Review Article

Review of Energy Management in Micro Grid in Power Engineering

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ABSTRACT

Energy management changes the electricity consumption pattern of customers. This change is done to achieve the optimal consumption curve. Using energy management, by reducing consumption in periods, besides the appropriate load curve, it reduces the cost of operation and planning. Electricity supply in traditional networks is done by large power plants that are concentrated in certain places. The generated energy must be transferred to consumption points by transmission and distribution networks. The above-mentioned power system has many problems, among which we can mention the decrease in reliability and availability due to the wear and tear of the electrical system infrastructures and the imposition of high costs of losses in the energy transmission to the load points. In other words, management includes a set of activities that affect the pattern and amount of consumer load. Basically, consumption management programs aim to achieve various goals, the most important of which are improving the efficiency of energy systems, increasing the load factor, reducing the need for investment to build and postponing the construction of new power plants, reducing the effects harming the environment, reducing the cost of electricity supply to customers, compensating for the shortage of supply and reducing the excess demand for electricity, improving the reliability and quality of power, promoting the development of energy economy, creating a culture of saving and effective support for customers pointed out.

Introduction

The purpose of the energy management system (EMS) is to decide on the best use of generators to produce power and heat in the micro grid, the best scheduling of the storage system, proper load management, proper buying and selling from the power grid [1]. In this thesis, load response programs are used to implement energy management on the micro grid. Load response programs also mean the implementation of activities that lead to a reduction in peak demand in the short term and are proposed in a short period (Figure 1) [2]. The US energy regulatory commission has divided load response programs into two main

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categories: incentive-based programs and time-based (tariff-based) programs [3].

Figure 1: Centralized control [3]

In this control structure, the central micro grid controller seeks to minimize the operation costs in the island mode and in the grid-connected mode, seeks to optimize the exchange power with the national network in order to reduce the operation costs. In this study, this type of control is used for the EMS. In decentralized control, each micro grid is controlled by a controller. Decentralized control is a possible solution for many control and energy management problems in micro grids [4]. This type of control is depicted in Figure 2. One of the best candidates for the decentralized control of micro grids is to use the concept of multi-agent systems. In this method, each agent uses his intelligence to determine the leading activities and make decisions independently from other agents. In the off-grid mode, the operator's goal is to minimize the operation cost, and in the grid-connected mode, since the micro grid has the ability to exchange power with the national grid, the operator's goal is to optimize the exchange power to reduce the operation costs. In this study, the problem of energy management is implemented by load response programs. Load response programs are aimed at reducing costs and solving the problem of consumption density. The system operator reduces the amount of demand by implementing load response programs, and using the centralized control of the micro grid, under these conditions, it issues the required signals of the production units for optimization [5].

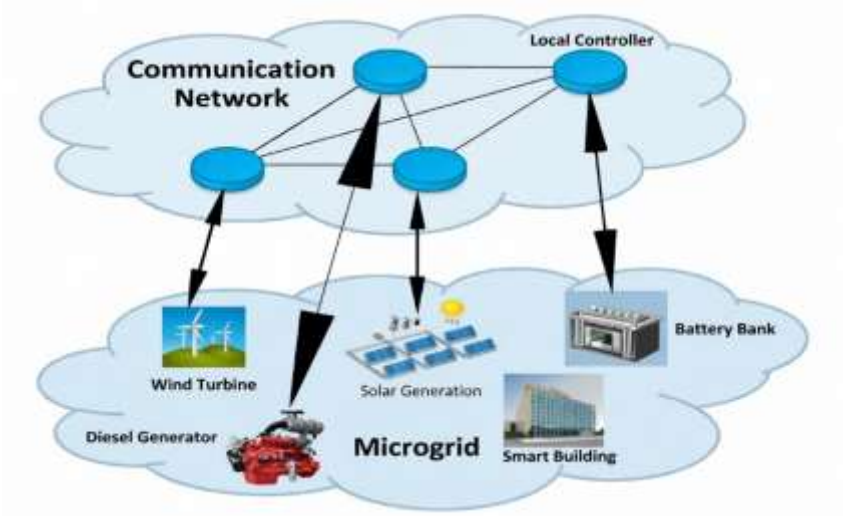

Figure 2: Decentralized control

Micro grid

The use of distributed production resources, keeping in mind the optimal level of security, adequacy and overall reliability, as well as the quality and availability of power in the presence of new control methods, the need to move towards the direction of distribution networks from passive to dynamic (active) mode. It increases conversion. To reach this definition, a new concept called micro grid has been created. Micro grids are small grids that include components such as distributed energy sources such as micro turbines, solar cells, and power storage such as batteries, along with controllable loads, along with a strong management and control system that can be separated from the main grid if necessary and work as an island [6].

