Optimally and Independent Planned Microgrid with Solar-Wind and Biogas Hybrid Renewable Systems by HOMER

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ABSTRACT:
Fuel shortages and environmental issues have made optimal and effective management of various resources one of the most pressing issues in the current situation. There is often a separation between the heating and gas network and the power system, which is not wise when considering the economics and effectiveness of the entire system. Examining the results shows that the installed capacity has grown significantly in the last few years. This research has investigated the microgrid including wind-solar turbine, along with energy storage (battery). This energy can be used as an alternative to fossil power plants because it is readily available and renewable. This paper proposes a multi-dimensional framework for a multi carrier energy supply with a solar-wind and biogas hybrid renewable system. In this study, the amount of power exchange of sources in a microgrid independent of the distribution network and power distribution between resources and load supply have been simulated in the HOMER environment, and the output results show the optimization of power management in this network. The proposed method is completely tested and programmed in an independent microgrid during a 24-hour period.

KEYWORDS: Optimal planning, Feasibility, Microgrid, HOMER.

1. INTRODUCTION

Microgrids have the ability to provide energy for the demand of local loads and operate in the connected-to-the-network mode and the independent or the islanded mode [1-2]. Various studies have addressed this approach for optimal planning considering different loads. In [3], various scenarios for energy management systems have been investigated using hierarchical genetic algorithms to maximize the income from energy exchange with the network. A multi-pumped storage unit MIP algorithm is presented in [4] to solve the hydrothermal scheduling problem by increasing flexibility. Based on target execution time and cost, the developed mixed-integer programming with hydro-thermal scheduling performs well. Based on a case study of Bangladesh, [5] investigated the optimal size of microgrid systems. This work aims to provide a general overview of how Homer software can be used to plan hybrid systems optimally. The use of these resources has led to cost and pollution reduction. In [6], the hybrid system (hydrogen, solar, and wind) has been investigated. There was a comparison between Mono-Facial and Bifacial panels in the article [7], analyzing a 100 kW photovoltaic system. A simulation shows that 150 MWh per year can be generated by the Mono-Facial module with an average performance ratio of 77.7%, and 171.1 MWh per year by the bifacial system with an average performance ratio of 87.31%.

It is appropriate to combine renewable energy technologies such as photovoltaics and wind turbines with an energy storage device. This is in order to address concerns regarding output reliability and intermittently [8]. Grid to Vehicle and Vehicle to Grid power transfer capabilities can be used as temporary distributed energy storage devices. [9] examines meta-heuristics, exploratory methods, and classical methods simultaneously. This paper examines the performance of renewable energy under changes in resource power, load, and unplanned outages through a pseudo-dynamic simulation. Short circuits, losses, and voltage can be reduced as a result of renewable sources; however, compensating measures need to be taken for improved transient stability and power quality. Particle Swarm Optimization (PSO) has been used in [10] to optimize a hub system aimed at reducing pollution and improving energy efficiency.

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In [11], demand-side management and energy storage systems have been investigated. The optimization method is used in [12] to maximize profit and minimize operating costs. DG distribution systems are sized and placed optimally in [13] to improve voltage stability.

References [14-17] present the latest methods for estimating the maximum transmission power statically and dynamically in a hybrid network (AC-DC) with a wind farm.

In [18], the stability of microgrids and their optimization have been investigated. Based on the geographical location, conditions, and available facilities, different energy sources such as photovoltaic and wind farm systems can be used harmoniously. In designing and operating a hybrid system for power supply, the energy demand of that area and the resources available in it should be carefully identified. The planners of the power system should analyze the necessary potentials for the generator of solar energy, wind energy and the size of the available resources to supply the necessary energy for that area. The need for accurate information of the area and an overview of the system design in order to respond throughout the year in hybrid systems to obtain the optimal size is of great importance.

In this article, a suitable solution for the optimal design of all types of grid-connected and independent microgrid systems is presented. Also, the capacity of scattered production units has been determined with economic evaluation and sensitivity analysis of energy cost and demand response strategies. In this article, Homer software is used for optimal system design. After the following sections, we discuss optimal microgrid planning, photovoltaic system modeling, and energy storage systems, and then we conclude with simulation, results, and conclusions.

