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Research Article

The Role of Energy Management in Microgrids *With Hybrid Power Generation System*

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Abstract

Nowadays, consumption of energy is gradually increasing, the conscious for protecting environment is improving and liberalization in energy market is proceeding. Furthermore, the distribution of traditional energy sources is not homogeneous. These reasons are increasing interest to create policies for benefiting from renewable sources better by developing newer technology and to fuel cell based alternative distributed generation systems. Energy generation systems like wind, photovoltaic (PV), micro hydroelectric are the promising and the most important renewable energy technologies. Moreover, fuel cell based systems will indicate a great potential for future applications of distributed generation because of their quick developing technology, high productivity, pollutant gases with no or low emission and their elastic structures. In this study, energy management of a hybrid microgrid that was renewable energy based (wind, photovoltaic, micro hydroelectric) was provided by a computer program reformed in Microsoft C Sharp(C#) programming language in order to supply electric energy to small locations like holiday camps which were far away from energy distributing systems and other locations. It was observed that demanded energy was met by the data taken from generation sources thanks to this developed program. The importance of the energy management was explained by analyzing one year results via graphics.

Keywords: Energy management, hybrid systems, microgrid, power generation, renewable energy sources.

1. Introduction

Electric energy is a type of clean energy of which transmission, usage, control is simple and that can easily turn into other types of energy and with which everything is meaningful in our life. This energy is the most significant factor that facilitates quality of life in human life, that is one of the essential requirements for industrial productions, that facilitates economical and social progress. Increasing energy prices, global warming and climate changes, population growth both in our country and in the world, increasing life standards, increasing energy demands parallel to industrial and technological improvements, the continuity of dependence to fossil fuel which is wasting quickly, avoiding dependency to other world countries, providing security of supply and improvements in newer energy technology areas lead the countries to novice searches. Therefore, this demonstrates that it is a great necessity to use renewable energy sources for generation of electric energy. It is expected that transmission and distribution sources a**2.** also the use of fossil fuel will decrease parallel to popularity of distributed renewable energy generation. Although there are various renewable energy sources (biomass, geothermal, solar energy, wave, landfill gas, etc.); this study is limited to hybrid renewable energy systems consisted of wind turbine, PV panel and micro hydroelectric generation units.

Turkey takes place in a very fortunate geography in terms of varieties and potentials of renewable energy sources. Costs of these energy sources are quite low, they are inexhaustible for being renewable and they aren't threads for health of human and environment opposite to conventional fuels. However, that renewable energy sources cannot be estimated discontinuously and naturally prevents them from using in a common way. This problem can be solved with the storage system and proper management strategy which prevents the time consistency between energy generation and load requirements

Electric energy generated from sources that take place traditionally far away from the settlements, is increased to high voltage in order to prevent loss, transmitted as an alternative voltage and distributed by reducing to low voltage (Sevgi 2005). In the previous years, electric energy has been generated, transmitted and distributed to long distances centrally; however, concern for distributed generation systems and microgrids is increased as a result of growing consumption and environmental problems caused by traditional energy generation.

2. Microgrid

Microgrid is a new energy source and grid management technology that has emerged at the end of last century and also it is the grid controlled independently, provides power with distributed generation systems. These might let renewable and clear sources involved, maximum use of present energy and management of demand. A microgrid system consisted of a part of main grid and industrial and commercial applications can work independent from the

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grid or dependent to grid. The structure of microgrid, wind generators, microturbines, fuel cells and PV modules, etc. can be seen in figure1.

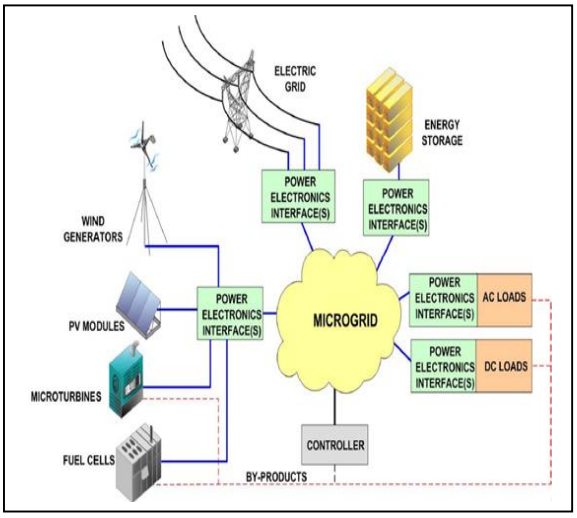


Figure 1. Structure of microgrid (Şimşek 2011).

