Future Business Model for Cellular Microgrids

Intisar Ali Sajjad, Roberto Napoli and Gianfranco Chicco
Energy Department, Politecnico di Torino, Turin, Italy
malik.sajjad@polito.it

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Abstract: Different studies which were carried out in the past revealed that the environment for microgrids is very complex and uncertain due to regulatory and legal barriers. Across and within the developed countries the suggestions and views of regulatory authorities and legal bindings about the infrastructure and operation of microgrids are quite different. According to the present scenario, the viability of microgrids mainly depends upon how microgrids are framed, who owns them, which are the customers served from them and how much revenue is generated from them. This paper investigates the potential barriers in current business models to deploy microgrids and proposes a business model, centric to users, with the concept of consumers owned microgrid.

1 INTRODUCTION

There are lots of uncertainties in the power system, especially for electric utility systems. These uncertainties range from capital costs and financing to fuel price fluctuations and operational costs. Due to these trends, it is very difficult to assess and formulate long term capacity planning. The ultimate impact is on consumers to compensate the additional costs through different tariff elements like fuel adjustment charges, capacity charges, etc. On the other hand, there are much more uncertainties associated with the capital costs and financing due to inflation and changing interest rates. This has affected the utilities' ability to obtain bonding for long term projects. The regulatory framework is also a key player affecting the day to day operation, together with the structure of the electricity market. In some aspects the regulation supports the utility industry to operate a stable, economic and reliable system, but in other cases it decreases the attraction of investors to invest in the system to cater for future challenges (Schweppe, Tabors and Kirtley, 1981).

The power system business has been restructured in the last decades. This was done to increase system efficiency, decrease costs and emissions, and attain reliability by using new emerging technologies in the generation, transmission and distribution sectors. Smart grid has been the unifying concept for the application of these emerging technologies. These technologies are based on the revolutionary findings in the field of power electronics, artificial intelligence, computer applications, networking abilities. These technologies have the ability to change the behavior of the electricity distribution system into an active one, where each component has the capability to talk and listen. But the goals have not been achieved yet. The progress is very slow and there is lack of investments in the field of smart grids. The major reason is the structure of the current business model in power market especially on the distribution side, more centric on utilities but less on consumers (Schweppe, Tabors and Kirtley, 1981).

Microgrids are the systems that link different distributed energy sources into a single small network and give service to its consumers with all or partial of their energy demands by increasing energy efficiency, reliability and reduce emission and energy costs (Center for Energy and Hyams, 2010). Fast growth in distributed generation, emerging ICT, power electronics technologies, efficient storage has made the dream of microgrids true and implementable. But one aspect that is not favorable, are the power market policies, regulations and legal bindings. These are very important components to attract investments from public and private sectors. One of the important reasons for the lag of such components may be the monopolization of the market, especially at the distribution level.

King (2006) assessed the different microgrid business models considering the ownership status.

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According to these models, the owner is responsible for all type of services and quality indices to consumers. The owner may be a utility, a single landlord, multiple individuals or firms, a single individual, or a single firm. Center for Energy and Hyams (2010) used this concept and further categorized the business models of King (2006) using physical and virtual microgrids. Center for Energy and Hyams (2010) also gives more detailed business models for utility, non-utility, also considering virtual microgrids depending on the aggregation level.

The main theme behind the proposed business model is to split the power system network into autonomous parts that replicate the *small world* concept. This technical splitting should be followed on the same lines as the splitting of communities. This concept of small world has been used in different real world applications including power systems, transportation system, social networks, and medical science (Pagani and Aiello, 2013; Bork et al., 2004; Hidefum, 2013; Eppstein et al., 2013). Each small world should have operating autonomy and ownership by the customers with responsibility. The business model should be structured in such a way that it will attract private investments and should leave space for entrepreneurship.

The rest of the paper is organized as follows. Section 2 gives a brief overview about the relationship between innovations and entrepreneurship. Section 3 and 4 discusses about the current business models and their pitfalls. Section 5 discusses about the proposed possible vision for the future business model centric to the active consumers. This paper is concluded in Section 6.

2 INNOVATIONS AND ENTREPRENEURSHIP

Entrepreneurship is the basic idea behind the possible business model of microgrids. Shane (2003) explains entrepreneurship and gives some characteristics of an entrepreneur that introduces innovations and new gears and transforms innovations into profit and financial goods.

