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Grid Modernization: A Roadmap to Tomorrow's Infrastructure… (Or "*Don't Get Lost on the Way to AMI*")

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"SmartGrid" and Advanced Metering technologies are being touted at the highest levels of American politics today. There is an air of inevitability pervading the utility industry, where 21st century technology promises to transform 20th century infrastructure, making it cheaper, cleaner, safer, smarter and more reliable. It's time to offer our customers the world class system they demand, but *is the grid really ready to be smart?* Or alternatively, *will our customers really get what they expect?*

The fact is many T&D systems are littered with legacy issues that not only impact daily performance, but compromise the potential benefits achievable through application of these newer technologies.

> **What is needed is not only a "SmartGrid" or AMI implementation plan, but an integrated approach for the grid which optimizes the costs and benefits of all initiatives, starting with the delivery system foundation (the current T&D system or Grid) and continuing all the way to the customer premise (AMI).**

In other words, a *holistic asset management strategy* is called for (heretofore referred to as a *grid modernization strategy*), one that embraces the possibilities of Smart technology but also acknowledges the challenges posed by the current aging infrastructure of many of today's T&D systems; and provides a road map to reliably meet the increased expectations of today's customers.

SITUATION ANALYSIS

With the emerging technologies that are changing the "state of the art" in Electric Distribution system engineering, a shift to implement "SmartGrid" and advanced metering technologies across the entire industry is occurring. Typically, the incremental costs cited for installing these capabilities are relatively modest and the time frame required ranges between 3 and 6 years. However, the underlying assumption that the grid on which to build this technology infrastructure has been modernized and is "automation-ready' proves false. Most electric utilities have operated under a planning and budgeting framework that places a premium on meeting near-term capacity and reliability requirements, but with limited (if any) discretionary capital to address the longer term programmatic challenges. This approach has allowed the industry to make significant improvement in its existing electric system reliability performance, but has left a plethora of technical legacy issues to address before an all-encompassing, ambitious "SmartGrid" undertaking can be undertaken, namely:

- Functioning yet aging assets bordering on obsolescence whose average service lives (ASL) have been extended well-beyond original design. In practice, with the exception of investments to address known system load growth / imminent capacity challenges or to directly improve present system reliability, the industry's current planning and budgeting criteria support a "run-to-failure" approach to prioritizing work and rely upon significant maintenance regimen resourcefulness for the system to remain operable.
- Non-standard and sub-optimally designed configurations, the result of implementing less costly, incremental "fixes" with little, if any, focus on a more comprehensive grid management strategy.
- Shortage of "automation-ready" elements (e.g. radio-controlled reclosers, remote-operated switches, "smart" relays, expanded telecommunications bandwidth and added margins for automatic load shifts) that will be required before the benefits of full-scale automation can be realized system-wide.

These technical legacy issues are largely the product of a construct for establishing rates that in effect limits capital spending. Ironically, with the current focus in Washington on infrastructure renewal and Smart Technologies, regulators are increasingly suggesting the combined impact of these issues will be a grid that appears modernized (e.g. the latest technology with respect to metering and communication), but that does not provide the customer (nor the utility) with the full benefits of automation; and from an overall system view is delivering gradually deteriorating reliability performance. Frederick Butler (a state regulator in New Jersey) said it well in his recent article, “A Call to Order-A Regulatory Perspective on the Smart Grid,” when he stated that “we should not focus immediately on the end-user and demand response; rather, we must start with the backbone – the transmission and distribution systems – before going inside the consumers’ homes.” He goes on later to state that “there is no doubt that the smart grid will bring consumers significant benefits; however, if we want to make the biggest impact, we should consider a different approach and focus on the operational side first.”