2. OPTIMUM MICROGRID PLANNING

The various components are considered in the studied microgrid (Fig. 1). This energy includes anaerobic reactors, absorption chillers, heat and hydrogen storage tanks, wind turbines, and fuel cells [19]. One of the important issues in the design and control of microgrids including renewable energy sources is maintaining the balance between generation and consumption. Dependence on renewable sources on climate changes on the one hand causes variable power and on the other hand, disrupts the possibility of supplying loads in a stable and continuous manner. Also, the variability of loads at the distribution level may cause a greater difference between the level of generation and consumption. It is the main objective of this task to determine the optimal schedule to minimize costs. Three different states of energy are considered in this study:

- Energy sources can provide both electrical demand and thermal loads.
- This study takes into account the load factor equivalent to ELF, calculated as follows [20]:

$$EFL = \frac{1}{N}\sum_{t=1}^{N}\frac{Qi_{(t)}}{Di_{(t)}} \qquad (1)$$

In the above relationship, Qi(t) is the load cut off per hour and Di(t) represents the electric load per hour. If the total energy produced cannot meet the demand of the system, 10% of the electric load can be cut off. As a result, the reliability of ELF is less than 0.01. In this study, the load cut penalty is considered equal to 0.482$/kWh.

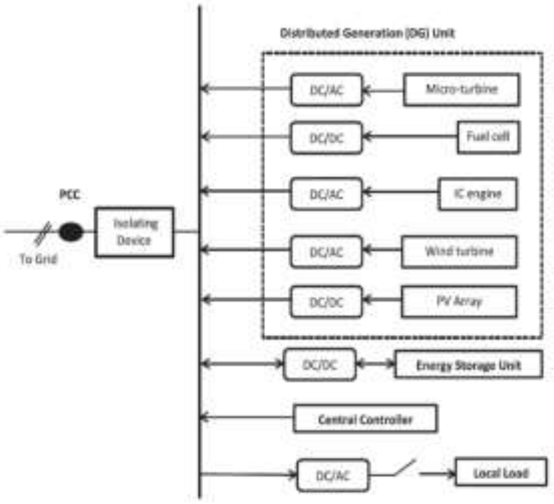


Fig. 1. Microgrid schematic.

2.1. Photovoltaic System Power Modeling

Solar panel output power is dependent on solar radiation intensity, absorption capacity, and panel surface and cell temperature. The intensity of sunlight has a possible nature. Therefore, the corresponding output power is alternating. An exponential distribution function is used to model solar radiation information. The beta probability distribution function is very suitable for showing the possible state of the solar radiation phenomenon. Solar radiation seems to be highly uncertain. There are several factors that affect solar radiation, including the angle of the cells, the time of day, and the weather. Solar radiation is modeled with the beta distribution function in the form of equation (1-4) [21]:

$$f(R:\alpha_\beta, \beta_\beta) = \frac{\Gamma(\alpha_\beta + \beta_\beta)}{\Gamma(\alpha_\beta)\,\Gamma(\beta_\beta)}\, R^{\alpha_\beta - 1}(1-R)^{\beta_\beta} \qquad (2)$$

Where, α_β and β_β are coefficients of beta distribution. The P_{SCG} of output power is given by equation (3):

$$P_{SCG} = \begin{cases} P_{rs} & if\ v \leq R < R_C \\ P_{rs}\ \frac{R}{R_{STD}R_C} & if\ R_C \leq R < RSTD \\ P_{rs} & if\ R_{STD} \leq R \end{cases} \qquad (3)$$

The solar radiation intensity is R, the specific radiation intensity is RC, the standard radiation intensity is RSTD, the generation power of the solar cell is Prs, and the output power is PSCG. Fig. 2 shows the annual profile of solar radiation based on geographic region through software. Fig. 3 illustrates the main index for average solar radiation based on the required area specified by longitude and latitude.

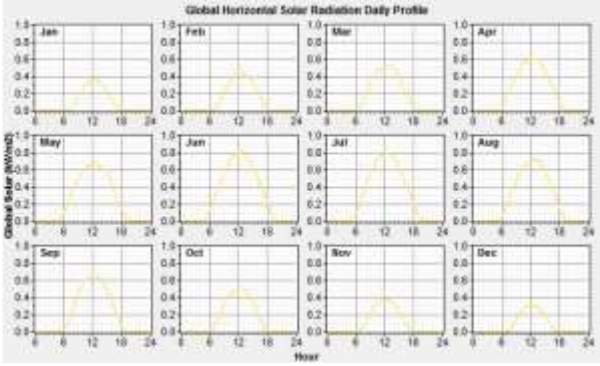


Fig. 2. Annual solar radiation profile (kW/m2).

