# TECHNO-ECONOMIC AND FEASIBILITY ANALYSIS OF A MICRO-GRID WIND-DG-BATTERY HYBRID ENERGY SYSTEM FOR REMOTE AND DECENTRALIZED AREAS

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***ABSTRACT***
*For the increasing demand of electricity in the offshore, port and Eco-tourism areas alternative power sources have been vastly required. During the last few decades, the governments around the world have been promoting to hunt energy from renewable or sustainable energy resources such as solar energy, wave energy and wind energy because of rising costs, contamination and uncertainties of overtiredness of oil and coal. To reduce atmospheric humiliation and for dislodgment of fossil fuel produced energy, the use of energy from alternative sources like wind has been circulated widely from the last few decades. This study explores to investigate the feasibility, efficiency and economic issues of energy production from hybrid wind-diesel generator-battery energy conversion systems to congregate the load demand requirements of a community of 85 residential households (with annual electrical energy demand of 26.645 MWh, primary load of 85 kWh/d with 8.7 kW peak) for the Eco-tourism management of Malacca, Malaysia. The hourly mean wind speed data of the year 2009 collected from the meteorological station, Malacca, Malaysia (2°12' N and 102°15' E in the northeast corner of the sate Johor, Malaysia.), has been considered for the current analysis. From the simulation result it can be seen that 11 Wind turbines (10 kW), 1 Diesel Generator (4 kW), 2 Battery (Surrette 6CS25P) hybrid RES is the most economically feasible and minimum cost of energy (COE) is nearing USD 0.235/kWh and least Net Present Cost (NPC) is USD 92,951 when the emissions of $CO_2$ has been decreased noticeably with renewable fraction of 0.88 and 0.4% capacity shortage.*

***KEYWORDS:*** *Wind turbine, HOMER, Hybrid Energy, Renewable Energy, Eco-tourism, Electrification.*

**Nomenclature**

| | |
|---|---|
| *A* | Swept Area (m²) |
| *E* | Electrical energy (kWh) |
| *P* | Power from Wind turbine (kW) |
| $C_p$ | Power Co-efficient |
| ρ | Air Density |
| V | Wind speed (m/s) |

**Subscripts**

| | |
|---|---|
| DG | Diesel Generator |
| RES | Renewable Energy System |
| Gen-1 | Generator 1 |
| WECS | Wind Energy Conversion System |
| NREL | National Renewable Energy Laboratory |
| HOMER | Hybrid Optimization Model for Electric Renewable |

## I. INTRODUCTION

Since 1970s oil crisis along with cost and interrupted supply has been arisen. From that moment researchers realized the importance of alternative energy resources. They have been focusing especially on renewable energy technologies. Day by day wind energy is getting popular along with other renewable energy sources like solar, biomass and tidal energy. There are several characteristics of the wind energy. Among them accessibility, inexhaustibility and environment-friendly are the main characteristics. Where the average wind speeds are about 5 to 10 $ms^{-1}$, developed as well as developing countries have been taking several steps for harvesting the wind energy.

Wind speeds are well enough in the hilly areas or in Islands. These are the most suitable places for implementing wind energy along with conventional diesel generators to minimize fossil fuel usage [1]. Statistics of 2002 shows that the capacity of harvesting wind energy was 31,000MW.Both producers and customers are highly attracted to this technology as the price of energy generation cost remains one of the major factors [2]. During last decades, the price of wind machines has fallen, and the present cost of wind energy is 4-5 cents/unit. The wind energy conversion system (WECS) has been updated during last few years. 3.2 MW WECS is available commercially in the present world market now-a-days [3].

To supply electricity in the tourist sector, it is a common phenomenon to use diesel generators rather than grid connections. If we consider the example of Australia, tourist sector consumes about 6% of total electricity energy that is generated from diesel. As a result, it is not only causing sound pollution but also responsible for huge greenhouse gas (GHG) emissions in tourist areas [4]. There is a massive difference in load patterns as well as power connections between the tourist sectors and domestic sectors due to the non-linear power consumption characteristics in a day. Therefore, the studies of energy efficiency of domestic and industrial sectors cannot represent the energy consumption of tourist areas [5]. Very few case studies for the feasibility of RES in the tourist accommodation is found in the literature. For example, Bakos reported a PV based RES [6] for supplying the electrical energy efficiently to a small cottage in Greece with 10 beds. For that small scale purpose, the set up was economically suitable as he concluded. It was suitable to use wind/hydrogen combined system to supply to a small scale hotel in Greece, and it was proposed by Bechrakis et al [7].

Besides, the other case studies concern of the functional SPS RES operations but not in feasibility analysis. . For example, there is research on a wind/diesel hybrid system that was installed in Cocos Islands for supplying the power in tourist operations in small scales [8], the PV/wind/diesel hybrid system in Australia [9] and Sarawak [10]. Fadaeenejad et al. [11] made a detailed research on hybrid renewable energy system on stand-alone power generation purposes and he architected a PV-wind-battery hybrid system that was suitable for off-grid electrification for rural area in Malaysia [12]. For off-grid power supply in Malaysian villages, the proposed system is highly cost-effective as they concluded. The number of national and international visitors has been increased for the last few years. At the same time, the demand for power in household activities has also been increased [13].

The interest in the renewable energy system increased as the demand for traditional power exceeds supply. High energy generation cost along with bad weather and climate conditions have increased interest in the renewable energy system. One of the main reasons for increasing demand of renewable energy system is low carbon emissions [14]. Therefore, this study proposes an off hybrid grid system consisting of diesel generator along with renewable energy technology like wind turbine. To solve the remote electrification problem along with environmental issues like $CO_2$ emissions, a completely feasible wind-diesel-battery hybrid system is introduced in this analysis [15]. By providing input parameters for a niche area such as the southern part of Malaysia, HOMER is used for simulation and estimation of different output parameters.

The current study mainly focuses on the following objectives below:

i. To reduce the $CO_2$ emission in comparison with other conventional and non-conventional power plant.
ii. To ensure an optimized risk free energy conversion system with applicable power demand in a community; especially for the decentralized areas.
iii. To finalize/determine the most economically feasible technology for RES and compare it with other technologies. Here, the comparison is made considering the NPC and COE for various RES in HOMER platform.

# II. METHODOLOGY

## 2.1 The Geographical Analysis with Wind resources:

The average monthly and yearly wind speed data have been collected for every month of the year 2009 from the Malaysian meteorological department for the Malacca of Malaysia. Moreover, the department of Labor and Regulation (DLR), Germany a technique has manifested, for average wind speed output is tested for specific distance of area and from the Malaysian Meteorological Department the considered data has been collected for Malacca of Malaysia [16].