As it can be seen in figure 1, they are connected via an interfacial unit as a converter based upon power electronic. Participation of power electronics converters into the system affects the quality of the system and also requires new control regulations (Arsoy et al. 2010).

Distributed energy sources might be both distributed generation and distributed storage energy in microgrid. Distributed generation technologies are generation units such as internal combustion engines, gas turbines, combined cycle gas turbines, micro turbines, fuel cells, wind turbines, PV solar panels, solar heat, tiny hydroelectric, geothermal energy, biomass, tidal energy and wave energy. It is expected that wind turbines, PV, small hydraulic generators, geothermal energy and fuel cells will increase power generation market shares in the entire world (Özdemir 2007). Energy storage units are flywheels, ultra capacitors, Superconduction Magnetic Energy Storage (SMES) and electrochemical batteries (Kocaman 2013).

Microgrid approach requires a structure that has sufficient power generation and stabilization sources in order to convey highly efficient system of energy distribution and supply as a result of proper placement of distributed energy sources and to create a safe and reliable system based on consumers' technological choices and power quality demands and also to operate independent from the grid during interruptions. As a microgrid, a hybrid grid being a renewable energy sources such as wind turbine, PV panel and micro hydroelectric plant was used in this study.

3. Hybrid power generation system

Hybrid power generation systems are systems that generate energy from two or more raw energy sources and units that contribute to each other correspondingly. The aim of hybrid systems is to increase capacity and to make the others meet the need of energy in case a source lacks or decreases, using energy sources together. In these kinds of applications, the most significant factors that determine the number of sources and the type of source are that source in power generation area should be at sufficient level and that sufficient technology level should be required for some types of energy to assemble the system. Energy sources such as hydrogen, biomass and fuel cells are examples of this. Increasing power qualities of hybrid systems and examining stable position of performances are also notable points (Demirtaş 2008).

3.1. Advantages of Hybrid Power Generation Systems

There are many advantages of hybrid power generation systems. These advantages can be listed as below (Ismail 2008).

- The possibility to combine two or more renewable energy sources, based on the natural local potential of the users.
- Environmental protection especially in terms of CO_2 emissions reduction.
- Low cost – wind energy, and also solar energy can be competitive with nuclear, coal and gas especially considering possible future cost trends for fossil and nuclear energy.
- They provide diversity and security of supply.
- They provide rapid deployment - modular and quick to install.
- The fuel is abundant, free and inexhaustible.
- Costs are predictable and not influenced by fuel price fluctuations although fluctuations in the price of batteries will be an influence where these are incorporated.

Modeling is a significant component for management of power energy system. A proper model helps decision of unit connection and electricity services in order to accommodate operating costs and emission levels. Moreover, it plays an important role to meet demands of burden. Major requisite is reliability of microgrid. Notable studies have been carried on about management and control of microgrids nowadays. Hybrid systems which are independent from the grid can also be combined with energy storage in cells so as to increase the length of independent energy. Therefore, wind energy generation system, PV energy generation system, micro hydroelectric energy generation system, the unit of storage, electrolyzer and units of fuel cell have been explained detailed as they are components of renewable energy system that creates microgrid.

4. Energy Management in Microgrids Based on Hybrid Power Generation System

Energy management product quality without all security or environmental conditions in line with the efficient use of energy and production of layered sacrifice structured and organized in a disciplined study. The purpose of energy management; ensuring the security of energy supply; energy sources to increase the diversity and the use of edible resources, electricity generation, transmission, distribution and use of reducing the losses of the economical, social development, competitiveness and national security holds an important place in the field of energy, is to realize the innovation activities.

