Intelligent Automation and Controls of Power Industry Microgrid solutions

Moving the world from bulk G&T to Distributed Automated Intelligent Power

Rajan Chudgar
Power Analytics
9208 Falls of Neuse Rd, Suite 215
Raleigh, NC 27615
rchudgar@poweranalytics.com

John Jennings
Power Analytics
9208 Falls of Neuse Rd, Suite 215
Raleigh, NC 27615
jjennings@poweranalytics.com

***Abstract* — Power is one of the fundamentals in developing and developed nations world-wide. Over 80% of the world's population does not have reliable power. Without guaranteed power, nations quickly lose capabilities, efficiencies, and other critical infrastructure to their people and livelihood. The barrier for reliable power, in the past was the large investment requirement for centralized bulk generation. Additionally, the belief was that without large centralized power, the nation would not get efficiencies needed to provide reliable power.**

Across the world today, still many countries have inconsistent power and see rolling brown or black outs hourly or daily. At best developed countries have, reliable and secure power that is centrally managed through a bulk power grid and sometime governed by central government or large corporations. However with the advancement of distributed generation, substation automation, Microgrid ("MG") control software, the industry is going through a fundamental change. The change is bringing on smaller Microgrid pockets, smaller generation due with less capital investment, and higher efficiency solutions that can compete neck and neck with large bulk generation. All of these items, while critical for the new "World Power Infrastructure" still lack some basic building blocks for the transformation to take its final shape. This paper will describe some of the concepts, barriers, lessons learned, and next steps to move from either unreliable Power structures or Central Bulk Power to Microgrid solutions with Distributed Automated Intelligent Power solutions.

Keywords-component; Microgrid, Power Generation, Automation, Controls, Virtual Power plants, distributed generation, frequency droop, communications, co-optimization,

I. INTRODUCTION

Virtual power plants and Microgrid solutions ("VPPs") utilize hardware and software systems to efficiently manage an increasing diversity of electricity generation, energy storage, net metering, and demand assets. In the United States, VPPs not only deal with the supply side, but also help manage demand and ensure reliability of grid functions through demand response (DR) and other load shifting, load optimization, load shedding, load shifting, and load cycling approaches, in real time. Some of the examples, barriers, and lessons learned can help with development countries jump start their programs into greater power reliability.

Developing countries without any large-scale fundamental bulk power infrastructure upgrades (which are very costly and timely), utilizing VPPs can stretch supplies from existing bulk generators and secure reliability MG programs, delivering greater value to the customer and the country, while also creating benefits to the host distribution utility. One of the key advantages is the ability for VPP solutions to provide additional energy, capacity, and ancillary services to secure reliability of the grid in real time when needed. When compared to the peaker power plants that dominate electricity markets worldwide in utilization for response to market and reliability events, one of the primary advantages of VPPs is they can react quickly to changing reliability conditions without a significant ramp time in real time. An additional advantage is that the capital investment for VPPs and Microgrid solutions is the fraction of the price, and the time to market, of what is required for larger bulk generation facilities. This would be a huge advantage to developing countries that are looking to "jump start" power capabilities and tie points to their grid.

The VPP universe specifically pertaining to reliability can be divided up into three distinct segments: (1) Large Industrial and Commercial Microgrid based demand side VPPs, enabling load shedding, load shifting, or load curtailment; (2) Supply-side VPPs, as in distributed small generation, back up generation, or battery storage; (3) Mixed Asset VPPs, the ultimate goal of the VPP, bringing distributed Generation and Load together and providing energy, capacity, ancillary services, and the capability to assist with frequency and voltage control during reliability events.

II. AUTOMATED MICROGRIDS (AUTO MG)

A. Background

Active Microgrid programs are where the utility manually sends out information associated to reliability events and participants make adjustments due to agreements that they traditionally have had with the utility. Traditionally, Active Microgrid programs are not a good fit for reliability events due to the manual operations and the lack of real time automation, controls, and capabilities. As Microgrid programs evolve and real time events become more important for reliability due to the initiation of distributed intermittent generation, storage, and electric vehicles, regulatory entities are seeking a transition to Auto MG based programs as one option to address this concern. Auto MG is a fully automated solution that can programmatically shift generation or load to address market and reliability events at low voltages. Auto MG is becoming an important resource in several jurisdictions and markets worldwide for reliability implications including additional capacity, voltage, and frequency control, where time is critical.

Auto MG is an important application of the VPP approach that is already well-established in the commercial and industrial market through automation and intelligent controls. In an Auto MG solution, a customer, typically supported by automated controls and information technology solutions, installs minimal equipment which enables responses to events or system reliability needs/conditions, signaled by a utility. The versatility of these solutions is that they provide real time capabilities at low voltages that can be leveraged into the market to address immediate reliability and commercial requirements. The customer and utility in turn, are compensated for power performance by following dispatch instructions including energy, capacity, voltage, and frequency response.

