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Optimal Sizing of a Hybrid System of Renewable Energy for Lighting Street in Salalah-Oman using Homer software

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Abstract

The hybrid systems of renewable energy can contribute in a significant way to the strong development in several isolated areas far from the main utility grid. But, because of climatic change which is one of greatest challenges that must take up the international community, the supply of these isolated areas with their needs of electricity by the renewable energy source can have interruptions. For that, a wind turbine with PV hybrid system can ensure a reliable supply without interruption. This paper discusses an optimization solution of a hybrid system of renewable energy to lighting 10 km street in Salalah, Oman by using the Homer software and comparison of results if the separated system is used as the grid for the PV, wind turbine, and diesel generation.

Keywords: *Hybrid system, Renewable Energy, Diesel generator, Optimization, HOMER*

1. Introduction

The fast fossil-fuel resources depletion has called for an urgent search for alternative energy sources of on a worldwide basis. From the many options available; photovoltaic (PV) are considered as promising technique toward meeting the continually increasing demand for energy [1]. PV cells can be regarded as a technology for an inexhaustible source of energy, they are free from smoke and pollution, and have no moving parts. It can be used for remote systems that are far from conventional power systems such as wireless communications and satellite ground stations. Hybrid systems were considered as attractive alternative sources and preferable [1]. It was found that the hybrid energy systems can reduce the total cost of the energy produced significantly. Also, they can provide more reliable electricity by combining many power generation sources. The initial step for the foundation of a half-breed framework is the plausibility examination. The wind and sun powered vitality are controlled by the climatic conditions that decide the significance and the accessibility of it in specific site [2]. A pre-achievability study depends on the climate information (wind speed and sunlight based protection) and the heap required for the specific area. After that stride, the estimating of the half and half framework segments (limit of wind generator, quantities of PV boards, and quantities of batteries, and so on) depends on the climatic information and the greatest size. This stage assumes a critical part in the determination of the consistent quality and the economy of the framework.

There are several software's can be used to plan for the PV system, or as a monitoring tool. It can cover different categories like analysis, economic evaluation, etc. Homer software is one of the known software to find the best optimization results, and it can support variable systems. Homer is a powerful tool as an energy modeling software that facilitates the designing and analyzing hybrid power systems. These systems contain a mix of wind turbines, solar PV, conventional generators, cogeneration, hydropower, batteries, fuel cells, biomass and other inputs [3]. Hybrid systems are used all over the world by tens of thousands of people nowadays. HOMER's enhancement and affectability investigation calculations make it simpler to assess the numerous conceivable framework arrangements [1]-[2]. Homer reenacts the force frame operation and creates vitality parity accounts. It additionally shows a rundown of settings positioned by net present cost, which can be utilized to pick the most appropriate framework plan. Numerous scientists have contemplated the ideal configuration of the PV modules using Homer project [3]-[7].

Ref. [3] analyzed supplying the power request a well-being center in the country ranges in southern Iraq by utilizing PV solar system. HOMER programming was used with a PC model to choose the suitable financial framework. The study proposed a PV module framework with 31.6 kWh/day made out of PV modules with 6 kW, 80 batteries (225 Ah and 6 V), and a 3-kW inverter. The proposed total expense of the framework was 50,700 US$ while the net present cost was 60,375 US$. The cost of structure produced power was 0.238 US$/kWh. The study reasoned that the diesel created energy cost is four times more prominent than that delivered by the PV framework, which highlights the benefit of utilizing this framework as a part of remote ranges.

Ref. [4] proposed an advancement arrangement of a crossover arrangement of renewable vitality for remote areas in Tunisia utilizing the Homer programming. The proposed half and half frameworks include a blend of variable vitality sources like wind/battery, PV/battery, wind/PV/battery, wind/PV/diesel/battery. The Hawaria in Tunisia region climatic data was used. The optimal hybrid system configuration was selected to compose 8 kW PV module, two wind turbines, 118 batteries and 12 kW power converters. The initial cost of the scheme was 165.450US$, and the operation cost was 2.102US$/yr. The aggregate net present expense and the cost vitality delivered were 189.559 US$ and 0.540 US$/kWh, separately. For the chose diesel/battery framework, the ideal arrangement made out of 5 kW diesel generator, 18 batteries, and 2 kW power converters. The underlying expense of the plan was 11.934 US$, and the operation expense was 10.707 US$/yr. The aggregate net present expense and the expense the produced vitality were 134.747 US$ and 0.382 US$/KWh, individually while the expended diesel was 11.269 liter. For the wind/PV/diesel generator/battery with a heap of 85 kWh/d the ideal setup is made out of 8 kW PV board, two wind turbine, 118 batteries, 5 kW diesel generators and 12 kW power converter. Likewise, the best answer for the surety the stable supply without the intrusion of the heap under the climatic information change in the mix of a diesel generator, as a buck-up source, with the half and half wind/PV/battery framework. The study presumed that the ideal measuring of the half and half wind/PV/diesel/battery framework can be concluded from two perfect chose arrangements: (wind/PV/battery) and (diesel/battery).