**Figure 1** shows the geographical position of Malacca of Malaysia (Lat.: 2° 12' N, Long.: 102° 15' E) [16]. DLR method used the data collected from the satellite for various factors such as rainfall, water vapor and vaporizer optical depth, cloud cover, water vapor to Calculate GHI [17]. To calculate wind resources data, Malaysian Meteorological Department has measured wind speed for the year 2009 by maintaining the height of 30 m upwards from the ground surface level. Renewable energy analysis with biomass had not been fruitful yet, because of insufficiency of electrical power generation. Tidal research stations were set up by Malaysian Meteorological department and Malaysian Renewable Energy Committee for the practicability analysis about tidal energy [18]. The result was not up to the expectation level that is why just the wind and solar resource and average temperature data have been considered to discover the most efficient hybrid renewable energy system [19].


**Figure 1:** Malacca of Malaysia [18].

**Figure 2** shows the schematic diagram of a typical wind-diesel hybrid energy conversion system with an applicable model.

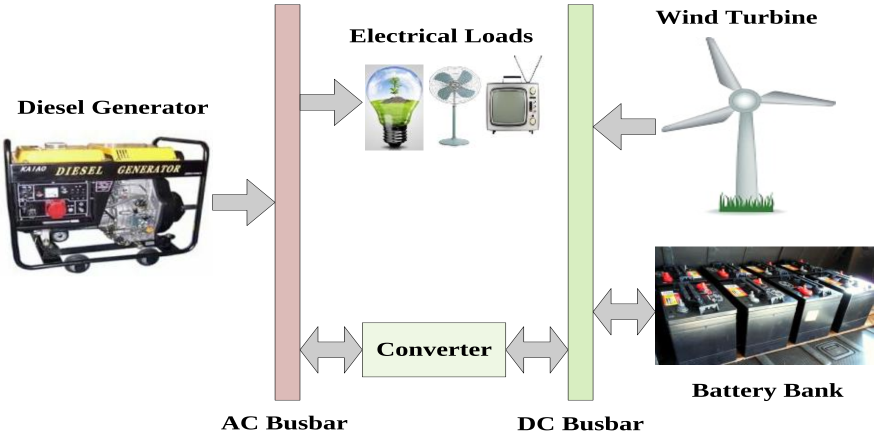



**Figure 2:** Schematic Diagram of a Wind-Diesel Hybrid Energy Conversion System.

## 2.2 Hybrid Energy System Descriptions

### 2.2.1 Wind Module

A rotor combining of two or more blades mechanically joined to an electrical generator can generate wind's kinetic energy can be captured by the wind turbines [20]. For the calculation of wind power from the wind turbines the equation mentioned below has been utilized in HOMER to get the optimization results.

$$P = C_p \times 0.5 \times A \times \rho \times V^3 \qquad (1)$$

Here, the standard diurnal coefficient value has been considered as 0.5. The power of wind module has been represented by $P$ [21].

**Table 1:** Yearly wind Power density and wind energy density.

| Station | Year | Meteorological | | Weibull | | $V_{mp}$ | $V_{max,E}$ |
|---|---|---|---|---|---|---|---|
| | | P/A | E/A | P/A | E/A | | |
| Malacca | 2008 | 75.26 | 650.24 | 73.56 | 635.56 | 3.40 | 6.25 |
| Malacca | 2009 | 70.79 | 611.63 | 68.89 | 595.21 | 3.45 | 6.06 |

**Table 1** shows the meteorological data of Malacca in the year 2008 and 2009 and also defined the Weibull values with power density and energy density [22]. From the monthly averages data the hourly data can be engendered unnaturally if hourly data cannot be collected. There is a minor difference between the global radiation data and average artificial wind speed data generator of HOMER [23]. The measurement of the wind speed allocation throughout the twelve months is called Weibull rate which can be addressed by k. The value of k has been taken 2 for this analysis. The measurement of the arbitrariness of the wind has been conducted by the auto-correlation parameter [24]. From the observation of the higher values of the wind speed in 1 hour leans it is cleared that the wind speed leans of 1 hour is firmly depended on the wind speed of the past hour. The vacillation of the wind speed leans in a more arbitrary way from time to time has been indicated by the lower values [25]. The rate of autocorrelation parameter has been taken as 0.85. How firmly the wind speed confides on the time of the day can be identified by the diurnal pattern strength. The value of diurnal pattern strength has been taken as 0.25 for this analysis. The time of day leans to be the windiest on a standard all through the year can be addressed by the term hour of peak wind speed. The value of the hour of peak wind speed has been taken as 15 for this analysis [26]. AXLS Generic 10 kW wind turbine has been considered for this off-grid hybrid renewable energy system [27]. Table 2 represents the financial and methodological factors for preferred wind turbine. **Figure 3, 4, 5** and **6** shows average wind Speed in profile view of every month in 2009 for Malacca of Malaysia, average monthly wind speed D-view, power curve of wind speed and cost curve of wind turbine respectively.

