Optimization Of Hybrid Renewable Energy System (HRSE) Using Homer Pro

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Abstract- The responsible way of utilizing energy sources is highly debatable these days. It is crucial to select the right source of energy with proper reasoning. A vast majority of factors ought to be taken into account such as being environmentally friendly, stable, cost effective, efficient and clean. As higher wind flow and hydro energy sources. Various methods of harnessing these renewable energy sources are already available. But the main challenge is the utilization of these resources in a sustainable and sufficient manner. Factors such as wastage of excess power wastage due to less demand is a major concern in this type of systems. Properly designing a system which can utilize this extra produced power into converting or conserving power for future use is the main concern in this design proposal. Following these reasons are why the exploration of new and effective renewable energy sources and methods of harnessing are done. To further increase efficiency and productivity, stand-alone hybrid renewable energy systems are designed. In this paper, the possibilities of solar and wind renewable energy systems are discussed and possible methods are presented with comprehensive supporting data and reasoning by Homer Pro software.

Indexed Terms- Renewable Energy, Stand-alone, Homer Pro, Photovoltaic, Solar Energy, GHG

I. INTRODUCTION

Renewable energy is defined as obtainable energy harnessed from a limitless source. Energy converted from crude oil, gas and coal powers almost everything around us, hence making these elements the main resource for providing energy for this world. But this heavy use comes with a cost. These energy sources are not renewable and the amount we have is limited. Over a certain period of time, the reserve amount will definitely run out. As it is predicted that with the growth in technological advancement and the increasing rate of fossil fuel consumption it will take 35, 107 and 37 years for oil, coal and gas respectively to deplete completely [1]. However, fact remains that industries around the world still rely on fossil fuels for generating power. These fuels can produce power effectively but there are many disadvantages in the long run. Eventually, fossil fuels will run out and industries will turn to renewable energy. Apart from being a finite resource, fossil fuels pose a large threat to the natural balance of environment and will lead to several ecological hazards. The strategies to build a sustainable development that involves renewable energy sources such as wind, solar, wave and biomass is to combine them in an efficient manner according to the location it needs to be employed. Such strategies usually require considering aspects such as sustainability of the system, energy savings on the demand side, improvement of efficiency in energy production over time. Therefore, in large scale renewable energy implementation needs to consider strategies on integrating various sources of renewable sources in comprehensible energy systems that focus on energy savings in an efficient manner.

II. LITERATURE REVIEW

The optimum design of hybrid renewable energy systems is a hot topic and there is a rich literature dedicated to this topic. The mentioned design problem to be formulated is related to the determination of the optimal configuration of the power system and optimal location, type and sizing of generation units installed in certain nodes, so that the system meets load requirements at minimum cost [2].

Aydin M. [3] explore geological information system (GIS) based site allocation for solar–wind HRE Sat western turkey. In this paper Fuzzy logic and geographic information system tool are used to search best and alternative location of the target area that benefits financial and ecological criteria. A researcher Tao Ma [4] presented a comprehensive feasibility study and techno- economic assessment of a remote solar–wind hybrid energy system with battery energy storage for an isolated island. Climatic condition is the major input to carried out pre- feasibility analysis. Figure 2.1 and Figure 2.2 show global map solar energy and wind energy potential in all over world [5].

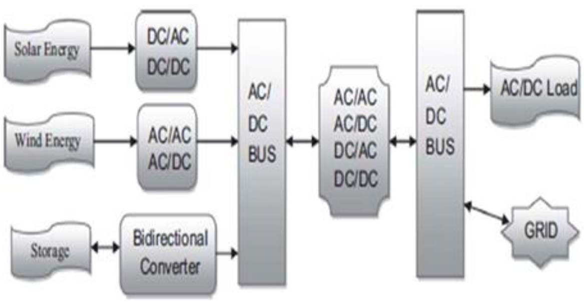

Figure 2.1: Basic component of solar-hybrid renewable energy system [5].

