existing T&D system models can be used to build the real-time analysis database. This process can usually be completed in a few months at a reasonable cost to the utility.

Accurate and detailed data is often impossible to acquire for distribution transformer impedances and the secondary voltage system between the transformers and customers' meters without a complete field inventory. Part of the challenge of real-time analysis will be development of algorithms that can establish an acceptable level of accuracy without knowing the impedance from the primary transformers to meter locations. However, having this accuracy from a field inventory and maintaining it from that point forward through continuing property records will significantly improve accuracy and detail of results.

#### B. *SCADA Data*

Real-time analysis requires measured data for the sources (generators / transmission lines / substation bus bar) of power and energy. Fortunately, SCADA has reached almost universal usage by transmission and distribution utilities of all sizes. This makes it possible to monitor and control generators, transmission lines, substations, distribution lines, and in-line equipment and devices.

Real-time analysis requires connection at the substation (or other source point) for each distribution line:

- on/off status of switch or over current device;

- amps for each phase;
- power factor for each phase;
- voltage on each phase.

To the extent that this data is available from SCADA for other elements or nodes on the distribution system, it can also be incorporated in the real-time analysis to improve accuracy and usefulness of the results.

The SCADA system must communicate all of the voltage, current and power factor values to the real-time analysis server for each feeder every time that the analysis is run. While it may eventually be technically feasible for real-time analysis to run continuously, it is not likely in the foreseeable future for a number of reasons; first, it is not likely that the customer demand and energy consumption will be available continuously for reasons further described below; secondly, running real-time analysis at intervals (every hour, every fifteen minutes or perhaps more often during system disturbances) may be sufficient. Even hourly real-time analysis runs provide information for grid management that is infinitely more manageable than what utilities have available today.

SCADA installations at most utilities can provide these readings at least every 15 minutes and many do so much more frequently, as often as every few seconds. Utilities have demonstrated the ability to obtain, evaluate, and use this kind of SCADA data for generation dispatch, customer load management, and outage management systems.

The ability to obtain these readings at points on the distribution system down line from the substation will greatly increase the accuracy and usefulness of real-time analysis. Most utilities are not currently using SCADA or distribution automation systems to read and communicate loading and device status at down line reclosers and breakers. This practice will grow in the future. Further, many automatic meter reading (AMR) devices can record and report, either periodically or in some cases upon demand, voltage, status, and cumulative energy flow for the most recent interval, i.e., the past fifteen minutes.

#### C. *Smart Meter Data*

Real-time analysis requires measured data for the sinks (customers) of power and energy. Smart meters have, in the last decade, become an important and widely used tool not only for reading residential and commercial meters, but also for collecting data about the distribution system. Unfortunately, only about one third of all meters in the country are smart meters.

The availability of customer demand and energy in real-time from smart meters is a new development that makes real-time analysis possible. Real-time analysis will require, for every customer meter, or at least as many meters as possible, the kW loading. This might be instantaneous kW, but is more likely to be the average

kW over an immediately preceding interval, (i.e., one hour or fifteen minutes).

One of the greatest challenges for real-time analysis is obtaining the necessary information. Most utilities do not have AMR fully deployed, and even if they do, most AMR systems simply do not have the bandwidth or speed to make this data available for all customers on a real-time, or even near-real-time, basis. Most will only be able to provide stored data for a certain period, such as the previous 24 hours, within a few minutes to a few hours after the end of that period.

With adequate SCADA data, as well as some experience in applying the analytical methods, real-time analysis may be possible with an acceptable level of accuracy without measured kW loading data from all meters. It remains to be seen what proportion of actual meters will be required to achieve acceptable accuracy.

Even “nearly” real-time analysis based upon historical customer data received within a few hours will give electric utilities capabilities for analysis and active grid management that are light years beyond what they can do today.

Wide experience with AMR systems suggests that, even on a sparsely populated rural distribution system utilizing slow power line communications, it should be possible to obtain accurate hourly data for perhaps 90% of meters within approximately eight hours after usage. Urban systems with municipal broadband coverage, or common carrier digital wireless service, should have the capability to see every meter every 15 minutes.

Smart meters that can measure and report current, voltage, and power factors in real time will contribute significantly to increasing the accuracy of real-time analysis. Since so few utilities have full deployment of smart meters, and since most smart meters do not yet have these advanced capabilities, real-time analysis will require algorithms that approximate these functions. Voltage and power factor measurements with down line SCADA or distribution automation equipment at strategic points will be required to compensate for not knowing the voltage at each customer meter. Even when the voltage is known at each meter, strategic measurements of the primary voltage may be necessary to offset the lack of impedance data for transformers and secondary systems, and to provide a benchmark for the accuracy of the computations.

