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Use of Hybrid Renewable Energy Systems to Supply Power to Telecommunication Stations

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Abstract: The Hybrid Renewable Energy Systems (HRES) are becoming increasingly widespread in power supply in remote areas, due to advances in renewable energy technology and rising oil prices. The hybrid energy system usually uses two or more renewable energy sources, which together increase system efficiency and balance in energy supply (Lee *et al.,* 2016; Rodríguez et al., 2016). In this paper, the Homer software is used to simulate and evaluate the technical and economic aspects of the hybrid systems in order to supply the power of a telecommunication tower in Kaboodarahang, Hamadan. The hybrid system uses turbines, solar panels, diesel generators, and batteries in two on-grid and off-grid forms. The results indicate that the use of hybrid sources is cost-effective in the areas far away from the network. The government can further develop the tendency to use renewable resources, especially wind and solar, for reasons such as availability, less pollution and, more importantly, sustainable economic development in the country by providing financial incentives, including low-interest loans, awareness and supporting involved companies (Clement *et al.,* 2009).

Keywords: Hybrid System, Homer Software, Solar System, Wind Power Plant, Battery.

Introduction

The smart electricity distribution network is one of the newest technologies in the world and is the result of the experts' efforts to modernize distribution networks and enter the digital age. The main goal is to provide reliable electricity and meet the growing needs of customers with the least damage to the environment. The core uses of smart grids include advanced metering infrastructure, demand response or demand-side management, distributed generation sources and new energy, energy storage, distribution automation, comprehensive awareness of the regional location, and electric transportation.

One of the most important applications of smart grids is electric cars. These vehicles need to be on-grid to charge their batteries (Rahmani *et al.,* 2011; Bastani and Damircheli, 2016).

In recent years, the development of electric and hybrid vehicles has led to many economic and environmental benefits. However, the huge influence of electric vehicles in the power grid will increase the peak load at different hours of the day. Also, electric vehicles have other negative effects on the network, such as a decrease in power quality, an increase in losses, a voltage fluctuation, and even a rise in subscriber energy prices. Low power quality may cause damage to sensitive power consumer like humanoid robots (Fakoor *et al*., 2015). Since the parameters in modeling the effect of charging these vehicles, such as battery capacity, daily mileage, and time of arrival of vehicles to stations are random, it is necessary to provide a comprehensive model of how to charge these vehicles. In order to manage vehicle charging at home, the power received from the network for charging cars can be controlled by the Control Center on the network, so that no overload would be in the network during peak hours and the electric requirement of the vehicle is met from other suppliers (Ashtari *et al.,* 2012, Bastani and Damircheli, 2016).

One way to compensate for these disadvantages is the use of hybrid systems (photovoltaic-wind turbines, batteries) as distributed power plants in the infrastructure of charging stations for electric cars in the smart grid. It will enhance power quality, improve stability and network load factor (improvement of technical indicators), and reduce subscribers' energy costs (improvement of economic indicators) (Fakoor *et al*., 2015; Bastani *et al*., 2013).

1. Various types of hybrid renewable energy systems

2.1. Biomass-Wind-Fuel Cells

Suppose a power supply has to supply 100% need for one load, and no renewable system alone can meet this need; so two or more renewable energy systems can be combined. 60% of this system can be supplied from a biomass system, 20% from a wind energy system, and the rest from fuel cells. Therefore, the combination of all these renewable energy systems can provide 100% of the power and energy needed for a load like a home or an office (Dan *et al*., 2013).

2.2. Solar-Wind

Another method for the combined energy system is a photovoltaic array coupled with a wind turbine. The advantage of this system is the higher output of wind turbines in the winter, while solar panels produce their peak output during the summer. This combined energy system often leads to more economic and environmental returns than single wind, solar, geothermal or trigeneration stand-alone systems (Dan *et al*., 2013; Bastani *et al*., 2013).

2.3. Completely renewable hybrid power plant

A completely renewable hybrid power plant (including solar, wind, biomass and fuel cells) is a hybrid power plant that consists of these four renewable energy sources that can be exploited through the proper use of these resources in a fully controlled manner.

The energy supply market is a competitive market in which wind power plants has brought new advantages to users compared with fossil fuels plants. The advantage of wind power plants is that they will generate power without the cost of fuel over their lifetime, while the cost of other energy sources will increase over these years.