Remote from the city network and renewable energy source in energy management and production of microgrids connecting to electrical energy, they produce a

hybrid of resources the power to transfer the load or load aksed me need more 18144 kW, which is part of the storage unit (battery or super capacitor) is provided for use when you need storage. In cases where the battery is full, the energy produced is transferred either directly to the load, or later, to be used for the production of hydrogen fuel cell will be redirected to electrolysor. For prevent excessive discharge or overcharge the battery the charging regulator is used. The battery's minimum charge has been selected %40 and maximum charge has been selected %80. In addition, in cases the production of energy resources in the production of the battery power failing and a part of the energy needs of empty fuel cell, it will be held with the energy management. Thus, the energy production unit and the load between a continuous energy flow is targeted. The program was created for the microgrid system block diagram in Figure 2 are given. As shown in Figure 2 the block diagram wind turbine, solar panel, micro hydro power plant, fuel cells and electrolysis unit has been integrated with the system, consisting of the AC connection bar. The production units are used, the desired supply voltage (400V) and frequency (50 Hz) AC voltage, it is necessary to have the values were obtained using converters.

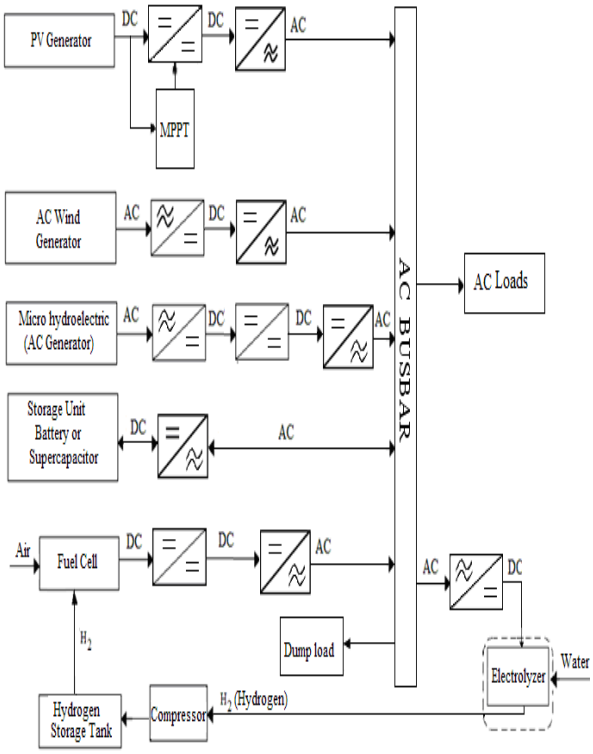


Figure 2. The block diagram of micro grid system

The energy management strategy that was developed, optimize that how much power will be used. So the amount of power requested by the loads, the power produced by renewable energy sources is more than energy management, detect the most appropriate shape to meet the power deficit. Generated renewable energy source used in the microgrid system specification Table 1 shows the volumes.

Table 1. Units of microgrid system and characteristics

Sources	Type and installed power	PV panel , 10 kWp
	Type and installed power	Wind turbine ,15 kWp
	Type and installed power	Micro hydroelectric , 8 kWp
Battery	Type and energy capacity	Lead acid, 4 kWh
Electrolyzer	Type and power	PEM, 4 kWp
Hydrogen Storage	Type	Pressure tanks(137 bar)
	Density capacity	2856 Nm^3 H_2
	Energy capacity	10,127 kWh
Fuel Cell	Type and power	PEM, 4 kWp

Ensure the load is created to provide an integrated hybrid system energized energy management strategy, the need for instant energy, which is in the circuit and the other units of the system resources to show the status of the Microsoft Visual Studio C Sharp language program has been developed. The similar works of that received data, the data is provided by the use of this program by transferring data to the database. The flowchart of control strategy of the program that is used to control the generated strategy is seen in Figure 3.

