Innovative Retail Strategies in Smart Grid Solutions

Jiyuan Fan, Ram Shetty
GE Digital Energy
Atlanta, GA 30339
jiyuan.fan@ge.com, ram.shetty@ge.com

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Abstract

The core value of Smart Grid is to enable Smart Energy Consumption and Generation, which requires innovative retail strategies to empower the consumers for wisely consuming energy. This paper addresses a few novel concepts in defining the retail market strategies for improved overall energy efficiency through proper incentives to the key players of Smart Grid in the value chain, i.e., end consumers, distribution utilities, energy producers, and regulators. With the development of advanced Smart Grid technologies for enhanced grid reliability and availability, the retail strategies can be well deployed at the distribution level and all the way to the end users. This paper also discusses the anticipated impacts and challenges on issues like consumers' behavior, the distribution grid operation and wholesale market operation.

1. Introduction

Power Marketing is one of the seven important domains identified by the NIST Smart Grid Interoperability Roadmap. But, so far the attention has been mainly paid to the wholesale market at the transmission level, where the market mechanism enables the competition among the bulk generators for the most economical energy generation. The incentive mechanism in the wholesale level can lead to economical generation schedules in meeting the naturally formed total demand from the consumer population, but has little impact on the distribution level of operational efficiency or on changing the consumption behavior of individual consumers on as-need-basis, leaving a big loop hole in optimizing the overall energy efficiency. Studies have indicated that as much as 40% or more of the electric energy produced in the United States has been either wasted or consumed at incorrect time periods. Such wastes and inefficient consumption affect everyone's benefit. Such wastes include the energy that the consumers use carelessly but may not actually need or consume during periods when it is more expensive to produce and deliver, resulting in the electric utilities, on the other hand, spending more for the excessive energy resources and infrastructure needed to meet the electricity demands.

The core objective of Smart Grid is to enable smart energy consumption at the consumers' side and smart energy generation and efficient delivery at the utilities' side. It is the consumers' behaviors that drive the entire value chain of energy efficiency, starting from the end users, the distribution and transmission operators, and all the way up to the bulk energy generators and the wholesale markets. In the idea scenario for maximizing energy efficiency, the consumption trend should closely track the economical generation capacity, i.e., the combination of the base-loaded fossil and nuclear generation and the variable renewable and hydro generation. This would happen only if consumers could take actions at their end to manage their power consumption in a most economical way, which requires that consumers are empowered with cost-reflective dynamic pricing information on the electric energy as they need. It is the utilities' responsibility to provide such information to consumers. This requires a well-designed retail marketing mechanism that can ensure all the stakeholders, i.e., the consumers, the utilities and power providers, can work together toward the maximum energy efficiency and share the benefits from the end-to-end efficiency improvement as rewards among all parties involved in the transaction. While considering the growing penetration of renewable energy resources and the distributed generation at the distribution grid, the value chain becomes more complicated because the end users will no longer be purely consumers but energy producers also at some time periods. More advanced and innovative retailing strategies are needed to ensure the effectiveness of the market mechanism with all participants, either the bulk energy providers or the end users with generation capability, being treated equally, without discrimination.

In this paper, we discuss a few novel ideas in defining the Retail Power Market (RPM) mechanism for improved overall energy efficiency. The key RPM players are the consumers, the energy providers and the distribution utilities and the critical success factor for the RPM mechanism to succeed is on developing a financial incentive program that motivates the RPM players to take appropriate actions. Once the incentive plan is defined, it is fairly straight forward to implement it using state-of-the-art Smart Grid technologies. This paper will also discuss the anticipated impacts and

challenges to the distribution grid operation and consumers' behaviors, and the overall energy efficiency at both wholesale and retail levels.

2. Novel Concepts in Defining RPM Strategies

As discussed above, the key to improving system-wide energy efficiency relies on empowering the consumers to change their energy consumption behavior. That means facilitating a better consumption patterns which aligns more with economic generation curves; instead of always having the generation capacity reactively catching up the consumption patterns.

Secondly, consumers also should have the freedom to choose their preferred energy providers to promote Open Competition (OC). The RPM mechanism should be designed to offer both the Open Competition and the Cost-Reflective Pricing (CRP) structure. However, it is the CRP that provides the key incentives to the consumers for smart use of energy. It provides a mechanism for consumers to consume by keeping in mind their objective to maximize their incentives offered under the RPM program. This raises an important question – what would motivate electric power distributors and power providers to support the RPM mechanism and make it available to consumers? The following sub-sections attempt to answer the question by addressing a few of the key points in defining the RPM strategies:

✓**Roles of Regulators:** Power distribution Regulators, such as the Public Utility Regulation Councils, can play a critical role in defining the RPM strategies and they should take the lead to design the CRP structure. The CRP structure has to be comprehensive enough to ensure fair and effective pricing rules and policies to guarantee the energy providers and the consumers can effectively work towards maximizing the overall energy efficiency and appropriately get rewarded from the savings achieved. The pricing rules and policies also have to ensure the grid operators, e.g., the utilities, get rewarded for operating the grid, delivering the energy with high reliability, availability, and for expansion and technology upgrade oriented investments to improve service quality. To compensate for these expenses, utilities should be allowed to charge certain amount of fixed grid connection fee and grid usage charge proportional to the energy delivered as they sign-up consumers. They should also be allowed to add certain amount of surcharges to high peak consumptions on a daily basis to discourage possible inefficient consumers with extremely abnormal peak usages, especially during high demand periods. Regulators should also be responsible for governance of the RPM mechanism, which includes closely monitoring and auditing energy providers and the utilities for their compliances to Retail Power Market rules, compliance to grid reliability and the efficiency guidelines. Regulators may need some special rules or regulations to apply proper penalties or punishments to RPM traders and grid operators in case of severe violations or non-compliances to the market and grid operation regulations.