The vast activity of many countries in the world to generate electricity from wind energy is an example for other countries that have a long way to go. Many of the growing economic resources are located in the Asian region, and the growing economies of Asian countries, including Iran, have caused these countries to increasingly feel the need to generate electricity and generate electricity from non-fossil sources. In addition, the lack of a nationwide grid in many rural parts of Asia has also confirmed the wind power generation systems (Karnama, 2009).

3. Introduction of Homer Software (HOMER)

The Homer software is used to simulate and evaluate the technical and economic aspects of hybrid systems. This software was developed by the US National Renewable Energy Laboratory and enables users to compare different design options technically and economically based on HOMER. It also allows for changes and uncertainties in the inputs. The performance of a specific array of the energy system is modeled for each step of the year by determining the possible energy supply methods and cost of its life cycle. In the optimization process, all the various arrays for power supply, according to the limitations, seek to achieve the most economical mode of the life cycle. In order to model a system including photovoltaic cells and wind turbine, the Homer software should include information about the solar source and the wind speed of the study area. The software calculates the amount of renewable energy in one-hour steps. For most types of small energy systems, especially those with renewable alternating energy sources, one-hour steps for analysis are considered to be precise. The software uses the current net value equation for life-cycle cost, which includes initial investment costs, replacement costs, repair costs, fuel, electricity purchase from the network, fines for air pollution and electricity sales to the network. In the calculation of current net value, the costs are considered positive, and earnings are negative. The costs and earnings are assessed with a fixed interest rate throughout the year. In this type of assessment, the effect of inflation on calculations at the end of the analysis process should be applied by calculating the actual interest rate resulted from inflation and according to special relations. In the simulation process, all feasible scenarios are simulated, and then they are arranged according to the net cost value. Eventually, the feasible array by the lowest net cost value is introduced as the optimal array (Rodríguez *et al.,* 2016).

HOMER (Hybrid Optimization of Multiple Electric Renewables), the micropower optimization model, simplifies the task of evaluating designs of both off grid and off-grid power systems for a variety of applications (HOMER). When you design a power system, you must make many decisions about the configuration of the system: What components does it make sense to include in the system design? How many and what size of each component should you use? A large number of technology options and the variation in technology costs and availability of energy resources make these decisions difficult. HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations. HOMER simulates the operation of a system by making energy balance calculations in each time step of the year. For each time step, HOMER compares the electric and thermal demand in that time step to the energy that the system can supply in that time step, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuelpowered generators, HOMER also decides on each time step how to operate the generators and whether to charge or discharge the batteries (Liwei Ju *et al.,* 2016).

Also, HOMER performs these energy balance calculations for each system configuration that you want to consider. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the conditions that you specify, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest (Rodríguez *et al.,* 2016).

Optimization: After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost), that you can use to compare system design options (Abolfazl *et al.,* 2009; Arani *et al.,* 2014).

Sensitivity analysis: When you define sensitivity variables as inputs, HOMER repeats the optimization process for each sensitivity variable that you specify. For example, if you define wind speed as a sensitivity variable, HOMER will simulate system configurations for the range of wind speeds that you specify (Olatomiwa *et al.,* 2016; Rodríguez *et al.,* 2016).

4. Introduction of Hybrid Energy System of Kaboodarahang site

The Kaboodarahang new energy site is located in a mountainous region with a longitude of 40 degrees and 24 minutes, latitude of 39 degrees and 6 minutes, and at an altitude of 1600 meters above sea level. The average annual sunlight radiation is equal to 3.7 $kWh/m^2/day$ and based on information obtained from the site's anemometer station, the average annual wind speed is 3.6 m/s, with the dominant wind being in the north to northwest. The hybrid energy system consists of a wind turbine, photovoltaic cells, and a water electrolysis apparatus, a fuel cell system, a hydrogen gas storage tank and DC / AC converters. One of the components of this energy system is the need to provide a wind turbine, which is also recommended using the information of anemometer mast and examining the wind speed data at 15, 25, 55 meters, installing a wind turbine with a capacity of 28 kW at an altitude of 40-50 meters. In this study, the hybrid energy system was simulated using the HOMER software and its technical and economic information was analyzed.

5. Calculation of the hybrid power system to provide the power required by a telecommunication tower by Homer software

In this section, by using Homer's software, a hybrid renewable energy system will be provided to supply the consumption load of a sample telecommunication mast in Hamadan, Kabudarahang. In order to determine the capacity of the hybrid renewable system, it is first necessary to estimate the electricity consumption of the mast in different months, which we will be considered in the following:

5.1. Calculation of consumption load of the telecom masts in Kabouderahang, Hamadan

In this section, monthly consumption load of the telecommunication mast in Kabouderahang, Hamadan has been presented in different months (Table - 1-6; Figure - 1-6).

