Typology of Business Models for Adopting Grid-Scale Emerging Storage Technologies

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Abstract--**Electricity grids are nowadays facing various market and technological challenges that influence their reliability and profitability. As a viable solution to those challenges, energy storage technologies provide multiple service delivery along the electricity grid value chain. In addition to their role for penetration of renewables in future of electricity grid, electricity storage technologies possess a number of societal and environmental benefits, such as reducing carbon footprint and securing regional energy demands. The primary challenge for utilities and regulators, however, is to find a business model that best fits to technology, application, and regional electricity market. We propose a typology of different business models for adopting energy storage technologies among utilities. The business model frameworks are tailored to provide a customized analysis platform for adopting emerging energy storage technologies. For industry looking to adapt new energy storage technologies, such analysis can provide multi-dimension considerations (cost, efficiency, reliability, best practice business operation model, and policy instruments), which can potentially lead to complete view for strategic decision making purposes.**

I. INTRODUCTION

The increasing use of unconventional energy sources is changing the blueprint of the world's energy resources; yet, a secure and reliable energy supply is of vital importance for today's modern societies. Electricity security, in particular, has been a matter of high priority in energy policies for countries throughout the world. In the majority of those policies, development and adopting more efficient, environmentally benign forms of power sources with reliable and secure services are seen as key challenges in the next two decades [1]. The electricity grid is an important national and regional infrastructure for domestic use and export purposes [2]. Electricity grids, however, are facing various market and technological challenges that influence their reliability and profitability [3]. One challenge is that under increasing electricity demand conditions, the grid capital assets are coming to the end of life. Another challenge is related to the grid stability that is associated with increasing use of intermittent renewable energy generation. Finally, in order to achieve their full potential, distributed "smart" grids require efficient, stable, durable, and cheap energy storage solutions. The main interest in stationary energy storage technologies in the past two decades is in their use for the deployment of renewable energy sources, such as solar and wind energy [1,4,5].

Energy storage technologies provide multiple service delivery along the electricity grid value chain, including electricity generation, transmission and distribution (T&D), and end-user consumption. In addition to their role for penetration of renewables in future of electricity grid, electricity storage technologies possess a number of environmental benefits, such as reducing carbon footprint and securing regional electricity demand to avoid long-time service interruptions [4]. Energy storage is an established technology concept in electricity power grid [4]. Some storage technologies, such as pumped-hydro, are more mature than the other emerging storage technologies [1,4]. For instance, Compressed Air Energy Storage (CAES) has already been used for decades. The new generation of energy storage technologies such as lithium-ion batteries, flow batteries, flywheels, and sodium-sulfur batteries (NaS) has been emerged in recent years and are in the early market adoption stage. The main advantage of the new generation of storage technologies to the old ones is in their "operational flexibility, improved charge/discharge cycle life, and longer duration or fast response capabilities" [1]. The cost and reliability of an energy storage technology are function of several key factors. Among those factors are round-trip efficiency (the ratio of the released electrical energy to the stored energy), cycle life (the number of times that the device can get discharged and charged while maintaining a minimum required efficiency), power rating ($/kW), and energy rating ($/kWh). Moreover, capital and operating costs determine economic viability and service profitability, Figure 1.

The real benefit of energy storage technologies have been studied extensively in different markets (e.g., arbitrage, regulation services, and T&D). As indicated in various studies, no single energy storage system can provide multiple grid application requirements. Moreover, some storage technologies may complement each other for multiple services, where combining services could lead to cost recovery and profitability in the long run [6]. The challenge of "aggregating" the value of energy storage technologies [6], often referred to as "Benefits-stacking" [1], is related to how the market attributes (regulated vs. deregulated) and electricity system owners or operators can share the cost and revenue streams. It also depends on how the usage of storage can be decentralized by different grid "actors" [6]. A sophisticated business model framework can allow systematic stacking of the value and benefits of multiple technologies.