B. Automated Controls

Automated Controls solution industry giants have entered this market as full-service providers mostly on the hardware side, as have new IT-oriented competitors following with “apps” that can provide additional automation and intelligent controls. These companies typically provide a suite of services including design of control installations and telemetry, remote management of energy equipment, management of response to calls for power/voltage/frequency, and fulfillment of technical and administrative requirements, such as monitoring and verification of performance. The ultimate goal to the utility is to provide secure 7/24 reliability and commercial based products to the regulatory bodies without the customer ever noticing a change to their conditions.

In the residential sector, which is traditionally around 50% of power consumption; utilities have long used one-way direct load control to reduce peak loads in the face of emergency conditions. As of 2006, over 232 such programs were in operation and controlled over 6,000 MW of load throughout the US. As Microgrid enabled appliances and intelligent controls become more widely available and less expensive, and control solutions are more secure and adopted with the installation of advanced hardware (meters, distribution automation), the scope of residential Auto MG programs is likely to increase. For example, customers receiving dynamic signals may be able to choose thresholds at which their settings would be automatically adjusted without changing their behavior, or water heating or refrigerator operation would be automatically reduced in a passive manner based on reliability events to prevent rolling brown out or black outs.

C. Autonomous Control Functions

Autonomous control functions imply that the microgrid can continue operating with the loss of a component or generator. With one additional source (N+1), the system can ensure complete functionality with the loss of any source. [1] One important aspect of autonomous controls for distributed generation is the ability of islanding from the utility grid. The important steps in regards to islanding are transferring power from a steady state when both the grid and microgrid are regulating output power. Important control functions must take into account:

- Voltage regulation is necessary for local reliability and stability. A Voltage vs. Reactive Power (Q) Droop controller is required to prevent large circulating reactive currents and eliminate voltage and/or reactive power oscillations.
- When the microgrid goes to islanding mode, Power flow vs. Frequency Droop is an important factor. Many electrical items are frequency dependent. As the distributed generation shifts for the macrogrid to microgrid, frequency increases and decreases based on the generation capacity available.

III. THE NEED FOR CO-OPTIMIZATION [2]

Larger commercial and industrial customers have increasingly advanced energy management systems or, indeed, industrial process management systems capable of responding to demand response control signals reliability events, and/or real-time prices, and capable of providing information and validated response data back to utilities and market operators. More sophisticated building management systems are able to manage on-site thermal storage. They can also use the building itself as a source of thermal storage, for instance, by "pre-cooling" the building in early morning hours to enable reduced energy consumption later in the day at peak hours (Load Shifting). However, many of these Microgrid solutions lack the capability to make real time adjustments for reliability events due to the lack of telemetry, performance of metering signals, security concerns, and/or any number of software solution issues.

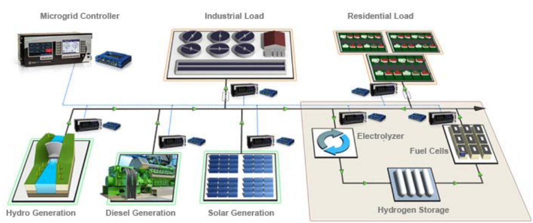

Figure 1: Typical Microgrid Components [3]

In the near future, with the introduction of cutting edge secure software solutions and advanced meters these kinds of facilities will have the potential to combine building and process energy usage, on-site generation, thermal and electric storage, and even electric vehicle charging into a local network to co-optimize all resources against forecast weather conditions, basic usage demand, market reliability information and energy and capacity market prices, so as to minimize the impact of reliability events onto the grid by providing products that reliability entities can leverage, such as ancillary services for frequency response events.

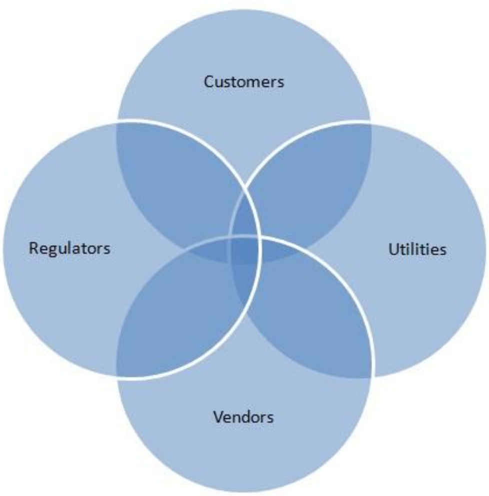

Figure 2: Interface for smart grid [4]

Advanced solutions can provide continuous updating of what is available and factor the potential revenues and market events from ancillary service provisions into the co-optimization.