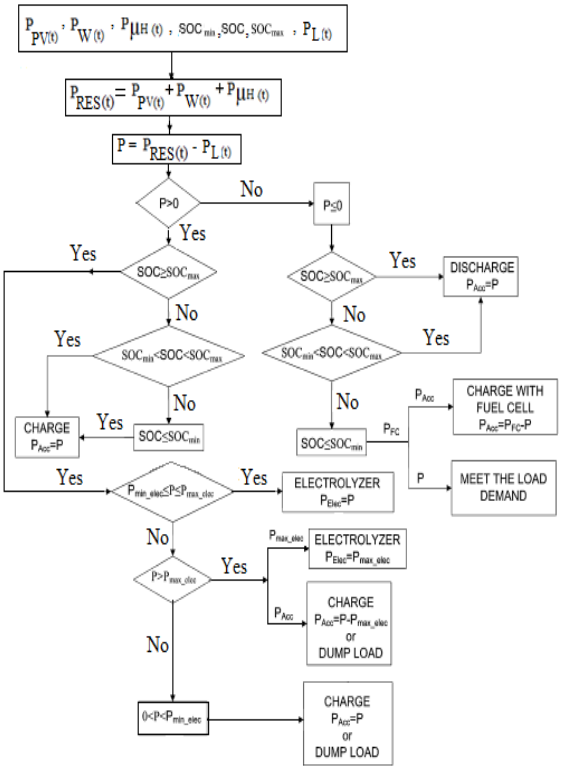


Figure 3. Flowchart of control strategy(Kocaman 2015).

Where $P_{RES(t)}$ is the power of renewable energy sources (kW), SOC is state of charge of the battery (%), SOC_{min} is minimum state of charge of the battery (%), SOC_{max} is maximum state of charge of the battery (%), P_{elec} is power of electrolyzer (kW), P_{FC} is power of fuel cell (kW), P_{ACC} is power of battery (kW) is shown as this.

In case the total power of wind, PV and micro hydroelectric is bigger than the need, we have to look at the SOC of the battery. If SOC is equal or bigger than the maximum percentage, in this case, the excess power is worked to the electrolyzer's maximum and minimum percentage. If the excess power percentage is bigger than the electrolyzer's maximum percentage, electrolyzer is worked and the remaining power is directed to excess load. If the excess power percentage is between zero and electrolyzer's minimum percentage, in this case electrolyzer is not worked and the excess power is directed to whether battery percentage reached to the maximum level, the charging process is stopped with the help of contollers.

If the power that is generated from renewable energy sources is equal to the need or if it is less, it is looked to the state of battery charge. If state of battery charge is above the maximum level or if it is between the minimum and maximum level, the discharge must be started with the help of controllers. When the battery charge level is lowered to minimum level, the connection of battery is cut. In this case fuel cell is worked. Both the battery is charged and the the needed power is generated. When the total energy that is generated and load demand is equal, the battery charge level will remain the same.

In case, the power that is generated from renewable energy sources is more than the needed power, the excess power can be used whether by charging the battery or for generating hydrogen (H_2) in electrolyzer. This process is called "charge". In contrast if renewable energy sources is not enough for all the need, the needed energy can be generated from batteries or by using hydrogen. This process is called "discharge". In the process of discharging the needed energy is used by battery and fuel cell. The water, when fuel cell is working, that isgenerated is recycled to water storage tank for use in electrolyzer. The electrolyzer and fuel cell can not work at the same time. Lead acid battery is used for energy wave and for the system to work poperly.

Written in Microsoft Visual Studio C Sharp screen when the computer program runs the wanted day (e.g. March month) selected and clicked the box analyse to the screen as shown in figure 4, the current energy situation comes up.

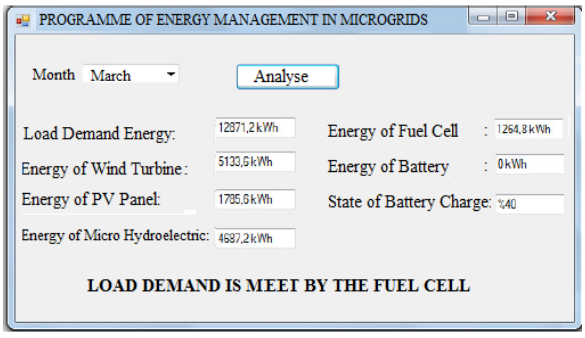


Figure 4. Energy situation for the March month of the year.

As shown in the figure 4, the load demand energy is 12871,2 kWh. The energy generation from renewable energy sources not meet load demand. Thus the needs of 1264,8 kWh of energy to meet the fuel cell.