CERTS micro grid definition

According to CERTS, a micro grid is a small grid with low power generators. The sources of power generation in micro grids are mostly new energy sources. Micro grid has two main components. Network switches and small producers. This structure consists of several radial feeders, each of which can be a part of the distribution network. In this structure, there is a point that is connected to the upstream network using the network connection key. Unimportant loads will be cut off due to network failure [7]. On the other hand, when the micro grid is connected to the grid, it is possible that unimportant loads are fed by the micro grid generators. The main difference between this definition and the previous definitions is that it considers micro grid loads to include only sensitive and uninterruptible loads, while in the previous definitions, micro grid loads are defined with different degrees of importance, which requires the capacity of available resources. In the micro grid, it can be compared with the existing loads, so that in the island state, loads can be supplied often [8].

Micro grid structure

According to Figure 3, the micro grid is a part of the distribution network, which includes different types of distributed energy sources and consumers of electricity and heat energy. The micro grid has the ability to connect and disconnect from the upstream network by a switch and the accompanying transformer, and different subscribers such as households, serves commercial and industrial [9]. As can be seen in Figure 3, the micro grid can be connected to the upstream network and provide other services such as thermal energy supply or ancillary services in addition to the task of providing energy.

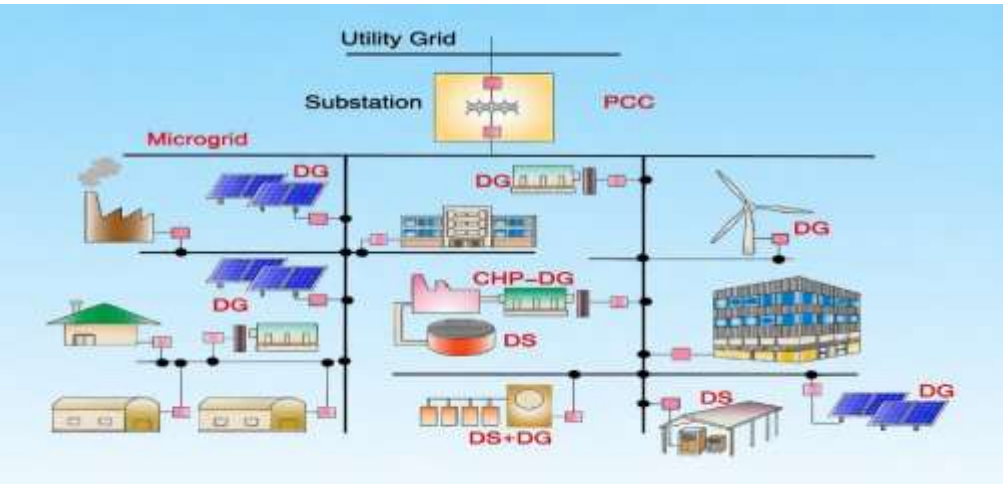

Figure 3: Energy producing and consuming elements in the micro grid

After being separated from the upstream network, the micro-grid must have the ability to supply the load of its subscribers in an island mode. Many tools have been used in micro grids, the most important elements in micro grids are as follows: 1)Scattered energy sources. 2) Connection interfaces. 3) Micro grid loads. 4) Management systems. 5) Control structure [10]. In the following, brief explanations are provided about these elements.

Distributed energy sources

Distributed energy sources are responsible for providing energy in micro grids. Based on the definition (IEEE std547.3), these sources can be placed in the following three categories: 1) Scattered products. 2) Scattered reserves. 3) Burden response sources [11].

Connection interfaces

Depending on the type of distributed energy sources, their connection to the micro grid is different. As an example, power electronic devices such as inverters and filters are used to connect some sources to the micro grid. Figure 4 demonstrates the keys to connect to the upstream network. These switches include equipment such as disconnecting and connecting switches for control circuits, telecommunication circuits and measurement circuits. According to Figure 4, it can be seen that the current and voltage measurements measure the current and voltage values of the micro grid and network and then send the signal to the digital processor. The digital signal processor makes disconnection and connection decisions according to the conditions [12]. The high importance of connecting to the network and the need to control the key to connect to the network increases the importance of this key for the micro grid. The key to connect to the network has a controller that decides to determine the state of the key according to the commands of the control center as well as examining the technical conditions [13].

