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Simulation of PV/WIND DIESEL hybrid power systems for rural electrification in Algeria

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Abstract- **Adrar is the most rural zones in Algeria where grid connected electric system for the inhabitants will not be possible to establish even in future. Diesel is the main fuel for fulfilling the energy demand. Solar and Wind resources are the hybrid options for this site. HOMER, a software for optimization of renewable based energy efficient system for single home and 20 homes. It shows that the energy costs and breakeven grid distances are more attractive for the electrification of 20 homes where per unit (kWh) cost of energy varies from 1.49 USD to 1.19 USD for Adrar site's. On the other hand It is found that the optimum results of hybrid renewable system show a 22% reduction of emissions including CO2, SO2 and NOx. The RF of the optimized system is 22%. It is also found that the reduced NPC and COE are only equal to about 99% of energy consumption from standard system (diesel only)**

***Keywords*—rural zones, grid, renewable energy, economic, environnemental.**

1. INTRODUCTION

In remote Algerian's villages, far from the grids, electric energy is usually supplied by diesel generators. In most of this cases, the supply with diesel fuel becomes highly expensive while hybrid/photovoltaic/wind generation becomes competitive with diesel only generation [1], [2] . Photovoltaic/wind/diesel hybrid systems are more reliable in producing electricity than photovoltaic only/wind only systems, and often present the best solution for electrifying remote areas. The diesel generator reduces the photovoltaic/wind component while the photovoltaic/wind systems decrease the operating time of the generator, reducing the running costs of the diesel generator [3], the addition of storage reduces the start/ stop cycles of diesel generators thus, considerably reduce the fuel consumption [4] and [5].

In order to effectively explain the benefits of Hybrid system. A program called HOMER [6] was used in this study. HOMER is sophisticated software developed by the National Renewable Energy Laboratory for analyzing the economics of small power systems. After inputting the solar/wind resources along with the cost of equipment HOMER crunches the numbers to give us the "Optimal System Type" based purely on economics and availability of resources.

Analysis has been done for single home user as well as combination of 20 home users to get the most economic, technical and environnement viable options. For the purpose of illustration, one Algerian's rural site has been considered (Adrar).

Many power hybrid systems have been proposed in the past for remote area but the vast majority had been based on the technical PV- diesel systems or PV-Wind systems [7-19]. Many tools are also available for sizing and simulation of a power hybrid system but fewer included the technical and economic study of the PV-Wind-Diesel hybrid system with battery storage using different load combination. The authors have adopted a new approach to the PV-Wind-Diesel hybrid system with battery storage including the technical, economic and environmental study using different load combination and a site from a rural Algerian's area.

2. USED DATA

In the present study four Algerian sites have been selected in were solar radiation, ambient temperature and wind speed were available. Thus, the geographical coordinates and the climate type classification according to Koppen Geiger[19] were given also in Table 1.

TABLE 1

The geographical coordinates and the climate type classification

Site	Latitude (°)	Longitude (°)	Altitude (m)	Climate type
Adrar	27.8 North	0.18 West	264	Bwh[19]

3. PRESENTATION OF THE CASE STUDY

An hybrid energy system generally consists of a primary energy sources working in parallel with standby secondary energy storage units. HOMER has been used to optimize the best energy efficient system for Adrar considering different load and wind-PV-Diesel combination and based on the solar/wind resources. Fig.1 shows the schematic diagram of reflect the scheme as implemented in HOMER simulation tool. HOMER simulates the operation of a system by making energy balance calculations for each of the 8760 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply in that hour and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries.

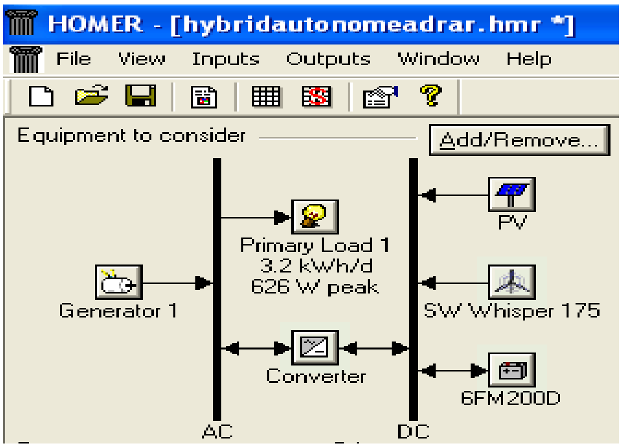

Fig. 1: Proposed hybrid system in HOMER

Table 2

Appliances for single home user [2]

		Power (W)	Duration of consumption (hours)	**Day load (wh)**
Lighting	Rooms	22	8	176
	Lounge	22	6	132
	Corridor	22	4	88
	Bathroom	22	4	66
	Toilet	22	1	22
	Kitchen	11	7	77
Equipments	Refrigerator	120	12	1440
	TV	80	7	560
	FAN	100	4	400
	Various	100	2	200
Total load				3198