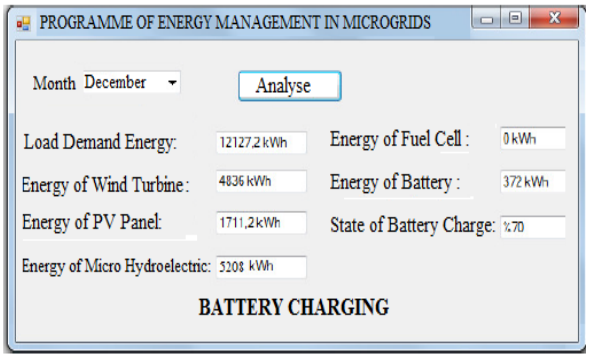
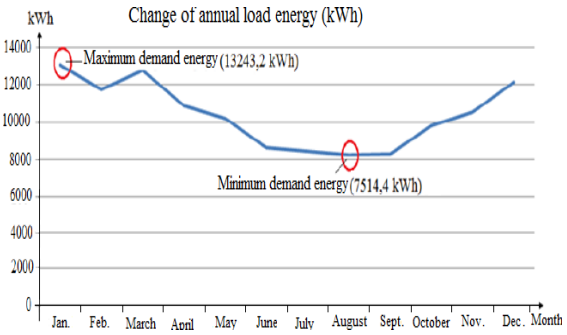
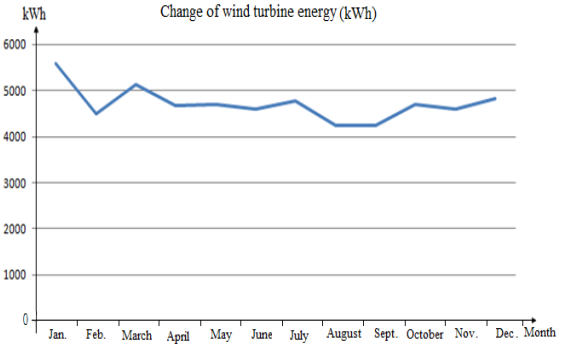
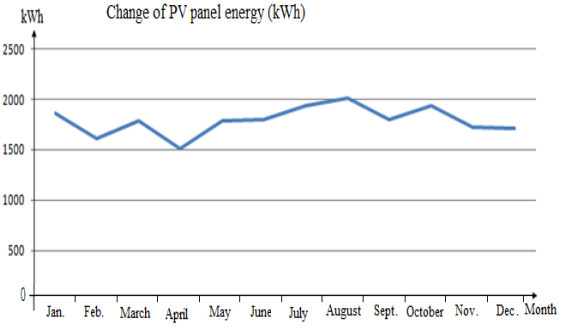


Figure 5. Energy situation for the December month of the year

As shown in the figure of 5, the load demand energy is 12127,2 kWh. The energy generation from renewable energy sources not meet load demand. Thus the needs of 372 kWh of energy to meet the battery. With the same program, the figure 6 is generated by running the program seperately for 12 months.







