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Market Structure and Business Model for Microgrid as a Part of Smart Grids

Omid Palizban and Kimmo Kauhaniemi
University of Vaasa, Finland
Omid.Palizban@uva.fi
kimmo.kauhaniemi@uva.fi

Abstract

Technical and economic considerations can both affect the feasibility of microgrids. During the implementation of a microgrid, a very significant issue for participation in the energy market is the economic evaluation, which also can improve the efficiency and the advantage of investing in this type of system. This report surveys the literature for information on the economic evaluation, market structures, and business models of microgrids. The structure of energy markets for microgrids is oligopolistic and involves four agents. Also discussed here are the benefits of electricity generation by DG units near the point of consumption, the different ways of selling electricity with Distribution Network Operators (DNOs), and the current barriers and solutions to entry.

Keywords; *Business model, Market structure, Microgrid*

Introduction

The use of small-scale power sources to support a group of electrical loads has increased with growing demands for electrical energy [1]. The power sources are normally mixed, and may be variable renewable energy sources, such as photovoltaic or wind-turbine generators, complemented with fossil-fuel generators, that meeting local heating requirements and electricity demands. The microgrid's principal feature is a local electricity generator for matching the local power requirements in the microgrid, in order to facilitate operation in the absence of an external grid connection. The microgrid may even exist as a remote power system in regions where utility supply is not available, with the grid then operating continuously in island mode.

There are two significant areas in microgrid research: the technical and the economic. The technical research discusses issues regarding the main utility and microgrid interface schemes, voltage, and frequency regulation, as well as active and reactive power control and several other issues [2, 3]. Aspects of the economic evaluation—such as market structure, business model, and the energy market—are discussed in the section on economics [4]. A comprehensive review of market strategy and tariff structure is given in [5]. Microgrid energy market topics, including spot marketing and pricing that can be applied to predict and ensure its economic viability, are covered in [6]. Additionally, [4] present the economic evaluation of an autonomous independent network of distributed energy resources.

With the recent increased interest in microgrids and smart grid issues, a microgrid energy market has begun to seem much more significant. This report covers two broad issues: first, economic efficiency is discussed, and then the potential market structures available to microgrid are reviewed. In fact, the first part is based on the information, data, and ideas of [4], and most of the second part of this report summarizes chapter 10 of [7]. Finally, some conclusions are drawn on the basis of the literature survey.

Economic efficiency

The costs of implementing a microgrid first of all include the cost of Distributed Energy Resources (DERs), such as DGs and energy storage. The second investment is the price of power-electronic devices, such as the different types of converters. Moreover, there are several other pieces of equipment required, such as protection devices, communication links, and the basic power system (mainly lines and cables). The final investment cost, which arises after microgrid implementation, is maintenance and operation. The total of all the above costs is the price of the system as paid for by the customer, so optimizing of these costs is necessary. In [4], these costs of a microgrid system are evaluated in three different categories:

- Operational costs of DERs (include fuel costs, and inspection and maintenance costs);
- Capital costs of DERs (installation of DGs and other necessary devices);
- Electricity charges (paid by consumers when the microgrid purchases electricity from the main grid)

Indeed, there are some individual devices for the installation of microgrids, such as Distribution Management Systems (DMS), Network Control Systems (NCS), and communication links. Customer payments should thus cover all installation, operation and maintenance costs and these should be minimized. The principle of assigning different priorities for loads and of shedding loads during peak demand are not acceptable in microgrid with high power quality. Hence, there is another cost that arises as damages caused by power interruption; these are called Power Interruption Costs (PIC). These are calculated based on three factors: the duration of the interruption, the type of consumer, and geographical attributes [4].

In line with the findings of [4], the following four models are the most commonly used to evaluate the economic feasibility of a microgrid:

- Model 1: All consumers have a contract with the main utility, and they do not install any DERs.
- Model 2: Each consumer has a contract with main utility, but they also install DERs.
- Model 3: The consumers connect to an island-mode microgrid and support the all load using only DERs.
- Model 4: The consumers connect to a grid-connection microgrid, and their loads are supported with DERs and the main grid.

The total costs of these models are evaluated in Fig.1, which shows that, even taking into account the high cost of constructing a microgrid, energy costs will decreased in a microgrid as compared to present practice (model 1). Comparing all models, it is clear that the first two models are clearly less economical than models 3 and 4. Indeed, model 4 is slightly more economical than model 3 because, power quality for all consumers in model 4 is more satisfying, with minimal PIC [4].

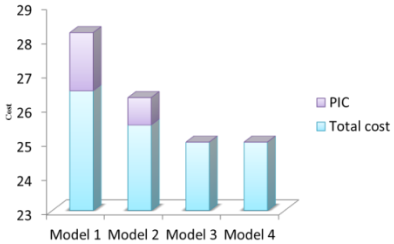

Fig. 1 Total costs of all cases [4]

It should also be noted here that the literature review summarizes data collected from a research project in Japan [4], and it is clear that the costs will not be the same in all countries in the world. However, the result of the investigation into the models is the same for all counties, meaning that the model 4 is the best, with the highest efficiency in all cases.