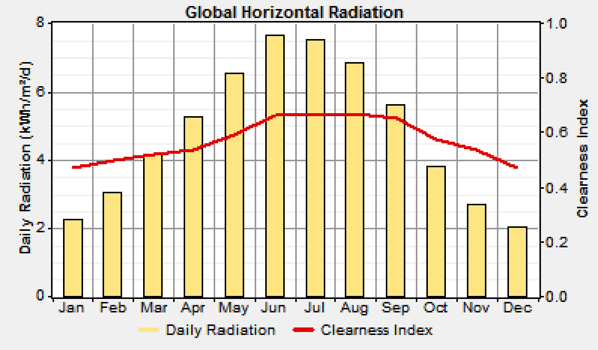


Fig. 3. Diagram of solar energy radiation.

Changes in pressure and temperature are caused by the sun's different radiations at different latitudes on the uneven surface of the earth. There is no specific period for wind energy to blow continuously, as it is often intermittent and fluctuating. Wind energy has some disadvantages, such as varying amounts of generation and low reliability. The nature of wind speed is probabilities that can be described by the following Weibull probability distribution function.

$$exp\left[-\left(\frac{v}{Cw}\right)\right]^2 f(v) = \frac{Kw}{Cw}\left(\frac{V}{Cw}\right)^{Kw-1} \qquad (4)$$

In this regard, Kw is the scale parameter of the wind speed of *Weibull*, Cw is the parameter of formation of the *Weibull* speed, v is the wind speed. Wind turbine power curves are used to calculate the output power of each mode in equation (5):

$$P_{WTG} = \begin{cases} 0 & if \quad v < Vi\ or\ v > V0 \\ P_{rw}\ \frac{V-Vi}{Vr-Vi} & if \quad Vi < v < Vr \\ P_{RW} & if \quad Vr < v < V0 \end{cases} \qquad (5)$$

vi, vo, vr, respectively, are the start speed, stop speed and nominal speed of the turbine. According to Figs .4 and 5, the amount of wind speed and the profile of wind in different months of each region have been determined.

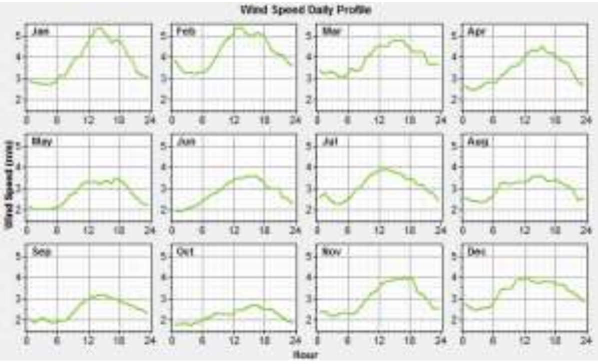


Fig. 4. Regional wind profiles in different months.

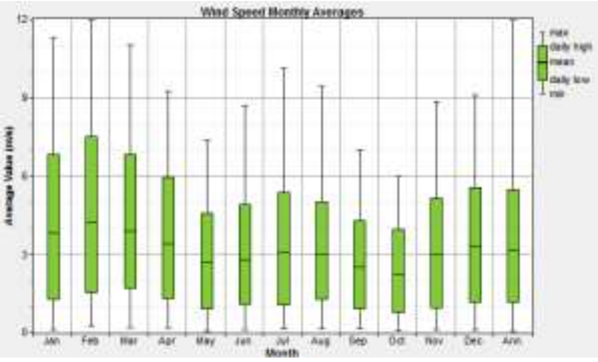


Fig. 5. Monthly wind speed.

2.2. Energy storage system modeling

According to the amount of consumption of the load and generation power, the battery bank can be charged or discharged. The purpose of this section is to explain the relationship between the battery and the power of discharging and charging. Discharging or charging performance determines whether the batteries' input power is negative or positive.

$$P_B = P_{WT} + P_{PV} - \frac{P_L}{\eta} \qquad (6)$$

Where, P_B is the battery, P_L represents the total current consumption and η is the converter efficiency. If P_B=0, then the battery bank remains unchanged. The charging and collection of each battery is limited to prevent the battery's useful life from being reduced.

