Opportunities and Challenges of Integrating Wind, Solar and other Distributed Generation & Energy Storage

Kevin Meagher, *CTO,* and Rajan Chudgar, *Member, IEEE*

***Abstract*--Basic guidelines for the preparation of a technical work for in nearly every industry vertical, as the industry matures the industry goes through a transformation that involves innovation and efficiencies. For each of these areas the innovation and efficiencies are a direct correlation of the technology and capabilities and commonly societal and business development of the time. For example, as our far past farmers moved from hand planting to plows and wheels. In the near past, the introduction of cell phones completely changed what had been a highly regulated environment and then further innovations in the cell phone business has changed how we all talk, text, and surf thanks mainly to the iPhone and the "killer apps". The energy vertical is very similar to the cell business, where to most people it is a commodity that is a monthly expense item on a bill or a line item in the GL. What our industry is looking for is the "killer app" that can transform and "jump" the industry into something that customers get excited about, enable the promised value propositions, and make Power solutions easy to use from a central controls basis. This paper talks about the opportunities and challenges for distributed energy or "new energy sources" and how the strategy most companies are using are flawed due to the lack foresight of the Killer application and changing the business proposition including parallels to other industries and technologies.**

***Index Terms*:**

1. Building Energy Management System [1] – This system is based on IT hardware and software with three primary components: Building automation and control; Energy efficiency technology and systems; and demand response systems.
2. Distributed Energy [2] - The location of distributed generation is defined as the installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the customer site of the meter
3. Killer APP - A software application that is exceptionally useful or exciting. Killer apps are innovative and often represent the first of a new breed, and they are extremely successful.
4. I-Phone [4] - The iPhone is Apple's first Internet-enabled smartphone. It combines the features of a mobile phone, wireless Internet device, and iPod into one package.
5. Microgrid [5] - A Microgrid is defined as an integrated power delivery system consisting of interconnected loads and distributed generation units which as an integrated system can operate in grid-connected mode, autonomous (islanded) mode, and ride-through between these two modes.
6. New Energy Sources [6] - focus on energy systems that tap into inexhaustible, ubiquitous, and clean sources of energy generation, such as solar, wind, tide, and geothermal, but also including non-conventional avenues such as zero point energy, radiant energy, cold fusion, and magnet motors
7. Power Management Systems [7] - ability to diagnose the reliability and energy efficiency of complex electrical infrastructure in real-time. Armed with this information, site operators are given the insight they need to optimize facility performance and anticipate downtime, maintenance or repairs
8.

I. Introduction

THIS document covers the integration of distributed generation and storage into mainstream systems.

Most of us in the world today view electricity like any other commodity – similar to gas, water, telephone, trash – we do not pay attention to it accept for once a month when our bill comes in and then for about 5 minutes. Market studies show that most people consider these commodities to be a necessary evil and they only pay attention to any detail when there is a perturbation or abnormality that would cause a measure for concern (e.g. spike in a bill). In general for power and energy services, customers pay their bill without looking at what are other options or suggestions on how to improve our efficiencies or improve their current situation. Basically they do not want to go through the trouble.

This was also true of the telephone industry for years. Back in the 80's and 90's most people had a land line where they

Kevin Meagher is with Power Analytics, 9208 Falls of Neuse, suite 215, Raleigh, NC 27615 USA (e-mail: kmeagher@poweranalytics.com).
Rajan Chudgar is with Power Analytics, 9208 Falls of Neuse, suite 215, Raleigh, NC 27615 USA (e-mail: rchudgar@poweranalytics.com).

would pay attention for about the same amount of time as paying their electric bill. The sea change event that began first the regulatory change was in introduction of long distance carrier MCI. This led directly to the breakup of the Bell operating companies, spurring competition and innovation that ultimately created the environment for the introduction of the cell phone.

