Performance Analysis of a Stand-Alone Photovoltaic-Wind-Diesel Power System

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ABSTRACT— For consumers in the remote areas that are not served by grid electricity, diesel generators are the most choice for electrical supply. As a result, plenty of servicing and maintenance needed to be done onto these diesel generators. But whereas most of these stand-alone systems are still based on fossil fuel power production, the use of renewable energy within these systems is growing as a consequence of rising fuel prices and environmental concerns. The integration of PV system based on storage in batteries (in form of chemical energy) is considered as a promising solution to overcome the limitations associated with the intermittency of renewable sources. This paper is aimed to modeling of hybrid (Diesel, solar and wind) for power generation using HOMER simulation software. This paper presents a comparison between using diesel plus wind turbine and using diesel plus PV array for small village in Red Sea, Egypt. The simulation and optimization of cases study have been performed by using the HOMER software tool to satisfy the electric load is in the region of 299 KWh/day, the peak load is 18 KW for small standalone communities which do not have access to the main electricity grid.

The results show that the most optimum combination is diesel plus PV.

KEYWORDS: photovoltaic, wind turbine, diesel, standalone power system

1. INTRODUCTION

The demand for alternative energy sources is increasing each year due to need for clean and renewable sources of energy. Hybrid energy systems are ideal for outdoor and/or remote area applications**.** Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Amongst the above mentioned sources of energy there has been a lot of development in the technology for harnessing energy from the Solar & wind. Solar and wind energy are non-deflectable, site dependent, non-polluting, and potential sources of alternative energy options. Many countries are pursuing the option of wind energy conversion systems; in an effort to minimize their dependence on fossil-based nonrenewable fuels. Also, presently thousands of photovoltaic (PV) deployments exist worldwide, providing power to small, remote, grid-independent or Stand-alone applications. For both systems, variations in meteorological conditions (solar irradiation and average annual wind conditions) are important. The performance of solar and wind energy systems are strongly dependent on the climatic conditions at the location. The power generated by a PV system is highly dependent on weather conditions [1].

Solar energy is the energy gained from solar radiations. This energy can be utilized mainly by using two techniques. One is the use of PV panels and other is Concentrating Solar Power System.

DATA SURVEY

Loads are demand requirements that the power system must supply. Electric loads can be primary, meaning they must be served on demand or deferrable, meaning there is some flexibility in when they can be served.

2. Background Data of Proposed System:

2.1 Load Profile

For this paper, a small village area in Ras Gharb is selected as case study and the load profile is obtained. A village area coordinates of selected location are 28° 2̀1N and 33° 0̀4 39‶ E. Load of 10 houses is considered. Peak demand of the selected area is 18 kW. Load profile of selected area is given in Figure (1).

Small village in Ras Gharb which do not have access to the main electricity grid. This village has been electrified by Red Sea governorate for a period of 24 hours per day, in the context of which an autonomous power system based on a diesel generator. [4].
This load demand also varies day by day or season to season. So, during HOMER calculations we can add random variability factor of 1.5 % for day to day and 1% for time step to time step. These factors compensate the variation in peak demand.

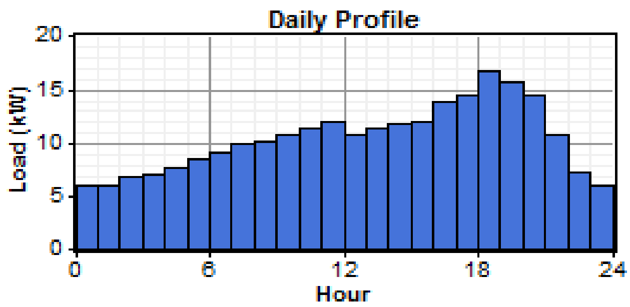

Fig.1: Electrical load profile for a day

3. SIMULATION RESULTS of CASE STUDY (Ras Gharb, Red Sea, EGYPT)

(DIESEL ENGINES) The inherent advantage of these prime movers is that they are low inertia structures that can be started and shutdown quickly, so that immediate requirements for additional power can be met without significant delay.