Recognizing that (1) energy and specifically electricity is playing an increasingly significant role in our daily routines and the economy as a whole, (2) the regulatory and political pressure to continually “raise the bar” in system reliability remains, and (3) there is growing sentiment to apply new technologies to effect a stepped improvement in system performance and overall energy efficiency / conservation, the paradox of not being able to afford to address the technical legacy issues, yet being pressured to fund some degree of enhanced automation, must be addressed. This realization points toward the need to develop a comprehensive grid modernization strategy that:

- Systematically assesses a utility’s electric transmission and distribution assets against a twenty-first century, world-class standard,
- Establishes actions in a manner that evolves from the more reactive “do what we can within the limited resources we have” approach to one that more proactively and comprehensively integrates past and current technologies within an optimized long term view, and
- Develops an accompanying public outreach plan that outlines the benefits and costs of the “Optimized” plan through the lens of each external stakeholder group (e.g. customers, regulators, legislators, environmentalists, and shareholders).

This strategy will lay a foundation to gain public understanding and acceptance of the investment necessary to realize the full benefits of automation (which can range up to four to five times the amount today typically associated with automation), and with the properly defined context and transparency provided in the plan, will establish a constructive dialogue with regulators and legislators, aimed at minimizing the risk and uncertainty around recovering the required capital investments.

The following discussion addresses a number of the key challenges and lessons learned in embarking on this endeavor, with the dual goal of leveraging general acceptance of the need for investments in “SmartGrid” and advanced metering technologies (including keeping the full range of options open – e.g. distributed generation and central dispatching of household appliance DSM) and simultaneously addressing the ever-expanding list of technical issues that otherwise will pose significant constraints to customers realizing the full benefits of automation. Major education, marketing and outreach campaigns, all essential to successful implementation, will be for naught if the basic needs for improved reliability and increased capacity are not met.

A TALE OF TWO UTILITIES

There are a number of motivations behind the need to develop a strategy (and subsequent plan) for the grid, including:

- Achieving sustainable improvement in system reliability,
- Developing a lifecycle view of the needs and capabilities of the network,
- Earning high ratings in customer satisfaction, and
- Satisfying stakeholder mandates around customer premise automation (AMI/Demand Response), environmental emissions reduction and energy efficiency.

Examining these motivations in some depth can be useful in determining the optimum scope and depth of the plan (technical vs. strategic), identifying the relevant internal and external stakeholders, defining the benefits to be analyzed, and assigning the focus of the plan (e.g. internal for business planning vs. external in support of a rate case). Regardless of the motivation though, the need for a comprehensive grid modernization strategy remains. The following two case studies (the actual identities of the utilities must remain confidential) illustrate this point.

Case Study No. 1 – Traditional Power & Light (TP&L): TP&L was operating on a traditional three to five year planning and budgeting horizon, necessarily directing the majority of its discretionary capital to maintaining (and marginally improving) average system reliability (SAIFI, CAIDI, and SAIDI), addressing "worst performing circuits," and responding to forced replacement situations. Increasingly concerned about the substantial number of functioning, yet technically obsolete assets operating beyond their accounting and engineering life and confronting the reality of diminishing returns with respect to investments to improve reliability (e.g. sectionalizing, adaptive relaying, lightning protection, and vegetation management), management commissioned a study to "modernize" its network. The number of technical legacy issues was daunting, and though not a reliability study per se, there were concerns that an aging infrastructure would eventually lead to deteriorating performance.

In parallel with this effort, a separate initiative developed a "SmartGrid" roadmap which was predominantly AMI and IT infrastructure focused. It quickly became apparent that full-scale automation would be limited by the aging infrastructure issues, if automation were to span from the substation to the customer premise (and beyond the meter); and that adopting an AMI/IT-only perspective would most certainly result in suboptimal decisions regarding other network investments.

Further compounding the situation was acknowledgement that the estimated costs associated with the network modernization plan far exceeded any estimates for automation (approximately five times the cost). The fact that funding would likely be available for the automation efforts, but that modernization would be subjected to the traditional rate case process, (presenting both risk and unfavorable cash flow challenges to the utility) created a real dilemma. By combining these efforts, and developing an integrated grid modernization / Smart Grid strategy, the utility, in essence, developed a portfolio of all investments requiring funding, aggregated the sum of costs and benefits at the enterprise level, and translated the resulting plan in terms easily understood by all stakeholders. The end-result was a transparent strategy that readily supported ongoing discussions with the regulator and provided a financial catalyst to offset the impact of continually declining depreciation, a comprehensive plan to substantiate a state level request for available economic stimulus money aimed at improving infrastructure, and a way to communicate and establish realistic expectations with all stakeholders (e.g. shareholders, regulator, customers, and legislators).