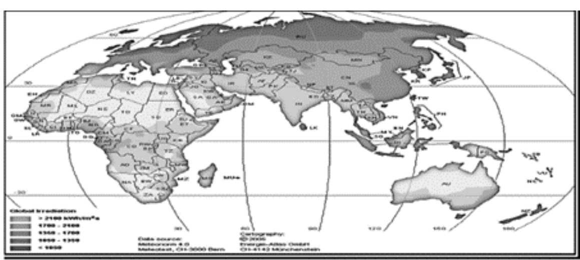

Figure 2.2: Global solar radiation potential[5].

Feasibility of solar– wind hybrid renewable energy system mainly depends on solar radiation and wind energy potential available at the specific location. Designing a hybrid renewable energy system requires appropriate weather data. The optimization of the FHAWT blades has achieved which shows high lift and drag ratio than an untwisted blade. Although the FHAWT twisted blade was designed for the variable speed operation in offshore environment it can be applicable for constant speed operation as well [6].

III. MODELLING OF HRES

There are different types of renewable energy sources such as solar, wind, hydro, biomass, fuel cell, tidal etc. Modeling is the first step to design a system according to the different parameter and constraint. Marchetti & Piccolo [6] gave statistical modeling of solar wind HRES based on annual cost, battery autonomy function, sizing criteria and ecological statistical factor. Step by step optimization practice is used to find out the befitting result of the solar wind HRES model. Kalogirou[7] developed solar wind hybrid system model based on long term simulation. This system integrates diesel generating sets with the renewable energy source. Bonanno[8] presented logistical model of HRES to evaluate fuel and energy saving and reported the problem related to the exploitation of combined renewable and conventional energy sources. A special feature of logistical model is that a supplementary fictitious source is introduced in order to obtain the power balance at the bus-bar during the simulation stage. Ghali et al. [9]used loss of power supply probability (LPSP) to develop integrated renewable energy system model. Based on load distribution, the probability density function of the storage is obtained and consequently.

Simulation programs are the most common tools for evaluating performance of the hybrid renewable energy systems. Currently, there are many software programs available that can be downloaded from the websites of several research laboratories and universities. By using the mentioned simulation programs, the optimum configuration can be found by comparing the performance and energy production cost of different system configurations. Among them, one of the most famous sizing programs for hybrid systems is HOMER developed by National Renewable Energy Laboratory (NREL), United States [10]. HOMER includes several energy components models, such as photovoltaics (PVs), wind turbines, hydro, batteries, diesel and other fuel generators, electrolysis units, and fuel cells, and evaluates suitable options considering cost and availability of energy resources [11].

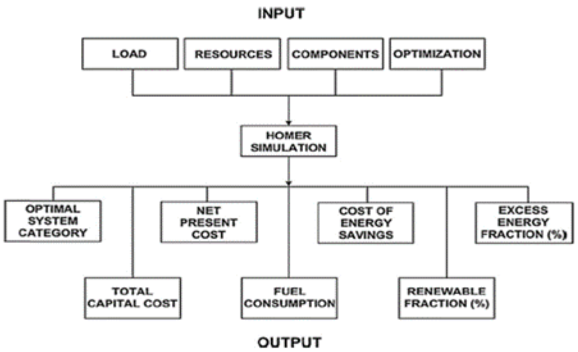

Figure 3.1: Architecture of HOMER software [12].

HOMER includes several energy component models, such as photovoltaics (PVs), wind turbines, hydro, batteries, diesel and other fuel generators, electrolysis units, and fuel cells, and evaluates suitable options considering cost and availability of energy resources [11]. The software requires initial information including energy resources, economic and technical constraints, energy storage requirements and system control strategies [13]. The architecture of the software is presented in Figure 3.1 [14].

IV. DATA COLLECTION

In a single run, HOMER examines all conceivable combinations of system types and arranges them according to the optimization variable of choice. HOMER Pro includes a new optimization method that makes selecting the lowest-cost choices for micro-grids and other distributed generation electrical power systems much easier. Homer Pro simulation setup procedure is discussed in the later figures with brief explanation.

