

AUPTDE Conference, December 2009 Tunisia

Title:

DEMAND OPTIMIZATION WITH SMART GRID TECHNOLOGY.

Author:

Derek Macfarlane B Sc. C.Eng MIET MIEEE

GE Energy

Derek.Macfarlane@ge.com

Introduction

A few years ago, the business drivers for investing in electricity infrastructure were safety, customer service and economic. The relatively low fuel prices created a situation in which it was difficult to justify large, long-term investments in alternate technologies for generation. However, today there is awareness of some challenges to our lifestyles on this planet that are permanent, and provide a sure foundation for investment that is needed to address the new drivers affecting our environment:

- The ecological end game threatened by global pollution
- The available fossil fuel end game threatened by our burn rate compared to the rate of creation (irrespective of the amount discovered or extracted)
- The increasing demand for electricity as more of the world's population seeks their rights to life, liberty and the pursuit of happiness, in their own countries
- The increasing demand for electricity in the affluent, mature economies as they attempt to reduce their carbon footprint, moving towards sustainable forms of energy production and usage. (Electricity is the most flexible and convertible energy form)
- Competitiveness across the global village as different countries win or lose a manufacturing base to their economy.

Demand optimization is the realization that complete customer freedom to achieve their lifestyle or business aims by switching on electricity usage as they need it and paid for it, is today a simplistic solution the world can no longer afford.

Demand optimization is an essential tool for the utilities because the complexities introduced by renewable embedded and micro-generation are confusing the traditional means of assessing load connected to the network; the utility and the utility systems need to get smarter. Our customers are being sensitised to their impact on the planet and there is a will to a) achieve or protect a lifestyle above survival and with a growing number of comforts, and b) save the planet with minimal change to lifestyle plan or company direction. Very few individuals or businesses are going to fundamentally change their direction' they are, however, open to achieving the same aim with a smaller carbon footprint.

Smart Grid technology represents an opportunity to create a fundamental shift in emphasis for electricity utilities as they move from reactive to pro-active strategies. For instance, to date, technology in the form of IT systems have focussed on efficient REACTION to loading issues, Energy Management Systems, (EMS) scheduling generators to FOLLOW load patterns as economically as possible, constrained by reliability and contingency planning. These developments have been successful in

keeping a high reliability at an affordable cost to customers and enabled stable countries to develop their economies with little constraint from energy supply, but their operation is based on an assumption of unending dependence on nuclear and fossil fuel combustion to generate electricity and there was negligible effort in place to pro-actively negotiate with the customers to change their pattern of demand to optimize generation mix. (larger industrial interruptible tariffs being the exception).

Distribution Management Systems (DMS), REACT to customer expectations of continuous electricity supply in whatever quantity they require, while dealing with network loads, new construction and planned maintenance outages and REACT to unplanned events such as faults on the network. These developments too, have been successful in reducing customer minutes lost per incident and improve CAIDI and SAIDI performance of networks – but they did little for Customer Interruptions (CI) as measured by CAIFI and SAIFI, the interruptions continued to occur, its just that the duration of the outages was reduced. Today the grid requires becoming PRO-ACTIVE in outage avoidance rather than reacting to outages which could have been foreseen if data was available in the right hands at the right time.

With these new drivers in place, the energy industry, governments, entrepreneurs and customers are seeking solutions with all the ingenuity that the human race can bring to bear. Smart Grid is a prism through which the electricity power industry views the spectrum of new initiatives and provides the tool sets that utilities can use to adapt their existing infrastructure to meet the challenges of these fast, large and unique changes to their networks and network operation capabilities.

What is a Smart Grid? And where does Demand Optimization Fit

Smart Grid is the integration of power network equipment, communications network and IT applications to deliver reliable, safe, good quality electricity, efficiently to customers and yet mindful and constrained by the economic and ecological impact of the generation scheduling adopted to meet that load. It can be considered as a concept built on three pillars:

- Delivery Optimization – dealing with decreasing the use of polluting generation options, increasing the overall efficiency in converting energy to electricity and increasing the efficiency with which the transmission and distribution systems deliver power to our meters at home and at work. The electricity generation portfolio increases diversity introduced by wind generation, biofuels, clean coal technologies, solar generation and other renewable energy sources and can include embedded connection of these generation sources within the Distribution networks and micro-generation activities within customer premises.
- Asset Optimization – dealing with the good management of the utility industry’s assets, making full use of the assets without destroying them or shortening their viable lifetime. The transmission and distribution networks technologies including loss reduction techniques, improved information availability, improved network loading and performance visibility, improved monitoring and diagnostic technologies enabling improved anticipation of network behaviour and loading. These tools impact on both delivery and asset optimization.