Case Study No. 2 – Reliable Energy Corporation (REC): REC had no study underway to modernize its grid. Though some of the same technical challenges that plagued TP&L existed, the number and depth of issues attributed to aging infrastructure and suboptimal system designs was small by comparison. Therefore, management's major focus was on developing a business case evaluation for Advanced Metering Infrastructure (AMI), and to a lesser extent distribution and substation automation. The primary driver of this focus was a legislative mandate around demand response and energy efficiency. The evaluation endorsed an aggressive AMI installation and suggested an extremely attractive internal rate of return (IRR) based on anticipated benefits to be realized in the areas of meter reading, credit and collection and metering. Thus, regulatory approvals were secured and plans were put in place to proceed with installation. Though management was confident that this was a positive outcome, they quickly discovered a number of risks inherent in this approach:

- Capital dollars allocated to AMI installation, though approved and recoverable, at least during the initial installation period (in this case five years), reflect capital dollars not invested in the basic poles and wires infrastructure. These "redirected" funds were approximately the amount of "discretionary" capital normally earmarked for gaining on the "reliability improvement treadmill." The resulting reductions in traditional reliability improvement efforts produced a gradual deterioration in overall system reliability. Although AMI benefits promised customers greater control over their usage and potentially lower bills, these same customers soon realized a growing number of service interruptions, which produced frustration and dissatisfaction.
- Beginning by implementing automation at the customer premise is usually putting the cart before the horse. Not only does it provide the illusion of a sophisticated and automated system (which may or may not be true depending on the condition of the transmission and distribution assets), it dissipates any leverage the utility might have had to recover investments tied to improving the basic electric infrastructure. REC's regulator felt that such infrastructure investments primarily benefited the utility and that they should therefore be paid for by REC themselves. Had the utility instead developed a total grid modernization strategy and plan, then consolidated the benefits, and demonstrated that REC was already investing at levels beyond that which can be sustained by current levels of depreciation, they could have framed a compelling case for partial, if not total recovery of the entire grid modernization effort.
- Further, extending the service life of components that would likely have been replaced but for the installation of the AMI, led to declining depreciation rates. These declines resulted in lower levels of depreciation embedded in current rates, which then led to a highly negative self-reinforcing pattern, wherein low depreciation rates resulted in low levels of reinvestment, which in turn, stretched service lives and further reduced the depreciation rate. This "spiral" of lowering depreciation rates precluded any potential to increase rates through traditional means, and posed a critical challenge to maintaining, let alone improving the material condition of REC's distribution assets. Without major changes in regulatory methods regarding investment recovery, REC found that any subsequent attempt at grid modernization was a virtual impossibility.

Several key insights can be gleaned from these two scenarios, (which currently represent the spectrum of circumstances that are driving the need for overall grid modernization strategy). First and foremost, the costs and benefits of addressing the range of technical legacy issues that afflict most of today's electric distribution infrastructure, are highly interrelated with the economics and likely benefits of SmartGrid and AMI, and should not be analyzed separately. Second, any comprehensive long-term strategy and plan must place a high priority on meeting near-term reliability performance mandates.