20–kW diesel engine generator set operating in this country (including the diesel tank), resulting in a total capital cost of 8000 $. Moreover, a diesel fuel price of 0.2 $/L is used in the calculations. As can be seen from Table (1), the project lifetime used in the techno-economic analysis is 15 years. [3]

Table.1: HOMER input summary of the diesel power system

AC Generator	Size	20 KW
	Capital	8000$
	Replacement	7500 $
	O&M	0.024 $/hr
	Lifetime	15,000 hrs
	Min. load ratio	30%
	Heat recovery ratio	0%
	Fuel used	Diesel
	Fuel curve intercept	0.08 L/hr/kW
	Fuel curve slope	0.25 L/hr/kW
Fuel (Diesel)	Price	0.2 $/L
	Lower heating value	35.42 MJ/L
	Density	820 kg/m^3
	Carbon content	88.0%
	Sulfur content	0.33%
Economics	Project lifetime	15yr
	Capacity shortage penalty	0 $/kWh
	System fixed capital cost	1500 $
	System fixed O&M cost	1500 $/yr
Emissions	Carbon dioxide penalty	8 $/t
	Carbon monoxide penalty	8 $/t
	Unburned hydrocarbons penalty	8 $/t
	Particulate matter penalty	8 $/t
	Sulfur dioxide penalty	8 $/t
	Nitrogen oxides penalty	8 $/t
Constraints	Maximum annual capacity shortage	5%

3.1WIND AND DIESEL GENERATION

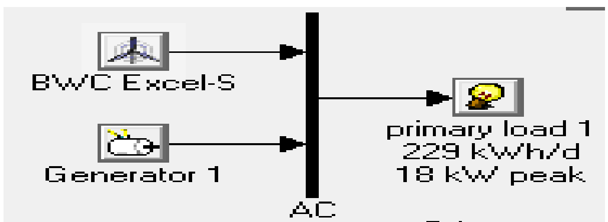

Fig.2: basic configuration of wind and diesel system

Table.2: wind and diesel system simulation results

	XLS	Label (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)
	1	20	$ 38,000	12,543	$ 199,171	0.185	0.33	0.00	30,313	8,756

For the wind turbine (PWC Excel-S) simulated in this community in a total capital cost of the order of 28,500$ for each wind turbine, replacement cost is 24,500$ and Operation and maintenance costs for wind turbines constitute 200$/yr of the total capital cost per year. The lifetime of the wind turbine is 15 years [5]. The optimization of the wind-diesel autonomous power system, presented schematically in Table (2) revealed that the optimum system configuration comprises 1 wind turbines with a capacity of 10 kW AC, a 20 –kW diesel generator.

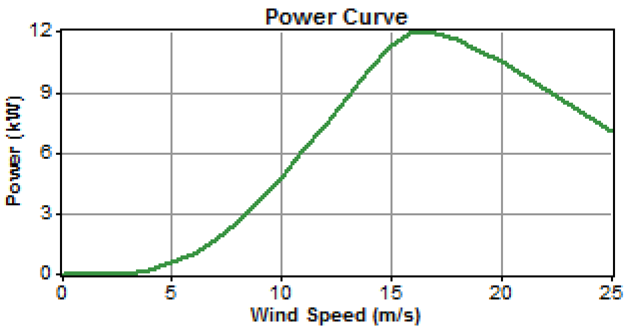

Fig.3: Power curve of the wind turbine

Figure (4) shows the monthly average wind speed in (Ras Gharb, Red Sea, Egypt). [3]

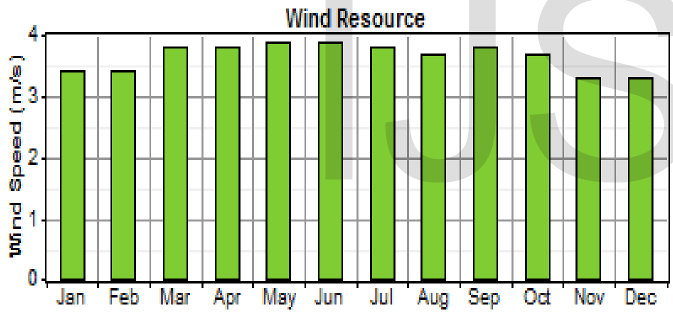

Fig.4: Average monthly wind speed m/s

Table.3: Cost summary

Total net present cost	199,171 $
Levelized cost of energy	0.185 $/KWh
Operating cost	12,543$/yr

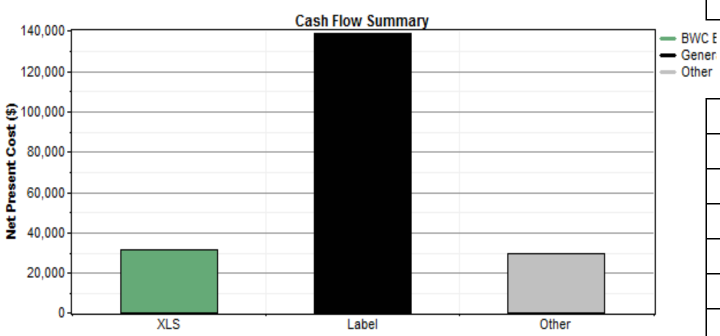

Fig.5: Cash flow summary by component wind turbine and diesel generation.

