TACKLING SMARTGRID DEPLOYMENT CHALLENGES

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ABSTRACT

Ongoing research and development (R&D) and demonstration activities are resulting in the maturation of a number of SmartGrid systems, technologies and devices. Deployed SmartGrid systems are evident in the areas of Advanced Distribution Automation (ADA) and Active Network Management (ANM), although solutions available on the market are few in number. ADA systems tend to address reliability and security concerns, whereas ANM is concerned with the connection and operation of increased levels of distributed and renewable generation. This paper presents a model for the development of a SmartGrid solution or technology, with particular emphasis on ANM systems. The authors are well placed to present this material based on experience of developing an ANM solution in the UK from research and development through to full deployment.

INTRODUCTION

In this paper, the authors identify how conventional models for the adoption of new technology can be applied to emerging SmartGrid solutions. The paper will identify and discuss examples of differences from this conventional model specific to the market environment of a regulated monopoly and how these challenges can be addressed by a provider of SmartGrid solutions and devices.

The archival value of this paper lies in the identification of key concerns and drivers for participants in a regulated and liberalised electricity sector engaged in developing or implementing SmartGrid systems or technologies. The paper looks closely at how to manage the concerns and integrate with the business models and processes employed by generation developers and network operators in a regulated business environment, thereby providing a road map for technology development that is distinct from traditional technology development processes in other industries. Addressing these issues is key to the deployment of SmartGrid systems and technologies.

ACTIVE NETWORK MANAGEMENT

Active Network Management (ANM) is concerned with the connection and operation of distributed generation (DG) within real-time network constraints. ANM can be an economically preferable alternative to network reinforcement for connecting increased levels of renewable and distributed generation. ANM forms one area of work within the SmartGrid arena; more background on ANM is available through an online database of activities [1]. ANM in the UK has been examined through the work of the Embedded Generation Working Group [2] and solutions for individual generators have been proposed [3]. The authors have taken an ANM scheme from research and development [4] through to trial on the North-Scotland distribution network [5] and will deploy the ANM scheme in early 2009. The emerging view of ANM is that there are substantial prospective benefits but also important potential drawbacks in realising those benefits. The main benefits and drawbacks are outlined below.

Benefits of ANM

Network Operator Perspective

- Maximisation of use of existing infrastructure
- Provide an alternative to network reinforcement
- Increased revenues due to greater asset utilisation
- Network reliability/security maintained or improved
- Potential improvements in power quality
- Provide intermediate connection solutions prior to reinforcements being performed

Generator Developer Perspective

- Cheaper grid connections
- Increased development size (MW)
- Increased development production (MWh)
- Reduced project timescales for grid connections

Drawbacks of ANM

Network Operator Perspective

- In conflict with established practice and business model
- Requirement to assess suitability of ANM solution(s)
- Requirement to offer ANM and reinforcement as alternatives options for generator connection
- Additional analysis workload
- Technical and commercial complexity
- Devolving control of the power system
- Unproven technology and techniques

Generator Developer Perspective

- Reduced energy production

- Additional inaccuracies in revenue forecasting
- Commercial complexity
- Harder to raise project capital due to perceived risks

Clearly there are potential barriers to adoption of ANM and it is important that these are put in the context of understanding technology adoption lifecycles.

TECHNOLOGY ADOPTION LIFECYCLE

In 1957 at Iowa State University, Bohlen *et al* [6] proposed a sociological model to describe the diffusion of new ideas in the local farming economy. They chose as the basis of their study the purchase of hybrid seed corn. Over the period of the next ten years they refined this model and in 1962 published "Diffusion of Innovations" [7], in which the Technology Adoption Lifecycle was born. This Lifecycle is embodied in Roger's Bell Curve where adoption increases over time (this is adapted as discussed for SmartGrids in Figure 1 below).

Bohlen *et al* identified that for the local farming economy innovation had a number of distinct phases, with the purchaser at each phase possessing unique characteristics:

- ***Innovators*** - had larger farms, were more educated, more prosperous and more risk-oriented
- ***Early adopters*** - younger, more educated, tended to be community leaders
- ***Early majority*** - more conservative but open to new ideas, active and influential in community
- ***Majority*** - older, less educated, fairly conservative and less socially active
- ***Non Adopters*** - very conservative, had small farms and capital, oldest and least educated

Geoffrey A Moore [8] presented an interpretation of this model, applied to the "disruptive" technologies that have been a feature of the last 20 years, e.g. personal computers and mobile devices. Moore further explored these characteristics as applied to high-tech markets. In doing so he identified that at each stage the shift from one group of adopters to the next was not a smooth process but rather involved "chasms" where the product and how it was sold to each group was markedly different. Moore adapted the model applied to the farming economy to groups of consumers in a high-tech market, such as that which would apply to SmartGrid systems.