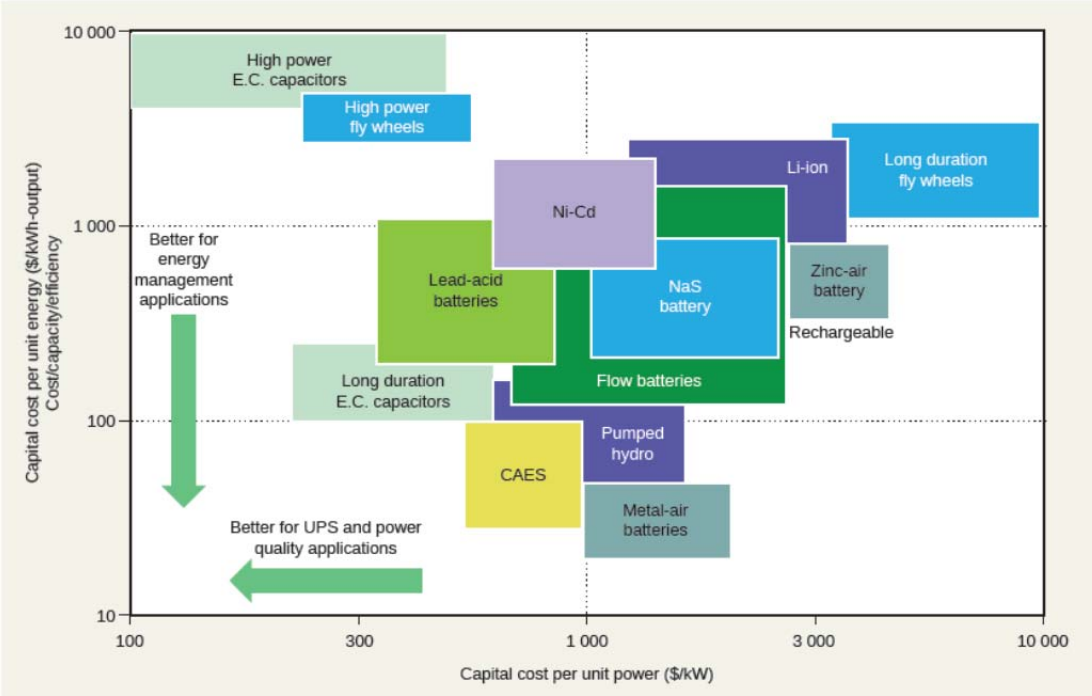

Figure 1. Commercial characteristics for different battery technologies, reprinted from [3] with permission.

The appropriate strategic business models need to realize and develop the potential market for all of these market segments. In summary, the limitations of adopting emerging energy storage technologies for future grid structure are (i) Electricity market structure is not flexible enough to adopt the new operation/technology; (ii) Ambiguity between cost takers (undertaken by utilities only) and benefit (shared between utilities and consumers) and a lack of appropriate service based business models; (iii) High capital expenditure (CAPEX) and a low rate of return; (iv) Power management cost; (v) Siting and permitting cost; (vi) Complexity and cost of managing energy storage projects [1].

II. RESEARCH OBJECTIVE

This research aims to analyze the existing and develop new business models in order to assess the value proposition of storage technologies by formulating their risks and opportunity profile. The review of the current technical and business-management literature reveals the need for developing sophisticated business models for grid-scale electricity storage technologies. The characterization of various business models should be able to address temporal (size and maturity of the storage technology) and spatial contingencies (the type of service, location, application and market or electricity pricing structure). There is a need to analyze existing business models and develop practical frameworks that ensure accurate assessment of profitability and value created by adopting electricity storage technologies in electricity power grid. Here we attempt to benchmark and analyze business models and assess the value proposition of storage technologies by formulating their risks and opportunity profile. We demonstrate a typology of business models for grid-scale storage technologies that can be used as a practical framework for management decision-making purposes. The framework tackles some of the existing issues for accurate screening of storage technologies to capture the value and unique benefits of an energy storage medium.