IV. Advanced Control system requirements

Transmission expansion is clearly an important aspect of grid modernization, but this path includes all the challenges described above with the additional challenge of land availability. Hence, applying advanced technology to enhance the existing grid is the appropriate parallel path, one that deploys the concepts of a smart grid.

National control standards are under development based on the Energy Policy Act of 2005, section 1254 [5] and IEEE 1547 [6]. These standards provide a uniform standard foundation for interconnection of distributed resources with electric power systems. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.

There are five key technology areas, as shown in the Figure 1, which serve as smart grid enablers. These technology areas apply to every level of the grid and represent an important opportunity to address most transmission concerns. [7]

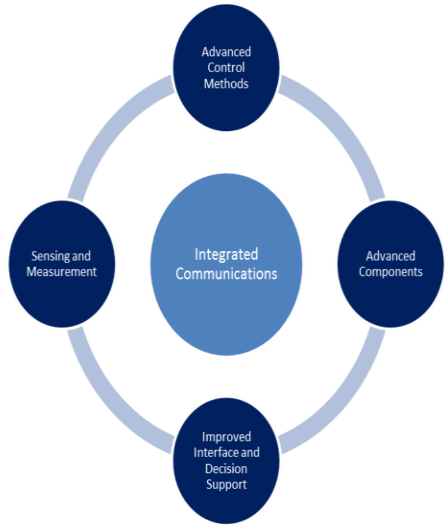

Figure 3: Advanced Control System Requirements

A. *Integrated Communications*

The key to success for industrial microgrid solutions is integrated communications. This feature ties the hardware, software, and infrastructure seamlessly together to act as a single system or network. It is important that the information is analyzed thoroughly and correctly in a network configuration – simple metering does not provide a system wide solution for the microgrid.

B. *Advanced Control Methods*

More complex transmission and distribution systems require more sophisticated controls. Historically, the electrical system coordination removes faulted components as quickly as possible from the network. Future solutions will utilize real-time data that can be applied to relaying schemes to prevent outages and adapt to reflect real-time operating conditions.

Integrating renewable sources can be a challenge due to their intermittent nature; however, they can be very useful in buffering variations in supply and demand. The control method must be scalable to take into account integrating multiple generation sources seamlessly for the customer.

C. *Advanced Components*

Power electronics is enabling the technological requirements to enable greater control of flow, voltage and power quality. One significant advancement in power electronics is in fault limiting devices. As additional generating sources are added, existing equipment short circuit ratings are eventually exceeded.

One of the most important advanced components is storage, since it transforms intermittent renewable generation from a simple energy source to a provider of dispatchable energy.

D. *Sensing and Measurement*

Metering is essential to providing valuable information to the master control power management system. Voltage, current, and power quality data can be analyzed with diagnostic tools to reveal issues before they occur and offer mitigating solutions.

E. *Improved Interface and Decision Support*

The complicated world of transmission and distribution has made operators jobs extremely challenging. Many systems have data mining tools within their system; however, data must be analyzed and displayed in a useful manner to be effective. Dashboards are an important aspect of displaying information accurately and quickly to operators and managers to make informed decisions.

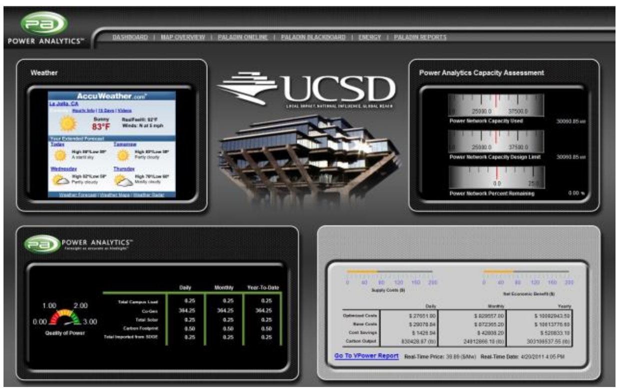

Figure 4: Typical user Interface Dashboard [8]

V. Laying the Foundations for the Future Distributed Power Infrastrucre

Utility executives, policy makers, and regulators at worldwide levels mostly agree upon the barriers to broader integration of auto Microgrid solutions into bulk grid operations and the steps needed to overcome them are complex. The following points identify some key elements of a policy and regulatory agenda to support the development of the MG:

- Reliability event mechanisms to guide the development and deployment of VPPs wherever possible to minimize reliability events.
- Develop consistent, long-term customer incentive and technical assistance programs to support the development of key elements of the MG.
- Within jurisdictions, coordinate the marketing and operation of VPP with energy efficiency programs conducted by system operators, utilities, and government agencies.
- Develop and disseminate frameworks for consistent inclusion of mixed based resources in forecasts used for supply planning.
- Development of standard reporting and aggregation of data for utility and regulatory consumption.
- Worldwide consolidation of standards, regulations and value propositions for MG