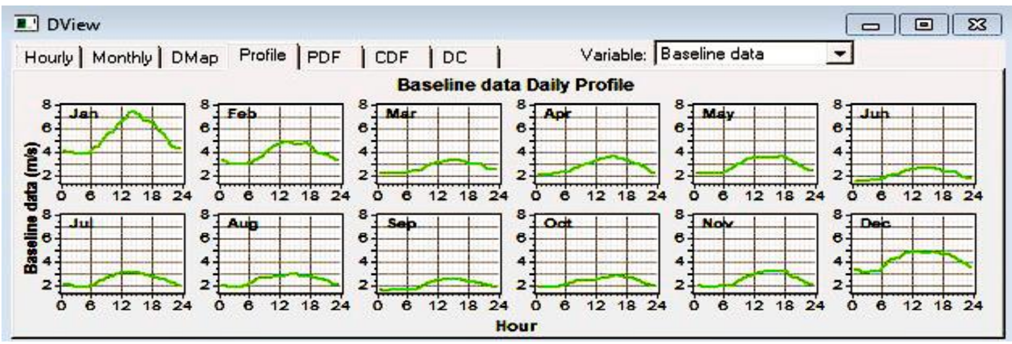



**Figure 3:** Average Profile Wind Speed.

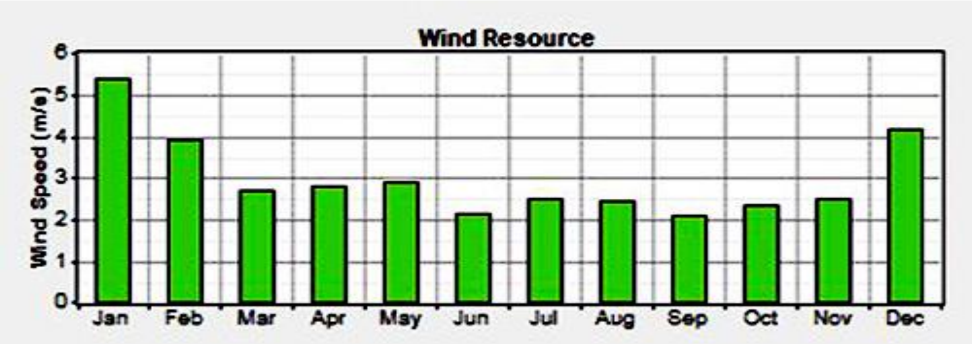



**Figure 4:** Average Wind Speed D-View.

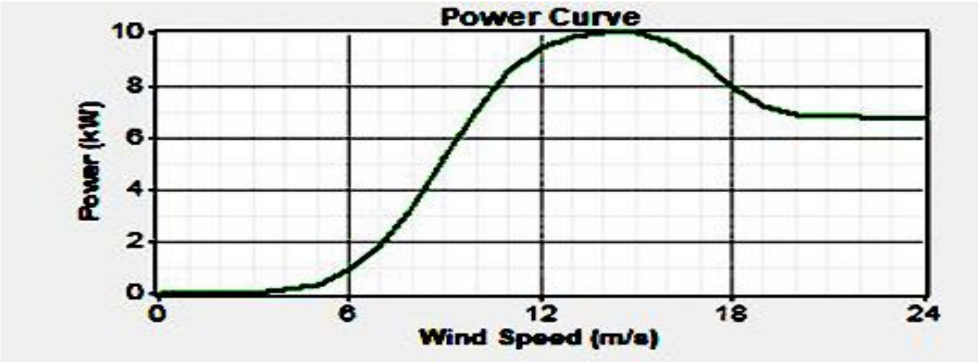



**Figure 5:** Power Curve of Wind Turbine.

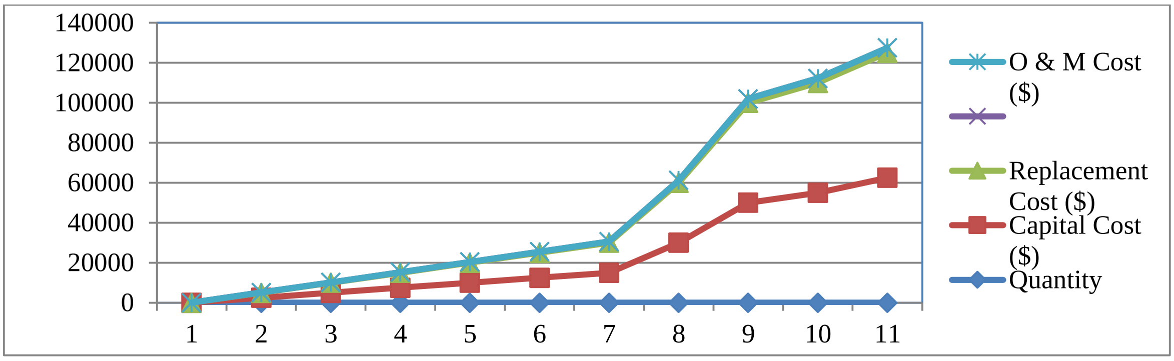



**Figure 6:** Cost Curve of Wind Turbine.

### 2.2.2 Diesel Generator Module

The fuel used in HOMER is modeled by a linear curve characterized by a slope and intercept at no load. **Table 2** shows the assumptions of cost for a diesel generator and the other factor related with power generation on and range of capacity.

**Table 2:** Procedural parameters with Cost conjecture for Diesel Generators.

| Factors | Value |
|---|---|
| Net Cost | 70 $/kW |
| Substitution Cost | 60 $/kW |
| Maintenance and Operation expense | 0.025 (4 kW) $/kW |
| Lifetime | 900000 Minutes (15,000 Hours) |
| Least Load quotient | 30 % |
| Fuel Curve Slope | 0.25/h/kW $_{output}$ |
| Fuel Curve Intercept | 0.08/h/kW $_{rated}$ |
| Fuel Cost | 0.6 $/liter |

**Figure 7** shows the cost curve generated by the diesel prices in terms of cost analysis. **Figure 8** shows the efficiency curve of a diesel generator to evaluate the power generation rate [28].

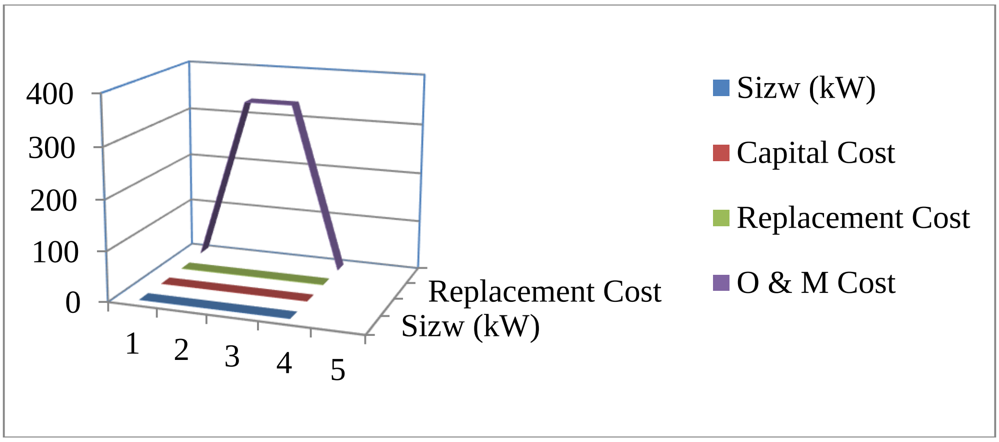



**Figure 7:** Cost Curve of a Diesel Generator.

### 2.2.3 Battery Module

In that off-grid hybrid renewable energy system, the Surrette 6CS25P 2 storage batteries have been utilized [29].There are six stipulations such as effectiveness, life time, rectifier effectiveness, rectifier aptitude, substitution and net cost have been shown in **Table 3. Figure 9** shows the discharge current of a battery in accordance with the conversion rate. **Figure 10** shows the depth of discharge for a battery in compiling with state of charge rate.