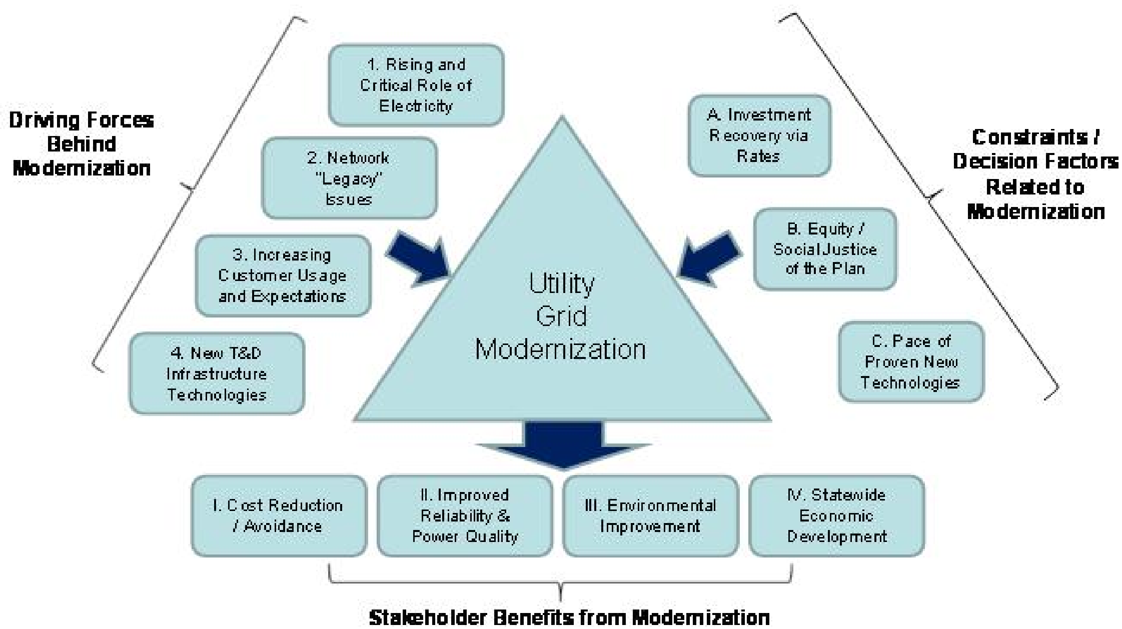
And third, successful Grid Modernization and implementation of Smart Grid technology will likely require significant changes to the current asset strategy, planning and budgeting criteria. And beyond these insights, there are a few critical challenges that need to be addressed to ensure the effectiveness of any grid modernization strategy and plan.

CRITICAL ELEMENTS TO DEVELOPING A SUCCESSFUL STRATEGY

An Organizing Framework

There is no question that developing a grid modernization strategy and plan is a complicated endeavor, requiring the integration of disparate data, multi-tiered plans, and a variety of perspectives. The complexity that these elements connote, combined with the natural inclination (for the sake of expediency) to reduce rigor, points towards the need to develop an organizing framework. Figure 1 provides an example of such a framework which has been applied successfully in several regulatory jurisdictions.