Much like the evolution of the telephony world and especially cell phones, the power industry is seeing regulatory change an introduction of innovative technologies like photo voltaic, electric vehicles, energy storage and other forms of generation that are well suited for the distributed and deregulated power industry. The primary issue is how to facilitate the introduction of these technologies in a manner that serves the best interest of the consumers of power and the producers of power.

Much like the experience of early adopters of telephony changes early attempts were of limited value. The biggest suggestion at the time was if there was a way to get consolidated billing with some of their other bills, consumers would be interested. Additionally, customers had very little education on optionality and capabilities that they had, and frankly they did not believe that these value added options were worth the trouble in order to get marginal savings to their bottom lines. Part of this was due to the budgeting cycle and the division of responsibilities (facilities folks did not pay the billed and CFOs did not maintain equipment) and the other part was that they did not want to "go through the trouble".

With the cost advantages that deregulation brought to the end users, new technology like cell phones quickly found early adoption and growth initially as a business convenience then as a necessity. Developing economies in fact never had the centralized model of telephony and jumped immediately to the distributed cellular model. A very compelling model for developing economies now with distributed power generation rather than the primary model we have today for centralized generation and distribution.

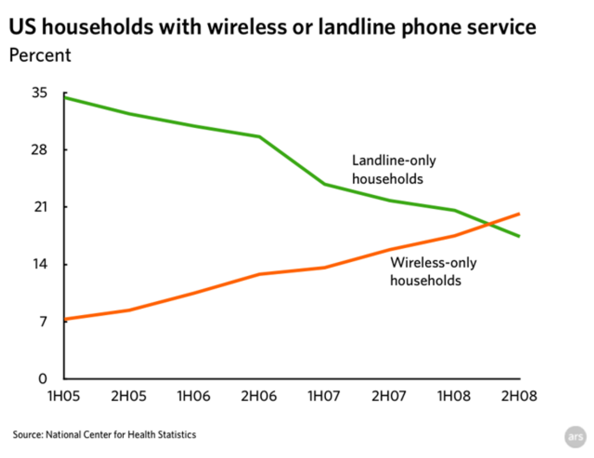

Fig. 1. US household shift from landlines to cell phone technology graph

Continuing a growth trajectory of cell phones meant expanding the use cell phones of cell phone capability and breaking the traditional barrier the fact that most people thought that cell phones were a privilege (mainly due to cost barriers) and many customers used cell phones as a methodology for improving reliability of their business. After years of throwing more and more hardware to try to get customers to buy cell phones (new phone types, new boards, new chips) including lowering the price due to economies of scale, the major innovation that changed the industry was the smart phone including Blackberry, Apple iPhone and the "killer apps". This innovation brought a new way of thinking to the industry and greatly increased the market penetration of how people use their cell phones as well as ease of use (now the question is not "why go through the trouble" but instead "what else can the cell phone do").

What the iPhone did was provide a centralized intuitive platform for customers, but this alone was the not reason for the massive cell phone expansion. Instead it was the "software applications" that were created to allow customers to use their cell phone to do everything from calling a friend to surfing the net, to using their phone as a GPS, and finding the nearest gas station in a rapid ease of use manner without purchasing more hardware. The cell phone became MORE THAN just a bill that people paid once a month; it became a part of their lives. This is the transformation that the Power business is on the brink of moving towards.

II. Power as the "Killer APP"

In the electric power industry, we have been on the forefront of numerous innovative and technological solutions. Back in the 70's when mainframes were first developed; the electric industry was one of the first industries where it was determined early on, that with computer technology you could increase reliability of the grid due to the automation and centralizing, and reduction in response times. In the bulk generation and transmission grid, we have made further advancements in automation, centralization, planning, efficiencies, and equipment that have allowed us to view thousands of data points in milliseconds and respond rapidly as quickly. We have also developed contingency plans and security plans that have allowed the USA bulk power grid to provide over 99% up-time. [8]

These capabilities and lessons have been long in development and costly, but they have provided the foundation that is critical for the distributed generation and new energy environment. Some of the key elements in the bulk grid that were early lessons is that thorough planning of changes to the electric grid provided greater predictability of the outcome, which is critical for reliability. We also learned that centralized data and controls are critical for automation, operations, and general management. There were also learning around requirements for state estimation and information, real time analytics, scenario planning and operational training, ease of use for operational screens, and standardization of data integration. Finally, the bulk grid learned that throwing more and more hardware at a problem, while providing incremental value, the overall marginal cost did not justify the investment.

