AN ANALYSIS OF RENEWABLE ENERGY TECHNOLOGIES USING TWO SIMULATION SOFTWARE : HOMER AND RETScreen

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Abstract - This paper concerns on modelling renewable energy technologies including PV standalone system (PVSS) and wind standalone system (WSS) as well as PV-wind hybrid system (PVWHS). To evaluate the performance of all power system configurations in term of economic analysis and optimization, simulation tools called HOMER and RETScreen are used in this paper. HOMER energy modeling software is a powerful tool for designing and analyzing hybrid power systems, which contains a mix of conventional generators, wind turbines, solar photovoltaic's, hydropower, batteries, and other inputs. RETScreen uses a Microsoft Excel-based spreadsheet model that consists of a set of workbooks which calculates the annual average energy flows with adjustment factors to account for temporal effects such as solar-load coincidence. Sizes of equipments are calculated and inserted as inputs to HOMER and RETScreen. The result obtained are analyzed and discussed. The cost per kWh to generate electricity using the standalone system to supply the average demand of 8.4kWh/day ranges between RM 1.953/kWh to RM 3.872/kWh. It has been found that the PVSS gives the lowest cost of energy compared to the other proposed two technologies that have been simulated by using HOMER and RETScreen.

INTRODUCTION

Designing a renewable energy system (RE system), such as PV standalone system, wind energy system and PV-wind energy system required various decisions on the configuration of the system that must be taken into consideration. The components need to be includes in the system and the size of each component should be properly design. Large number of technology options (components available) and the variation in technology cost and availability of energy resources such as wind energy, solar energy, biomass energy, hydro energy and etc., make these decisions more difficult.

Configuration models of RE system can be developed by using available software tools such as Matlab for investigation purposes. There is also commercially available software for free on the internet use to model RE system. Commercialize available software tools (HYBRID2, HOMER, Pvsyst, RETScreen) for modeling renewable power systems that have been developed by several organizations and companies make it easier to evaluate the numerous possible system configurations[1]. HOMER, and RETScreen are all available for free on the Internet. These two types of software have a wide range of capabilities that can be use to model different type of RE system configurations. HOMER and RETScreen each relies on different modeling approach to simulate the performance of renewable-based power systems [1,2]. They are also accompanied by documentation that describes on how to use the software and the theory behind the design.

HOMER is a Windows application that requires no other software to run. This software is based on time-series models that predict the performance of power systems either hour by hour or minute by minute. It will determine in each time step on how to dispatch power equipment in the system. Besides that, HOMER also performs an energy balance calculations for each system configuration to be considered. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the specified conditions, 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. After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost), that can be used to compare system design options.

On the other hand, RETScreen are a Microsoft Excel-based spreadsheet model that consists of a set of workbooks. Each workbook models a particular kind of power system or application. RETScreen calculates the annual average energy flows with adjustment factors to account for temporal effects such as solar-load coincidence. The core of the tool consists of a standardized and integrated clean energy project analysis software that can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies (RETs). RETScreen significantly reduces the costs (both financial and time) associated with identifying and assessing potential energy projects. These costs, which arise at the pre-feasibility, feasibility, development, and engineering stages, can be substantial barriers to the deployment of Renewable-energy and Energy-efficient Technologies (RETs). By helping to break down these barriers, RETScreen reduces the cost of getting projects on the ground and doing business in clean energy. Each RETScreen energy technology model is developed within an individual Microsoft Excel spreadsheet called Workbook files [2]. The Workbook file is in-turn composed of a series of worksheets. These worksheets have a common look and follow a standard approach for all RETScreen models.

Renewable energy technologies produce sustainable, clean energy from sources such as the sun, wind, plants, and water. Renewable energy systems are developed to fulfill three main goals, provide reasonably price energy, mitigate climate change and also provide energy independence [4]. In addition, the use of renewable energy sources leads to a more sustainable energy mix, reduced greenhouse gas emissions and a lower dependency on oil. Besides that, renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies.

A Stand-alone system is a generation system that is not connected to the main grid. Stand-alone power systems are designed and sized to supply certain DC and/or AC electrical loads. The electricity produced is stored in batteries. When power is required, the stored electricity is transformed into 240V. It can be used in remote locations to provide a constant and reliable form of electricity. For rural areas where there is no electricity available, a simple stand alone system usually consists of a solar panel or wind turbine, charge controller and a rechargeable battery.