Ref. [5] researched the efficient arrangement of maintainable renewable vitality for household utilized and its aggregate expense as a part of Khartoum-Sudan. The study employed HOMER programming to build up the half-breed enhancement recreation. The proposed burden was 5.3 kW as a crest and 54 kWh/d in standard power request. The PV module cost included and besides the turbine incorporated the establishment costs. The study found that it is ideal to utilize wind/PV blend framework for 50 homes rather than a solitary home framework. Additionally, in Khartoum city, the general expense of vitality would be low if the turbine expense was diminished.

Ref. [6] led a study in Nigeria to locate the best money saving advantage of using a cross breed sun oriented influence era utilizing the HOMER programming for enhancement. The study showed that the focal lattice power era is the least costly choice. In any case, it may not be accessible in provincial zones a long way from the framework. Furnishing these districts from segregated force sources is essential. The study proposed a framework utilizing (0.05 – 0.4 kW) PV module, (0.4 kW DC) FD arrangement wind turbine, (200 Ah/12 V, bank size: 1-8 batteries, Vision 6 FM200D) battery, and (0.1 – 1.5 kW) converter. The framework introductory capital expense and the working expenses were 3,455 US$ and 69 US$/year, separately. The aggregate net present cost (NPC) and the expense of vitality (COE) were 4251 US$ and 1.74 US$/kWh, individually. The study inferred that the half and half framework has a payback time of around thirty-three years and at current expenses. Ref. [7] designed a hybrid power generation system that can be used for remote area application by using HOMER software. The proposed system had a primary load of 3 kWh/d and a 307 peak. The proposed framework made out of a Micro-hydro model, wind turbine models, PV exhibit models, a diesel generator, and batteries. The Micro-hydro model is intended to deliver a 100 kW of limit, having a capital expense of 300,000 US$ and a substitution cost of 300,000 US$. The study conveyed to light the significance of the adjusting between economy, environment and vitality by deciding the ideal crossbreed arrangement. The expense of vitality in the purposed plan was equivalently higher than the customary vitality sources, yet with more effectiveness and less ecological symptoms.

This study aimed to design with the aid of Homer Software an optimum hybrid system to light a 10 km street in Salalah city in southern Oman. This study is a part of continues efforts of the Omani Sohar University Solar Energy Research Team to establish a culture of the use of renewable energies in the Arabian Gulf and Iraq [11]-[32].

1.1 The studied location

Oman has a long coastline and experiences an intense summer and winter monsoon winds. It's average wind speed about over 5 m/s and an estimated 2,463 hours of full load per year, considering wind power as an economically viable form of renewable energy. Latest studies in 2010 have established that four locations at Thumrait, Masirah, Sur and Qayroon Hyriti have a suitable place for the wind turbines stations. Many studies estimated constructing two wind farms at Thumrait and Qayroon Hyriti with total generation power of 375MW each. This generated power will fulfill about 12 per cent of Oman's 2010 electricity production.

1.2 Wind Energy

The Wind is more seasonal as one of the disadvantages of the wind over solar. Studies show that wind speed is higher in summer months (June, July, and August) and is lower in October and November.

Although, wind speeds are higher in the months which Oman reaches peak demand, this is a further clue of the feasibility of wind-powered electricity generation. The economic benefit of wind energy has led to auxiliary studies being undertaken to assess the technological routes for implementing this [8]. Figure 1 shows the wind speed during one month for Salalah [9].

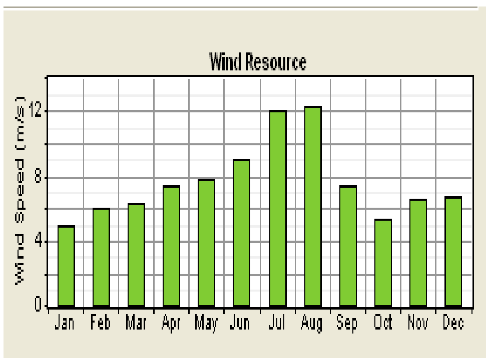

Fig. 1, monthly average wind speed in Salalah

1.3 Solar Energy

Oman has a high “sky clearness” ratio and receives wide daily solar radiation ranging from 5,500-6,000 Wh/m^2 a day in July to 2,500-3,000 Wh/m^2 a day in January, which considered as one of the maximum solar energy densities in the world. The technology that uses the principle of generating electricity by solar cells, where they are arranged on the solar PV panels to convert solar energy into electricity. Currently, PV panels are used in many locations in Oman to provide lighting, water, heating, and water pumping.