✓**Role of Consumers:** To effectively empower the consumers to change their energy consumption behaviors, the CRP should be defined in terms of daily or hourly schedules or even down to minute level of dynamic signals in each rate program option. These dynamic pricing schedules and signals should be made available to consumers in real time or in advance, depending upon the rate program a consumer chooses. The objectives of the rate programs should be able to incentivize consumers to shift the consumption from higher demand periods to lower demand periods. For the utilities, the resulting benefits would be the reduced use of peak generators during high-demand periods, the reduced need to down-shift power generation during lean periods, reduced congestion and overloading conditions on the grid infrastructure, further prolonging the life of their investments. As part of the RPM mechanism, it is necessary to define a fixed price-quota of energy consumption for each tiered price plan; similar to how wireless phone companies' tiered usage plan. All consumers consuming at or below their plan will be charged at the contracted base-rate. Any additional consumption exceeding the quota will be subject to higher pricing. This "Stairway Pricing" strategy is explained in Figure 1.

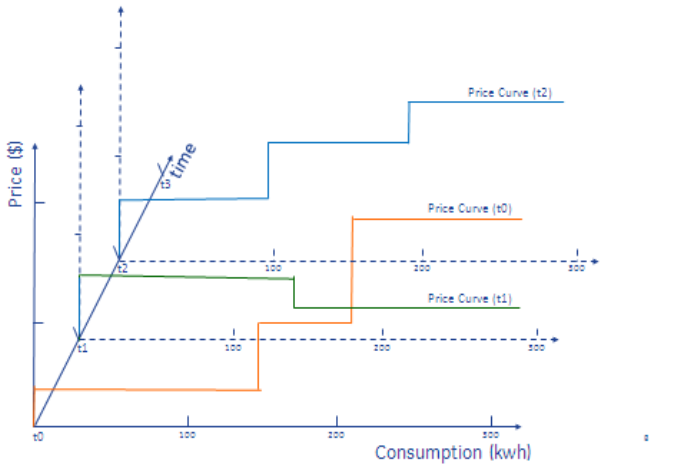

Fig. 1. Dynamic Stairway Pricing

In Fig. 1, a 3-dimentional chart is depicted to show the layout of "Stairway Pricing". It can be seen from the

chart that a stairway shaped price curve can be defined for each time interval to implement the dynamic pricing. It can be noticed from that users are discouraged for any extra consumption above their base-quota at certain time periods by applying higher rates. This can effectively urge the users to think of the economic justification for any extra energy consumption at those time periods. For the users who consume the power below their base-quota, only the base-rate is applied even though in a peak time periods. On the other hand, at some time periods when the grid is with lower demand and surplus generation capacity, the consumers may be encouraged to consume more but pay reduced rates for their extra consumption to reward their contribution toward the cost savings, e.g., avoided base-load units' shunting down. The size of the base consumption quota and the sizes of the incremental steps of a user may be determined on the basis of the user's normalized daily average consumption over the most recent histories, e.g., last 3 – 12 months. Moreover, an upper limit may be applied in determining the base quota for each user to limit possible extreme cases that a user may significantly waste energy and form high monthly averages but pay the discounted base-rate. At the same time, a low bound of the base quota should also be applied for users to take either their average consumptions or the low bound as their base quota, whichever the biggest is. All the rates, including the base rate and the incremental rate steps in the "Stairway Pricing", should be defined as globally applicable to all users who choose the same pricing program. The sizes of the incremental energy blocks subjecting to the increased rates may also be defined as global and equally applicable to all users. Advanced cost-reflective pricing algorithms are needed to determine the incremental energy blocks and the corresponding incremental rates for different time periods for the best compromise between the optimal overall energy efficiency and the users' best needs for their life style.