With most power customers, if they believed that they needed reliable power supply, the customer would purchase an automated transfer switch, a back-up diesel generator, and register their equipment with the local utility and they were off and running. The barrier for entry to ensure additional end point reliability against what the utility provided was very low since the utilities ENCOURAGED their customers to “plan” for outages, disasters, or abnormalities in the bulk power grid. The motivation for the utility was that if the customer had back up generation on-site and there was a mass power outage; the customer could stay on back-up power for some time before they would call in and complain to the utility. This allowed the utility to prioritize other outages/restorations and still provide high value service. Additionally since the generation was predictable, there were not voltage or frequency issues that needed to be addressed.

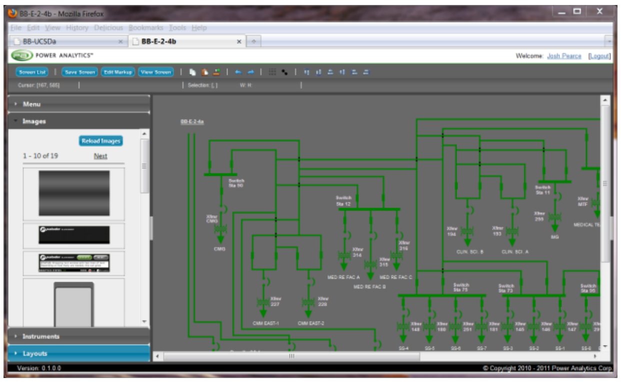

Fig. 2. Flexible, Built in layout manager and designer provides single point integration and design experience.

Since many customers have diversified electrical equipment (e.g. switch gear, interconnections, meters) and diesel back up generation, and given the fact that many of these customers do not understand power management, they invest in new energy sources like solar, wind, or storage based on commercial value propositions that many times do not provide the outcome that is expected. Additionally, when customers invest in these items they do not take into account additional costs (interconnections, additional equipment, etc.) and do not understand the drop in efficiency due to lack of central coordination. Lastly, the utilities for the most part do not endorse distributed generation since it is not predictable and does not (in many cases) increase reliability. For these reasons, there is a large barrier for entry for distributed generation to end point customers. One of the key findings in our industry is that there is not a simple methodology to show customers the value proposition for distributed generation that is reliable due to the last of a centralized power management solution.

These predicaments as well as bad or no power planning are causing a lot of utilities to question the value of distributed generation coming onto the grid as well as the ability to sustain stability at the bulk grid level. In specific instances where there is a high level of solar or wind installed at customer sites where the customers are sending excess power back to the grid, the utilities have put in requirements for costly interconnection studies BEFORE additional distributed generation can be implemented, or cutting the ability to sell power back to the grid, which greatly diminishes distributed generation value proposition. So you have to ask the question, “What is missing that would allow for seamless integration of distributed generation onto the bulk grid and how can we overcome these barriers”.

With the lack of rules around storage and the cost barriers storage has against standard UPS (uninterruptable power system) equipment, in many cases customers do not believe that batteries are the best economical option. What is difficult for customers to understand is the value proposition for energy storage and why a single customer would need to purchase batteries when these could be used for more global reliability.

All these items and more suggest that the lack of the “centralized killer application” is what is needed to help the industry move forward. As mentioned, right now our industry either throws additional costly hardware at the solution or the customer does not understand the value proposition. , One unfortunate approach is the utility does not endorse the solution by putting up costly barriers to dissuade the use of distributed generation. All these items make the value proposition for distributed generation difficult for customers to move forward. In addition, many distributed generation and energy storage companies will tell you that due to these reasons the sales cycles for customers greatly expands due to the need for pilots or 3rd party analysis. All these items lead to some of the following questions that are distributed generation barriers.