Hybrid power systems are designed for the generation of electrical power. They are generally independent of large centralized electric grids and are used in remote areas. Hybrid systems is a combination of two or more energy conversion devices, or two or more fuels for the same device, that when integrated, are able to overcome limitations inherent in either. Hybrid systems can address limitations in terms of fuel flexibility, efficiency, reliability, emissions and/or economics. The components for a hybrid electricity generation may utilize renewable energy sources such as wind turbines, photovoltaic, solar thermal, hydro power, and wave power or biomass power stations. Furthermore, fossil power plant like diesel generators, gas turbines or fuel cells can also be added. Generally, Hybrid Power Systems are considered to supply loads in the size of several watts up to several megawatts. This paper is focusing on three different types of RE technologies configuration namely PVSS, WSS and PVWHS. HOMER and RETScreen are the simulation tools employed in this paper in order to analyze the system optimization and economic feasibility for the proposed RE technologies.

SITE METEOROLOGICAL

The environmental data for the daily solar radiation is obtained via internet from HOMER software tool which is link to NASA data base. Meanwhile, the wind speed data is obtained also via internet from RETScreen Climate Database. The location chosen for this paper is Mersing, Malaysia. The latitude and longitude for Mersing is 02°26’ N and 103°49’E respectively. The monthly average daily solar radiation data incident on horizontal plane and wind speed data of the site is shown in Figure 1 and Table 1 respectively.

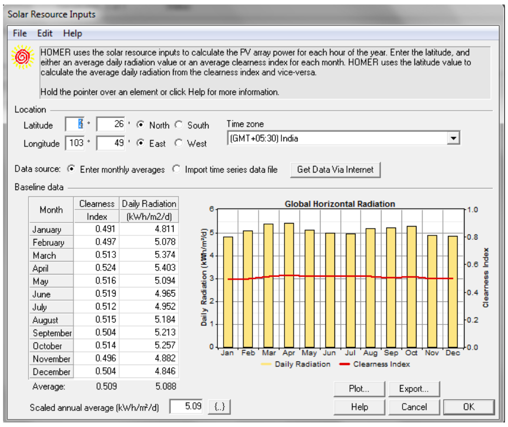

FIGURE 1: Monthly Average Daily Solar Radiation

Table 1: Wind Speed Data

Month	Wind Speed (m/s)
January	3.7
February	3.2
March	2.5
April	1.7
May	1.8
June	2.8
July	2.8
August	3.0
September	2.3
October	1.9
November	2.5
December	3.6
Annual	2.6

LOAD CHARACTERISTICS

A typical urban house is chosen for the simulation in HOMER and RETScreen whereby the loads are as shown in Figure 2[4].

Load Characteristics			Estimate		
Application type		-	Off-grid		
Use detailed load calculator?		yes/no	Yes		
Description	**AC/DC**	**Solar-load correlation**	**Load (kW)**	**Hours of use per day (h/d)**	**Days of use per week (d/wk)**
Washing Machine	AC	Negative	0.450	2.00	2
Iron	AC	Negative	1.000	1.00	7
Fan 1	AC	Negative	0.040	8.00	7
Fan 2	AC	Negative	0.040	10.00	7
Fan 3	AC	Negative	0.040	2.00	7
Light 1	AC	Negative	0.040	6.00	7
Light 2, 3, 4	AC	Negative	0.120	3.00	7
Light 5	AC	Negative	0.040	2.00	7
Microwave Oven	AC	Negative	1.200	0.30	7
Rice Cooker	AC	Negative	1.000	1.00	7
Oven	AC	Negative	0.800	0.10	7
Television	AC	Negative	0.350	5.00	7
Radio	AC	Negative	0.200	5.00	7
Computer	AC	Negative	0.200	2.00	7
Air-cond	AC	Negative	1.100	1.00	7
			Daily average	*Annual*	
DC energy demand		kWh (DC)	0.000	0.0	
AC energy demand		kWh (AC)	8.427	3,075.9	
AC peak load		kW (AC)		6.620	
					Return to Energy Model sheet

FIGURE 2: Typical Household Electrical Appliances and Operating Times

POWER SYSTEM DESIGN

This section will discuss steps required for determine the size of equipments used in PVSS, WSS and PVWHS.