Pike Research expects the adoption rate of microgrids to follow a trend more analogous to exponential growth during the forecast period. As with any new innovation, the adoption of microgrids will increase more rapidly as awareness of, and confidence in the technology's capabilities to grow. [9]

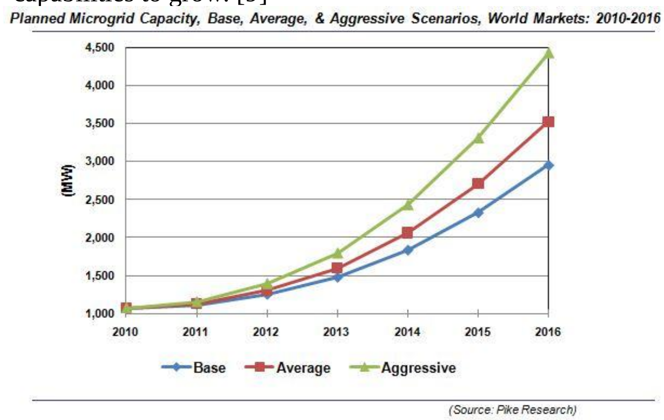

Figure 5: Planned Microgrid Capacity (MW)

VI. Conclusion

Capabilities such as reduced energy costs, implementation time, downtime, alarm management and advanced monitoring lead to reduced power infrastructure management direct and indirect costs through unsurpassed power availability and reliability.

The future of Microgrid solutions providing real time capabilities to solve reliability events are at the brink of becoming a reality. Significant advances in software and telecom technology around situational awareness have greatly increased performance and capabilities in providing secure data communications in real time for customers in a secure mechanism. Opening up Microgrid in providing "active" or "auto" Microgrid solutions for greater grid reliability could be used in capacity sparse, frequency deviation, or any number of reliability event situations, which could be a watershed event for increased reliability and energy surety worldwide. The value behind these solutions is reliability organizations and the utilities are drawing on energy, capacity, voltage and ancillary services without a significant effect on the end use customer and increasing energy surety.

REFERENCES

[1] Autonomous Control of Microgrids. Paolo Piagi and Robert H. Lasseter. IEEE PES Meeting, Montreal, June, 2006

[2] Unlocking Microgrids; Taming the Beast: Microgrid Strategies for Effective Cost Management of your Electrical Infrastructure. Raj Chudgar and Kevin Meagher. May, 2011

[3] GE MICROGRID CONTROL SYTEM. http://www.ecomagination.com/portfolio/microgrid-control-system

[4] SMART, SMART, SMART… SO WHAT? ABB BLOG. *Dr. Mietek Glinkowski*, Director of Technology, ABB. November, 2011. http://smartgridupdate.blogspot.com/

[5] "Energy Policy Act of 2005 SEC 1254" (PDF). August 5, 2005. Archived from the original on 2007-12-01. http://web.archive.org/web/20071201050339/http://www.doi.gov/iepa/EnergyPolicyActof2005.pdf.

[6] [6] Vaughn (2007-12-21). "IEEE SCC21 1547 Home Page". IEEE. IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power systems http://grouper.ieee.org/groups/scc21/1547/1547_index.html.

[7] Modern Grid Strategy - THE TRANSMISSION SMART GRID IMPERATIVE. Developed for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability by the National Energy Technology Laboratory September 2009. http://www.netl.doe.gov/moderngrid/

[8] Power Analytics Corporation. UCSD System Microgrid dashboard screen. Raleigh, NC, 2010. www.poweranalytics.com

[9] Pike research report. Microgrids: Compelling Value Proposition, But Lack of Clear Policy Support. Peter Asmus — January 10, 2011

Raj Chudgar currently works at Power Analytics as the VP of Business Development. He graduated with his Masters of Engineering from University of Louisville Speed School. His employment experience includes ExxonMobil, Black & Veatch, SunGard, ERCOT, and numerous utility clients. 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.

John Jennings has been an IEEE member since 1989 and is an active member on IEEE 1584, IEEE 1683, and IEEE 2030 working groups. John currently works at Power Analytics as the Director of Product Management. He holds a BSEET from Southern Polytechnic State University in Marietta, GA. John served 6 years in the US Navy as a naval nuclear operator. John has a background in the Electrical Distribution and Control Industry with ABB, Eaton Electrical and Schneider Electric. John also has experience in the Pulp and paper industry, pumping applications, and Nuclear Power Industry with Bechtel. John is lead auditor NQA-1 qualified and has published several papers on arc flash hazards and product development.

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