Table - 1: Hourly consumption load of telecommunication mast in April 2016

Consumption Load (kW)	Hour
0.9	00-01
1	01-02
0.8	02-03
0.6	03-04
0.4	04-05
0.4	05-06
0.2	06-07
0.4	07-08
0.6	08-09
0.5	09-10
0.6	10-11
0.7	11-12
0.7	12-13
0.8	13-14
0.6	14-15
0.4	15-16
0.7	16-17
0.9	17-18
0.7	18-19
0.8	19-20
0.9	20-21
1.3	21-22
1.04	22-23
0.9	23-24

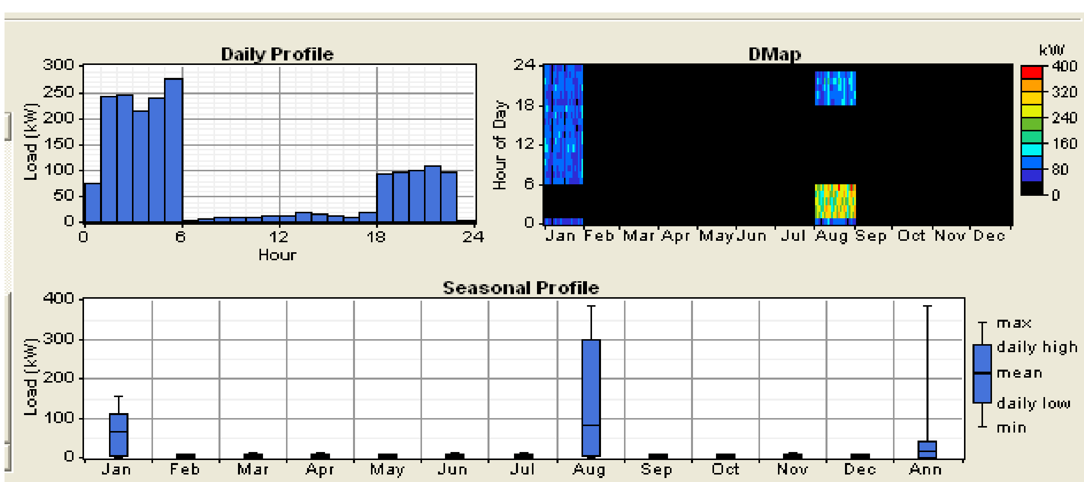

Fig. 1: Load Profile in April 2016

Table 2: Hourly consumption load of telecommunication mast in May 2016

Consumption Load (kW)	Hour
3.41	00-01
235.4	01-02
222.9	02-03
214.5	03-04
216.6	04-05
229.1	05-06
0.83	06-07
1.25	07-08
3.3	08-09
3.75	09-10
3.54	10-11
3.16	11-12
2.91	12-13
2.7	13-14
2.5	14-15
1.6	15-16
2.08	16-17
3.54	17-18
4.16	18-19
8.3	19-20
11.66	20-21
11.25	21-22
9.16	22-23
6.25	23-24