Market participation of Microgrids

There are in general three main transactional models, the first of which is known as a pool. This method is based on centralized marketing, in which all power suppliers inject their own production, as well as the price of generation, into the pool, and customers then submit their demand to the same pool in order to make a deal. A significant aspect of all marketing models is the Independent System Operator (ISO), whose main objective is not generation dispatch, but rather matching energy supply to demand in order to ensure reliable system operation. ISO systems in the pool method usually receive bids based on the demand forecasted for the following day. With this strategy, their consumers are supported with the lowest electricity price, and the optimal price for generation is received. There are three types of ISO power pool:

- Tight power: This method’s function usually is based on bounding a control area through metering and interconnection;

- Loose power: Unlike with tight power, there are no control area services in loose power pools. Supporting for consumers is only during emergency conditions;

- Affiliate power pools: The power generation and the energy demand of the consumer cooperate as a single utility by using an aggregator.

A bilateral contract, or direct access, is the second transactional model. This method can be adapting well to microgrid conditions, because energy buyers and sellers can have electricity marketing directly without a connector system. The third model is a combination of the first two, and is the most complete method because it uses all the features of the pool and the bilateral method together. In this model, customers can select pool power generation first, and on this basis sign a bilateral contract. Moreover, marketing options can be very flexible in the hybrid system, which means there are many different prices, based on different services and on power quality [7].

4.1 Microgrids in power market competition

The microgrid can participate in the energy market, same as an ancillary service markets. The oligopolistic method, based on a multi agent system, is the best market structure for microgrids [5, 8]. The authors of [9] and [10] present a comprehensive review of the implementation of multi-agent systems based on the technical challenges, approaches, and defining concepts, as well as the standards and tools. In [11, 12]a market-based, multi agent system framework for microgrids is provided. Microgrid agents are divided into production, consumption, power system, and Microgrid Central Controller (MGCC) agents [5, 13]. Controlling of Microgrid and energy management is the main responsibility of the MGCC, and it must also coordinate the priority of loads. The MGCC, along with the consumption agent, participate directly in the marketing operation. Moreover, the power system agent is one of the most effective components for determining the buying and selling price for electricity, but does not itself participate in the marketing operation [5]. Microgrids buy and sell the shortage or surplus of power to or from a main grid through an aggregator. Therefore, the microgrid and main grid have different perspectives to the aggregator. For instance, during the selling of power by the microgrid to main grid, the aggregator is the seller from the point of view of the main grid, and is the buyer from the perspective of the microgrid [14].

Aggregators take care of local distribution systems and greatly reduce the workload burdens on both ISO and the local DNO, particularly when there are great numbers of retail market participants in the networks. Retail market trading for DER energy is depicted in Figure 2.

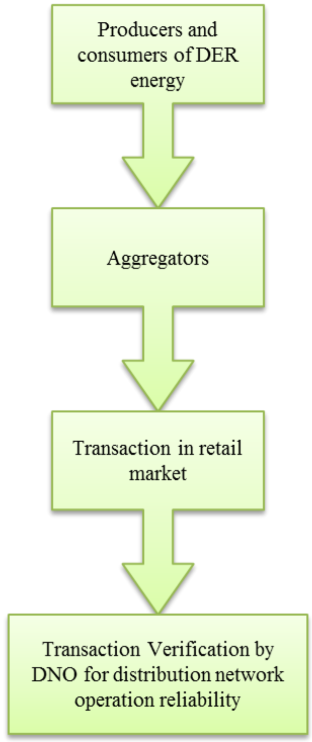

Fig.2 Retail market trading for DER energy[7]

In recent years, many proposals have been provided to change power transactions, of which retail wheeling is one. The main target of the method is to produce a market strategy for reducing the cost of electrical energy. A simple description of it is that electrical suppliers and customers can perform transactions remotely. Moreover, excess power is injected into the utility through the microgrid in open competition [7].

The retail markets for generated electricity and for ancillary services presently lack the scope for open competition. If DER technologies and their ancillary services—including cogeneration facilities and minimization of environmental impact—are to be successfully introduced and properly utilized, open competition will be necessary. Without this, the survival of DERs is in doubt. Microgrids, with their associated new paradigm [7], are the only way to apply DERs efficiently and cost-effectively to the development of distribution systems. Microgrids are capable of fully using DER ancillary services to provide reasonably low-cost solutions to maintain frequency and voltage profiles and to ensure the reliability and security of systems [7]. The following five business models for smart renewable energy are described in [15]. First is the development of technology capable of effectively shifting renewable energy to on-peak from off-peak availability. Second are technological methods that could improve power quality (in particular, in terms of voltage fluctuation and power factor) by adjusting for the variability of renewable sources. Third, predictive methods for the production of wind energy and management of power exchange. Fourth, the use of grid-load status in determining output control. Finally, the use of island-mode operating technology to cover grid blackouts with electricity from renewable sources.

Conclusion

A survey on existing research literature about the economical evaluation and market structures of microgrids is presented in this report. The review shows that building a Microgrid with an optimal operation of DERs is more economical than having each consumer operates DERs independently and microgrids have the potential to provide ancillary services as well as the benefits of these should be considered in the economic evaluations of future studies. A number of barriers for DG are listed in this report as well as the solutions on the way.

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