Figure (5) shows the net present cost of the diesel is more than the wind turbine.

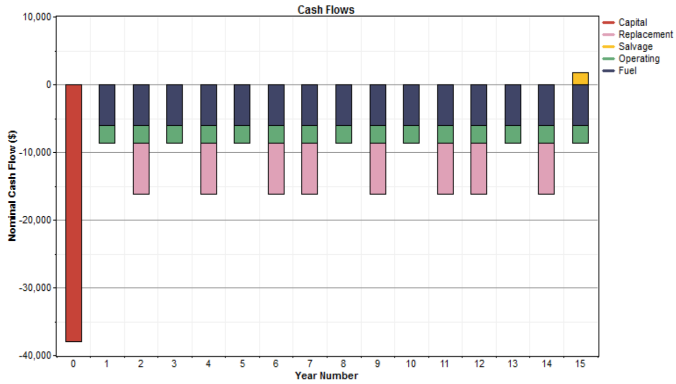

Fig.6: cash flows by cost type (diesel and wind power generation)

Table.4: Electrical energy production and demand

Annual electricity production	
Wind turbine	32,771 kWh/ yr (33%)
Generator1	65,217(67%)
Total production	97,988 kWh/yr (100%)
Annual electric load served	
3AC primary load served	83,585 kWh/yr
Total load served	83,585 kWh/yr
Other	
Excess electricity	14,403KWh/yr
Unmet electric load	0 kWh/yr
Capacity shortage	0KWh/yr
Renewable fraction	0.334

Table.5: AC wind turbine: PGE20/25

Variable	Value	Units
Total rated capacity	10	KW
Mean output	3.7	KW
Capacity factor	37.4	%
Total production	32,771	KWh/yr

Table .6: diesel generation

Quantity	Value	Units
Hours of operation	8,756	hr/yr
Operational life	1.71	Yr
Capacity factor	37.2	%
Electrical production	65,217	KWh/yr
Mean electrical output	7.45	KW
Min. electrical output	6	KW
Max. electrical output	17.2	KW
Fuel consumption	30,313	L/yr

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Specific fuel consumption	0.465	L/kwh
Fuel energy input	298,277	KWh/yr
Mean electrical efficiency	21.9	%

Table.7: Emissions of wind turbine and diesel generation

Pollutant	Emissions (kg/yr)
Carbon dioxide	79,823
Carbon monoxide	197
Unburned hydrocarbons	21.8
Particulate matter	14.9
Sulfur dioxide	160
Nitrogen oxides	1,758

The average monthly energy production of the wind turbine and diesel generation system is given in figure

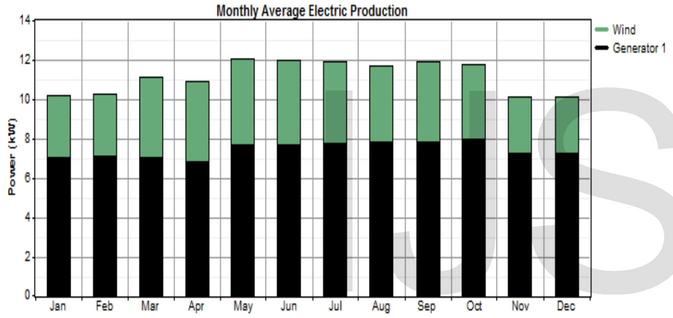

Fig.7: (wind and diesel) monthly average electric production

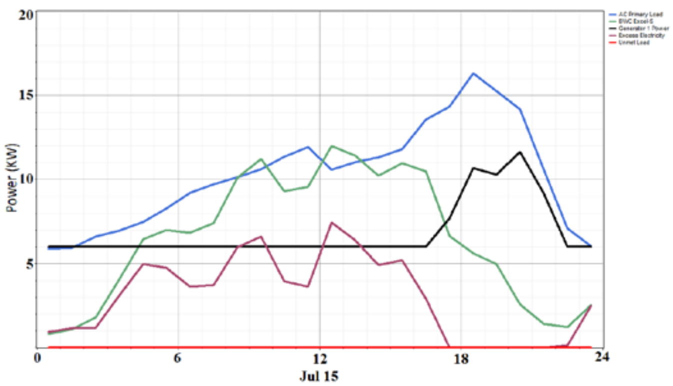

Fig.8: Hourly data for a day in January

Fig.9: Hourly data for a day in July

3.2 PV AND DIESEL GENERATION

Specifications of different components is given as

1) 10kW from PV (Photovoltaic Panels).The capital cost of these panels was provided as 12,147$ and a life time is taken as 25 years which is equal to the life time of designed system so there will be no replacement charges. Derating factor for PV panels is taken as 80 %. [4]