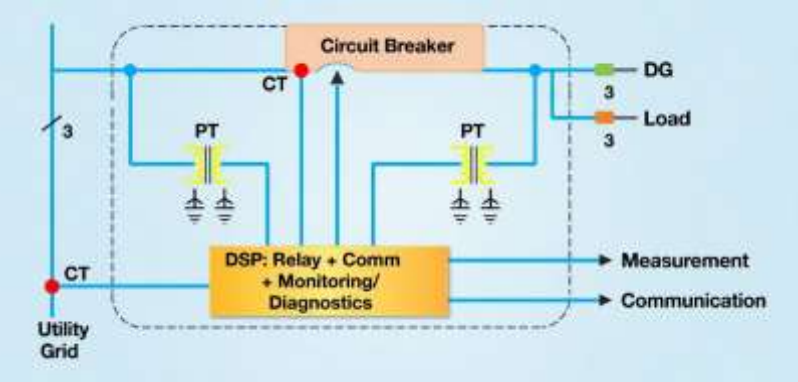

Figure 4: Micro grid connection key

Micro grid loads

A micro grid can feed both electrical loads and thermal loads. From the perspective of the upstream network operator, a grid-connected micro grid is often considered as a slack bus capable of receiving and transmitting power. In this case, to establish a power balance in a micro grid, load-generation interruption is used if there are limitations for the power sent or received from the main network based on the exploitation strategies or two-way contracts.

In the operation of a micro grid in the off-grid mode, production-load interruption is often used to establish power balance, which ultimately leads to voltage-angle stability [14]. Loads in a micro grid are classified into the following two general categories in terms of feeding priority: 1) Sensitive loads. 2) Insensitive loads.

Management systems

To properly exploit a network that includes more than two scattered production units, especially in the case of separation from the network, a power management strategy and an energy management strategy are needed. Figure 5 illustrates the route of receiving and sending information as well as the functions used in PMS/EMS for a micro grid. In Figure 5, the power-energy management block in real time receives the information related to the predicted value and the real time data of the load, production and market, and based on this received information, appropriate control signals are sent to spread the load, determine the amount of load sends [15].

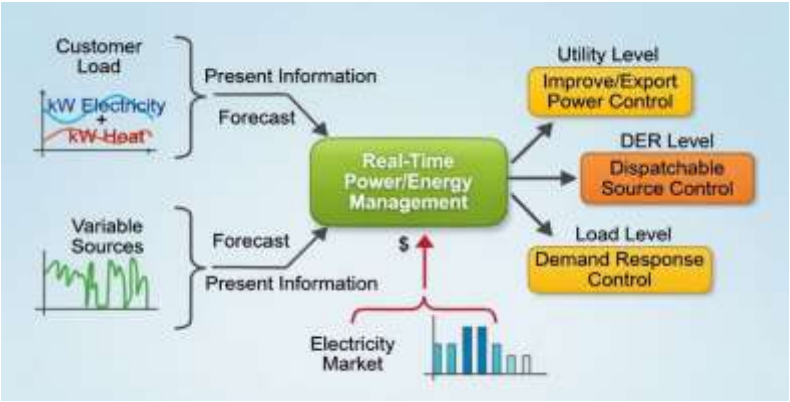

Figure 5: Information path and functions used in real time of a PMS/EMS in micro grid

Control structure

The control structure in the micro grid is divided into two main categories: centralized and decentralized. Each of these control structures includes three sequential levels: 1) Distribution system operator (DNO) which can be combined with market operator (MO). 2) Micro grid central controller (MGCC) which is also a micro grid operator (Figure 6). 3) Local controllers (LC) that are related to each of the scattered production units or loads.

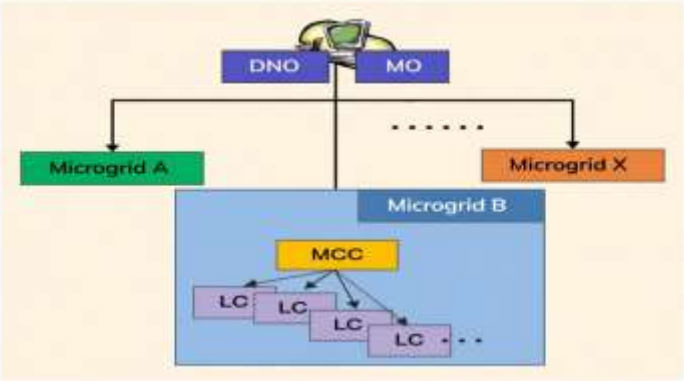

Figure 6: Structure of management and control in micro grids

The operator of the distribution company is at the highest level of control, overseeing the area where there is more than one micro-grid. Likewise, one or more market operators are in charge of market related duties for each specific area [16]. The operator of the distribution company and the operator of the market do not belong to the micro-network, but are dependent on the main network. The microgram central controller or the microgram operator is the main link between the microgram operator of the distribution company and the market operator. The microgram central controller is responsible for various tasks, from maximizing the value of the microgram to coordination between local controllers. The local controllers, which include the lowest level of control, are in charge of controlling distributed generation units and controllable loads in the microgram. Depending on the control structure, each of the local controllers may have a certain level of intelligence [17].