#### *D. Fast and Easy to Use Software*

New approaches to circuit modeling and analysis software will be required to provide the necessary speed of calculation. Much of the circuit analysis power already exists in proven engineering analysis systems being used to plan and operate distribution systems. However, even the best existing systems will have to be adapted to work in real-time. It will also be necessary to develop algorithms to offset missing and inaccurate data. None of

these items represent a serious barrier to real-time analysis.

Real-time analysis will also require new ways of reporting, displaying, and analyzing distribution system status and conditions so that electric utility operators, analysts, and management can take proper advantage of the results to proactively manage the T&D grid. This will include processing and communicating data for automatic control of utility equipment and devices and will require a great deal of “learning by doing”. This method is already underway for G&T grid dispatch.

There are a couple of software challenges that are more daunting. First is the need to integrate data from disparate SCADA and AMR vendors, and from various telecommunications protocols. This is already a work in progress as utilities attempt to integrate their SCADA and AMR with their CIS, GIS, and E&O applications.

The other challenge is the development of the software required to nearly continuously accept large amounts of data from many sources into the real time analysis computer server. Again, this is a challenge that is already being worked on by utilities and vendors for real-time pricing.

#### *E. Experience*

This new tool will not be a turn-key development. Electric utilities will have to learn how to view, analyze and use the results as well as learn how to make and implement good strategies for planning and operations. As has already been the case with OMS, there will be immediate improvements in the planning and operations of T&D grids because there will be more accurate data and more options available. Even so, it will likely be many years before real-time analysis and active grid management reach their full potential. Operators, analysts, planners, and management (not to mention regulators, customers, and other stakeholders) will have to learn to deal with the new data and tools.

#### *F. New Grid Designs and Equipment*

The modern utility, also called the smart grid, represents a drastic departure from the way that electric utilities are planned and operated. Coupled with profound changes in the business environment and new advancements in technology, this will result in new ways to plan and construct electric T&D grids, and new kinds of equipment and devices to use in operating them. This strategy will not be successful if it is shoehorned into a century old approach to planning, construction, and operations. New circuit topologies, new monitoring and control equipment, and new automation devices will be necessary.

Real-time analysis is not an incremental or evolutionary change. It’s not just about bettering what is already being done. It’s about doing entirely new things. As has already occurred in computing, telecommunications, media, and most other businesses, new developments in

technology will make it possible to do new things that we can't even imagine today.

## V. PILOT PROJECT(S)

The smart grid will not be conceived fully formed and ready to go. As has been the case with every new technology, every new strategy, every new order of things, there will be a learning curve. Utilities can't advance along the learning curve until they start using real-time analysis and active grid management. The way to start is with pilot projects.

The leading T&D circuit analysis vendors must work with the leading SCADA and AMR vendors and the most progressive electric utilities to field pilot projects. These must be limited in scope so as to be affordable and manageable, but must also be broad enough to be useful.

Milsoft Utility Solutions is in the process of planning a pilot project with Cannon Technologies AMR at Owen Electric Cooperative in Kentucky. This pilot project will involve as close to complete real-time analysis as is possible with existing technology, starting with a single feeder and expanding to an entire substation. Milsoft is also pursuing pilot projects with other SCADA and AMR vendors and other electric utilities.

One of the important outcomes of pilot projects will be establishing a starting point for the minimum number of meters and down line SCADA points that are required, and the maximum amount of approximation that can be accommodated in the circuit model and load flow computations and still achieve accurate, dependable results. Knowing more about this will be crucial for utilities to be able to plan and implement system wide deployment of real-time analysis.

## VI. SUMMARY

This is not your father's electric utility business any more. Business as usual won't work. Real-time distribution analysis will be an essential tool for electric utilities in the near future. While real-time distribution analysis is not possible today, it is not hard to see how it can be done. While there are significant challenges, there are no insurmountable ones. Significant software development and testing will be required. SCADA and AMR will have to be more widely deployed and utilized. Utilities will have to become experienced in using real-time analysis for active grid management. Electric distribution grids and equipment will begin to be designed and operated differently. New technologies will emerge and be deployed.

No other technology advance has so much potential for changing in positive and beneficial ways how we engineer and operate the electric distribution system. Real-time analysis will allow us to dynamically engineer and operate our dynamic systems.

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