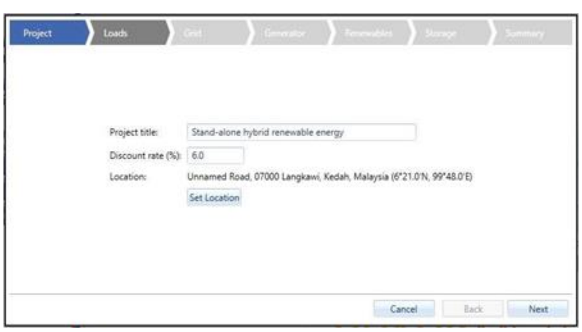

Figure 4.1: Project title, discount and location for the system simulation.

In this Figure 4.1 the project title is stated with a discount rate of 6 % and location is fixed which is Malaysia.

Figure 4.2: Load settings for the system simulation.

In this Figure 4.2 the loads are estimated for a community which is Average daily load (kW.h/day): 170 and the peak month is assumed to be July as that time of the year is summer season. Moreover, other usage pattern is shown for example in the figure such as for the residential, commercial and industrial including the one used in the study which is commercial.

Figure 4.3: Grid settings for the system simulation.

In this Figure 4.3 it is stated whether the system is connected with the grid or not, as an objective of the study this a stand-alone system study without connected which is not connected with the grid for which the option is not choose.

Figure 4.4: Generator settings for the system simulation.

In Figure 4.4 the Homer pro software will consider the system estimated with and without the generator, additionally the estimated cost of the generator and the fuel price is also stated.

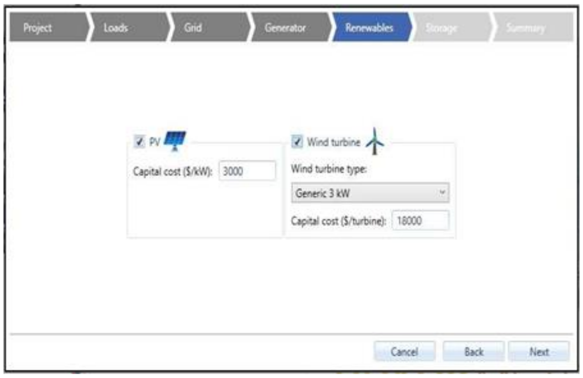

Figure 4.5: Renewable system settings for the simulation.

In this Figure 4.5 the option for PV and wind turbine both is chosen because the study comprises solar power system and wind turbine system for generating power for the consumption.

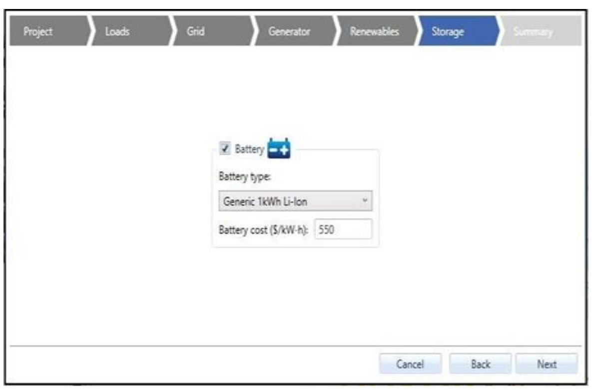

Figure 4.6: Storage configuration settings for the system.

In this Figure 4.6 power storage option is stated where the type of battery is used including the cost of battery is also stated.

Figure 4.7: Overall summary of the system simulation.

In this Figure 4.7 the summary of the overall system configured is stated to look at a glance before calculating the estimation the system used in the study. Schematic diagram of the system has been illustrated below derived from the Homer pro simulation software.