**Table 3:** Procedural Parameters with Cost Assumptions for Battery.

| Parameters | Value |
|---|---|
| Lifetime | 1 decade |
| effectiveness | 95 % |
| Rectifier aptitude | 90 % |
| Rectifier effectiveness | 89 % |
| principal Cost | 50 $/kW |
| substitution Cost | 40 $/kW |
| Round Trip Efficiency | 80% |
| Minimum State of Charge | 40% |

**Figure 11** shows the cost curve indicated the cost analysis for the battery module.

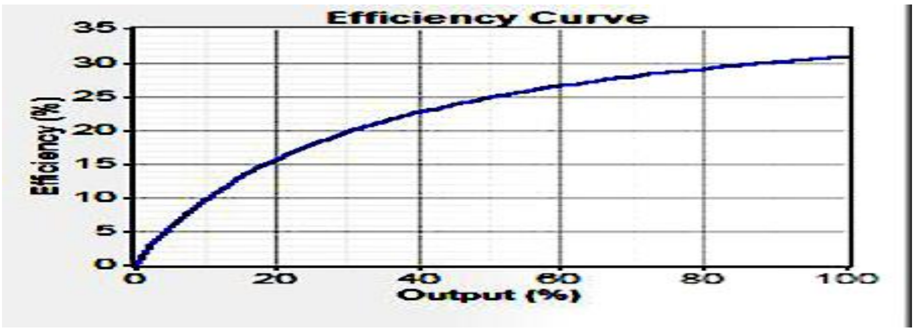



**Figure 8:** Efficiency Curve of a Diesel Generator.

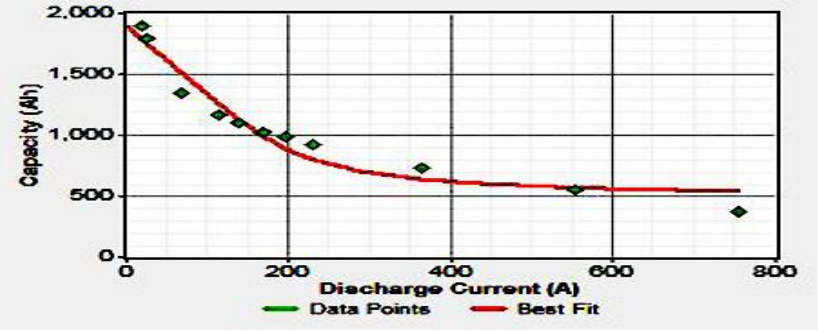



**Figure 9:** Discharge Current of a Battery.

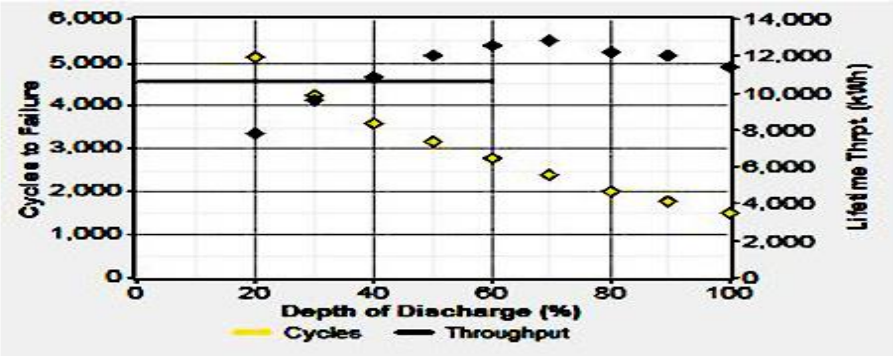



**Figure 10:** Depth of Discharge for a Battery.

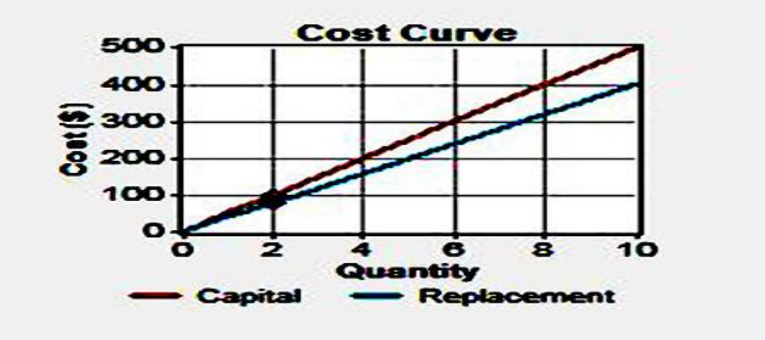



**Figure 11:** Cost Curve of Battery Module.

### 2.2.5 Converter Specification

The converter is one kind of device that can convert electrical power from ac to dc in a process called rectification and from dc to ac in a process called inversion. There are two types of converters such as rotary (rectifier or inverter) and solid-state can be sampled by Homer renewable energy software. The verdict variable refers to the converter size that delegate to the inverter capacity; by inverting dc power with the device can generate the utmost amount of ac power. A 1 kW inverter and a 1 kW rectifier have been used for proposed hybrid System. The life time is 20 years and the efficiency for inverter and rectifier as follows 90 % and 85 % respectively. The cost analysis with converter has been represented by the cost curve mentioned by **Figure 12.**

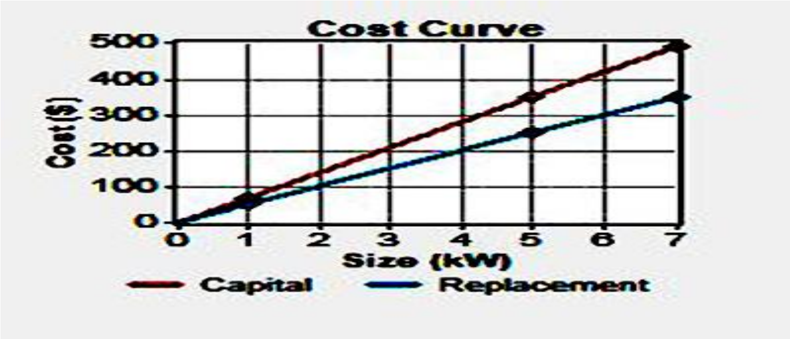



**Figure 12:** Cost Curve of Converter.

### 2.2.6 Equations for Cost of Energy

To calculate the optimum Cost of Energy for a hybrid system in HOMER the following equation has been used:

$$COE = \frac{C_{ann,tot}}{E_{prim} + E_{def} + E_{grid,sales}} \quad (1)$$

Where,
$C_{ann,\ tot}$ = Total annualized cost.
$E_{prim}$ = Total amounts of primary load.
$E_{def}$ = Total amounts of deferrable load.
$E_{grid,\ sales}$ = Amount of energy sold to the grid per year.