Figure 1
Context for Grid Modernization
Illustrative Example

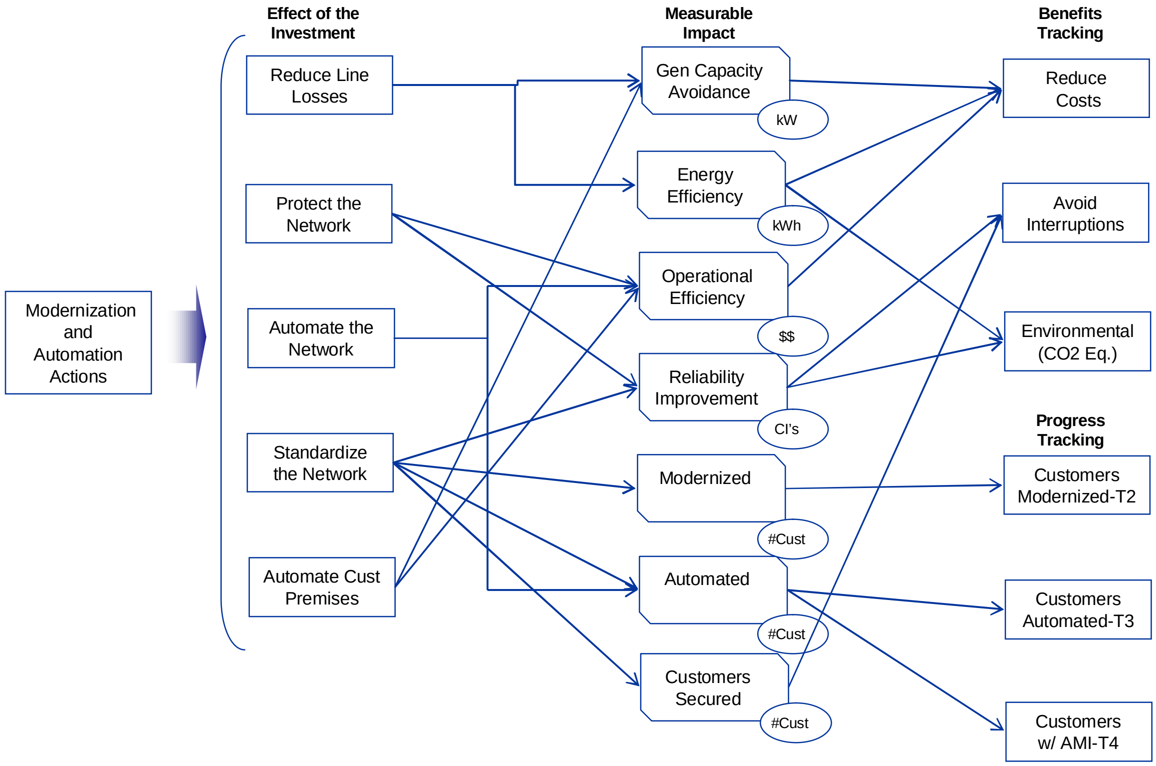


By instituting such a framework, utilities can ensure a comprehensive, yet disaggregated view of the driving forces and constraints at play here. The resulting understanding of various drivers and tradeoffs involved can greatly aid in facilitating communication across a broad and varied constituency, capturing and translating all technical benefits in terms easily understood by all parties, and supporting the integration of the broader-view grid strategy with the current operational planning process. Further, it can speed the identification and estimating of all actions necessary to achieve a modernized grid.

Benefits Measurement Framework

Tantamount to success in implementing this strategy is the ability to engender the support of all stakeholders amidst a political environment that promotes energy efficiency and reduced carbon emissions, but also within an economic climate that resists any substantial increase in rates. This requires a comprehensive benefits measurement framework which can quickly and efficiently translate the technical actions of modernization into non-technical benefits realized by external stakeholders, can capture and model the numerous "many-to-many" relationships between investments (actions) and benefits, and can ensure that all the benefits of a given investment are systematically captured. Figure 2 provides an illustrative example of such a framework where actions are initially categorized by their effect, which in turn has an impact, and ultimately translates to a series of delivered benefits.

Figure 2
Benefits Measurement Framework
Illustrative Example



Automated Analysis

There are typically 50 to 75 modernization and/or automation actions or strategies, hundreds (if not thousands) of circuits, scores of substations, and hundreds of thousands of combinations, for which actions must be sequenced, and costs and benefits assigned. Depending on the audience and specific agenda, transparency and traceability of the conditions and assumptions driving the estimates must be provided for each action and system component, with roll ups and summaries at the total system level. Further, the ability to quickly respond to the inevitable queries of management and external stakeholders and make adjustments to the plan as conditions change is essential in gaining support for the overall plan. This can best be accomplished through automating the analysis, facilitating the maintenance of a "living plan" amidst a dynamically, ever-changing environment. Figure 3 offers an illustrative example of such computational software which can be used to compute the benefits and costs of such a plan, to sequence the various investments among each applicable circuit and substation, and to provide basic cost and benefit analyses at the circuit/substation and total system level.