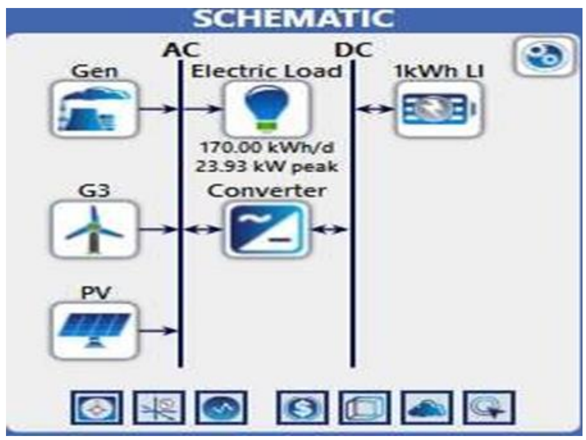

Figure 4.8: Schematic diagram of the system.

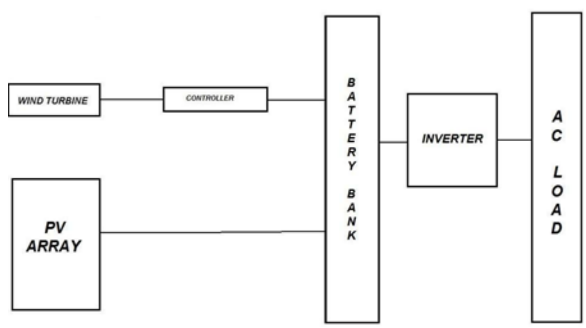

Figure 4.9: Block schematic diagram of the system.

During simulation some of the sensitivity input is also considered where for the system for better estimated results which is also given as the input in the simulation software. In the Figure 4.9 the sensitivity input regarding the diesel fuel price and average wind scale is stated

Diesel Fuel Price ($/L)	Wind Scaled Average (m/s)
0.5	3.1425
0.25	3
1.00	8

Figure 4.10: Comparison of diesel price and wind average.

Additionally, for accurate estimated results of the system detail inputs are given which are briefly discussed in the following figurative parts below

Figure 4.11: Overview of the economic aspects.

In terms of economics here only nominal discount rate percentage is stated 6% and project life time is stated as 25 years, other than there are different options which can be considered such as expected inflation rate capacity shortage penalty etc as in the Figure 4.11.

Figure 4.12: Constraints of the system.

It is normal to have constrain in a system because none of the system can be 100% perfect for which some constraints have to be applied for example in this study maximum annual capacity shortage is stated 5%, solar power output is taken 80% and many more as can be observed in Figure 4.13.

Figure 3.13: Overview of overall emissions.

As this is a stand-alone renewable energy system which comprises PV and wind energy, it is considered as zero emission system. But in case of using generator for backup negligible emission is considered.

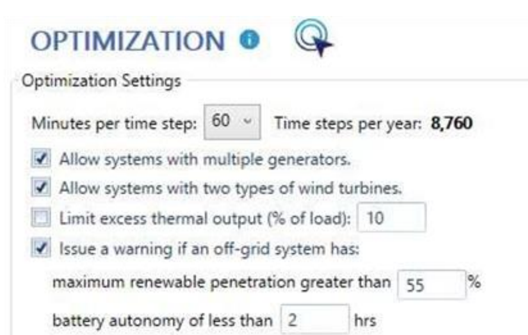

Figure 4.14.1: Optimization options for the system.

Optimizer Settings	
Maximum simulations per optimization	10,000
System design precision	0.0100
NPC precision	0.0100
Focus factor	50.00
Slower (thorough)	Faster
☑ Optimize category winners?	

Figure 4.14.2: Optimization options for the system.

Overall optimization settings are stated in the Figure 4.14(1 & 2) where multiple generators can be used if needed, systems allow two different types of generator if needed and many other options are mentioned in the system settings.