- Demand Optimization, the subject of this paper, is the management of peak demand by controlling the timing of power consumption. The introduction of means of managing point of usage and times of usage of electricity in the customers' premises focuses around deployment of smart meters, smart appliances and industrial processes, integrated communications and IT applications all supported by commercial incentives to influence end customer behaviour.

Demand Optimization

The reality of the situation is that customers do not identify Demand Optimization as their responsibility; most of them do not understand electricity any more than they understand the internal combustion engine that drives their car. Electricity is a commodity they have paid for – it is to be delivered with the quality and reliability promised and at a price they can afford. Incentives through tariff design, therefore, need to be meaningful and must encourage the desired behaviour. Similarly in business, their interest is proportional to the percentage impact of energy costs, quality and reliability on their profitability. In heavy engineering and processing industries it is vitally important to their viability and competitiveness, and in many commercial organizations heavily dependent of IT services, the quality and reliability of delivered power is crucial to the delivery of their services.

Therefore, Demand Optimization has three Critical to Quality challenges:

- Optimization operations must be near invisible in their effect on lifestyle or business or customers will not bother to use it
- Provide cost effectiveness to customers measured in reliability, quantity and quality of supply and cost.
- Enable the dissemination of energy data as useful information to customers and to the complete utility community who subscribe to it across the various departments

Demand Optimization also has two allies:

- The environmental challenges affect everyone and every business and a growing minority of customers are looking for ways to reduce their global carbon footprint, and Demand Optimization can be used to meet this requirement.
- The tools provided with Demand Optimization also provide customers with the means to identify the energy usage that creates their maximum demand and their overall electrical energy usage and this is the starting point in reducing their overall consumption, and, more importantly, can identify ways to spread their load and reduce their peak demand.

Demand Optimization, therefore, is concerned with capturing more detail about energy usage in the premise and is also concerned with distributing this data in the form of information and knowledge to customers, incentivised through availability of tariffs to alter their pattern of energy consumption and to network operators, asset managers and network designers as well as to the traditional use of usage data to create electricity bills from which the utility income is derived. A key concept in Demand Optimization is, therefore the ability to communicate between a meter with embedded intelligence, the

premises owner, the network operator, and the energy supplier – each with relevant information to enhance their decision-making and effectiveness in their respective tasks.

Demand Optimization Explained by Scenario

The customer, therefore, has enabled the utility, via an interruptible tariff, to adjust space and water heating settings and control the times at which these devices are heating. The customer, of course, has unimpeded access to use the heat. Further sophistication could detect an empty house or business premises and restrict the building to low maintenance activity, switching off devices on standby, etc. and then switching them on and re-synchronising them on detection of the motion. The domestic solar panel continued to generate whilst the house was empty and the meter, in fact, exported power to the grid for several hours using an export tariff. The owner's car is now an electric vehicle and on return to his premises he connected the car to the charger. The owner has the option to charge now at a peak tariff rate, or let the network operator schedule the charge any time before 6 am next morning at half price via an off peak tariff. The customer can check the energy usage and carbon footprint of their decisions over time and also see the financial position compared to an historical reference point. In this scenario, there is integration between tariffs available and the usage behaviour of the premises owner; there is integrated communications between the meter and the appliances, the solar generation, the car charger and the security system. There is integrated communications from the meter backhauled to a meter management system from which the wider community of utility departments can access information useful to their activities. There are proactive features avoiding unnecessary energy usage avoiding peak times and filling in discretionary load in times of low demand. This has the beneficial effects of increasing the base load component, generation that can be continuously and efficiently running, constrained by the lowest demand from the network and decreasing the peak demand. By publishing this data beyond the metering and billing applications, other departments can become pro-active based on the availability of information. The next scenario will follow this data back up through the delivery process chain.

The network operator can obtain the details of energy consumption, and voltage levels from the premises via the DMS interfaced to the meter management system. The DMS already knows the connectivity of that address to the local transformer from its network model, and can check the common node loading with similar data from every other connected customer, the request to charge the car overnight has been added to the predicted overnight load profile of the transformer and a new load scheduling function plans the sequence of loading instructions for this and neighbouring premises to remain within the capacity of the transformer and the LV feeders. The system alerts the DMS that now 4 premises have taken the electric car-charging tariff, the LV feeder is at risk of overload should 3 more premises adopt electric cars. This alarm is routed through to the design office as a request to assess the design options. The current situation is shown via SCADA enhanced by periodic load flow interpolating at points where no SCADA exists. The transformer itself has a three phase smart meter and the correlation between the customer meters summated and the transformer meter is reaching the lowest acceptable correlation factor. This implies losses – possibly from an incipient fault or occasional contact with vegetation or theft or additional unmetered connections for street lighting.