2) A 3kW converter is used to convert power from PV panels into AC. Capital Cost of converter is provided as 3000 $.It is assumed that converter has efficiency of 96% and a lifetime of 25 year.

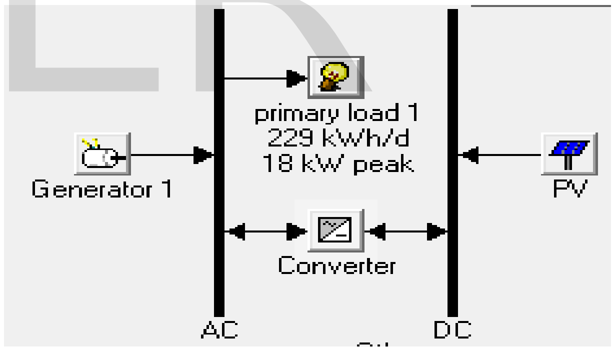

Fig.10: basic configuration of PV and diesel system

Table.8: PV and diesel system simulation results

	PV (kW)	Label (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)
	10	20	3	$ 24,647	12,626	$ 186,887	0.174	0.20	0.00	32,551	8,760

Figure (11) shows the monthly average of solar radiation in KW/m^2/day: [3]

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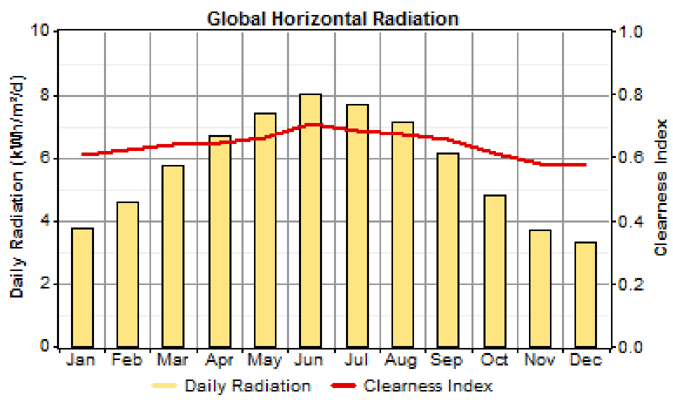

Fig.11: average monthly solar radiation

Table.9: Cost summary

Total net present cost	186,887$
Levelized cost of energy	0,174$KWh
Operating cost	12,626$/yr

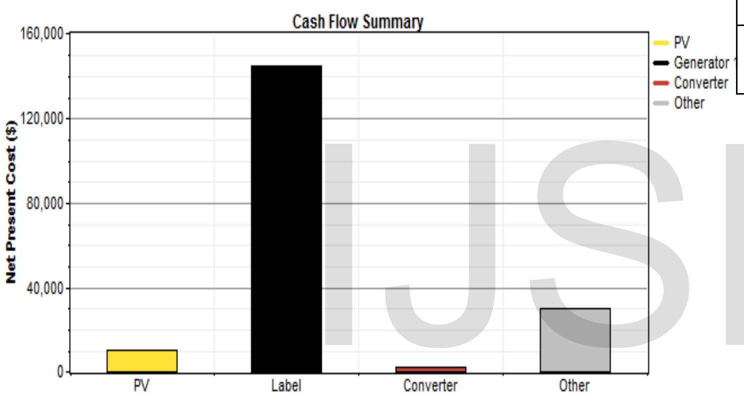

Fig.12: cash flow summary of PV-diesel power system

Table.10: Electrical energy production and demand

Annual electricity production	
PV array	18,313kWh/ yr (20%)
Generator1	74,141KWh/yr (80%)
Total production	92,453 kWh/yr (100%)
Annual electric load served	
AC primary load served	83,585 kWh/yr
Total load served	83,585 kWh/yr
Other	
Excess electricity	8,447 KWh/yr
Unmet electric load	0 KWh/yr
Capacity shortage	0 KWh/yr
Renewable fraction	0.198