III. OVERVIEW OF BUSINESS MODELS

The business model is defined as a strategies guideline that constructs the "organizational and financial architecture of the firm" [7]. It is a way that firms deliver value to their customers, make customers purchase that value, and create profit from those purchases [8,9]. The latter concept of business models have been extensively tested [10] in the real world and is fully applicable to renewable energies. Business model innovation is a strategic alternative taken by firms to respond to externalities [11,12,13]. Richter defined business model innovation as "*development of new organizational forms for the creation, delivery, and capture of value*" [14]. The opportunities and barriers of business model innovation is of vital importance for clean energy industry due to the extensive presence of disruptive innovations [15] and "organizational ambidexterity" (16,17,18).

A recent review by Richter [14] has provided extensive analysis of how utilities need to revamp their business models to overcome new challenges related to grid security and integration of renewables. Richter [14] identified two basic choices as "utility-side business models" and "customer-side business models". Although a utility-side business models are preferred by utilities for which a blueprint exists; the business models for customer-side has not been developed extensively [14]. In followings, we unravel more insights into each of these choices and discuss the applicability of such models for storage technologies in power grid.

The choice of business models for renewable energies has been addressed by a number of recent studies [19, 20, 21,22, 23]. Richter has identified two generic business models: *Utility-side and consumer-side business models.* Utility-side renewable energy business model consists of few large-scale projects with a capacity between 1-100 megawatts [14]. On- and offshore wind energy, large-scale photovoltaic systems, biomass, and large-scale solar thermal energy are few examples of technologies that may adopt a utility-side business model. The value proposition in this business model is in "*bulk generation of electricity*" [24]. The customer-side business model is best described by energy generation in small-scale systems close to the point of consumption, often referred to as "distributed generation" [14].

A. Business Models for Electricity Storage

In a recent study [6], He et al. proposed a new business model that aggregates multiple revenue streams of storage. The model, also referred to as "Benefits-stacking" [1], consists of multiple ways to utilize the storage unit at different time intervals. The results from [6] show that under aggregating revenue streams, a storage unit can reach to a higher rate of return and profitability [6]. A set of consumer-side business models are proposed and communicated to a group of utility and power system operators for a particular installation of energy storage systems in UK [25]. The business models were designed and analyzed from an investor or "controlling entity" perspective [19]. The suitability of the business models for projects of a similar distribution-scale and of similar technology-type was discussed as well**.** Such studies could complement previous work on the macro-economic benefit of storage, similar to those introduced for the valuation of storage technologies in the previous sections. The business model framework in [19] contains three main attributes, based on which each business model is characterized. The attributes include (i) Ownership: this attribute describes who takes the risk of construction and operation for the installation of large scale storage systems; (ii) Commercial operation: this attribute identifies the entity who is managing the risk of monetizing and capturing the value of storage; (iii) Market: this attribute describes the relevant market structure to which the operator or owner provides storage services.

IV. TYPOLOGY OF BUSINESS MODELS

Previous studies indicated that many utilities have already developed and implemented viable business models for large-scale utility-side renewable energy generation. Thus, there are choices of business models for those large-scale storage technologies at generation side. However, small scale customer-side energy storage technologies suffer from lack of existing business models adopted or tested by utilities. As appropriate business model framework should be able to combine the business model concept with technological innovation of the storage technologies to provide recommendations for utility mangers and policy makers. For the purpose of this study, the business model is a way that storage asset owners or operators (on behalf of the owners) deliver value to their storage customers, make customers purchase that value, and create profit from those purchases [13,14].

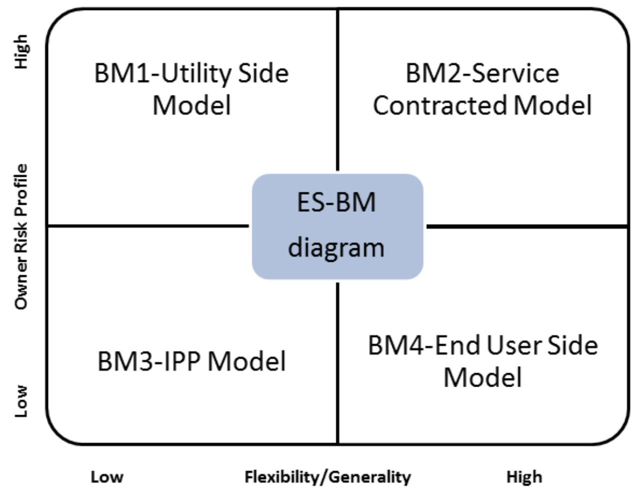

Figure 2. The business model (BM) grid, representing four distinct categories; BM1: Utility side model; BM2: Service contracted model; BM3: IPP model; BM4: End user side model.