V. HOMER SIMULATION RESULTS

More detailed optimization results of different configurations and sensitive cases results which is estimated in terms of base case system failures are tabulated in the figures below

a. Optimization results

Architecture						Cost				System	
PV (kW)	G3	Gen (kW)	1kWh LI	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
13.8		27.0	25	16.6	CC	$213,665	$0.269	$10,958	$73,588	23.2	14,715
		27.0	27	18.6	CC	$228,400	$0.288	$15,213	$33,933	0	21,027
13.5	1	27.0	25	16.6	CC	$237,982	$0.300	$11,526	$90,644	23.1	14,737
	1	27.0	27	18.4	CC	$252,513	$0.318	$15,695	$51,872	0	20,919
		27.0			CC	$298,461	$0.376	$22,292	$13,500	0	30,876
0.223		27.0			CC	$298,972	$0.377	$22,279	$14,168	0	30,818
	1	27.0			CC	$323,370	$0.408	$22,832	$31,500	0	30,827
1.78	1	27.0			CC	$327,653	$0.413	$22,749	$36,844	0	30,423
82.7			177	33.3	CC	$418,407	$0.546	$4,931	$355,371	100	0
85.5	1		170	24.0	CC	$442,778	$0.577	$5,286	$375,200	100	0

Figure 5.1.1: Tabulated results for the optimization results of the system.

Gen							
Hours	Production (kWh)	Fuel (L)	O&M Cost ($/yr)	Fuel Cost ($/yr)	Capital Cost ($)	Production (kWh/yr)	Capital Cost ($)
2,300	47,651	14,715	1,863	3,679	41,357	21,550	
3,065	69,504	21,027	2,483	5,257			
2,308	47,693	14,737	1,869	3,684	40,417	21,061	18,000
3,054	69,119	20,919	2,474	5,230			18,000
8,760	74,823	30,876	7,096	7,719			
8,760	74,577	30,818	7,096	7,705	668	348	
8,760	74,611	30,827	7,096	7,707			18,000
8,760	72,902	30,423	7,096	7,606	5,344	2,785	18,000
					248,029	129,244	
					256,500	133,658	18,000

G3		1kWh LI			Converter
Production (kWh/yr)	O&M Cost ($)	Annual Throughput (kWh/yr)	Nominal Capacity (kWh)	Usable Nominal Capacity (kWh)	Inverter Mean Output (kW)
		25,824	25.0	20.0	2.66
		35,805	27.0	21.6	3.68
356	360	25,820	25.0	20.0	2.66
356	360	35,663	27.0	21.6	3.67
356	360				
356	360				
		30,045	177	142	3.09
356	360	29,777	170	136	3.06

Figure 5.1.2: Tabulated results for the optimization results of the system.

b. Sensitivity cases results

Sensitivity		Architecture				
Diesel Fuel Price ($/L)	Wind Scaled Average (m/s)	PV (kW)	G3	Gen (kW)	1kWh LI	Converter (kW)
0.250	3.14	13.8		27.0	25	16.6
0.250	3.00	13.8		27.0	25	16.6
0.250	8.00	13.8		27.0	25	16.6
0.500	3.14	17.2		27.0	28	18.5
0.500	3.00	17.2		27.0	28	18.5
0.500	8.00	13.8	1	27.0	29	18.7
1.00	3.14	30.9		27.0	114	13.0
1.00	3.00	30.9		27.0	114	13.0
1.00	8.00	17.0	2	27.0	33	20.5

	Cost				System	
Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
CC	$213,665	$0.269	$10,958	$73,588	23.2	14,715
CC	$213,665	$0.269	$10,958	$73,588	23.2	14,715
CC	$213,665	$0.269	$10,958	$73,588	23.2	14,715
CC	$258,705	$0.326	$13,498	$86,161	27.8	13,457
CC	$258,705	$0.326	$13,498	$86,161	27.8	13,457
CC	$258,374	$0.326	$12,818	$94,512	34.5	12,177
CC	$339,622	$0.428	$13,045	$172,860	59.6	8,031
CC	$339,622	$0.428	$13,045	$172,860	59.6	8,031
CC	$326,331	$0.411	$15,775	$124,674	47.7	9,609

Figure 5.2.1: Tabulated results for the sensitive cases.