The cost of producing power from the solar cell is competitive with the diesel based electricity generation systems that are currently used. Environmentally, the use of this form of power generation systems instead of the current ones as diesel and natural gas generators will result in a drop in thousands of tons of greenhouse gas emissions per year as it can be seen clearly in the recent study results. Fig. 2 shows the solar radiation for Salalah [9]-[10].

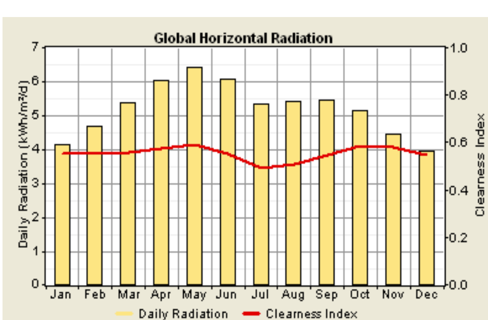

Fig. 2, monthly average solar radiation in Salalah

2. The proposed system load data

The system will be supplying lighting for the street of 10 km street in Salalah. The LED lights will be used due to their less consumption of power, good performance, and long lifecycle. The lights will illuminate the street for 12 hours from 6 PM to 6 AM with 114 W for each light with a separation distance of 35 m of the total 10 km. Numbers of required lights are 286 lights with full rated power of 33,060 W. There will be no lightning during the day time. Load power flow shows in Table 1 and Fig. 3.

Table 1,load power flow

Total power	Separation distance	Needed number	Hours of working
33060 W	35m	286	12h(6 AM to 6 PM)
P(rated)	Type	Load	
114 W each	Light	1	

2.1 System Configuration

In this part, each system will be studied as a separate system (stand-alone) in case if we have only PV system, wind turbine or generator.

2.2 PV System

In this sector, a PV system as a stand-alone will be considered to light 10 km street in Salalah with a total load of 33.06 kW. Figure 4 shows the PV system configuration.

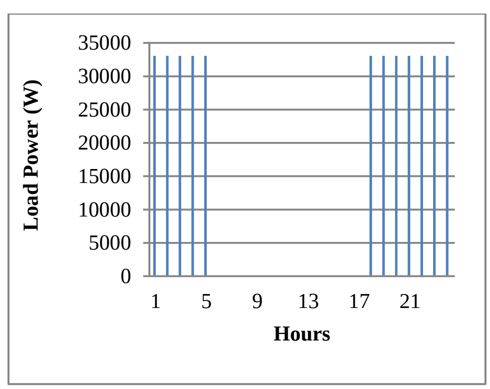

Fig. 3, load power flow during the day.

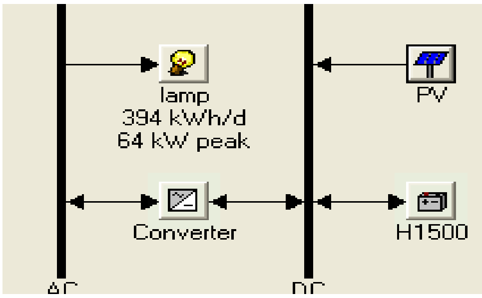

Fig. 4, PV system configuration

According to the proposed load, Homer selected the most optimum results for 160 kW PV size, 490 Batteries, and 61 kW converter size. The capital cost of all the system was 540400$, with operating cost of 24774$/yr. The Total Net Present Cost and the Cost of Energy were 857092$ and 0.467$/kWh respectively.
The Cost of Energy is a critical value that concern because it reflects how much the system is reliable and useful to use. As much as the Cost of Energy reduced the best optimum system is achieved. Fig. 5 illustrates the results of that system.

Sensitivity Results | Optimization Results

Double click on a system below for simulation results.

	PV (kW)	H1500	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	160	490	61.0	$ 540,400	24,774	$ 857,092	0.467	1.00

Fig. 5, optimum results for PV system

2.3 Wind Turbine System

In this part will concern the same load that is used previous and will be powered by using only wind turbine. Figure 6 shows the wind turbine system configuration.