Sizing of PV Array

Equation 1 [3] is used to calculate the size of PV array in this paper.

$$PVArea = \frac{E_L}{G_{av} \times eff_{PV} \times TCF \times eff_{out}} \tag{1}$$

If the cell temperature is 47.5°, then the temperature correction factor (TCF) will be 0.578 as indicated in [10]. The PV model used is NT-175U1, 175 WATT by SHARP Company. The efficiency, η_{PV} for this module is 13.45% while the efficiency for battery and inverter is 98% and 85% respectively. The type of the battery used is Deep Cycle battery and it's model is S-460. Meanwhile, for the inverter, GP SW-600 model is used. Thus, using equation (1), the PV area is computed to be $25.5m^2$. The PV peak power under Illumination of 1 kW/m^2 at a cell temperature of 25°C is computed using the following Equation 2 [3]. The PV peak power is computed to be 3497 Wp.

$$PV_{peakpower} = PVarea \times PSI \times Eff_{PV} \tag{2}$$

Sizing of Wind Turbine

A 1.5 kilowatt wind turbine will meet the needs of a home requiring 300 kilowatt-hours per month in a location with a 14 mile-per-hour (6.26 meters-per-second) annual average wind speed [5,6]. The cut-in speed of the selected 0.08 kWac wind turbine is 1-2 m/s and the diameter blade is 2 meter. The number of wind turbines required in order to meet the load demand is 19 units. The calculation is shown using Equation 3.

$$N\text{umber of wind turbine} = \frac{1.5kW}{0.08kwac} = 19units \tag{3}$$

Sizing of Battery

The storage capacity of the battery is computed using the following equations [3,7].

$$BatteryStorageCapacity = \frac{N_C \times E_L}{DOD \times eff_{out} \times V_B} \tag{4}$$

The typical largest number of continuous cloudy days N_c at Mersing is about 3.5 days. For the deep cycle battery type, the maximum permissible depth of discharge, DOD of the battery is 80% or 0.8 [9]. Using Equation (5), the battery storage capacity is calculated to be 7352.94 Ah. Since the selected battery is rated at 6V 460 Ah, therefore the quantity of battery required is computed as follows.

$$Quatity \text{ of battery} = \frac{7352.94Ah}{460Ah} = 16units \tag{5}$$

With 12 V DC bus voltage, 16 units of batteries are arranged such that 2 units are connected in series with 8 strings are connected in parallel.

Sizing of Inverter.

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watts of appliances. The inverter must have the same nominal voltage as battery [9]. For standalone system, the inverter must be large enough to handle the total amount of watts to be used at one time. The inverter size should be 25% to 30% bigger than the total watts of appliances which in this paper is

350 watts/day. If the size of inverter is considered 30% bigger than total watts of appliances, thus the size of inverter becomes 455 watt.

SIMULATION

In this paper, three configurations are considered, PVSS, WSS and PVWHS. Table 2 shows input summary for both optimization software, HOMER and RETScreen. The same sizes of PV array and wind turbine are used for both HOMER and RETScreen software in all configurations. The quantity of the battery used is equal for both PVSS and WSS while for PVWHS the number of battery is reduced to 3680 Ah. This is because for HOMER software, it can optimize the system by changing either the size of PV array, the number of wind turbine or the quantity of battery. To make the comparison between PVSS, WSS and PVWHS, the size of PV array (3.5 kW) and the number of wind turbine (19 units) used is fixed but the quantity of the battery is varied. For RETScreen, the size of battery used is based on the suggested capacity calculated by RETScreen.

Figure 3, Figure 4 and Figure 5 show the schematic diagrams for all configurations considered for in this paper. The schematic diagrams are obtained from HOMER software. For RETScreen, all the input data are inserted into three worksheets namely Energy Model, Solar Resource & System Load Calculation (SR&SLC) and Cost Analysis.