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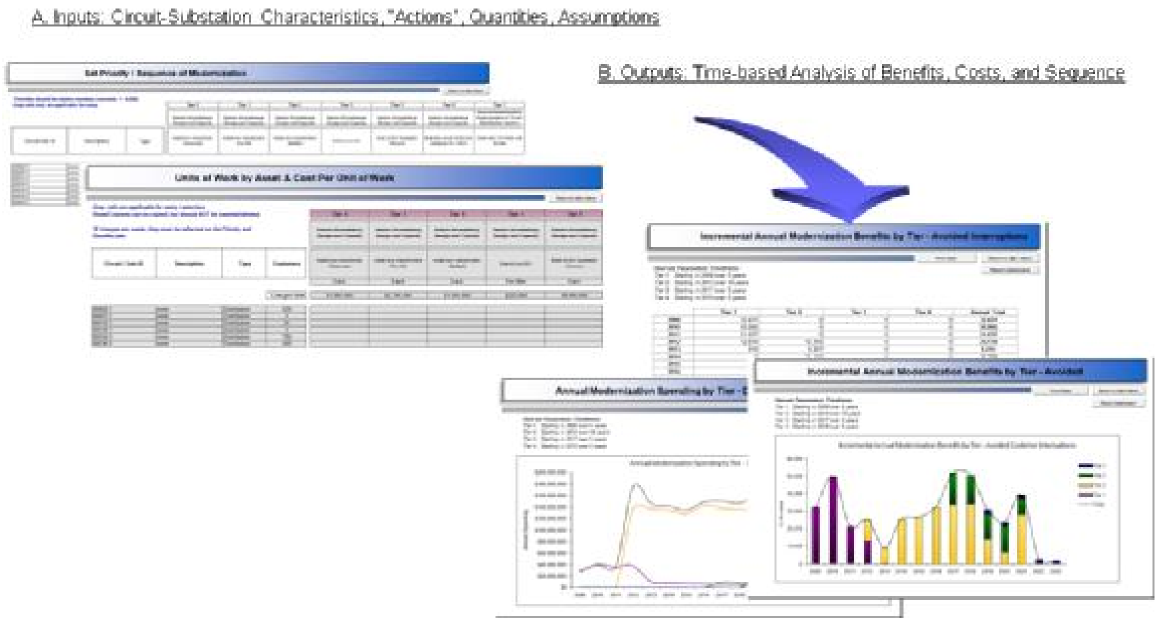
Figure 3
Computational Model
Illustrative Example



Properly configured, such a computational model not only aids in creating the "base case" plan, it allows for continued refinement throughout implementation.

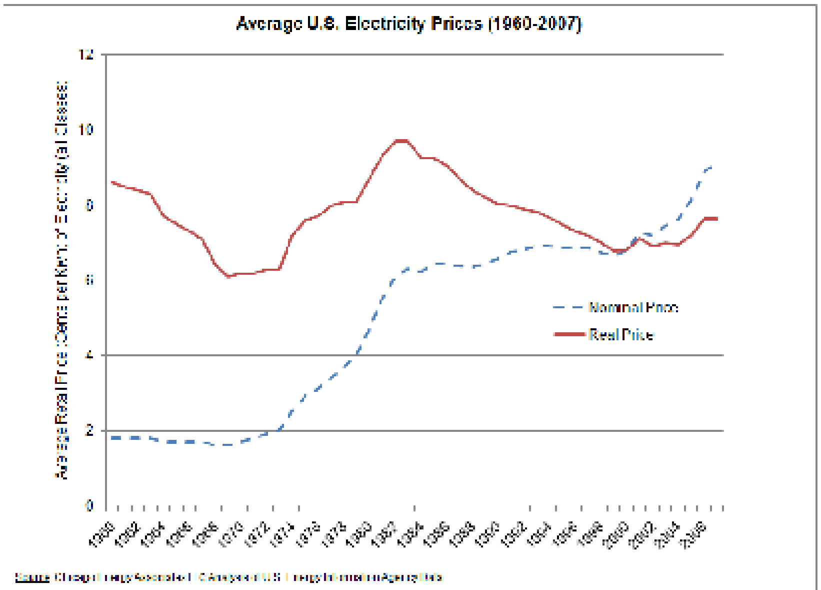
Stakeholder Communication

The list of relevant stakeholders has expanded significantly, to include regulators, legislators, customers, shareholders and in some cases labor unions; necessitating a multi-faceted outreach program to address the varying interests and knowledge levels of each group of stakeholders. All have vested, though differing stakes in the outcomes attributed to any grid modernization strategy and plan, including for example the creation of new jobs, improved reliability, reduced operating costs, reduced carbon emissions and elimination of risks. A successful strategy and plan must therefore include a communication plan to inform and put in perspective the added investments and anticipated benefits to be realized by each group of stakeholders; and in the case of AMI, ensure the customers are knowledgeable enough to change their habits and consumption patterns. Failure to develop and execute such a communication plan will likely result in unmet expectations, skepticism and under-realization of any anticipated benefits.