Table.11: PV array generation

Variable	Value	Units
Total rated capacity	10	KW
Mean output	2.1	KW
Capacity factor	20.9	%
Hours of operation	4,388	Hr/yr
Total production	18,313	KWh/yr

Table .12: Diesel generation

Quantity	Value	Units
Hours of operation	8,760	hr/yr
Operational life	1.71	Yr
Capacity factor	42.3	%
Electrical production	74,141	KWh/yr
Mean electrical output	8.46	KW
Min. electrical output	6	KW
Max. electrical output	17.5	KW
Fuel consumption	32,551	L/yr
Fuel energy input	320,301	KWh/yr
Mean electrical efficiency	23.1	%

Table .13: Converter

Quantity	inverter	Units
Capacity	3	KW
mean output	1.16	KW
minimum output	0	KW
maximum output	3	KW
Capacity factor	38.5	%
Hours of operation	4,388	hr/yr
Energy in	10,543	KWh/yr
Energy output	10,121	KWh/yr

Table.14: Emissions of PV and diesel power system

Pollutant	Emissions (kg/yr)
Carbon dioxide	85,717
Carbon monoxide	212
Unburned hydrocarbons	23.4
Particulate matter	15.9
Sulfur dioxide	172
Nitrogen oxides	1,888

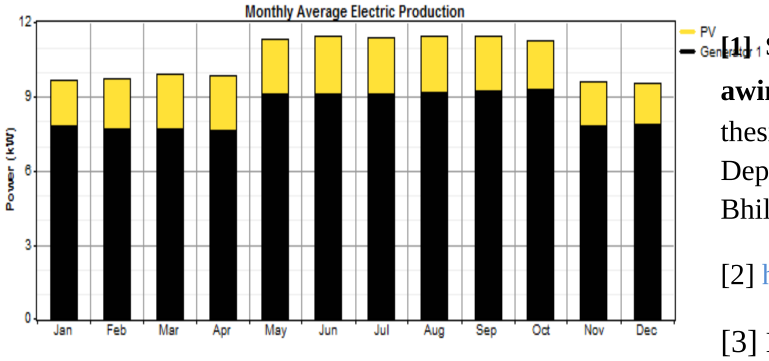

Fig.13: monthly average electric production of PV and diesel generation system

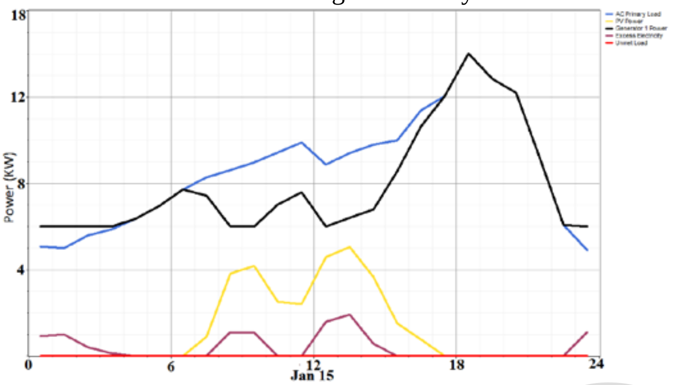

Fig.14: Hourly data for a day in January

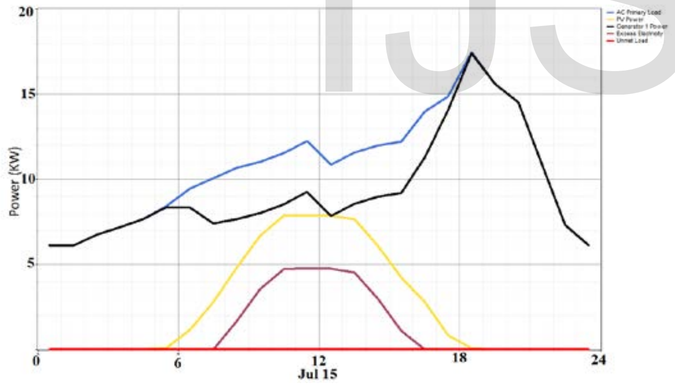

Fig.15: Hourly data for a day in JULY

4: Conclusion and summary of results

This paper presents a comparison between using diesel plus wind turbine and using diesel plus PV array to product electricity for standalone community

The results show that the most optimum combination is PV and Diesel with Net present cost 168,887$ and cost of energy 0.174 $/KWh

REFRENCE

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