Micro grid centralized control

Figure 7 shows the path of information exchange in this case and states that the existence of a two-way communication between the local controllers and the microgram central controller is necessary. This communication can be done by telephone lines, power transmission lines or wireless [18].

Figure 7: Information exchange path in a micro-network with a centralized structure

In this control structure, the micro grid's central controller seeks to optimize the exchange power with the main network and also to maximize production based on market price and security restrictions. Scheduling is done by the microgram central controller at predetermined intervals, for example, every 15 minutes for the next hour or hours. Concerning the market-based policy of the microgram operator by receiving the following information:

1) Market price.
2) Suggested price and determination of feeding priority by local controllers of loads.
3) Proposed price and production rate by controllers of scattered production resources.
4) Network security restrictions.
5) Forecast data of renewable resources (Figure 8).

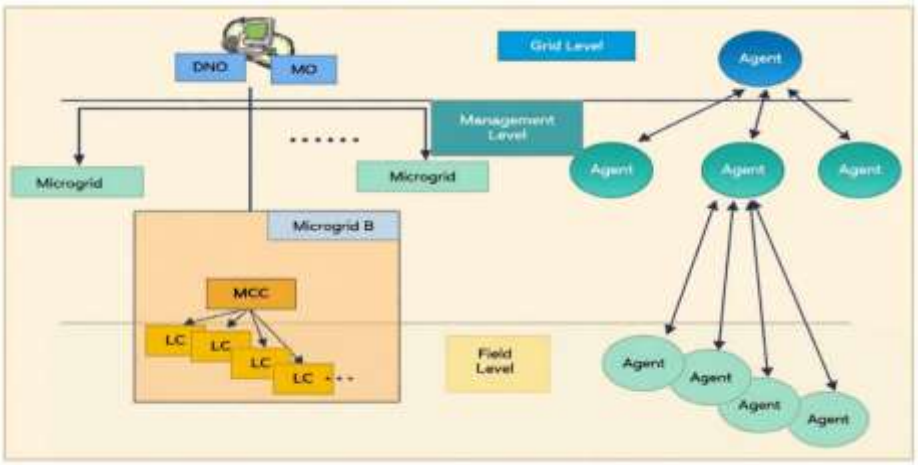

Figure 8: MAS architecture for decentralized microgram control

Planning and operation of micro grids

The operator must consider limitations for planning and operating micro grids in the short and long term. The restrictions related to short-term exploitation are: 1) Cut off the load if necessary. 2) Voltage and frequency regulation in transient mode. 3) Acceptable dynamic response [18]. 4) Power quality for sensitive loads. 5) Synchronization with the network with the main network in case of disconnection.

Technical and economic advantages of micro grids

The development of micro grids is important for the modern electricity industry for many reasons.

Environmental issues

It is clear that micro grids have a much less destructive effect on the environment than conventional power systems based on the centralized exploitation of large thermal power plants. The use of non-fossil energy production sources and the subsequent reduction of greenhouse gas production is one of the biggest benefits of expanding micro grids. On the other hand, due to the proximity of consumers to energy production sources, they help consumers' awareness of the optimal use of energy and generally increase productivity [19].

Investment and operation

Reducing the physical and electrical distance between sources and loads can improve the reactive power support of the whole system and, as a result, the voltage profile, reduce density in transmission and distribution feeders, reduce transmission, and distribution losses, and finally the postponement of investment plans for development and transfer and production by proper management is endless [20].

Challenges of developing micro grids

Despite the potential, the development of micro grids faces challenges that need to be solved. Some of the most important ones are briefly mentioned below.

High initial investment costs

High costs for building micro-grids are a major weakness in the development of these networks. Although these costs can be reduced by setting up mechanisms to encourage investment by the government [21].

Technical problems

Lack of technical experience in controlling a large number of small resources as well as management and protection are among the research topics that should be addressed. Necessary telecommunication infrastructures and communication protocols should also be investigated. Especially when the microgram is designed for a remote area, the necessary telecommunication infrastructure must be considered.

The presence of micro grids in the electricity market

There are two general policies for the presence of micro grids in the market environment:

First, the entire demand of the microgram is provided by local sources, without taking into account the exchange with the upstream network. Based on this, the micro grid operator must minimize the costs of using the micro grid every hour [22].