3. THE OBJECTIVE FUNCTION

The useful life of a microgrid can be maximized by minimizing its net present cost (NPC). The system has a lifespan of 20-25 years, which is equal to the longest lifespan of its parts. The total NPC of the system is as follows (7):

$$T\ cost = NPCU_{PV} * N_{PV} + NPCU_{WT} * N_{WT} + NPCU_{B} * N_{B} + NPCU_{Inverter} * N_{inverter} \quad (7)$$

The decision variables include the capacity of solar and wind renewable resources, the capacity of the energy storage system that can be programmed in a defined time frame. The limitations of the problem include the physical and operational limitations of the components, generation resource, energy storage, energy balance, equipment capacity, and achieving adequate reliability of the consumption load.

For the purpose of economic evaluation, the NPC of the entire system is considered. Each component's total cost is determined by equation (8):

$$T_k = IC_K + R_{PK} + OM \quad (8)$$

Where, IC_K is the initial cost, R_{PK} is replacement cost and OM is maintenance cost. It is necessary to use the CRF investment return coefficient to convert the initial cost to the annual cost:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (9)$$

The lifetime of the system is n and the interest rate is (i). The initial annual cost is determined by relation (10):

$$AIC_k = IC_K * CRF \quad (10)$$

To calculate the NPC:

$$\text{Total cost(NPC)} = \frac{T_k}{CRF} \quad (11)$$

4. SIMULATION AND RESULTS

The proposed system is designed by HOMER software. This software has been developed by the International Renewable Energy Agency. A sensitivity analysis can be performed on variables with uncertain values using this software. For analysis, this software needs data on energy sources such as control methods, economic restrictions, the number of components, lifetime, efficiency, costs, and the type of system components. The purpose of this study is to optimize and analyze the sensitivity of different combination systems and compare them with each other and finally choose the most economical combination. Based on output parameters, panel costs, and solar radiation data, sensitivity studies have been conducted. For any region with known solar radiation, the optimal system can be determined. HOMER's simulation model is shown in Fig. 6.

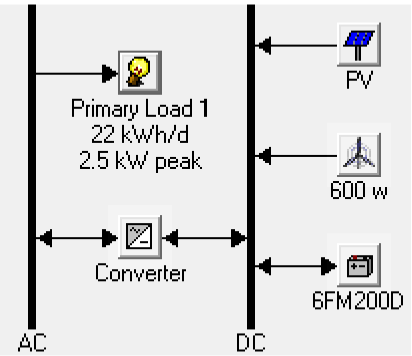


Fig. 6. The proposed and simulated model.

The daily load is equal to $22\ \mathrm{kwh/m^2/d}$. The average graph of electric energy consumption is shown in Fig. 7 where the peak load is 2.5 kWh.

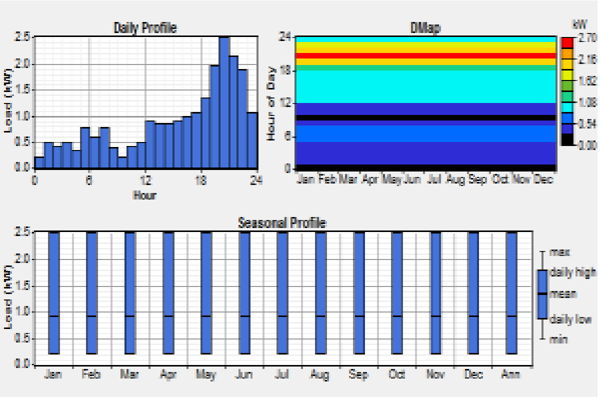


Fig. 7. Average electrical energy consumption.

As shown in Tables 1 to 4, the economic and technical specifications of microgrid components are as follows:

Table 1. Photovoltaic module specifications.

Nominal capacity	1Kw
The initial cost	575$ /unit
Maintenance cost	6$ /year
Useful life	25 years

Table 2. Wind turbine specifications.

Nominal capacity	1Kw
The initial cost	1300$ /unit
Maintenance cost	70$ /years
Useful life	20 years

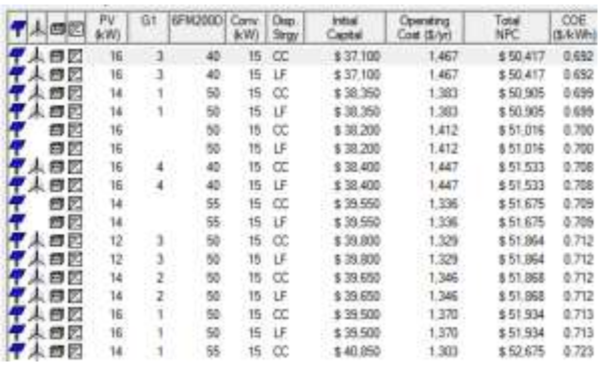
Table 3. Specifications of the battery bank.