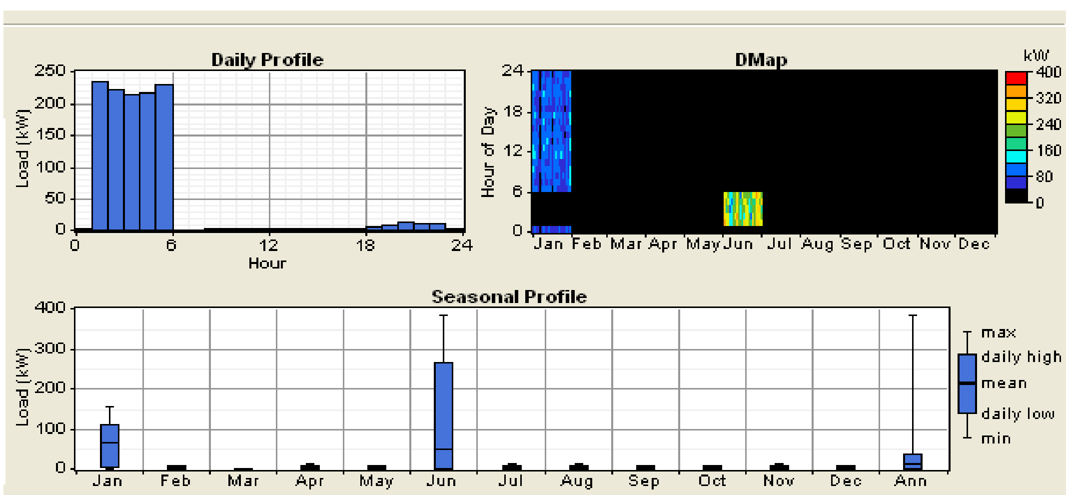

Fig. 2: Load Profile in May 2016

Table 3: Hourly consumption load of telecommunication mast in June 2016

Consumption Load (kW)	Hour
70.8	00-01
179.1	01-02
175	02-03
166.6	03-04
183.3	04-05
208.3	05-06
2.2	06-07
7.7	07-08
7.9	08-09
8.3	09-10
6.2	10-11
6.6	11-12
7.08	12-13
6.04	13-14
5.6	14-15
4.5	15-16
7.08	16-17
6.25	17-18
79.1	18-19
83.3	19-20
95.8	20-21
91.6	21-22
87.5	22-23
83.3	23-24

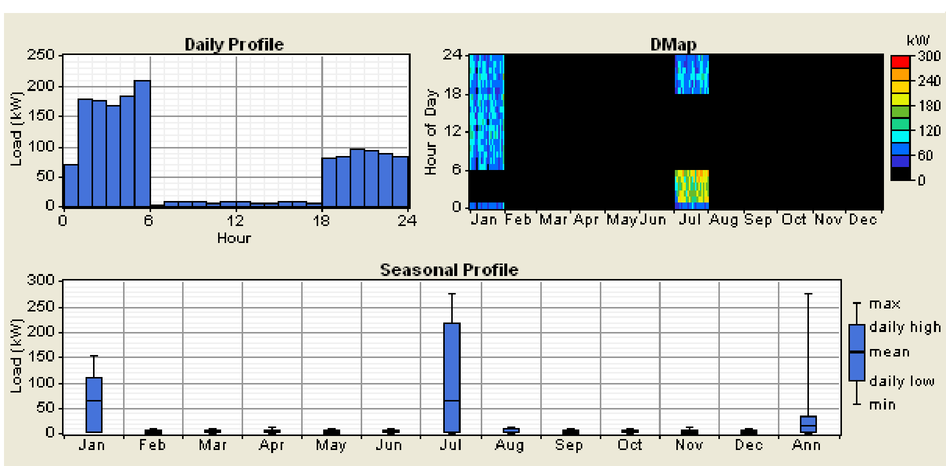

Fig. 3: Load Profile on June 2016

Table 4: Hourly consumption load of telecommunication mast in July 2016

Consumption Load (kW)	Hour
75	00-01
241.6	01-02
245.8	02-03
212.5	03-04
237.5	04-05
275	05-06
4.16	06-07
7.5	07-08
8.3	08-09
10	09-10
10.41	10-11
11.66	11-12
12.5	12-13
18.75	13-14
15	14-15
75	00-01
241.6	01-02
245.8	02-03
212.5	03-04
237.5	04-05
275	05-06
4.16	06-07
7.5	07-08
8.3	08-09