Anticipate Regulatory and Legislative Resistance

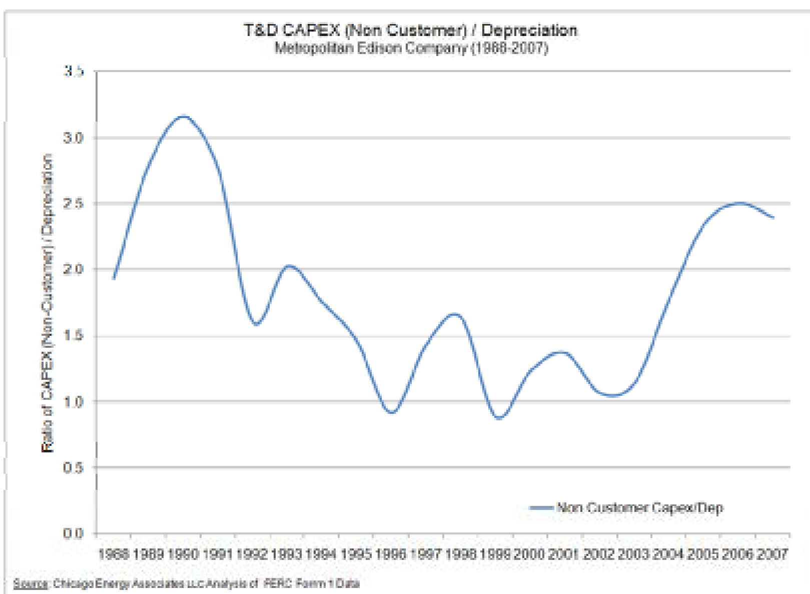
The development of a grid modernization strategy and its anticipated stakeholder benefits ultimately brings with it a healthy price tag, high enough to motivate the regulator and state legislatures to construct arguments that would deny the utilities recovery of any grid pre-automation capital investments. The rationale for this stance is that these investments are "already paid for" and/or only benefit the utility. The reality is the exact opposite, but each utility must proactively deal with this issue as part of its stakeholder strategy. Figures 4 and 5 offer interesting insights which suggest that the customer, first and foremost, is already receiving value commensurate to the current rates (in fact, an argument can be made that the value provided far exceeds the cost); and that the utilities, as a whole, are investing at levels consistent with their rate structures.

Figure 4
Nominal and Real Price Trends of Electricity



NOTE: The nominal cost of electricity has risen over time, but the real cost of electricity has been relatively unchanged for decades. This is a remarkable insight given the continually increasing role of electricity in driving the economy.

Figure 5
Relative Capital Spending Levels



NOTE: This represents a typical profile of the ratio of T&D CAPEX (Non-Customer) to Depreciation over the past 20 years. Since this plot indicates that the estimated replacement rate (industry-wide) has been greater than 1.0, the industry has invested at levels consistent with current rate structures. Applying that logic, customers (on the whole) have not only been "getting what they have been paying for," and argument can be made that from strictly a shareholder perspective, the utilities have been "over-investing" in their electric infrastructure.

The point of this discussion is to emphasize the importance of anticipating the perspective of each stakeholder and proactively address any potential misconceptions that might impact implementation of the grid modernization strategy and plan.

A CALL TO ACTION

Thus, the challenge is multi-faceted: to provide greater clarity in differentiating between strong current performance and a strong underlying system, shift the focus from evaluating the benefits of individual investments to assessing the cost and benefits of an entire portfolio, partner with your external stakeholders to redefine asset management, budget and planning criteria, and assume a leadership role in educating and setting the pace for simultaneously modernizing and automating the entire network – from the substation to the customer premise. A confluence of factors, ranging from regulatory and legislative interest in AMI, to renewed national interest in revitalizing electricity infrastructure, translates to greater receptivity to solutions proposed by today's utility executives, and the emergence of more creative funding strategies. The companies with a well-articulated grid modernization strategy with a clear and credible implementation plan will be in the best position to fully capitalize on and benefit from this opportunity.

ABOUT THE AUTHOR

Jeffrey W. Cummings is a Principal of UMS Group. His diverse background in strategic and operational planning for investor-owned utilities and larger municipalities has recently been applied to T&D network modernization, electric distribution reliability, fleet optimization and regulatory strategy. Email him at jcummings@umsgroup.com.