### 2.2.7 Equations for Net Present Cost

To calculate the total net present cost the following equation has been used:

$$C_{NPC} = \frac{C_{ann,tot}}{CRF(i, R_{proj})} \quad (2)$$

Where,
$C_{ann,\ tot}$ = Total annualized cost.
$i$= Annual real interest rate.
$R_{proj}$ = Project lifetime.
$CRF\ (.)$ = Capital recovery factor.

### 2.2.8 Equations for Calculating the $CO_2$ Emissions

To calculate the $CO_2$ emissions from the hybrid energy system the following supporting equations has been introduced:

$$tCO_2 = 3.667 \times m_f \times HV_f \times CEF_f \times X_c \quad (3)$$

Where,
$tCO_2$ =Amount of $CO_2$ emissions.
$m_f$ = Fuel quantity (Liter)
$HV_f$ = Fuel heating value (MJ/L)
$CEF_f$ = Carbon emission factor (ton carbon/TJ)
$X_c$ = Oxidized carbon fraction.
Another factor must be taken into account that in 3.667g of $CO_2$ contains 1g of carbon.

## III. A MODELED SMART-GRID HYBRID RENEWABLE ENERGY SYSTEM

Wind energy (wind turbine), Battery module, Converter module have been used with a diesel generator in this analysis. An electrical primary load demand, renewable energy resources such as wind resources and other mechanisms as like as battery storage, wind turbines and converters constitute an off-grid hybrid renewable energy system. **Figure 13** shows the complete model of a smart-grid s hybrid renewable energy system.

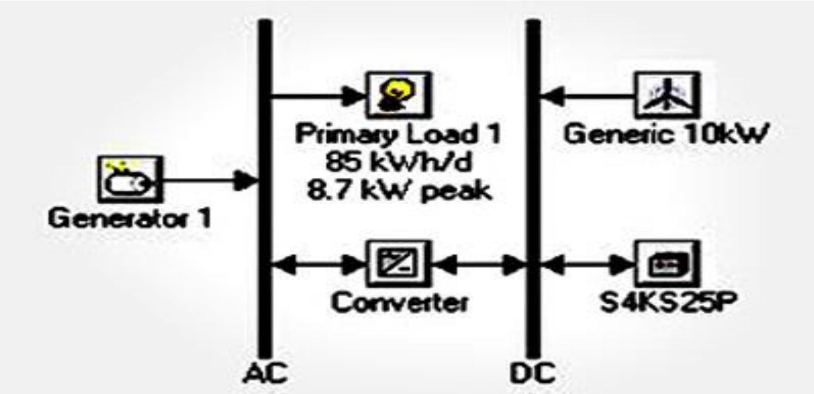



**Figure 13:** The complete Model Diagram of a Wind-Diesel-Generator-Battery Hybrid System.

A community of 85 residential households at Malacca has been considered in accordance with average load demand of that area in this analysis. Each apartment consists of 2 or 3 rooms. 1 fan (Star standard ceiling fan, 50 W), 4 energy savings bulbs (Philips tornado bulb, 20 W each), 1 television (Sony bravia, 50 W) and a table lamp (Emen 69076, 5 W) and 1 AC (Ideal Air, 180W) for each apartment have been calculated and considered for the load demand analysis for a community of off-shore households at Malacca's eco-tourism area. **Figure 14** shows the average load demand for each month of a year. The load demand can be varied in terms of earth temperature, humidity, and rainfall and changing of weather. The load demand can be classified by two groups such as pick hour and another one is off-pick hour. **Figure 15** shows the average monthly load demand D-view. The use of power can be varied apartment to apartment and people to people in different circumstances. Load demand data had been amalgamated through the specification of emblematic daily load demand profile data and after that some parameters has been added such as each day 11 % arbitrariness and every hour 16 % noise. Because hourly load demand profile data could not find out. Yearly peak load up to 8.7 kW and primary load demand up to 85 kWh/d has been balanced by the arbitrariness and noise.