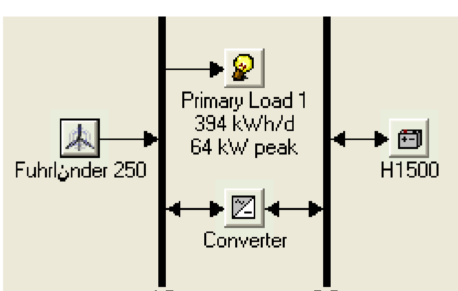

Fig. 6, wind turbine system

According to the suggested load, Homer selected the most optimum results for 25 wind turbine each of 250 kW size, 100 Batteries, and converter size 50 kW. The capital cost of all the system is 7887500$, with operating cost of 128398$/yr. The Total Net Present Cost is fond 9528861$ and the Cost of Energy 5.184$/kWh.
The Cost of Energy seems too large compared with PV system so using wind turbine as standalone for lighting not reliable. Figure 7 shows the best optimization result for the wind turbine.

Double click on a system below for simulation results.

	FL250	H1500	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	25	100	50	$ 7,887,500	128,398	$ 9,528,861	5.184	1.00

Fig. 7, optimum results for wind turbine

2.4 Diesel Generator System
In this sector, a diesel generator will be used to power the same load as Fig. 8 provides.

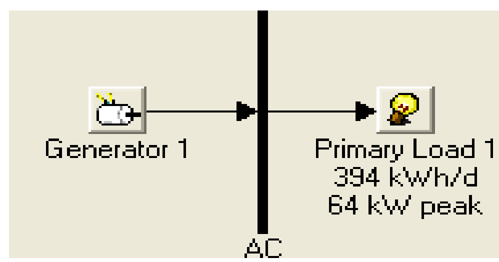

Fig. 8, diesel generator system

According to the proposed load, Homer selected the most optimum results for generator size of 60 kW with diesel fuel consumption of 57091 l/yr. The capital cost of all the system is 120000$, with operating cost of 72149 $/yr. The Total Net Present Cost is found of being 1042303$, and the Cost of Energy was 0.567$/k/Wh.

Pollutant	Emissions (kg/yr)
Carbon dioxide	150,341
Carbon monoxide	371
Unburned hydrocarbons	41.1
Particulate matter	28
Sulfur dioxide	302
Nitrogen oxides	3,311

Fig. 9, Gases emission

The resulted Cost of Energy was found less than that of the wind turbine and a little larger than that of the PV system. As there are many gases emission from the generator that may affect the environment in that surrounding, the generator was ignored from the system. Figure 9 shows the gases emissions concentrations (in kg/year) emitted by the proposed generator.

2.5 Integrated of PV and Wind turbine (hybrid system)

The hybrid system will be considered now as the PV arrays will be integrated with the wind turbine to power 33.06 kW of street light in Salalah, Oman. Fig. 10 shows the hybrid system.

According to the selected load, Homer chose the most optimum combination consisted of 1 wind turbine of 250 kW size, PV module with a capacity of 80kW, 200 Batteries, and 55kW converter size. The capital cost of all the system was 562000$, with operating cost of 10608$/yr. The Total Net Present Cost was 697601$, and the Cost of Energy was 0.380$/k/Wh.

The Cost of Energy is cheap compared to all the previous designs. So this system is more reliable and useful to use. Figure 11 shows the best optimization results for that system.

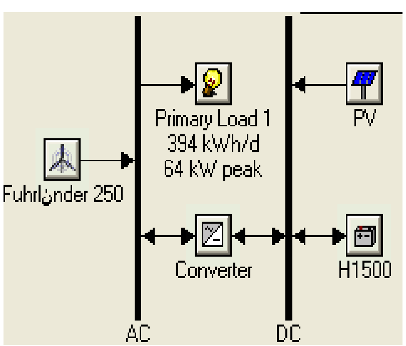

Fig. 10, PV/Wind/Battery Hybrid System

Double click on a system below for simulation results.

	PV (kW)	FL250	H1500	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	80	1	200	55	$562,000	10,608	$697,601	0.380	1.00

Fig. 11, best optimization results for hybrid system

Figures12proved the cash flow summary and the net present cost in $ for the PV, wind turbine, Batteries and converter.

Figure 13 proved the cash flows verse the nominal cash flow it seems from the graph the large price is for the capital cost on the other hand operating cost its fixed price for 25 years and its almost zero comparing with other cost.