Moore argues that the biggest step for a high-tech (or in our case SmartGrid systems) company to take is the step from selling a few innovative, heavily tailored products/projects to the Early Adopters (also known as Visionaries), to reaching the mainstream Early Majority (also known as Pragmatists) customers who do not want a tailored product but would rather purchase an off the shelf product. Crossing this divide or "chasm" is a critical aspect of growth. Most ANM developments are at present with Innovators and Early Adopters, as can de identified through closer inspection of the ANM Register [1]. The parties who appear in the Technology Adoption Lifecycle are now introduced in chronological order.

Innovators (Technologists)

Innovators possess a desire to work with the latest technology and assess its technical benefits. They are typically based within R&D departments evaluating new technologies, not focused on implementation but simply evaluating solutions and moving on to the next technology.

Early Adopters (Innovators)

Early Adopters identify strategic business opportunity as the driver for adopting the technology to leapfrog competition. They are typically younger, more ambitious individuals, who champion these high visibility projects.

Early Majority (Pragmatists)

The Early Majority do not adopt technology until it is fully debugged, with multiple reference sites. They do not seek quantum leaps forward but focus on percentage improvements in business performance. Key concerns surround living with the technology for the rest of its deployed lifetime.

Late Majority (Conservatives)

Late Majority are those that seek to buy fully tried, tested, packaged and discounted products off the shelf.

Laggards (Sceptics)

Laggards would almost always prefer to stay with the status quo despite compelling evidence of benefits.

CURRENT POWER INDUSTRY STATUS

In the developed world much of the existing electricity infrastructure was built in the 1960's and 1970's. Subsequent decades have witnessed a reduction in capital investment. As a consequence, a significant amount of the infrastructure today could be regarded as aged with respect to its initial design life. This is occurring at a time when the entire nature of energy supply systems is being reassessed in terms of environmental impact. Additional strain is being placed on the industry to connect and operate significantly greater amounts of renewable generation and continue to achieve least cost objectives.

It is often the case that market regulators set the rate of return that network operators can recoup from their assets (e.g. RPI-x in the UK), driving the growth of the regulated asset base and a desire to reduce (or avoid) potential operating costs when planning future networks.

Regulated markets also strive for reduced costs to the end consumer. Therefore, expenditure is tightly regulated to ensure efficient investment that will lead to lower prices, whilst ensuring adequate levels of reliability and security. Consequently, network operators face financial penalties for supply interruptions to load customers.

If we accept this as the general regulatory regime, we also must recognise that network operators tend to consider generator connections individually and on a least cost basis. The consideration of generator connections individually by the network operator is a natural response to the onerous contractual requirements and the commercial prudence of the parties involved. The 1989 UK Electricity Act [9] states a requirement "to maintain an efficient, co-ordinated and economical system of electricity distribution" and despite examples of a co-ordinated approach to multiple connection requests existing, such as the case study presented in this paper, this is not always common practice. The costed solution for an individual generator may then be so high as to prevent the project from proceeding. Therefore, a key challenge for today's industry is identifying and implementing cost-effective generator connections aligned with existing license obligations.

There are many more drivers and challenges for the power industry, and these provide both an opportunity for SmartGrids and are key to some of the largest challenges facing SmartGrid deployment. Specific characteristics of the structure and current status of the power networks sector presents some important implications for new technology adoption and these are discussed in the next section.

ANM TECHNOLOGY ADOPTION LIFECYLCE

Given the embryonic nature of SmartGrids and ANM, only the first three stages of the Technology Adoption Lifecycle will be considered: innovators, early adopters and early majority. Figure 1 highlights some of aspects of the Technology Adoption Lifecycle applied to ANM.

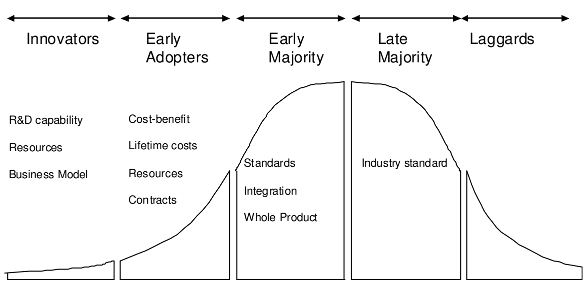

Figure 1. The ANM Technology Adoption Lifecycle

Innovators are typically found within R&D departments or product evaluation departments. With the key industry driver of cost efficiency and a business model based on a fixed return from a large deployed asset base there is little opportunity for such departments in utility companies to exist or spare resources to 'play' with new technology. The electricity networks are key assets and their security is vital to revenue generation. Incentives for quality of supply based on customer interruptions and minutes lost again discourage adopting solutions other than those that have already been successfully deployed elsewhere.

Early adopters are innovative consumers seeking to adopt new technology as early as possible based on the benefits it will bring and allowing them to leapfrog their competition. However, concerns remain regarding through-life costs and the suitability of operational rules [10].