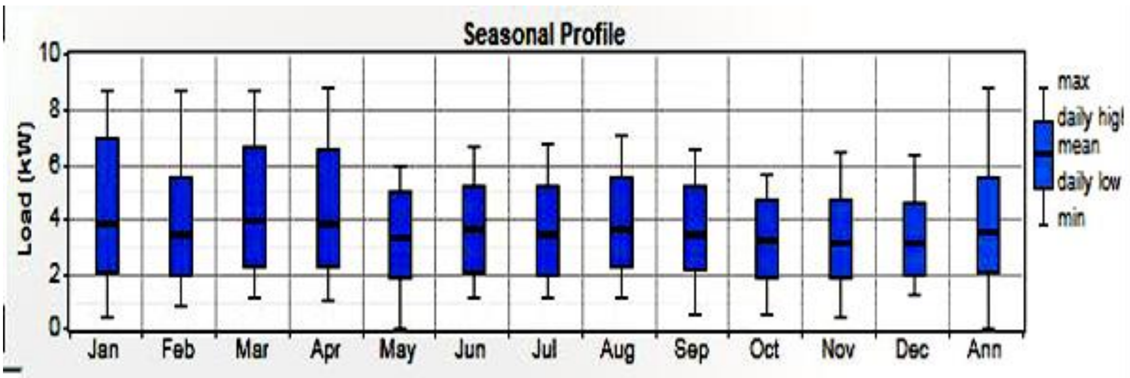



**Figure 14:** Load demand monthly average.

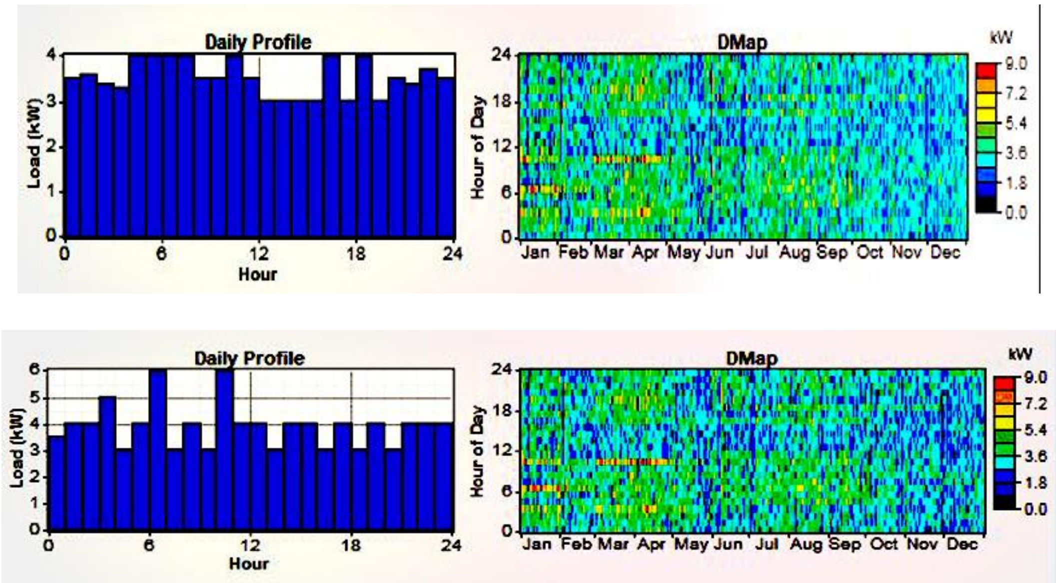
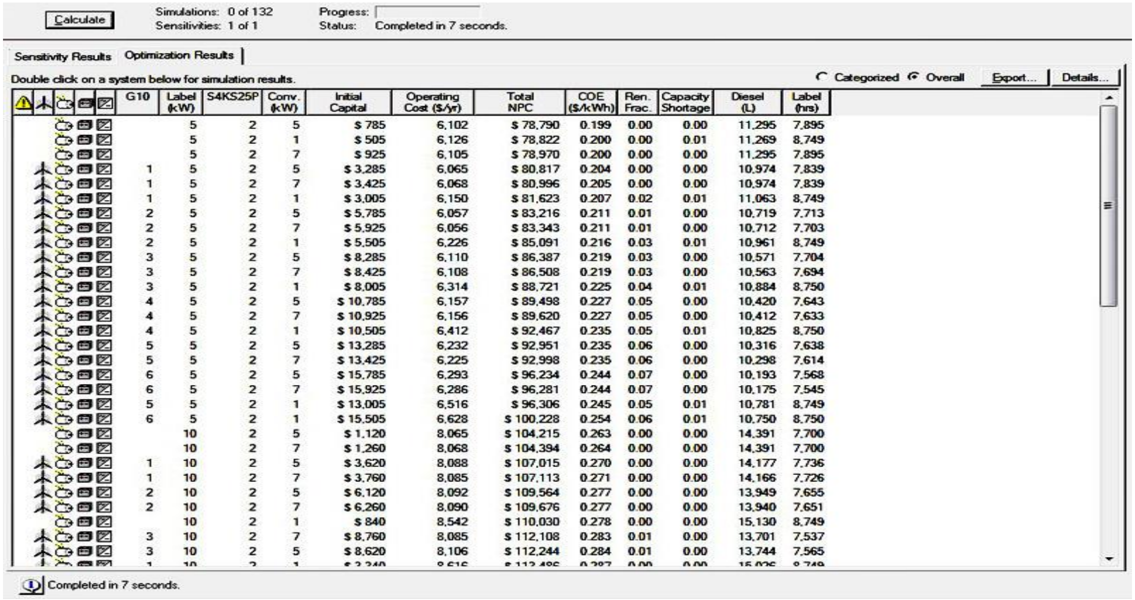



**Figure 15:** Load demand profile for two specific months.

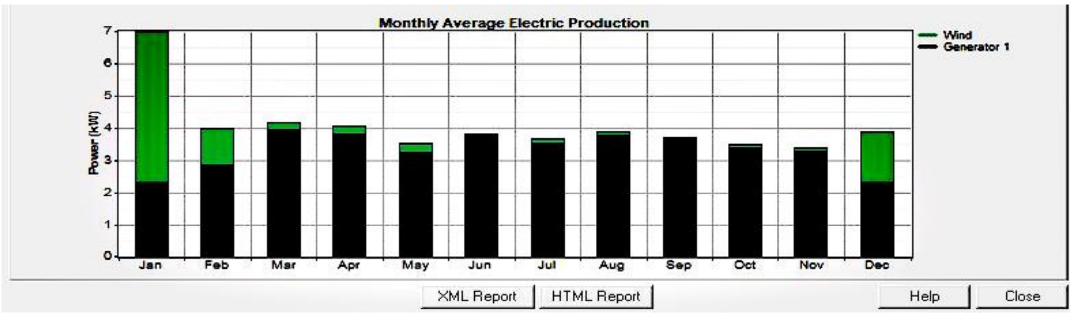
# IV. RESULTS AND DISCUSSION

For the assessment of the performances of different hybrid renewable energy systems in this research, HOMER simulation mechanisms have been used to perpetrate optimal systems performance analysis. The optimized outcomes for a specific group of sensitivity parameters akin to average wind speed, global horizontal solar radiation, highest yearly capacity shortage, diesel cost, and renewable fraction are represented emphatically in that optimization software. An optimal hybrid renewable energy system can be designed by HOMER renewable energy software through large number of hourly simulation results continuously. Various values for wind speed, diesel cost and least renewable fraction have been contemplated to conduct simulations and these values assuring much more suppleness in the analysis. **Figure 16** shows Simulation and optimization outcomes in considering an off-grid hybrid wind-diesel-battery hybrid energy model with an average annual wind speed of 4.010 m/s, diesel cost of 0.6$/L, highest capacity shortage of 0.03%.USD has been considered as the currency for all costs related with that hybrid system. **Figure 17** shows the electrical energy generated with practicability from the smart-grid hybrid wind-diesel-battery system. **Figure 18** shows the details calculation, simulation results and cost analysis with System architecture, NPC, COE, Operating cost, Electrical energy produced by wind turbine, diesel generator system, unmet load, excess electricity, capacity shortage and renewable fraction of the most monetarily practicable hybrid energy system relevant for the preferred area in both simple case and best case. In the same time, In **Figure 18** the consideration of different parameters such as specific wind speed 2.690 m/s and diesel cost 0.6$/L have been represented for the optimization results. With a base NPC of USD 82,405 and base COE of USD 0.244/kWh, an off-grid hybrid wind turbine, diesel generator and battery hybrid system is efficiently more feasible and this is observed by the sensitivity analysis. A hybrid energy system can be considered as a most feasible renewable energy system constituted of 15 generic wind turbines (10 kW dc each), a diesel generation with a divisional power of 4 kW and 2 storage batteries in cementation to 1 kW inverters and 1 kW rectifiers.