What if the customer did not have to have a full time electrical engineer on staff to purchase and interconnect solar or wind – where do I find these people? What if there was an application that could provide solid power planning analysis with a solid industry proven methodology at the customer level, and why is this not provided with distributed generation? What if interconnection agreements could be based on REAL data and REAL information on how the customer in installing distributed generation? What if all this information was available on a cell phone or touch pad or other ease of use and intuitive centralized systems? What if the guess work was taken out of the value proposition?

All these questions are what customers are asking, but yet our industry still believes that the answer is throwing more hardware at the problem, which is not the solution. Solving these questions is the answer to distributed generation and moving distributed generation into the mainstream customer value proposition.

III. Power Management System with Distributed Generation

All distributed generation sources "claim" that they have the ability to centrally manage the customer's power system, and they claim that they can do this without any additional information/integration. What we have found is that this is absolutely not the case. Additionally, if the customer has equipment from a competitors (multiple building management systems, BMS), solar, wind, diesel, plus switchgear etc., the competitors will not provide information on how their data can be accessed or how to integrate/control their information for a centralized solution. For example, if a customer installs solar and has a BMS and a diesel generator with an automated transfer switch (ATS) at the interconnection point from different vendors, none of these distributed systems can natively talk to one another to coordinate optimized generation/load management based on Microgrid conditions., None of these systems has the ability to centrally manage all the data or provide holistic understanding of the Microgrid capabilities or conditions.

IV. The solution – "Power Industry Killer App"

What our industry needs is a shift from hardware and control algorithms to simple applications that executives and facilities managers can easily configure and set up on a centralized platform. The applications have to be configurable to meet different customer requirements but also have interconnection and analysis capabilities to provide utilities assurance in the data, and connect to vendor equipment. Some of the base requirements would be:

1. Planning capabilities to create 1-lines and analysis around Power Flow and protective studies
2. Contingency Analysis and simulation capabilities
3. Ability to create Scenarios and Plans for 24-48 hours in advance for all Power equipment
4. Real time State estimation capabilities
5. Real time connection to all power consuming or generating devices
6. Near Real time analysis with the ability to provide results online
7. Near Real time notifications, warnings, and alarms
8. Converting Solar and Wind generation from intermittent generation to "predictable" using highly accurate data and converting information to fuel sources
9. Operational dashboards and screens for all equipment and sources of load and generation
10. Simple secondary controls
11. After the fact compliance and operational reports

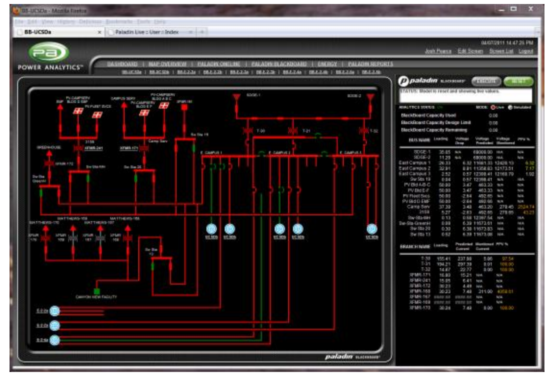

Fig. 3. Blackboard Screen provides analytical tool for power system with "what if" scenarios

V. Summary

With these high level requirements and a process to implement these requirements, what customers would be able to do is quickly enable distributed generation within their current environment, quickly obtain interconnection agreements, and also quickly determine what their real value proposition is. In general these are the base requirements for an end use customer Power Management System. The issue that many customers have is distributed generation vendors do not provide a Power Management system and most customers do not realize that this is the fundamental requirement in order to obtain the value from distributed generation.