In our typology, the maturity of energy storage technologies is assessed by using technology readiness (TRL) and Manufacturing Readiness Levels (MRL), based on a framework developed by US Department of Energy [26]. TRL1 refers to an innovation activity at the very basic research, while TRL9 represents the technology at the commercial stage. Most of the energy storages considered in this proposal are at the prototype stage (TRL5). Similarly, TRL2 refers to lab scale, TRL4 to Bench scale, and TRL6 to engineering scale along technology development path. TRLs between 7-9 are full scale development, where the highest TRL9 is assigned to Pumped hydro systems as the most deployed storage technology, whereas VRFBs are at TRL6. The MRL is similarly assigned to each of the storage systems, but the analysis therein is beyond the scope of this study [26].

The growth and success with the storage industry is relying on innovative business models. The most viable business model for adopting storage technologies at utility side is based on "Service Contract" model. This core business model consists of contracts with private and public partners, where the technology developers and enablers such as storage integrators can contribute to the planning and construction phase of the project. The enablers can also cover a variety of services from technology evaluation and assessment to project planning, coordination, resource management, implementation, execution, and managing operation from generation side to distribution. This type of business model usually does not target emerging storage technologies at low technology readiness levels (TRLs). The commercial viability of storage technologies lies on short- to long-term testing, demonstration, and integration by publicly owned utilities, independent power producers, power distributer, power authorities or operators, and end users. Some models are generally more capital intensive than others, but can attract clients among service recipients from communities (e.g. remote communities). As one the main focus of this research proposal, continuous effort will be put to exploring better typology of the business models and improve the classification criteria.

The business models are divided into four groups that have distinct characteristics to be met by ownership, commercial operation, application, revenue value stream, market structure, and asset maturity (TRL) level. The flexibility of business models to adapt to various location or market structures is another factor that should be considered. Table 1 and Figure 2 exhibit the four models with a few examples in each group. These groups can be determined as the four quadrants of two axes, asset maturity level and risk profile.

V. CASE STUDY

One strategic business model for adopting high risk, emerging technologies is to engage in large-scale projects by leveraging the partnership with strategic partners such as government and technology suppliers (strategic partner engagement model). Financial position limits the technology vendors to be directly involved in capital-intensive, large scale projects. The latter usually have high impacts on communities and could lead to substantial payoffs to the technology developer or Energy Storage System Operators (ESSO). By employing a strategic partner model, ESSOs or Independent Power Producers (IPPs) can generate projects mainly based on public-private partnerships. The services can follow different "revenue sharing" strategies among the end users, asset owner and the technology suppliers. Power authorities can play a role as a project evaluator, in which the feasibility and capability of a specific storage solution in fulfilling needs is evaluated. Other operational services depend upon ESO available resources and capabilities to directly participate in project execution as project manager or monitor the project as per the ISO or IPP request. The latter can cover technical and marketing services for developing adequate policy and regulation. In such circumstance, the public or private partner may finance and therefore own the storage facility [27,28,29]. By financing the asset, the public entity accepts the risk of capital investment. Similarly, the private party may fully or partially finance the asset, in return for a long-term service contract to operate the facility and generate revenue from the storage asset. In the following, examples of business models are provided in which services that ESO or storage technology vendor can provide to utilities within this framework are described in detail.