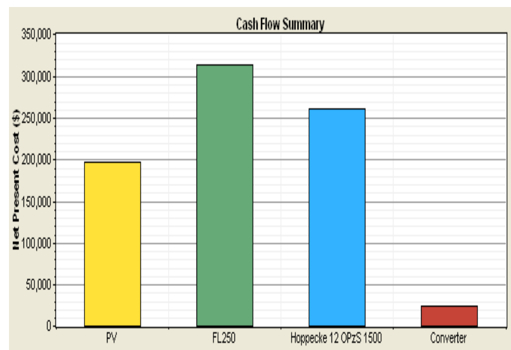

Fig. 12, Cash flow summary

Figure 14 proved the monthly average electrical production of the PV and the wind turbine for one year**.**

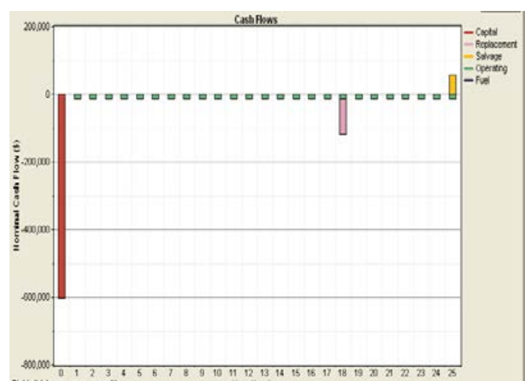

Fig. 13, Cash flow

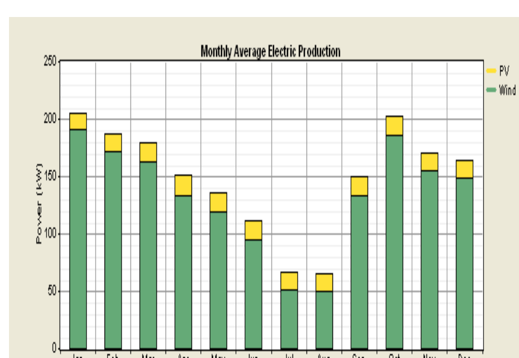

Fig. 14, monthly average electrical production of the PV and the wind turbine in a year.

Figure 15 shows that the PV and wind turbine output vs. an hour of the day and it seems from the graph the output power fluctuates between 18 kW and 72 kW.

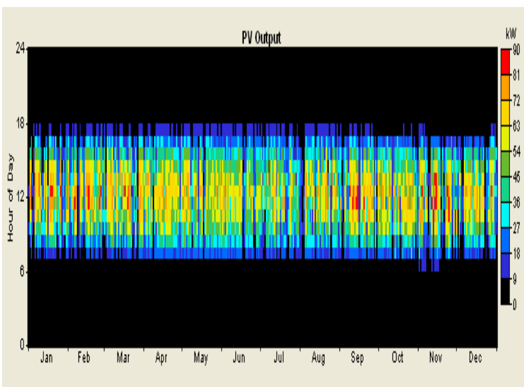

Fig. 15, daily PV output

3. Conclusions

In this study, a comparison between four systems to supply electricity for lights of 10 km street in Salalah with a total load of 33.06 kW which will be applied for 12 hours from 6 PM to 6 AM. The first analysis was using PV system only with optimum results for 160 kW PV size, 490 Batteries, and 61 kW converter size. The capital cost of all the system is 540,400$, with operating cost of 24,774$/yr. The Total Net Present Cost is fond 857,092$ and the Cost of Energy 0.467$/k/Wh. Second is Wind system with optimum results for 25 wind turbine each 250 KW size, 100 Batteries and 50KW converter size. The capital cost of all the system is 7,887,500$, with operating cost of 128,398$/yr. The Total Net Present Cost is fond 9,528,861$ and the Cost of Energy 5.184$/k/Wh.COE is much higher than the PV system. Third is for diesel generator with optimum results of 60 KW generator size and 57,091 L/yr. The capital cost of all the system is 120,000$, with operating cost of 72,149 $/yr. The Total Net Present Cost is fond 1,042,303$ and the Cost of Energy 0.567$/kWh, which considered to be less than COE of Wind turbine but greater than COE of PV system. Diesel generator emits greenhouse gases of 150,341 kg/yr of CO_2, 371 kg/yr of CO, 41.1 kg/yr of HC, 28 kg/yr of Particulate Matter, 302 kg/yr of SO_2 and 3,311 kg/yr of NOx. Lastly, PV/Wind/Battery Hybrid System with best optimum results of 1 wind turbine each 250 kW size, 80kW PV size, 200 Batteries and 55 kW converter size. The capital cost of all the system is 562000$, with operating cost of 10,608 $/yr. The Total Net Present Cost is fond 697,601 $ and the Cost of Energy 0.380 $/kWh, which is the lowest COE of the previous systems. From all above, it's been proved that using PV/Wind/Battery Hybrid System is the best, costless and cleanest option for generating electricity for lighting as in our case.

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