The role of opportunities carries central importance to establish an enterprise. Opportunities generate a situation to create means for the establishment of a profitable enterprise. Different economist and business experts explain their way to explore opportunities, with different theories.

In 1934, Schumpeter linked opportunities with innovations and said that new information is necessarily important for the existence of enterprise business. Technological, political, economic, regulatory changes provide new information to entrepreneur to recombine resources for more valuable and fruitful enterprise (Schumpeter, 1934; Urban and von Hippel, 1988). In contrast with Schumpeter, the theory presented by Kirzner states that the opportunities may need only differential access to existing information. People in a specific field use the information that they know to efficiently manage resources, but the decision making process has always shortcomings. These shortcomings lead to obtain and recombine resources for profitable business. Most of the research is done on Schumpeter's opportunities due to its diverse and innovation friendly nature (Urban and von Hippel, 1988; Schumpeter, 1934).

2.1 Consumer Centric Enterprises

The work on consumer centric enterprises started about 4 decades ago, and today it is clear that such firms and enterprises are very successful due to advances in technology, communication and computing (von Hippel, 2005).

Enos (1962) reported that the most of the innovations in the oil refining sector were developed by user companies. Also Freeman (1968) presented the results about the chemical production processes that most licensed processes were developed by user companies. More than 80% of common and important scientific instruments and semiconductor processes were developed by users. Empirical studies also proved that up to 40% of users of any services or products are engaged in developing or modifying products/services (von Hippel, 2005; Herstatt and von Hippel, 1992; Morrison, Roberts, von Hippel, 2000; Franke and von Hippel, 2003; Lüthje, 2004; Franke and Shah, 2003, Luthje, Herstatt and von Hippel, 2002).

Open source projects are one example of the above business model, where people develop products or services for themselves and share it free of cost or with very low cost to other consumers and users, e.g., open source and free software, Linux and Android applications.

2.2 Economics of Innovations

In 1957 Robert Solow presented the economic growth model based on innovation. He defined growth as the change in Gross Domestic Product

(GDP) per hour of labor per unit time (Solow, 1957). Recent prominent advances in literature give the concept of knowledge spillovers and human capital (Romer, 1986; Romer, 1990; Lucas, 1988).

3 CURRENT PRACTICES IN THE DEVELOPMENT OF MICROGRIDS

Today's scenario in the distribution system is centralized to utility and has very small or no participation of consumers.

A feedback system has been developed through smart metering, and these meters have been installed in huge quantities in some countries (Renner et al., 2011). In the past, the consumers had rarely received such kind of feedback from the operator or utility. As a result, they had a little opportunity to adapt themselves according to the need of the utility. The same case occurred for a utility to judge what kind of service (e.g., to improve continuity of supply) the consumers would really like to buy.

Research has revealed the fact that utilities may be reluctant to offer consumer centric services and price structures due to the issue of reduction in electricity sales. As far as the increasing trend of smart meters is concerned, this is only being used, in majority of the cases, to reduce cost related to billing data collection and remote load management (Kelly, Meiners and Rouse, 2007).

There are some microgrid projects like San Diego Gas and Electric's Beach Cities microgrid, Perfect power, Danish Cell Controller, AGTFTC/MCAGCC microgrid, which are implemented with participation of utilities and the private sector (GEA, 2012; GEI, 2014; Kelly, Meiners and Rouse, 2007; Becker, 2013; Russell and Sagoo, 2013). Some initiatives have also been taken in developing countries to promote the concept of smart and micro grids (Warshay, 2013).

4 PITTFALLS OF EXISTING BUSINESS MODELS

There are many participants, including utilities and consumers, in the construction of a microgrid. So, all parties are the potential candidates for the receipt of benefits obtained from microgrid services, e.g., peak load reduction. The main problem here is the definition of mechanisms for proportionate investments from participants. Also there is no adequate market on the distribution level to support microgrids (in broader sense, smart grids) to monetize benefits, and this leads to investments stranding especially from the private sector.

There are no appropriate existing regulations to compensate microgrids is case of participation in grid stability. Potential benefits of microgrid are negated in current regulatory framework, e.g., distributed generation is not allowed to manipulate peak loads (Becker, 2013). Furthermore, most of the focus in the design of microgrids in on electricity, but microgrids should be considered more widely in a multi-energy perspective.