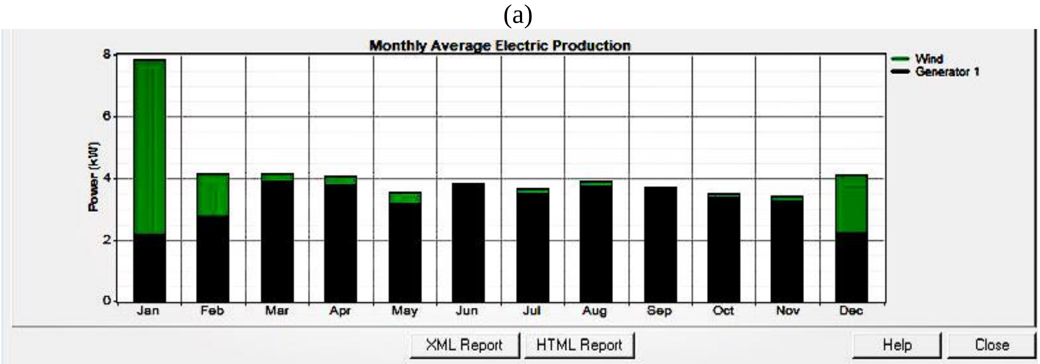



| G10 | Label (kW) | S4KS25P | Conv. (kW) | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kWh) | Ren. Frac. | Capacity Shortage | Diesel (L) | Label (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 2 | 5 | $ 785 | 6,102 | $ 78,790 | 0.199 | 0.00 | 0.00 | 11,295 | 7,895 |
| | 5 | 2 | 1 | $ 505 | 6,126 | $ 78,822 | 0.200 | 0.00 | 0.01 | 11,269 | 8,749 |
| | 5 | 2 | 7 | $ 925 | 6,105 | $ 78,970 | 0.200 | 0.00 | 0.00 | 11,295 | 7,895 |
| 1 | 5 | 2 | 5 | $ 3,285 | 6,065 | $ 80,817 | 0.204 | 0.00 | 0.00 | 10,974 | 7,839 |
| 1 | 5 | 2 | 7 | $ 3,425 | 6,068 | $ 80,996 | 0.205 | 0.00 | 0.00 | 10,974 | 7,839 |
| 1 | 5 | 2 | 1 | $ 3,005 | 6,150 | $ 81,623 | 0.207 | 0.02 | 0.01 | 11,063 | 8,749 |
| 2 | 5 | 2 | 5 | $ 5,785 | 6,057 | $ 83,216 | 0.211 | 0.01 | 0.00 | 10,719 | 7,713 |
| 2 | 5 | 2 | 7 | $ 5,925 | 6,056 | $ 83,343 | 0.211 | 0.01 | 0.00 | 10,712 | 7,703 |
| 2 | 5 | 2 | 1 | $ 5,505 | 6,226 | $ 85,091 | 0.216 | 0.03 | 0.01 | 10,961 | 8,749 |
| 3 | 5 | 2 | 5 | $ 8,285 | 6,110 | $ 86,387 | 0.219 | 0.03 | 0.00 | 10,571 | 7,704 |
| 3 | 5 | 2 | 7 | $ 8,425 | 6,108 | $ 86,508 | 0.219 | 0.03 | 0.00 | 10,563 | 7,694 |
| 3 | 5 | 2 | 1 | $ 8,005 | 6,314 | $ 88,721 | 0.225 | 0.04 | 0.01 | 10,884 | 8,750 |
| 4 | 5 | 2 | 5 | $ 10,785 | 6,157 | $ 89,498 | 0.227 | 0.05 | 0.00 | 10,420 | 7,643 |
| 4 | 5 | 2 | 7 | $ 10,925 | 6,156 | $ 89,620 | 0.227 | 0.05 | 0.00 | 10,412 | 7,633 |
| 4 | 5 | 2 | 1 | $ 10,505 | 6,412 | $ 92,467 | 0.235 | 0.05 | 0.01 | 10,825 | 8,750 |
| 5 | 5 | 2 | 5 | $ 13,285 | 6,232 | $ 92,951 | 0.235 | 0.06 | 0.00 | 10,316 | 7,638 |
| 5 | 5 | 2 | 7 | $ 13,425 | 6,225 | $ 92,998 | 0.235 | 0.06 | 0.00 | 10,298 | 7,614 |
| 6 | 5 | 2 | 5 | $ 15,785 | 6,293 | $ 96,234 | 0.244 | 0.07 | 0.00 | 10,193 | 7,568 |
| 6 | 5 | 2 | 7 | $ 15,925 | 6,286 | $ 96,281 | 0.244 | 0.07 | 0.00 | 10,175 | 7,545 |
| 5 | 5 | 2 | 1 | $ 13,005 | 6,516 | $ 96,306 | 0.245 | 0.05 | 0.01 | 10,781 | 8,749 |
| 6 | 5 | 2 | 1 | $ 15,505 | 6,628 | $ 100,228 | 0.254 | 0.06 | 0.01 | 10,750 | 8,750 |
| | 10 | 2 | 5 | $ 1,120 | 8,065 | $ 104,215 | 0.263 | 0.00 | 0.00 | 14,391 | 7,700 |
| | 10 | 2 | 7 | $ 1,260 | 8,068 | $ 104,394 | 0.264 | 0.00 | 0.00 | 14,391 | 7,700 |
| 1 | 10 | 2 | 5 | $ 3,620 | 8,088 | $ 107,015 | 0.270 | 0.00 | 0.00 | 14,177 | 7,736 |
| 1 | 10 | 2 | 7 | $ 3,760 | 8,085 | $ 107,113 | 0.271 | 0.00 | 0.00 | 14,166 | 7,726 |
| 2 | 10 | 2 | 5 | $ 6,120 | 8,092 | $ 109,564 | 0.277 | 0.00 | 0.00 | 13,949 | 7,655 |
| 2 | 10 | 2 | 7 | $ 6,260 | 8,090 | $ 109,676 | 0.277 | 0.00 | 0.00 | 13,940 | 7,651 |
| | 10 | 2 | 1 | $ 840 | 8,542 | $ 110,030 | 0.278 | 0.00 | 0.00 | 15,130 | 8,749 |
| 3 | 10 | 2 | 7 | $ 8,760 | 8,085 | $ 112,108 | 0.283 | 0.01 | 0.00 | 13,701 | 7,537 |
| 3 | 10 | 2 | 5 | $ 8,620 | 8,106 | $ 112,244 | 0.284 | 0.01 | 0.00 | 13,744 | 7,565 |

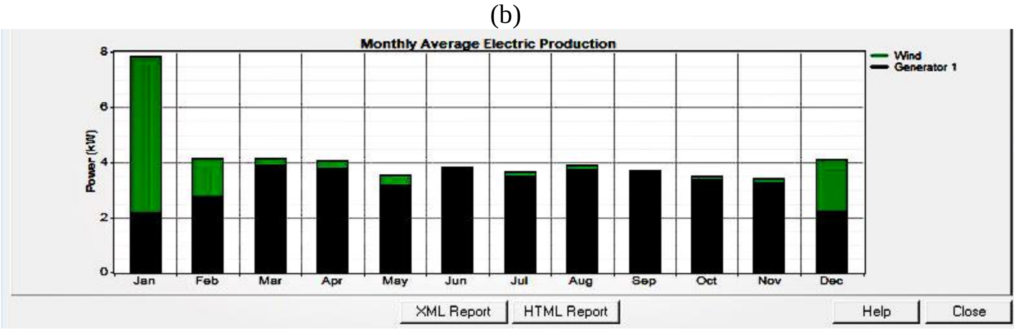
**Figure 16:** Simulation Results.