Gen					PV	
Hours	Production (kWh)	Fuel (L)	O&M Cost ($/yr)	Fuel Cost ($/yr)	Capital Cost ($)	Production (kWh/yr)
2,300	47,651	14,715	1,863	3,679	41,357	21,550
2,300	47,651	14,715	1,863	3,679	41,357	21,550
2,300	47,651	14,715	1,863	3,679	41,357	21,550
1,912	44,798	13,457	1,549	6,728	51,705	26,942
1,912	44,798	13,457	1,549	6,728	51,705	26,942
1,709	40,673	12,177	1,384	6,088	41,465	21,607
1,403	25,059	8,031	1,136	8,031	92,768	48,340
1,403	25,059	8,031	1,136	8,031	92,768	48,340
1,292	32,456	9,609	1,047	9,609	50,882	26,514

G3			1kWh LI			Converter
Capital Cost ($)	Production (kWh/yr)	O&M Cost ($)	Annual Throughput (kWh/yr)	Nominal Capacity (kWh)	Usable Nominal Capacity (kWh)	Inverter Mean Out (kW)
			25,824	25.0	20.0	2.66
			25,824	25.0	20.0	2.66
			25,824	25.0	20.0	2.66
			26,772	28.0	22.4	2.75
			26,772	28.0	22.4	2.75
18,000	7,923	360	25,413	29.0	23.2	2.61
			25,063	114	91.2	2.58
			25,063	114	91.2	2.58
36,000	15,847	720	22,676	33.0	26.4	2.33

Figure 5.2.2: Tabulated results for the sensitive cases.

VI. Discussion Analysis and Understanding

HOMER software is a computer model developed by the U.S. National Renewable Energy Laboratory (NREL). It is a tool that has been used in micro grid design optimization. HOMER helps in planning, designing and navigating the complexities of building cost effective and reliable micro grid composed by the conventional and renewable power, storage and load management. HOMER simulates the feasibility of the modelled system, giving the level zed cost of energy (LCOE) and net present cost (NPC) as the measurement parameters. HOMER is being developed from time to time by NREL in fixing the bugs as well as upgrading the old version to a better newer version. In this study, latest HOMER Pro has been extensively used for the system feasibility study. Figure above shows the homepage of the HOMER Pro summarizing the information on system/model, system architecture, description, economic and location. In this section, an installed hybrid solar-PV with diesel generator and energy storage at Island was used as a case reference. It is officially known as Island, the Jewel of Kedah, is a district and an archipelago of 99 islands in the Andaman Sea some 30 km off the mainland coast of north-western Malaysia. The islands are a part of the state of Kedah, which is adjacent to the Thai border. By using the simulation result can see that the hybrid system of wind turbine set-solar PV will be the best reliable and cost-effective option compared to the other hybrid combinations of solar PV- generator set, wind turbine-generator set or generator set operating alone to satisfy the power demand of the rural communities. From the simulation result of the wind turbine-solar PV hybrid system a variety of parameters like cost summary for each component, cash flow, economic comparison, electrical share of each component, fuel summary etc. can be analyzed. The figures for each parameter are shown here for better visualization of results. In HOMER Pro, the cost of the PV was determined in a kW basis. To get the direct analysis from HOMER, the search space for PV was directly based on the total of 13.8 kW installed. In hybrid energy system, the principal segments are power inverter as a conversation medium in feeding up the village AC loads. The inverter is an electronic device to convert the DC power into AC power.

The total cost analysis includes the quantities like Capital cost, Replacement cost, Operating & Maintenance cost. These cost calculations are done by the simulation tool and the cash flow graph will be generated for easy understanding by Homer Pro. The cost data is given in the Figure 5.1 in result section.

From the simulation results different system architecture were simulated among different configuration system the best system which can be used for the power consumption is illustrated in the Figure 5.1. it can be observed that the best components used for the maximum efficiency results are stated in the left section the results summary which are

Generator-27kW, PV- 13.8kW, 1kWh Li-25 battery and converter 16.6kW.