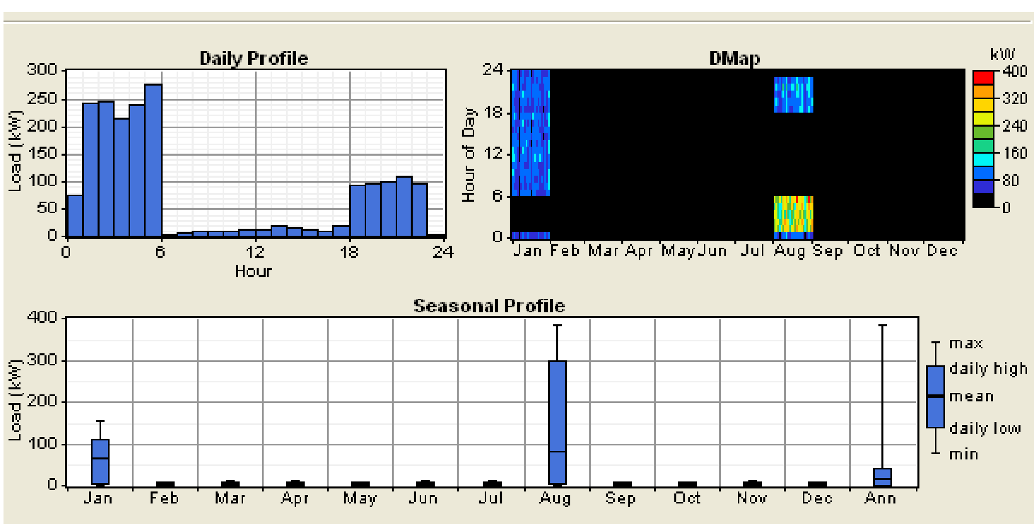

Fig. 4: Load Profile on July 2016

Table 5: Hourly consumption load of telecommunication mast in August 2016

Consumption Load (kW)	Hour
85.4	00-01
83.3	01-02
229.1	02-03
208.3	03-04
225	04-05
237.5	05-06
2.62	06-07
2.91	07-08
3.33	08-09
3.41	09-10
3.37	10-11
3.25	11-12
3.29	12-13
3.12	13-14
2.9	14-15
2.5	15-16
2.95	16-17
3.33	17-18
83.3	18-19
87.5	19-20
95.8	20-21
91.8	21-22
87.5	22-23
89.5	23-24

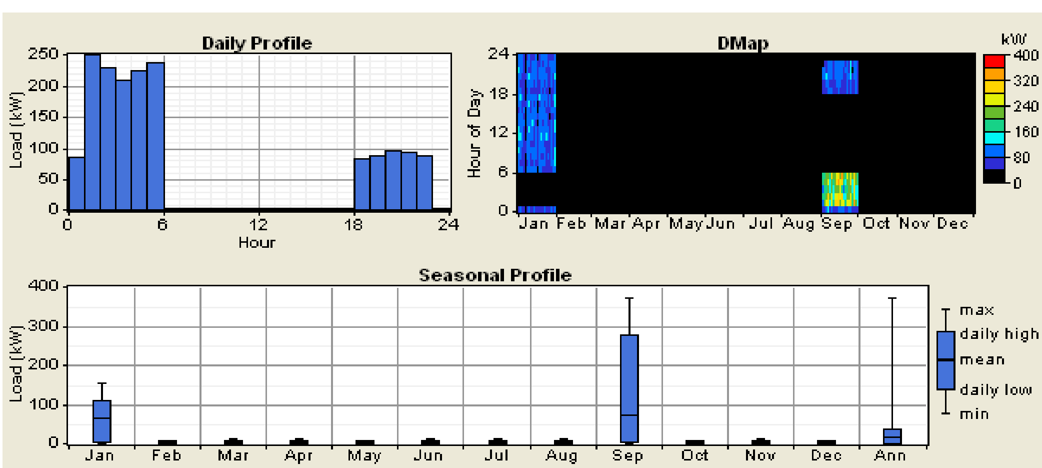

Fig. 5 : Load Profile on August 2016

Table 6: Hourly consumption load of telecommunication mast in September 2016

Consumption Load (kW)	Hour
85.4	00-01
83.3	01-02
229.1	02-03
208.3	03-04
225	04-05
237.5	05-06
2.62	06-07
2.91	07-08
3.33	08-09
3.41	09-10
3.37	10-11
3.25	11-12
3.29	12-13
3.12	13-14
2.9	14-15
2.5	15-16
2.95	16-17
3.33	17-18
83.3	18-19
87.5	19-20
95.8	20-21
91.8	21-22
87.5	22-23
89.5	23-24