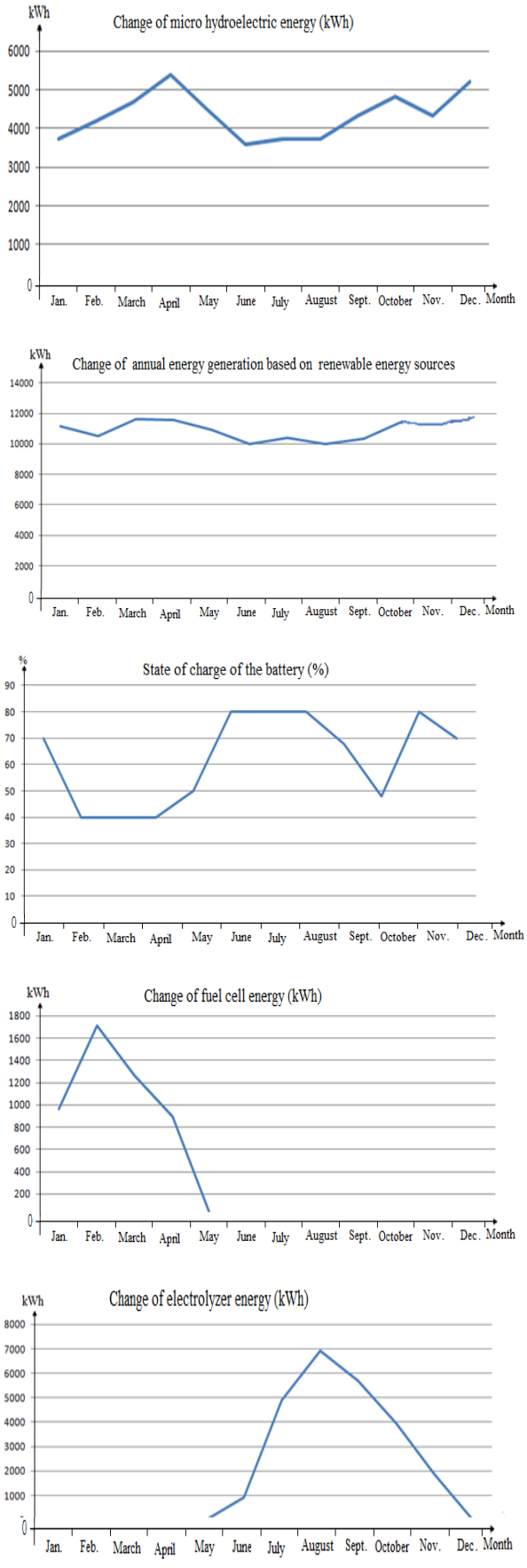


Figure 6. Graphics showing the status of annual energy change (Kocaman 2015).

In the figure 6, load demand for one year, renewable energy sources (wind, solar and hydraulic), fuel cell, elecctrolyzer and state of charge are given seperately. Acording to this information, load demand for one year is given in the figure 7.

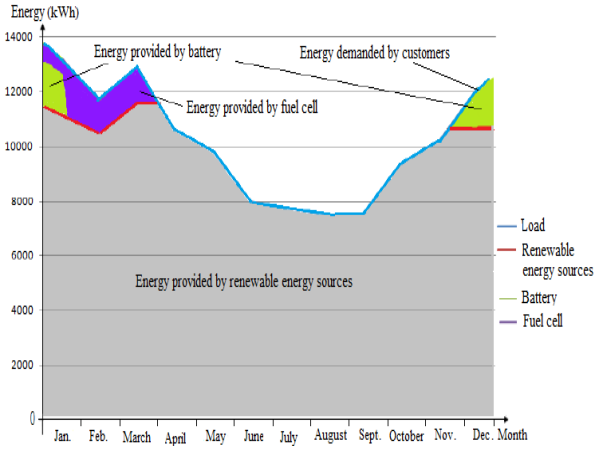


Figure 7. Annual of power demanded by customers, provided by energy generation unit (Kocaman 2015).

As shown in the figure 14, most of the needed power is generated from renewable energy sources. From the some days (e.g. between December to March months) of the year, renewable energy sources is not enough for generation of energy. At these days, the needed power is used from the batteries and/or from fuel cell. So the need for energy is met all year long.

The power that is generated from all the generating sources for one year is: 137284,8 kWh. The energy that is generated in microgrid is shown in the Table 2.

Table 2. Electric power sources and percentage for one year

Sources	Energy (kWh)	Generation (%)
PV panel	21472,8	15,64
Wind turbine	56572,8	41,21
Micro hydroelectric	52171,2	38
Battery	2232	1,63
Fuel cell	4833	3,52

As can be seen in the Table 4, the total energy for one month is generated from wind power: %41,21 (the most efficient way) and % 1,63 battery (the least efficient way). The needed energy for one year is 120813,6kWh. Some of the excess power is used in electrolyzer for later use in fuel cell for hydrogen generation. The rest of the excess power is used in battery charging. If the battery is charged fully, the excess power battery is emptied by directing the power to excess load.

5. Results and Discussion

Because the need for electric power is growing day by day, we need to use renewable energy energy power more for being independent from the other countries, for the security and for electric energy generation. The renewable energy sources gets more common, we will use less fossil oils. Energy management depends on the policy of corperations. The corparations should direct their energy policy, energy need, energy management programs for their aims.

With this study, it is aimed that a far vacation village from the city center can generate its own energy in a micro hybrid center. So that, they can save their energy for future use when needed. The usage life of electrolyzer and fuel cell is shortened by often working and stopping them. Also, their performance is reduced. Because of this reasons, for renewable energy sources, storage of energy has the utmost importance. Energy management is important for meeting the need for energy and for economical reasons. With the help of energy management when there is no sun at the early hours of the day and at night, the needed energy can be meet froom other energy generation units. For bigger demands of energy, this energy management has vital role. So, the role of energy management in microgrids with hybrid power generation system in provided load demand is obvious.

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