Nominal capacity	1Kwh
The initial cost	500$ /unit
Maintenance cost	2$ /years
Useful life	5 years
Replacement cost	330$ /unit
efficiency	٪85

Table 4. Specifications of the converter (inverter).

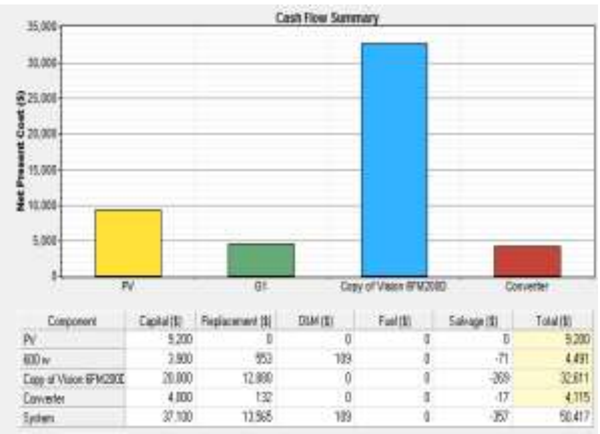
Nominal capacity	15 Kwh
Initial cost	400$ /unit
Maintenance cost	10$ /years
Useful life	15 years
Replacement cost $	550$ /unit
Yield- Interest rate i	90%-6%

After running the Homer program, the following results are obtained, as shown in Fig. 8. As seen, the most economically optimal state for the system in question is the first option shown in the set of answers. Operating the studied system, the total cost (NPC) will be $50,417 during the 20-year operation period. The amount of investment cost for each component is shown in Fig. 9.



PV (kW)	G1	6FM200D	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)
16	3	40	15	CC	$ 37,100	1,467	$ 50,417	0.692
16	3	40	15	LF	$ 37,100	1,467	$ 50,417	0.692
14	1	50	15	CC	$ 38,350	1,383	$ 50,905	0.699
14	1	50	15	LF	$ 38,350	1,383	$ 50,905	0.699
16		50	15	CC	$ 38,200	1,412	$ 51,016	0.700
16		50	15	LF	$ 38,200	1,412	$ 51,016	0.700
16	4	40	15	CC	$ 38,400	1,447	$ 51,533	0.708
16	4	40	15	LF	$ 38,400	1,447	$ 51,533	0.708
14		55	15	CC	$ 39,550	1,336	$ 51,675	0.709
14		55	15	LF	$ 39,550	1,336	$ 51,675	0.709
12	3	50	15	CC	$ 39,800	1,329	$ 51,864	0.712
12	3	50	15	LF	$ 39,800	1,329	$ 51,864	0.712
14	2	50	15	CC	$ 39,650	1,346	$ 51,868	0.712
14	2	50	15	LF	$ 39,650	1,346	$ 51,868	0.712
16	1	50	15	CC	$ 39,500	1,370	$ 51,934	0.713
16	1	50	15	LF	$ 39,500	1,370	$ 51,934	0.713
14	1	55	15	CC	$ 40,850	1,303	$ 52,675	0.723

Fig. 8. Set of optimized solutions.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	9,200	0	0	0	0	9,200
600 w	3,900	553	109	0	-71	4,491
Copy of Vision 6FM200	20,000	12,880	0	0	-269	32,611
Converter	4,000	132	0	0	-17	4,115
System	37,100	13,565	109	0	-357	50,417

Fig. 9. Investment cost by each subsystem.

5. CONCLUSION

There are many countries in the world that use clean and new energies because there is a lack of energy and non-renewable energy sources are finite. Conversely, microgrid systems that consider the local environment seem a reasonable option in areas far from the electricity grid. Uncertainty impact is investigated using efficient stochastic planning for realistic modeling. In this framework, forecast errors from wind turbines, photovoltaics, and consumption loads are simultaneously taken into account. Iran's potential for using renewable energy makes it a suitable replacement for fossil fuels. As a result, hybrid systems have been investigated in order to increase system reliability and respond to the area's load consumption. Based on general conditions and the investigations conducted in this area, it is also evident that the existing systems are more cost-effective due to the higher solar radiation, light reflection coefficient, and wind speed.

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