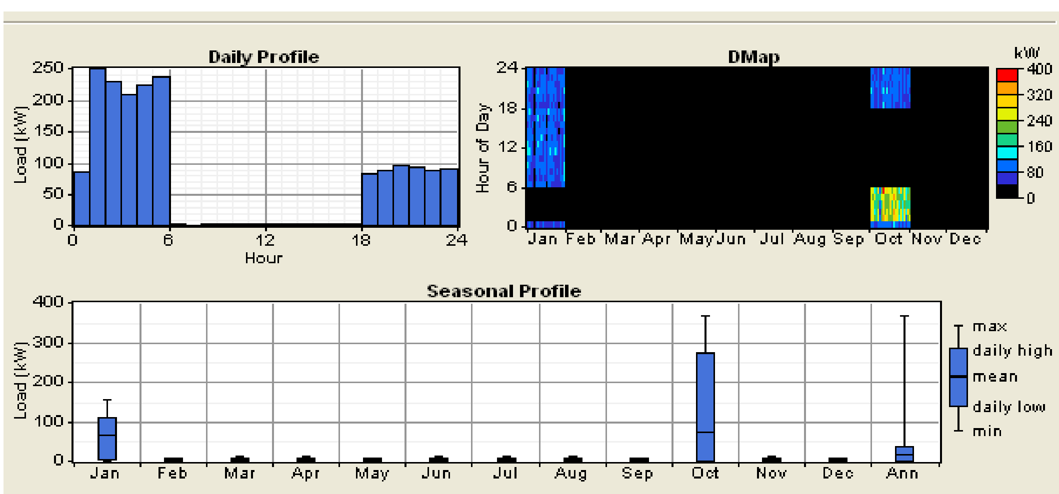

Fig. 6: Load Profile on September 2016

The average consumption of electricity of the telecommunications mast in Kaboudarahang, Hamedan in the second half of 2016 is shown in the following table -7; Fig.- 7-12.

Table 7: Hourly consumption load of telecommunication mast in the second half of 2016

Consumption Load (kW)	Hour
5	00-01
4	01-02
4	02-03
5	03-04
6	04-05
6	05-06
70	06-07
75	07-08
87	08-09
104	09-10
100	10-11
97	11-12
100	12-13
120	13-14
81	14-15
75	15-16
77	16-17
87	17-18
70	18-19
79	19-20
87	20-21
89	21-22
83	22-23
75	23-24

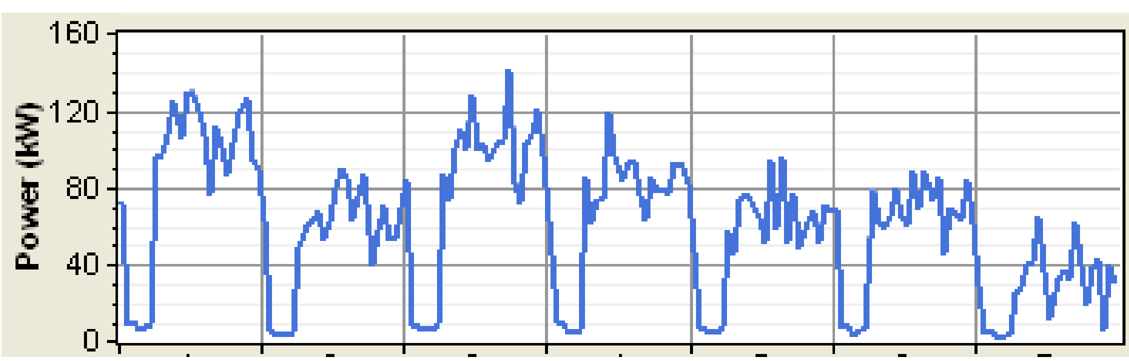

Fig. 7: Load Profile in the second half of 2016

2.1. Optimal Renewable Energy Equipment to Supply Electricity for the Telecommunication Mast in Kaboudarahadng, Hamadan

In this section, an optimal hybrid system to supply electricity for the telecommunication mast is provided with the help of Homer software. The system uses wind turbines, diesel generators, photovoltaic solar panels, and batteries (for energy storage).

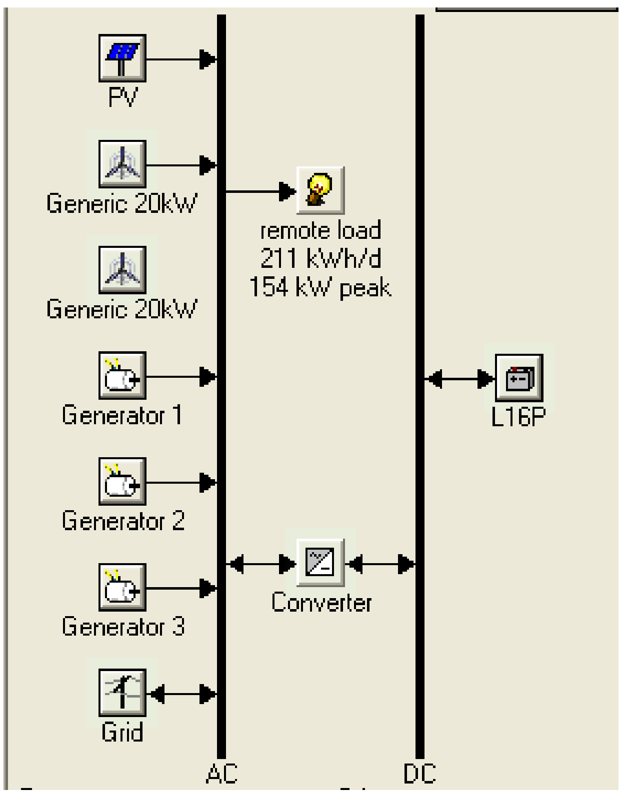

Fig. 8: Optimal Hybrid System for a telecommunications mast

The equipment features are shown below:

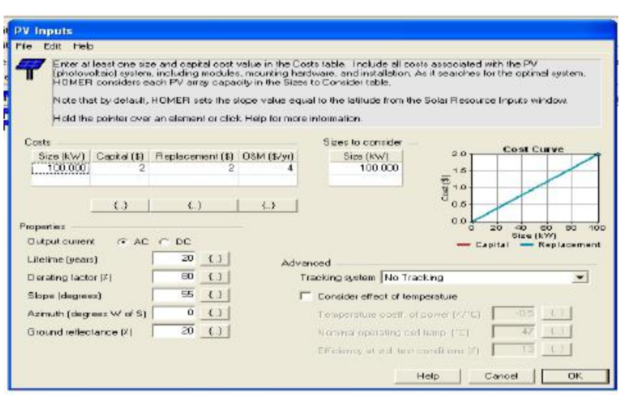

Fig. 9: Profile of the PV Solar System

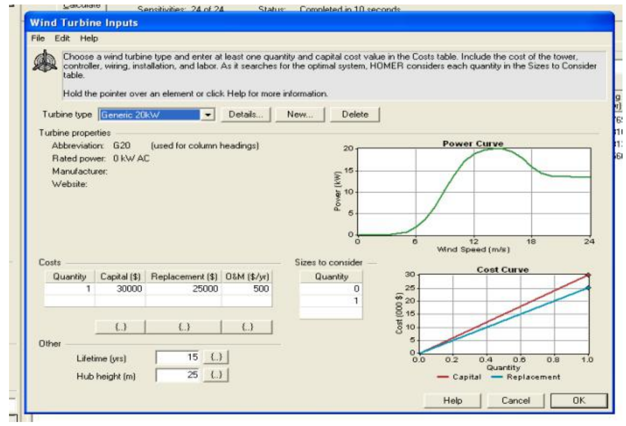

Fig. 10: Profile of the wind turbine

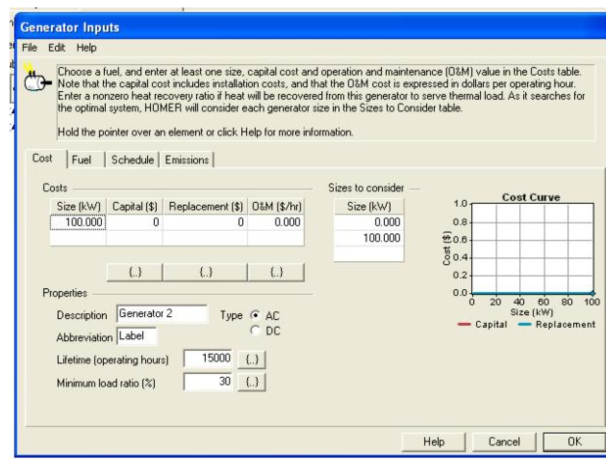

Fig. 11: Profile of the Generator

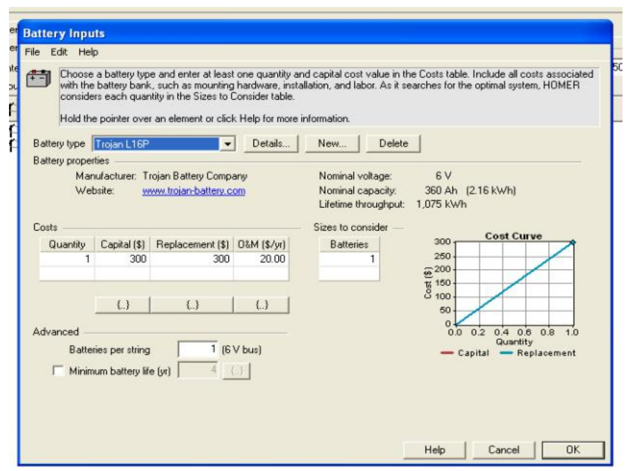

Fig. 12: Profile of the Battery

2.1. Specifications of the hybrid system in stand-alone mode:

In this section, the specifications of the hybrid system in the off-grid mode for supplying the power needed for the telecommunication mast are shown (Table- 8 Fig.-13)