There are many smart grid and microgrid projects implemented worldwide (as the ones summarized in Section 3), but the development is very slow. One of the main reasons for slow development is the lack of private sector interest in investments. This lack of interest is due to:

- Utility's "Big Brother" role, indicating how and when the consumers will use their appliances and processes.
- Inappropriate feed-in and net metering tariffs. Consumer's energy purchase options are very limited.
- No or very low consumer's involvement in adopting innovations and their promotion.
- Current business model doesn't allow consumers to participate in energy business and its services.
- Very little control of consumers over electricity bills.

5 FUTURE PERSPECTIVE OF BUSINESS MODEL

Potential questions of interest for the implementation of smart grid are where the money will come from and in how much time. How can the process be accelerated? Shall the consumers be involved primarily? If yes, then how? This section describes a possible future of distribution system with extended applications of computational and communication capabilities and technologies with consumer centric business model as an enterprise.

5.1 A Possible Future: Consumer Centric Enterprises

Entrepreneurship is the theory behind the concept of "cellular" microgrids, where each microgrid operator will be an independent enterprise and manage its microgrid operation and services with the help of consumer's owned firms. These services may be related to installation and maintenance services of microgrid distribution system, in buildings, houses, offices, etc. Micro financing firms will provide loans with very low interest rate to adopt innovations within microgrid premises, especially for homes and offices. Consumers will also contribute to energy needs of the microgrid through net metering and feed in tariffs. So, each unit of microgrid has an operator, providing services and micro-financing enterprises, and active consumers. All these will work together for the welfare of themselves and other participants. This complete setup is considered as a *cellular microgrid* unit. Each unit will support other adjacent units for more reliable, environmental friendly and cost effective operation of overall system. This will not only support the local distribution network, but will also be able to provide ancillary services to the grid. The pyramid shift from supplier-centric to consumer-centric is the key for competition and private sector investments. Some good analogies for this kind of change are mainframe computers to laptop computers, and conventional telephone sets to smart phones. Section 2 indicated an overall picture of enterprise business, its requirements, theories about its model and economics related to it.

Consumers will invest in emerging technologies related to communication and control to upgrade the electric grid due to their widespread adaptation. It will also lead towards commercialization of microgrids; and societies, communities, institutions and the commercial sector will be able to share their microgrid systems having local generations. These developments will lead towards new era of economic development in the field of power and energy.

5.2 The Starting Point

At present we are living in a period where each nation is fighting for the survival of its economy and social interests. Population is growing rapidly and everyone is looking for more energy resources to fulfill present and future needs. Furthermore, environmental issues need serious attention. A new economic equilibrium is needed for the existence in the war of 'survival of fittest'.

All these indicators give a hope for new business models because we are in the classical condition where a model of technological innovations can start a new stable economic wave with a creation of new paradigms in the economic market and in the society. An appropriate economic model of smart grids can be a triggering point leading towards a revolution for economic balance and social benefits, that is, the evolution of present into future.

5.3 Cellular Microgrids –Structure and Business Model

Fred C. Schweppe and his research group proposed the concept of Homeostatic Control in early 80's. Homeostatic control was founded on the following principles, presented by Schweppe, Tabors and Kirtley (1981):

- Consumer's independence;
- Two way communication and feedback between Utility and consumers.

The new model with cellular microgrids is actually based on these principles, evolving a new business model centric to consumers from the present model based on the utilities or system operators. The present smart grid structure is top down, where smart grid enables the smart cities and smart cities enable smart homes. It needs to be reversed by keeping in view the above principles. First we should made citizen smart to develop smart homes using smart innovations in technologies, then the combination of such homes will give birth to smart cities through cellular microgrids and ultimately smart grid. Such a smart home or smart city will be linked to the willingness of the city to struggle for personalized living style of its own, aimed to reach high level of sustainability and high quality of life for citizens. Figure 1 shows this paradigm for bottom up approach.

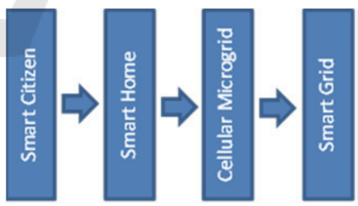

Figure 1: Bottom-up Evolution.