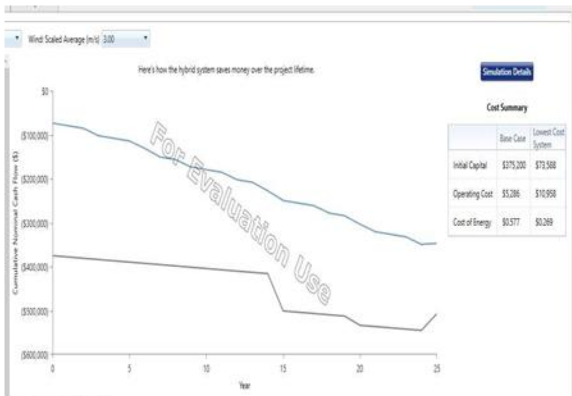

Figure 6.1: Graph for the best system and base case architecture.

Comparing with the base case system which includes PV- 85.5kW, 1kWh Li-170 battery, converter 24kW and G3- 1 unit of wind turbine, the difference between the lowest cost system and the base case is more than 200,000 dollars which make the low-cost system more preferable than the base case system. For more details between the low-cost system and base case system, the cost summary is estimated in the table on the right side of the Figure 6.1. From the graph difference pattern between the low-cost system and base case system can be evaluated.

The result captured from HOMER Pro explained that the modelled system is feasible to run an average of 186 kWh of village daily loads. It shows that the day started (8 A.M.) with the loads were being powered up by the engine and solar power combined. Moving towards noon, solar radiation escalated, the controller calculated the sources availability and priority, decided to call off the engine, and the system run solely on the generated solar power. At the same time, the excess power generated from the solar PV was also being consumed by the battery for charging process. The battery stored the energy to be used during night time when the solar PV is unavailable. Starting from 7 p.m., the solar PV stops producing, and the battery will kick in to feed the demand. At night time, whenever the demand is high, and the battery could not cope with the demand, the controller called the engine back on line to support the power feeding to the village. The battery normally will power the small demand up for the rest of the night until the next morning. The controller manages the energy to make sure that the energy movement is smooth and the power supply to the village is uninterrupted. In terms of economic, HOMER Pro analyzed the NPC at $213665 and LCOE at RM0.269/kWh for the system to run in 25 years' time. The LCOE was calculated based on the economic input considering all the aspects such as the diesel price using the dollars.

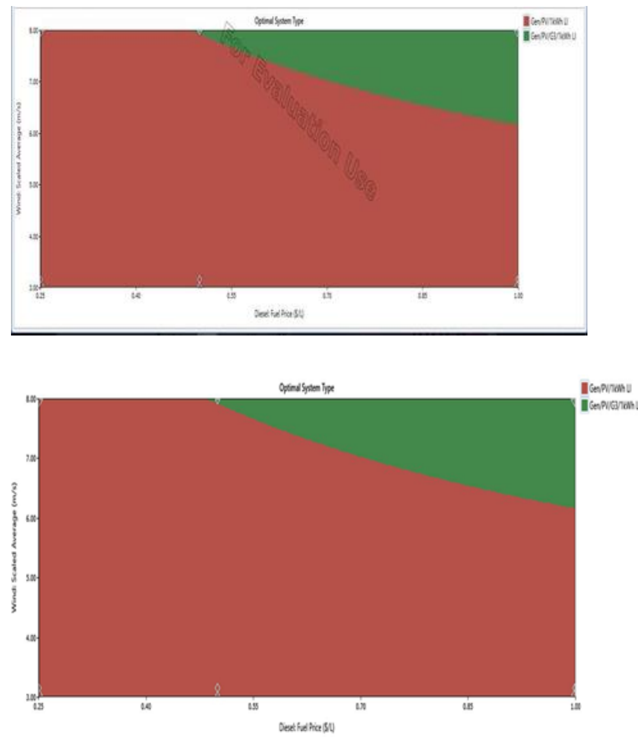

Figure 6.2: Optimal system graph for the overall system.