TABLE 2: Input Summary for HOMER and RETScreen

Technologies	Variables	Value (HOMER)	Value(RETScreen)
PVSS	PV size(kW)	3.5	3.5
	Battery Capacity(Ah)	7,360	7,232
	Inverter (kW)	0.6	0.4
WSS	Wind Turbine (units)	19	19
	Battery Capacity (Ah)	7,360	7,360
	Inverter (kW)	0.6	0.6
PVWHS	PV size (kW)	3.5	3.5
	Wind Turbine (units)	19	19
	Battery Capacity (Ah)	3,680	3680
	Inverter (kW)	0.6	0.6

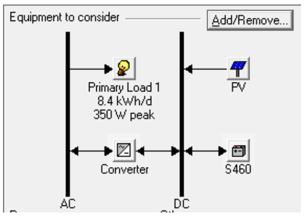

FIGURE 3: PVSS Schematic Diagram

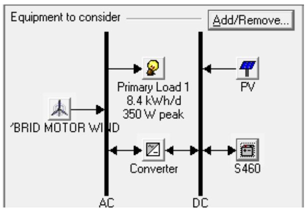

FIGURE 4: WSS Schematic Diagram

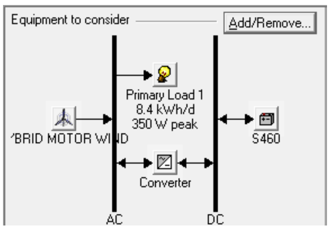

FIGURE 5: PVWHS Schematic Diagram

RESULT SIMULATED BY HOMER AND RETScreen

Table 3 shows the output summary obtained after all configurations are simulated by HOMER. From Table 3, it can be seen that the PVSS gives the lowest cost for capital (RM 70,987), NPC (RM 104,459), operating cost (RM 1,922 per year) and cost of energy (RM 1.956 per kWh). WSS gives the highest operating cost (RM 2,095 per year) as well as COE (RM 3.872 per kWh) while the highest capital cost (RM 137,765) and NPC (RM 168,389) is given by PVWHS.

TABLE 3: Output Summary for HOMER

Cost(RM)				
Technologies	Capital	NPC	Operating Cost(RM/year)	COE (RM/kWh)
PVSS	70,987	104,459	1,922	1.956
WSS	102,566	139,052	2,095	3.872
PVWHS	137,765	168,389	1,759	3.155

The output for configurations simulated by RETScreen are summarizing in Table 4. Total initial cost is the summation of energy equipment and balance of equipment (BOE). From Table 3, it can be seen that the PVSS gives the lowest initial cost (RM 108,118) followed by WSS with an initial cost of RM 118.008. Meanwhile, the initial cost for PVWHS is RM 147,134, which is the highest cost among other configurations. To determine the cost of energy (COE), the life cycle cost (LCC) of the system is computed by using Equation 6 and 7 respectively [3]. From calculation, the cost of energy for PV standalone, wind standalone and PV-wind system are RM 1.953 per kWh, RM 3.222 per kWh and RM 4.2085 per kWh respectively.

TABLE 4: Output Summary for RETScreen

Cost (RM)				
Technologies	Energy equipment	Balance of Equipment	Total Initial Cost	COE(RM/kWh)
PVSS	96,059	12,059	108,118	1.953
WSS	102,566	8,442	118,008	3.222
PVWHS	133,789	13,345	147,134	4.2085

$$LCC = C_{PV} \times C_B \times C_{INV} \times C_{INST} \times C_{MPW} \tag{6}$$

$$COE = \frac{ALCC}{365 \times E_L} \tag{7}$$

CONCLUSION

In conclusion, the result produced by HOMER and RETScreen give different cost for each configurations. HOMER calculates COE automatically but in RETSreen, the calculation is done manually. The cost for generating per kWh energy with 8.4 kWh average daily load demand by using PVSS (HOMER) is RM 1.959 per kWh while RETSreen produced a COE of (RM 1.952 per kWh). Meanwhile, for WSS, the generated COE (HOMER) is (RM3.872 per kWh) and for RETScreen is (RM 3.222 per kWh). Lastly, for PVWHS, the simulated COE is (RM 3.155 per kWh) by HOMER and RM 4.2085 per kWh by using RETSreen. It has been found that the PV standalone system is preferable to be installed in Malaysia compared to wind standalone system and PV-wind standalone system.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Higher Education (MOHE) and University Teknologi Malaysia (UTM) for providing funding under the GUP research grant of vot number Q.J130000.7125.01H52.

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