- ✓ **Roles of Utilities and Independent Energy Providers:** Power utilities or the independent energy providers can define their competitive rate programs to expand their customer bases. The dynamic pricing schedules or real time signals have to be available to their individual users in advance or in real time. Utilities may offer multiple rate plans to consumers to opt from. Upon completion of the contract terms, consumers should be allowed to switch their service providers. In order to offer competitive rate plans, the energy providers need to be granted with certain authorities and have automated systems to conduct the retail market operations, conduct extensive market studies and run the cost-reflective pricing algorithms. Ultimately, the pricing programs should be designed to incentivize consumers to consumer power smartly that aligns with real time cost-reflective pricing.
- ✓ **Net-metering Scenario:** Smart Grid enables not only pure energy consumers, but also enables small scale energy producers to sell back energy to the utility grid. Injection of the distributed energy can be beneficial to overall energy efficiency. However, net-metering can provide tremendous challenges to the distribution grid operation in terms of managing grid reliability and generation scheduling. It would be reasonable for utilities to apply additional charges to the consumers who can become energy producers and need net-metering capability for selling power back to the grid. While becoming energy producers, the consumers should be treated equally as the utility energy providers without discrimination, including the rate and operation rules.
- ✓ **Distribution Grid Congestion Scenario:** The implementation of RPM mechanism may lead to congestion problems to the distribution grid. Special strategies or policies need to be installed to provide rewards to the consumers whose actions help to reduce congestion, and on the other hand, impose penalties to those who contribute or increase congestion. But, utilities should not be allowed to take advantage of congestion penalty based income to prevent unscrupulous utilities from creating artificial congestion. In fact, the strategies or policies have to be designed by the regulators such that the utilities or the system operators will subject to penalties for any congestion that lead to the initiation of the financial rewards or penalties to the consumers. This means that the system operators should be encouraged to do their best in optimally planning and operating the grid to avoid the congestion problems, such as through feeder network reconfiguration, load balancing or transferring, as well as voltage and var controls for reduced energy consumption without the consumers' awareness.

For effectively tracking and responding to the dynamic pricing schedules or real time pricing signals, consumers need to install smart energy management units and smart metering systems to accurately monitor, optimally plan and dispatch their energy consumptions for the best compromise between the cost savings and the personal comfortableness or convenience of life-style. On the other hand, the utilities or the energy providers need to deploy advanced Smart Grid technologies to manage the grid for maximum availability, reliability and delivery efficiency. Advanced pricing algorithms and marketing systems need to be developed to determine the price schedules and real time pricing signals that can precisely reflect the aggregated energy cost and effectively lead the consumers to consume the energy in the

most economical way. Of course, all these have to be guided and managed through regulations.

Consequently, the introduction of RPM mechanism at the distribution level will have resultant impacts on the Wholesale Power Market (WPM), the bulk generation planning and scheduling. Today, the WPM and the bulk generation can do a great job on the generation planning and scheduling because the total demand in a grid fully depends on the natural factors on which the 24-hour or even 168-hour demand curves can be forecasted with accuracy of 2% or better. With the implementation of RPM, the total demand will no longer be determined by the habitual behavior of the consumption pattern, but will be driven by consumers' response to retail market price signals. The price schedules, on the other hand, are dependent on the demands at the individual time intervals. This forms a mutual dependency that will introduce considerable challenges to the generation planning and scheduling. Advanced technologies also need to be developed to successfully handle these challenges.

3. Conclusion

This paper addressed a few novel ideas in defining the retail power market strategies for improved overall energy efficiency with fair incentives to the key players in the value chain, i.e., the energy providers, electric distribution utilities, regulators and consumers, where the incentives to the consumers play the key role for the entire value chain. Today consumers are not able to get a share of savings from deploying in smart grid technologies. We believe that a RPM mechanism along with proper regulation to share the benefits accrued will address this disparity. The advanced Smart Grid technologies can help to implement the RPM mechanism at the distribution level. For achieving the desired end-to-end energy efficiency, the consumers should be allowed not only to choose their preferred energy providers but also to choose pricing programs that allow them to track the economic generation capacity and take advantage of the price differences for the best compromise between the economic benefits and the need, for a comfort level of life-style. It is also pointed out in the paper that the introduction of RPM is likely to introduce great challenges to the grid operation, the bulk generation planning and scheduling and the wholesale power markets, for which some new Smart Grid technologies may needed to be developed.

4. References

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5. Biographies

Jiyuan Fan (IEEE PES S'88, M'90, SM'95) received his BS degree from Taiyuan Univ. of Tech., Taiyuan, China in 1979, MS degree from Chinese EPRI, Beijing, China, 1982 and PhD's degree from Clarkson University, New York, USA, 1989. He worked as a Post Doctorial Research Associate at Texas A&M University, 1989-1990. Since then, he has worked in the Power System Automation and Analysis areas with the companies of Advanced Control Systems, Inc. (Efacec) in Atlanta, Valmet Automation (Televent) in Houston, Beijing Sifang Automation in China. Since 2008, he has been with GE Digital Energy as the Strategic Planning Leader responsible for technology and product planning in Smart Grid.

Ram Shetty (M'09) received his Bachelor's degree in Mechanical Engineering from National Institute of Technology, Karnataka, India and Master's degree in Robotics from National University of Singapore. As the Market Segment Leader for GE Energy's Digital Energy business he leads strategic programs to identify, develop and commercialize Smart Grid technologies. He has over 25 years of experience in automation technology field and strategic marketing area. He has led the development of end-to-end automation technology solutions for multiple industries including Electric, Oil & Gas, Automotive and Semiconductor manufacturing. He has a patent in M2M wireless communications. His other professional experience includes business owner, strategic marketing consultant, robotics research and development, and automotive manufacturing.