This alarm diverts automatically to the DMS where a task is created (within the integrated OMS function), for a crew to investigate loss detection; for now, it is a low priority fill in job, but should the situation develop, its priority can be increased.

The MV feeder is also modelled in the DMS; this includes all customer transformers, embedded generation capacitor banks, etc. deployed along the feeder. The DMS has data from integrated SCADA and periodic DPA calculations and loading conditions can raise alarms and invoke automatic load reallocation intelligently to lesser-loaded interconnected feeders. Again, as automation options dry up with increasing load, alerts can be sent to system design to assess the network loading and design a network upgrade. In this scenario, there is integration across all the functions of DMS, from SCADA load flow calculations, switching management and outage management as well as interfaces to meter management and system design, enabling pro-active action on incipient faults, theft discouragement and potential overload identification and redesign.

The DMS SCADA system is integrated with substation automation, protection and monitoring devices; again a correlation of load sent out from the feeder source and the customer transformer points of delivery will show a correlation factor affected by losses and by embedded generation and use of capacitor banks, etc. and a low correlation factor merits proactive investigation. Of course, the substation automation protection and monitoring systems in place are also detecting anomalies at the primary substation level, such as a monitor of partial discharge occurrences in switchgear and cables, and on line analysis of transformer insulation oil detecting trace gases in oil. This data is siphoned out of the real time SCADA into a Historian database where small changes in relationships between items of data can be fed into expert systems to predict deterioration that requires investigation prior to a fault occurrence. In this final scenario, the DMS SCADA system integrates with the wider network locations dispersed in primary substation sites around the network. The data collected there by the substation automation, protection and monitoring and diagnostic technologies is again made available to the wider utility community of departments enabling improved and pro-active decisions to be made.

Conclusion

All of these scenarios currently exist, in part, in various utilities around the world. There are very few totally new, undeveloped functions described; but, what is evolving, is greater integration, more standardisation and larger scale examples. There are three common themes:

- Integration
- Interfacing
- Pro-active initiatives

Integration of functions is used where these functions share the same values and qualities, such as within the DMS there is a shared imperative for real time events and data to be co-ordinated presenting a single consistent situation to all the users of that system 24 x 7. The interface of functions is used where data is useful across boundaries that are fundamentally different in nature, such as the interface from operations (24 x 7) to design (8 to 5), operations to asset management, operations to metering; in all of these cases, the systems have information of use to the other functions, however, there is a front office

/back office difference, a strategic or creative activity which is fundamentally different from the executive implementation. The co-ordination here involves a future event, such as the maintenance schedule for next month, including the information derived from the live systems in real time. The design department can project load increase based on planning data and developers investment plans, however, the incremental addition of load embedded within mature parts of the network is a regular source of unpleasant surprises as operators lose the spare capacity to swap load around. Demand optimization data plus the scope of common node connectivity from DMS can anticipate loading problems and electric car charging is an example of an emerging new load replacing a fossil fuel. The take up of electric vehicles will follow an affluence profile affecting the premises of the rich followed by the professional and the commercial van fleets, until eventually the van fleet drivers select electric for their own private cars. The alterations to LV/MV design to accommodate these substantial point loads will happen sporadically, therefore, it is all the more important and valuable to interface from operation to design and be pro-active in identifying networks at risk of overload.

Pro-activity is the final common theme, and this reflects right through the smart grid, commencing with Demand Optimization technologies enabling customers to select tariffs that will enable the desired outcomes of freedom to pursue lifestyle or company profitability, but doing so in a way that enables the utility to also pursue its imperatives of reducing carbon footprint through optimised selection of generation options.

The delivery infrastructure of transmission and distribution assets and operations control face huge changes in driving down losses, safely incorporating embedded and micro-generation which will consort with genuine load increases to confuse the real time assessment of connected load which is effectively masked by dispersed embedded and micro-generation. Data from Demand Optimization technologies are an essential component in the equation that elicits the real loads being met and, therefore, enables generation scheduling and the contingency plans that are needed to protect the supply reliability, supply quality and the protection of asset life expectancy. Demand Optimization, therefore, is an essential part of the integrated whole concept of smart grid.