Smart cities will be composed of smart grids and each smart grid will have smart buildings. These microgrids will behave like cells in entire power system structure because they can communicate and interchange energy with each other and also with the grid. That's why the name proposed here is cellular microgrids.

The proposed framework is consistent with currently evolving concepts and paradigms, such as:

a) Smart Homes: The future vision of smart homes is that they will be equipped with state of the art technologies related to computation, communication and information technology. Such technologies will be able to respond to the needs of consumers (occupants) with high level of intelligence to promote their comfort, enhance convenience, security and entertainment capabilities. Through the proper management of such technologies it is possible to accommodate most of the procedures and control actions. The application of such technologies is also strongly dependent on the social attributes of occupants. For example elderly people need more comfort and young people prefer entertainment. Cost saving is also dependent on daily life events. If there is a special event e.g. birthday party then cost saving will be the secondary issue.

b) Plug and Play: the Plug and Play concept is not new and can be implemented in smart homes in future. We can get inspiration from success stories of personal computers and laptops. If we want to connect any hardware in our PC then we just need a driver to use it. Hardware of different brands can be used on single workstation due to their compatibility with a specific operating system. The same concept can be implemented here for smart homes. There should be an operating system for the power system hardware (smart appliances, protection equipment, intelligent devices, PV modules, storage devices etc.) to accommodate different manufacturer's products. Each manufacturer will provide the driver for its smart products. Smart home residents just need to insert equipment; the operating system will recognize the type of equipment automatically and will be ready to use it after the installation of its driver. Within this general scheme, the consumers can manage their needs and respond to demand response programs (e.g., spot pricing) through the intelligent system set up with the user-defined rules for demand response management.

c) Smart Generation: On the same pattern as described for smart homes, the local generation can also be made smart. It needs fewer efforts because already generation plants have some level of smartness in control and operation.

d) Structure of Self Managing Cells: Each unit of smart homes and generation can manage itself in response to internal or external signals. We call these units as cells, same concept as in human body. The structure of the biological cells is very complex but we can get some analogies for our proposed network. Each cell can communicate to other cell and can share energy on demand through the central control of all cells. We call this central control as aggregator.

e) Smart Microgrid: If we have smart homes in place, then those smart homes can be combined with each other and also with smart local generating units through a smart master control center that will take care of the needs of the individual cells. Such a system is analogous to the organism in living things. We call this organism in power system as microgrid, because microgrids have the same properties as biological organisms. Microgrids can respond to incentives, grow in size and development. Microgrids can operate in a stable way in the island mode, provided that the characteristics of the equipment connected are suitable to keep acceptable quality of supply and withstand disturbances.

f) Aggregator: The aggregator is a central controlling unit in a microgrid. It is proposed that the aggregator must be a third party other than the utility. In other words cellular microgrid should be privately owned entities so that the influence of utilities on consumers can be nullified.

5.4 Energy Pricing Mechanism (Schweppe's Optimal Spot Pricing Theorem)

The conventional social welfare objective function needs to be modified for personal optimization. Pre-determined price rates (Time of Use) do not reflect social welfare for individuals but may be useful for utilities adding pre-determined cost margins to impact on their profit.

Schweppe had presented an electricity pricing mechanism in early 80's. It is an optimal spot pricing mechanism. Detail about this theorem is presented by Caramanis, Bohn and Schweppe (1982). Here the application of spot pricing is discussed with respect to the new and evolving concept of cellular microgrids.

For the enterprise-based business model of cellular microgrids, spot pricing is proposed with price update from few hours to 5 minutes depending upon the available technology and system economics. The structure of the proposed model is shown in Figure 2. The optimal interval of updating prices is that welfare gains are equal with the additional costs due to the metering and communication resources implementation. Theory about spot pricing mechanism provides rules for the optimal decisions in the short run and also for long run actions. These actions can be taken as investments. The global social welfare function is the difference between the cost related to electricity usage and cost of generation plus investment in the overall microgrid infrastructure. Welfare depends on many factors like safety, cost, entertainment, green style. Figurative description of personal welfare function is shown in Figure 3.