By the time that the Early Majority are ready to adopt the technology, standards require to be implemented and the ANM product would likely need to be offered as an integrated package of services, solutions and products.

ANM TECHNOLOGY CASE STUDY

In 2005, Scottish Hydro Electric Power Distribution plc (SHEPD) applied for the Orkney Isles distribution network to be designated a Registered Power Zone (RPZ) [11]. The focus of the Orkney RPZ was the trial of an ANM scheme developed as part of a collaborative project between SHEPD and the University of Strathclyde (UoS). The ANM scheme is designed to manage the output of multiple DG units to adhere to multiple thermal constraints on the distribution network. A trial of the scheme was successfully completed in late 2006 [12]. Both parties then considered routes towards deployment of the full ANM scheme, which introduced the following complex questions:

- Who will provide the ANM solution?
- What contractual arrangements are required between the generators, the network operator and the ANM solution provider?
- What support and warranty arrangements are required?
- Which party will pay for the ANM solution and on what basis?

With reference to the technology lifecycle in Figure 1, the Early Adopter understands that they are embarking on a high risk and potentially high profile project and as a consequence will have to invest more time and money than an Early Majority company. However, they understand the benefits of the technology. In SHEPD's case having funded and been close to the research for more than 4 years, they could see that the benefits of ANM have strong potential to outweigh the costs. They have been through the Innovator phase and fully understand the internal workings of the technology so despite the potential risks to their business (e.g. infringing license obligations or missing customer supply reliability targets) they feel that this risk is managed. Traditionally, an Early Adopter views the deployment of a new technology as a means to "leapfrog" the competition. However, in the power networks sector there is no real competition but rather regulated monopoly companies with revenue tied to the asset base, incentives for efficiency and for security of supply. Even with further incentives such as the Innovation Funding Incentive (IFI) [11] and RPZ in the UK, it appears that the fundamental reason (strategic advantage) for being an "Early Adopter" differs from the conventional model.

Addressing Deployment Risks

SHEPD and the UoS contracted with a third party system integrator experienced in deploying control systems for the utility industry. SHEPD provided the funding via the Innovation Funding Incentive (IFI) and RPZ mechanisms. UoS (the creator and owner of the Intellectual Property associated with the project) operationally managed the

delivery of the project by the system integrator. This was an innovative means of delivering the solution for all parties.
At the same time SHEPD and UoS worked towards establishing a suitable vehicle to exploit the knowledge created during the collaboration and the market potential for ANM solutions. In August 2008 Smarter Grid Solutions (SGS) was formed to provide a commercial entity for the deployment, servicing and development of the Orkney ANM technology. In addition to delivering the Orkney scheme in 2009, and in order to maximise the potential of the technology and accompanying services, SGS have adopted an innovative business model, designed to address the bridging of the "chasm" to the Early Majority. Existing practice in the power industry and the current regulatory regime in the UK also had to be factored in. The business model required for an ANM technology must consider through-life support and warranty, including due consideration of modifications, updates and audits of the ANM scheme as well as preservation of contractual obligations associated with Connection Agreements. The role of the ANM provider as a 3rd party should be defined to address providing these services to the network operator, in addition to the core ANM hardware and software required.

Commercial Issues

There is a key commercial relationship to be formed between the ANM solution provider and the distribution network operator (DNO). In the case of SHEPD and SGS, an appropriate balance of up front and ongoing costs has been identified and warranty and service provision through the life of the ANM scheme has been agreed.
The relationship between the ANM provider and the generation developer can be independent or through the host DNO. The generation developer stands to gain the most from the deployment of ANM, through access to greater revenue streams, and/or a cheaper or a quicker network connection. For this reason, participating generators connecting to the ANM scheme will pay a subscription charge, either directly to SGS or through the DNO, in addition to a one-off cost associated with integrating the DG unit with the ANM scheme.
The ANM scheme enables real-time capacity access but not "firm" MW connected capacity. Each participating DG unit will be given an indication of likely MWh annual output when connecting through the ANM scheme. However, conducting the subscription charge on a £/MW fits with the existing network operator Use of System charging methodology. An annual £/MW charging approach is also simpler and easier to administer, compared to £/MWh. The £/MW charge is applied on a sliding scale to each generator based on the size of project. This is evidence of the requirement for innovation in commercial arrangements as well as in the technical aspects of ANM.

CONCLUSION

The chasm between Innovator and Early Adopter is larger for SmartGrids than in conventional high tech markets. The Early Adopters exhibit many of the characteristics of the Early Majority as a consequence of the existing commercial and regulatory environment. However, the support of an Innovator who can also become an Early Adopter can help bridge the first chasm, resolving many of the challenges faced when crossing the greatest chasm from Early Adopters to the Early Majority. The case study presented is specific to the UK and examples from other regulatory regimes would be worth considering. Consideration of other SmartGrid technologies and routes to overcoming "chasms" is required to understand the challenges that lie ahead.

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