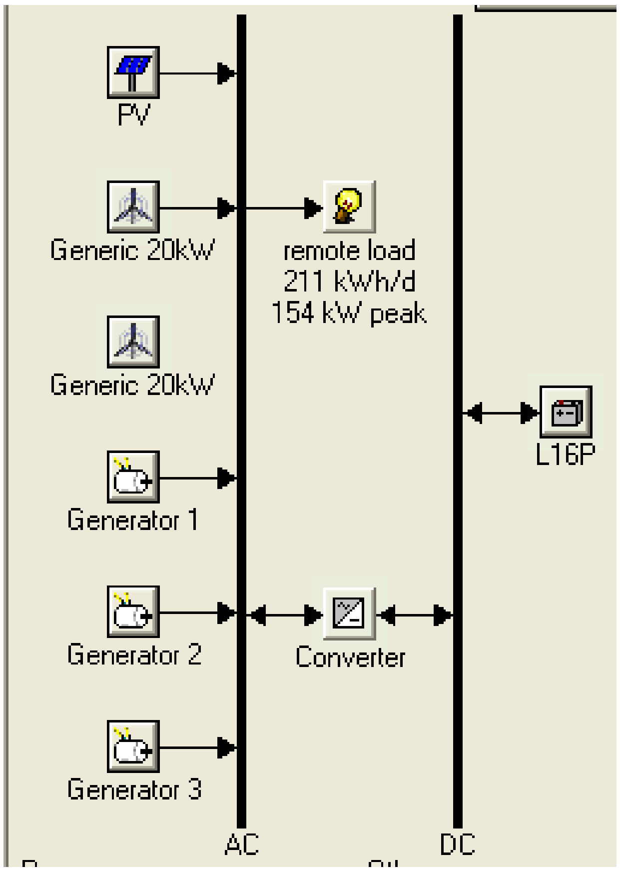

Fig. 13: The hybrid system for the telecommunications mast in the off-grid mode

The following table shows the specifications of the hybrid system for the telecommunication mast in the off-grid mode. This table also shows the optimal system specification in two versions with and without wind turbine. In the case of a wind turbine, which is suitable for windy areas, the initial investment cost is 36,627$ per kilowatt, and the operation cost is 14,971$ per year. In the case without wind turbine, the initial cost is 6627$ per kilowatt, and the operation cost is 15447 $ per year.

In this paper, the Homer software is used to simulate and evaluate the technical and economic aspects of the hybrid system in order to supply the electrical power of a telecommunication mast in Kaboodarahang, Hamadan. The hybrid system features wind turbines, solar panels, diesel generators, and batteries in the off-grid mode. The results indicate that using hybrid sources is cost-effective in the areas far away from the grid (Llaria *et al.,* 2011; Zhang Di 2013; Sortomme and El-Sharkawi, 2011).

Conclusion

The Hybrid Renewable Energy Systems (HRES) are becoming increasingly widespread in power supply in remote areas, due to advances in renewable energy technology and rising oil prices. The hybrid energy system usually uses two or more renewable energy sources, which together increase system efficiency and balance in energy supply.

In this study, the Homer software is used to simulate and evaluate the technical and economic aspects of the hybrid systems in order to supply the power of a telecommunication tower in Kaboodarahang, Hamedan.

The hybrid system uses turbines, solar panels, diesel generators, and batteries in two on-grid and off-grid forms.

The results indicate that the use of hybrid sources is cost-effective in the areas far away from the network.

The government can further develop the tendency to use renewable resources, especially wind and solar, for reasons such as availability, less pollution and, more importantly, sustainable economic development in the country by providing financial incentives, including low-interest loans, awareness and supporting involved companies. (Clement *et al.,* 2008 & 2009; Dickerman and Harrison, 2010).

Table 8: The main specifications of the hybrid system for telecommunications mast in off-grid mode

	PV (kW)	G20	G20	Label (kW)	Label (kW)	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Label (hrs)	Label (hrs)
	100			15	100	100	1	6	$ 6,627	15,972	$ 192,759	0.215	0.00	37,126	8,267	587	83
	100	1		15	100	100	1	6	$ 36,627	16,025	$ 223,372	0.249	0.17	34,459	7,380	587	77

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