Second, the micro grid operator has the ability to exchange power at the market price with the upstream grid, and based on this, the operator seeks to minimize the operating costs and maximize the amount of production to sell to the upstream grid and, as a result, optimize his income [20].

Types of load response programs

Load response programs or demand response programs are classified into different types in different authorities.

Classification of load response program from FERC's viewpoint: From FERC's point of view, load response programs are divided into two general categories:

A) Incentive-based load response: In this type of load response, incentives are paid to consumers to encourage electricity reduction in critical times [23].

B) Price-based load response: In this response, time-varying tariffs are used according to the costs related to electricity generation. Consumers can reduce their electricity bills by not using in high price hours or changing their consumption to low price hours. Incentive-based load response programs include the following:

B1) Direct load control: In this program, power companies have the ability to remotely turn off subscriber equipment for a short period of time. The equipment's that are usually remotely controlled in this method include the air conditioning system and water heaters. This method is mainly considered by home and small commercial customers.

B2) Load cut or load reduction: In this program, subscribers get monetary incentives or discount rates in exchange for reducing consumption, the amount of which is defined in advance. If the consumer does not reduce his consumption in the prescribed time, he will face a fine [24].

B3) Demand selling/repurchasing: In this method, major consumers offer the amount of load that can be reduced along with the price to the independent operator of the system, and after the execution of market operations, if the price is below the market settlement price, the offer is accepted and the customer is obliged to execute the contract (Figure 9).

B4) Emergency load response programs: In this program, subscribers receive a significant amount as a reward for cutting load in emergency situations. Of course, load shedding is optional and if the customer does not reduce the load, he will not be fined [25].

B5) Capacity market programs: In this method, subscribers undertake to reduce a certain

amount of load and if they don't do it, they will be fined. Usually, this method is performed for loads above 100 kw and continues for four hours and is notified to the subscriber two hours before.

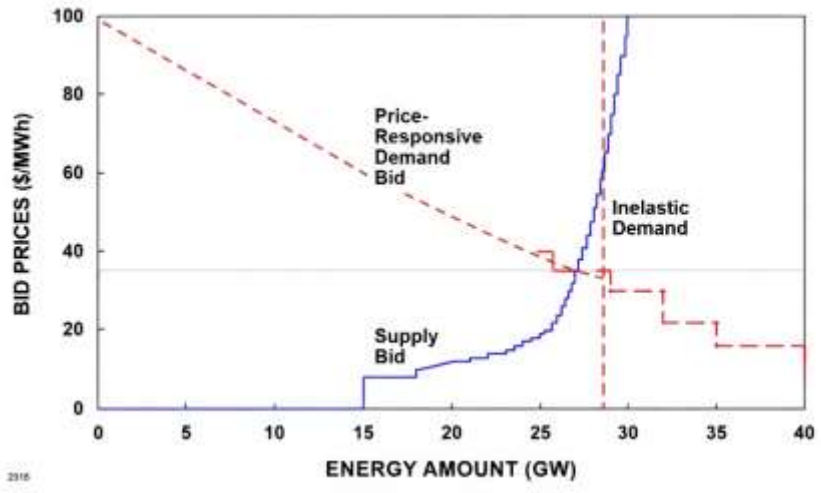

Figure 9: Demand sale/repurchase

The customer receives a guaranteed amount in exchange for his commitment, the independent system operator identifies these resources and considers them as the installed capacity of production and regularly inspects that there is no overload. It is also possible that there will be no need for these loads, but an incentive amount such as the insurance amount will be paid.

B6) Side service programs: In this program, subscribers offer their load shedding to the independent system operator. If their proposal is accepted, they will receive the market settlement amount for keeping their load ready. Of course, whenever they are called and cut off their load, they may receive the current price. These types of loads must be fast, to act quickly when accidents occur, and they must be large amounts, such as large water supply pumps, electric arc furnaces, and air compressors [26].

Conclusion

With the expansion of the penetration of scattered energy sources in power networks, methods have been proposed to collect these sources with various goals. As mentioned, one of the collection methods is micro grid. In the space of restructuring, there should be favorable financial incentives for investment, so that such networks are formed. Therefore, optimal use and planning of micro-networks should be in such a way that an acceptable justification for investment emerges. One of the strategies for optimal use and planning of micro grids is to use load response programs. The most important effect of using load response programs is that it encourages subscribers to reduce consumption. In this thesis, the effect of using the load response program in optimal micro grid planning in different operating conditions was investigated.

Conflict of interest

No potential conflict of interest was reported by the authors in this study.

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