(a)

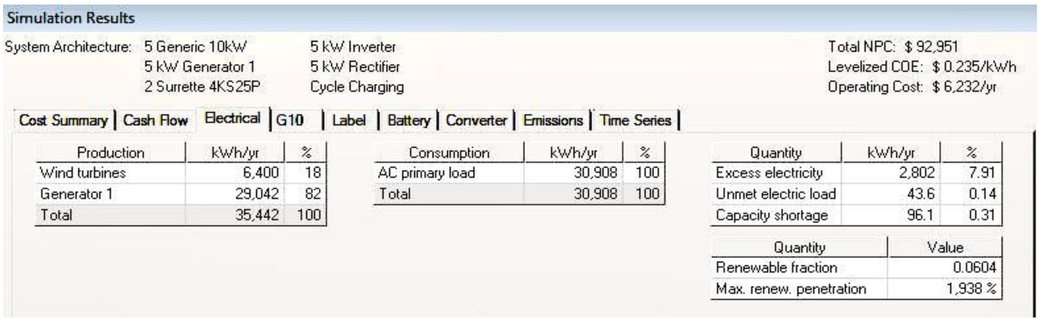



(b)

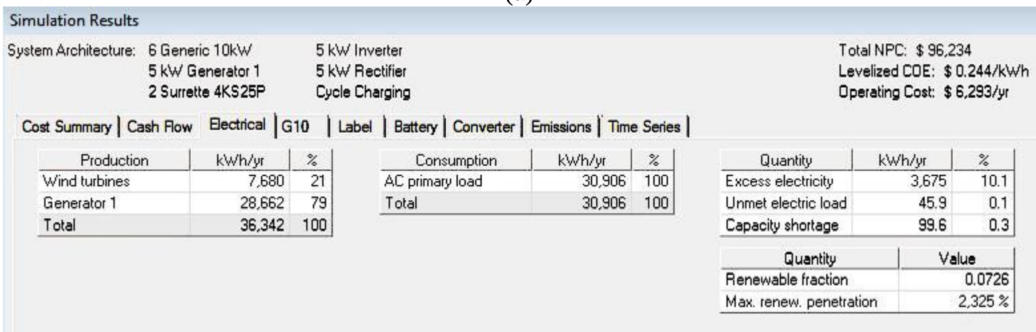



(c)

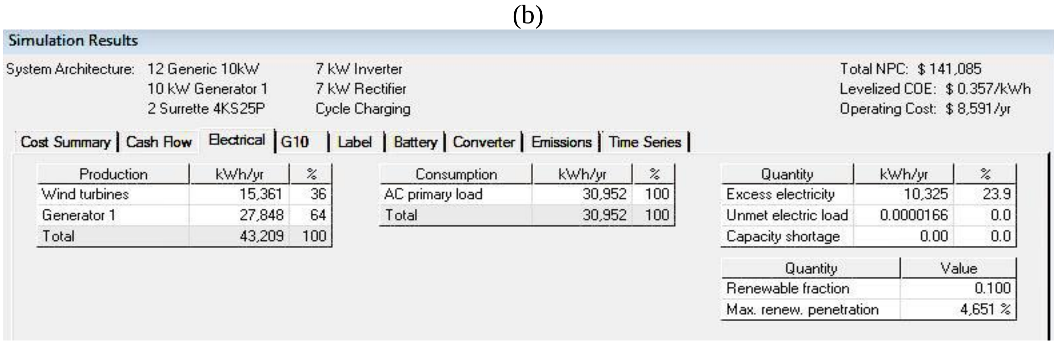
**Figure 17:**Power Generation in different Conditions.




(a)




(b)




(c)

**Figure 18:** Power Calculation in different conditions.

**Table 5:** Comparison of $CO_2$ emission and NPC between the RES and Conventional Power Plant.

| Parameters | Wind-Diesel Generator Hybrid Energy System | Conventional Power Station |
|---|---|---|
| $CO_2$ Emission/Year (Kt) | 168,451.984 | 198,348.00 |
| NPC/Year ($) | 92,951.00 | 297,000.00 |

According to the analysis and simulation results the $CO_2$ emissions rate per year has been found 168,451.984 Kilotons which is 29896.016 Kilotons less than the conventional power plants per year considering the year of 2009 for Malaysian perspective [30]. The net present cost can be varied by fuel cost, equipment cost, life time, operation and maintenance cost. From the analysis it can be clearly identified that the net present cost (NPC) for the proposed hybrid energy system has been reduced in comparison with the net present cost (NPC) for the conventional power station in Malaysian perspective. The net present cost (NPC) for the designed hybrid energy system is 72.25 % less than the net present cost for the conventional power plant per year considering the year of 2009 for Malaysian climate [31, 32].

## V. CONCLUSION

With the consideration of the demand of huge amount of electrical power a complete smart-grid hybrid wind-diesel-battery renewable energy system has been developed for Malacca of Malaysia. This hybrid energy system will be applicable especially for decentralized and remote areas where grid connection is not available. Since, diesel based power generation system completely depends on fossil fuel which is too expensive. For the economic feasibility analysis of the proposed system, it is found that for a community of eco-tourism area of Malacca would be composed of 15 generic wind turbines each of 10 kW dc together with a 4 kW diesel generator and 2 numbers of batteries of which each has a nominal voltage of 6, capacity of 1156 Ah and 6.94 kWh. The investigation of the best results shows that the COE of the optimized system is USD 0.235/kWh and the NPC of the optimized system is USD 92,951.The total sensitivity analysis, optimization and simulation process has been conducted through HOMER renewable energy software. Utilizing this system for electricity generation in comparison with the other diesel generator power system situation would decrease the operating hours and consequently the diesel consumption of the generators and would lead to reduction in emissions of GHG. In the near future we will try to introduce some more convenient renewable energy model and proper control system for the hybrid energy system for the different area of the world.

## ACKNOWLEDGEMENT

This work has been carried out by the financial support of the UMRG grant of University of Malaya. The project title is "Performance Investigation of Solar-Wind Hybrid Energy System for Malaysian Climate". The project no is RG-158, AET/12.

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