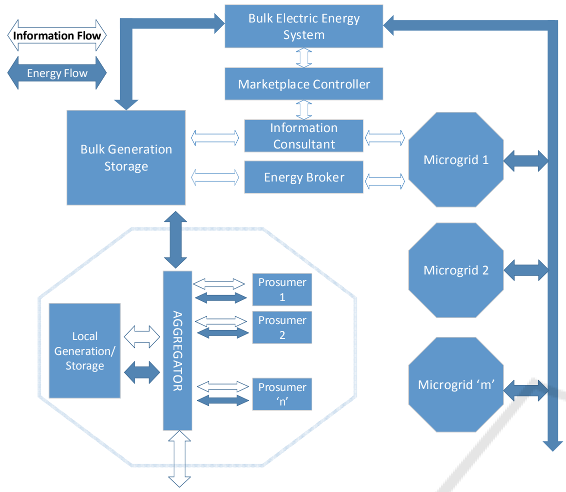

Figure 2: Information and Energy Flow in Smart Grid.

5.5 Net Metering

The concept of net metering/feed in tariffs is already implemented in some of the countries like Italy, Belgium, Canada, Greece, and Japan (REN21, 2013). It should be applied on aggregation level at the point of common coupling (PCC) to incentivize consumers and to promote local generation. The concept used in this business model is the net metering on the aggregation level at the intake of microgrid, and on a lower level for group of consumers, e.g., apartments and offices in a building, group of houses. Aggregator and building energy managers will manage internal billing mechanisms with individual cells.

5.6 Participant's Privacy

Caramanis, Bohn and Schweppe (1982) concluded that very few information of consumers are required to central control for decision making under spot pricing than time of use. Information is only related to losses, line flows and voltage overload conditions at each metering point without sharing the individual cost and profit functions. This metering point will be the PCC in case of net metering.

5.7 Business Opportunities inside a Microgrid

New business opportunities inside a microgrid, headed by the aggregator or independent of it, will be produced to support maintenance, installation services, micro financing to purchase state of the art appliances and instruments to make homes, offices, buildings and system smarter.

5.8 Social Impact

Long-term investments in the system will lead towards long-term welfare of the inhabitants residing in the area of a cellular microgrid. This welfare will be in the form of job opportunities in a local market place. This aspect has always been neglected and is very important for future investments and also to strengthen national social goals by reducing inflation.

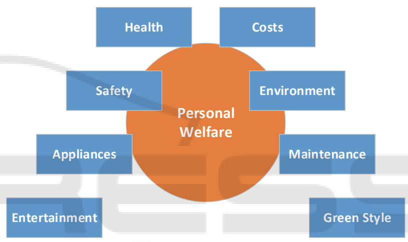

Figure 3: Personal Welfare parameters.

5.9 Regulatory Issues

Current policies and regulations are not generally favorable to user-centric business models. The Governments and the regulating bodies should be aware of the impacts of upcoming legislations that can directly or indirectly affect the business and innovations.

5.10 Is this model Evolutionary?

This model is evolutionary and can be evolved using the following initiatives:

- Net metering and feed in tariffs must be permitted and allowed for individuals and groups of consumers.
- Micro financing should be encouraged and regulatory bindings on micro financing should be relaxed for the energy business.
- Electricity bills should be totally understandable to consumers.
- Local online maintenance and installation

services should be strengthened under the aggregator supervision.

- Local skilled entities should be preferred for hiring for aggregation and other services.
- Legislation must support private sector involvement in energy business on distribution level to support, manage, own and operate a suitable size of consumers.
- Renewable energy based generation must be encouraged at the local level by incentives.
- Spot pricing mechanism must be incorporated with suitable price update time and should be decreased with innovations available.
- Distribution networks should be made more reliable by connecting consumers in meshed form, upgrading the present protection systems.
- Consumer's awareness should be enhanced through print and electronic media, and any other mean to adopt smartness.

6 CONCLUSIONS

A consumer-centric business model can be implemented using cellular microgrid structures with consumer's involvement. Small enterprises will strengthen the business structure by enhancing consumers comfort in the competitive environment. This business will also generate local job opportunities. There are regulatory issues in the implementation of such a structure, so local investment should be allowed with all kinds of feed in tariffs. Some recommendations are given in previous section to make this model more evolving. An economic study will be carried out in future work to strengthen the point of view on the cellular business model for microgrids.

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