If the private technology vendor has the ability to fund and run the project independently, the role of ESSO/IPP and the public partner (ISO) is limited to a predefined period to monitor and evaluate the viability and framework of the project. In this case, the business model is to establish a "Service Level Agreement" with the public sector or private vendor. ESSO, often referred to as ES integrators, can provide an independent and effective evaluation of the framework to the public sector and technical/market evaluation to the private partner, Figure 3. The model is particularly suitable when several private vendors can participate, decreasing the amount of capital investment needed from each vendor. The vendor(s) accept(s) the overall

TABLE 1. THE TYPOLOGY OF BUSINESS MODELS AND THEIR RELATIONSHIPS TO OTHER ATTRIBUTES. ISO: INDEPENDENT SYSTEM OPERATORS. BM: BUSINESS MODEL.

Type	Asset Owner	Asset operator	Application	Revenue Stream	Market Structure	Asset Maturity (TRL)
BM1	Utility	Utility	• Arbitrage • Backup • Arbitrage	End User to Utility	Regulated	High (TRL>7)
BM2	Utility	ISO (contracted)	All	End User to Utility	Mix	High (TRL>7)
BM3	IPP	Asset Vendor	• Supply capacity • Backup • Power quality • Frequency regulation	Shared	De-regulated	Medium to high (TRL>5)
BM4	End user	Asset Vendor	• Backup • Frequency regulation	End user	All	Medium to high (TRL>5)

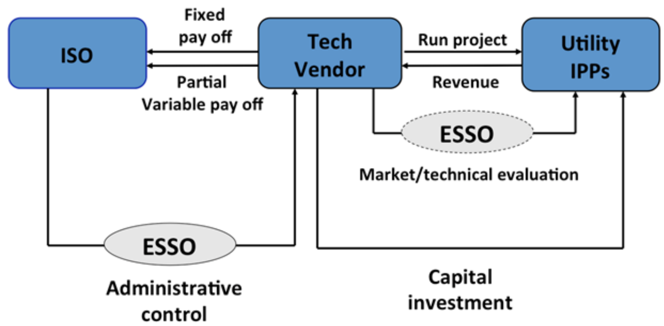

Figure 3. A business activity in which IESSO plays a role as project evaluator. The arrow between A to B shows the direction of transaction, where A is a service provider or payer and B is service buyer or payee.

financial risk of the project, whereas the public utility or power authority shares the risk of administrative control (which can also be transferred to ESSO). The latter could lead to end-user and end customer dissatisfaction; thus, ESSO has to ensure that its contribution will lead to improvements in power services [27]. Either fixed or variable payoffs by the vendor to the IESO or IPPs are expected. Several early stage technologies and market structures can fall into this model.

VI. CONCLUSIONS

In general, existing business models for adopting renewable sources to electricity grids consist of two classes in creating profits from storage assets: (i) those which are adopted from general business models for utility, the smart grid, or renewables ; (ii) those which are specific to storage systems with particular considerations for operation, ownership and revenue streams. The existing business models are mainly "technology-centric" meaning that the storage system is chosen based on maturity and suitability of the technology for specific market. There is a gap in the literature and for practical purposes on where the choice of energy storage system and an appropriate business model would meet. The typology of business models that was proposed in our study is based on four groups that have distinct characteristics to be met by type of ownership, commercial operation, application, revenue value stream, market structure, and asset maturity (TRL) level. The business model framework and a test case study indicated that the most viable business model for adopting storage technologies at utility side could be based on "service contracted" model, which include both "technology enabling" and "operation" services. The core business model consists of contracts with private and public partners. The technology developer and enabler such as storage integrators can contribute to the planning and construction phased and can cover a variety of services from technology evaluation and assessment to project planning, coordination, resource management, implementation, execution, and managing operation from generation side to distribution. These types of business model usually do not target emerging storage technologies at low TRLs. An innovation analysis based on technology management tools will be required in order to unravel the relationship between industry readiness level and innovation of the technology in one hand and the choice of appropriate business model on the other hand. This requires demonstration and certification or regulation of the facility together with required policy instruments, which need to be analysed in parallel. Finally, the commercial viability of storage technologies lies on short- to long-term testing, demonstration, and integration by publicly owned utilities, independent power producers, power distributer, power authorities or operators, and end users.

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