The use of HOMER Pro in determining the feasibility of a system especially in a technical aspect is very useful. It helps a lot of system designers to come up with and finalize the design system, especially when it comes to dealing with projects of many requirements. In fact, HOMER Pro could give the estimation on how the system would operate throughout the day. HOMER Pro also helps in preparing a full report of a modelled system and can be used as a material to support the designed model. However, a basic knowledge of sizing the system must be improved as the simulation will become easier if the complete set of configurations was prepared before running the software. A system with the lowest LCOE and NPC is preferred, but the best configuration may be selected based on other criteria, considering the perspective of the stakeholders.

The ecological advantage should be the important criteria, while preparing the renewable hybrid power generation system, for the reason that several developing nations tries to mitigate the global warming effect by reducing greenhouse gas emissions. Although there is no financial charging plan for polluting gas emissions in India but so many guiding principles applied in this perspective so far. So, the GHG emission costs should be taken into consideration while, analyzing the hybrid generation system. Here major apprehension towards Carbon Dioxide (CO_2) which is produced from burning diesel in generator as shown in Figure 6.2. The charges of carbon dioxide per ton are different from nation to nations. The current prices of CO_2 per ton are varying from country to country. However, the optimization performed in HOMER Pro is highly simplistic resulting in the loss of vital information. Firstly, HOMER Pro does not capture voltage and frequency variations due to the lack of an AC optimal power flow (OPF) algorithm. Hence, no transients can be analyzed. This can be especially critical in studying the integration of intermittent power generation into the future power systems. Furthermore, since a detailed AC OPF algorithm is not included, no contingencies can be considered in the analysis (e.g., loss of lines, sudden load increase or generation loss, etc.). This again proves to be crucial in investigating stability issues, which future power systems may face when the penetration of intermittent generation is high. In fact, HOMER Pro does not include power flow equations at all; therefore, no line losses can be captured, which could also be critical in analyzing distribution systems. The same applies for reactive power consumption. Even though HOMER Pro does have some advantages when designing small-scale micro grid networks (mainly used for residential or community purposes as in the case study presented here), the aforementioned points indicate that it lacks the capability to perform a deep investigation of more complex systems which require stability analysis, capture of losses and reactive power production, etc. In a subsequent publication, an enhanced design tool utilizing a fully developed AC OPF algorithm will be proposed to address the limitations listed above.

CONCLUSION

The goal is using renewable energy resources to lower the negative effects on the environment related to conventional energy sources like oil, natural gas and coal. Energy production companies should gradually migrate to the use of renewable resources because it does not deplete. A variety of energy sources (solar, wind and diesel generator) and storage devices (battery bank) were chosen for this analysis. The optimization tool developed by NREL, HOMER-Pro is utilized to select the best possible hybrid combination and their applications. Following conclusions could be abstracted based on this analysis: Solar resources in Island having outstanding prospective compared to wind energy and exploitation of wind resources might not be cost effective in most cases. At present, a PV-wind system is the most suitable solution for stand-alone applications. Cost of energy for such a system in Island area. A PV–wind system would be a more attractive for 100% renewable fraction. Larger hybrid systems would be cost competitive for remote communities, instead of using single stand-alone units, and the economies of scale might bring down the cost of energy towards the present utility electricity price. Finally, a theoretical discussion aimed at shedding light on some limitations of the commercially available optimization tool used in this study (i.e., HOMER Pro). A subsequent publication will present an enhanced design tool including a fully developed AC OPF that addresses all limitations discussed. The use of HOMER Pro in determining the feasibility of a system especially in a technical aspect is very useful. It helps a lot of system designers to come up with and finalize the design system, especially when it comes to dealing with projects of many requirements. In fact, HOMER Pro could give the estimation on how the system would operate throughout the day. HOMER Pro also helps in preparing a full report of a modelled system and can be used as a material to support the designed model. However, a basic knowledge of sizing the system must be improved as the simulation will become easier if the complete set of configurations was prepared before running the software.

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