Multiple groups and companies are determining the definitions of Smart grid and its interoperability. One of the best guidelines to date is IEEE 2030 [9] which "provides a knowledge base addressing terminology, characteristics, functional performance and evaluation criteria, and the application of engineering principles for smart grid interoperability of the electric power system with end-use applications and loads. The guide discusses alternate approaches to good practices for the smart grid. provides a knowledge base addressing terminology, characteristics, functional performance and evaluation criteria, and the application of engineering principles for smart grid interoperability of the electric power system with end-use applications and loads. The guide discusses alternate approaches to good practices for the smart grid."

Without a Power Management System solution the challenges in the Power industry with distributed generation becomes nearly insurmountable and unsustainable.

VI. Acknowledgment

The authors gratefully acknowledge the contributions of John Jennings for his work on the original version of this document.

VII. References

[1] Jevan Fox, "pike research Working definition of a Building Energy management System (BEMS)," Pike Research Blog, September 10, 2010.

[2] Thomas Ackermann, Goran Andersson, Lennart Soder, "Distributed Generation: A definition," Electric power Systems research 57 (2001) 195-204.

[3] Ziff Davis Inc., *PC Magazine Encyclopedia*, http://www.pcmag.com/encyclopedia_term/0,2542,t=killer+app&i=45817,00.asp. 1996-2011

[4] Sam Costello, About.com Guide iphone/ipad, http://ipod.about.com/od/understandingiphonemodels/g/iphone_def.htm

[5] IEEE Panel Session, "Renewable and Alternative Energy Resources", IEEE Canada – Electrical power Conference, October 25-26, 2007, Montreal, Quebec, Canada.

[6] Sterling D. Allen, "New Energy Congress", http://peswiki.com/index.php/New_Energy_Congress, November, 2005

[7] Kevin Meagher, EDSA Power Management patent, June 18, 2010

[8] Pew Center, *Global Climate change*, http://www.pewclimate.org/docUploads/SmartGrid.pdf p.14, August, 2011

[9] *IEEE: Draft guide for Smart Grid interoperability of Energy Technology and Information technology Operation with the Electric Power System (EPS), and End-use Applications and Loads*, IEEE Guide 2030, September, 2011.

:

VIII. Biographies

Kevin Meagher – CTO Power Analytics. Kevin Meagher is internationally recognized as a leader in defining power analytics, data acquisition and communications. Kevin is responsible for the introduction of key technologies in the power management world including the model based approach known as Paladin Power Analytics as well as advanced energy management and pattern recognition learning systems.

Mr. Meagher has authored numerous papers on power, energy, and high availability architectures and over the past 25 years has lead development organizations and provided strategic planning for companies including Eaton, Invensys, Computer Associates and IBM. In 2010, Mr. Meagher was listed as one top 100 most influential in Smart Grid by Green Tech Media. Mr. Meagher was selected by the National Academy of Sciences to be part of the "Shifting Power: Smart Energy Grid 2020" advisory team.

Mr. Meagher has undergraduate degrees in biochemistry and business and an MBA from the University of Colorado.

Mr. Meagher is the author and creator of the Paladin Power Analytics™ process and has to his credit more than 15 patents in analytical processes.

Raj Chudgar - Raj Chudgar was born in the USA on June 30, 1973. He graduated from University of Louisville Speed School. His employment experience includes ExxonMobil, Black & Veatch, SunGard, ERCOT, and numerous clients while working as a consultant. His special fields of interest include SmartGrid and Microgrid development, Power System market development and strategy, Business development for power management companies, and assisting innovative power technology companies around energy market entry and energy market capabilities.

Editor's Note: Kevin Meagher and Rajan Chudgar were employed at Power Analytics Company at the time this paper was published. Power Analytics is a privately held developer of software solutions for the design, simulation, deployment, and preventative maintenance of complex electrical power systems. Founded in 1983, its software products are used by thousands of commercial, industrial, governmental, and military customers worldwide to protect more than $100 billion in customer assets. Primary offices are located in San Diego, CA and Raleigh, NC with over 30 sales, distribution, and support offices located throughout North America, South America, Europe, Asia, and Africa.