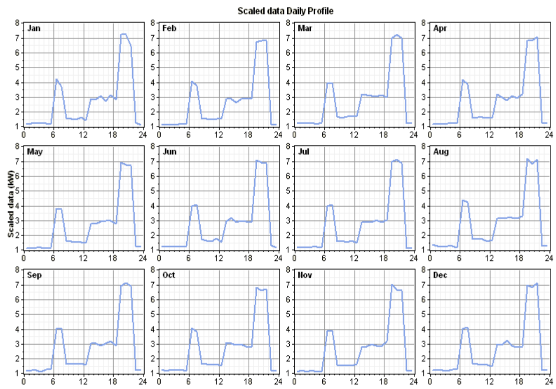

Fig.2: Monthly averaged hourly load profile for 20 home-users

HOMER performs these energy balance calculations for each system configuration that anybody wants to consider. It then determines whether a configuration is feasible, i.e, whether it can meet the electrical demand under the conditions that have been specified 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. Information about the load, resources, economic, constrains, controls and other component that have been used in HOMER are given below:

- Electric load: A typical load system (Table 1) for single home in the remote areas has been considered for the analysis. Monthly averaged hourly load demand has been given as an input of HOMER and then it generates daily and monthly load profile for a year for 20 homes.(Fig. 2). It has been found that for this system each home user consume energy around 3200 Wh/day with a peak demand of nearly 626 W.

- Renewable resources: The hourly data global radiation data has been taken from (WMO/OMM) [20] HOMER introduces clearness index from the latitude information of the selected site (Fig. 3) :(a) Hourly global radiation Data and (b)Hourly ambient temperature Data.

For wind Hourly measured data has been used with the information of height = 10m (WMO/ OMM) [20].HOMER generated and synthesized the monthly average data based on the other parameters such as:
Weibull factor ”k”= 2.35 , Autocorrelation factor= 0.961, Diurnal pattern strength(wind speed variation over a day)=0.153 , Hour of peak wind speed = 16 to generate hourly data for a year.

Figure 4 shows (a) the wind speed probability distribution function and (b) averaged hourly wind speed for 1year with the annually average wind speed equal to 6.25m/sm/s.

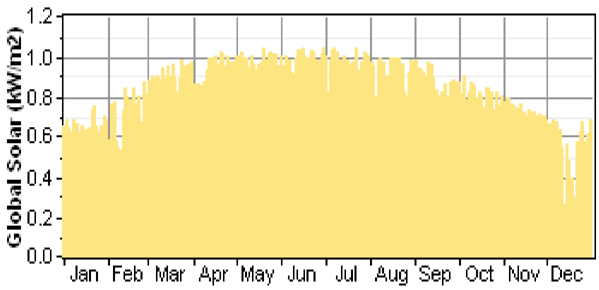

Fig.3 :(a) Hourly global radiation Data

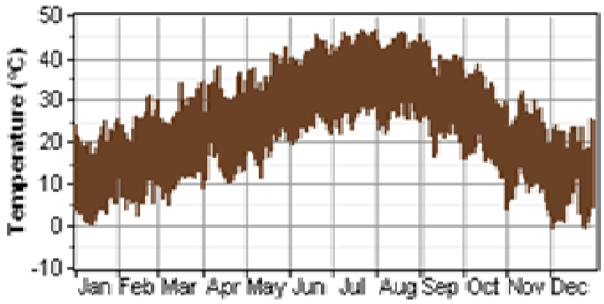

Fig.3 : (b) Hourly ambient temperature Data

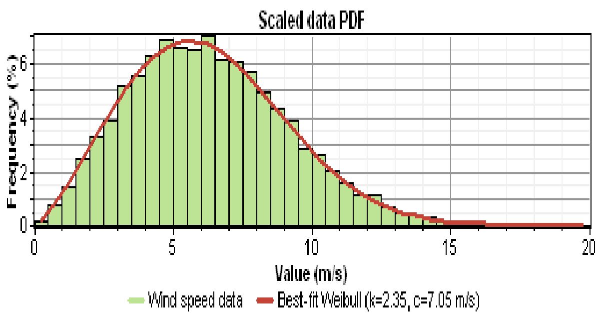

Fig. 4: (a) Wind speed probability density function

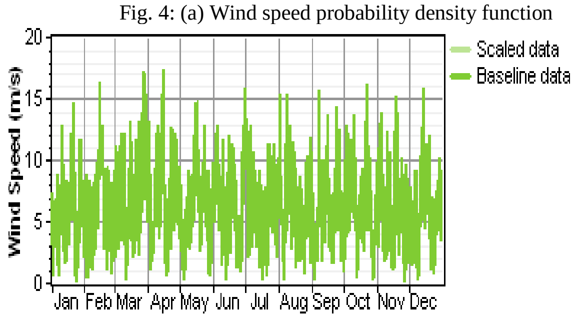

Fig. 4: (b)Daily wind speed

4. HYBRID SYSTEM COMPONENTS

- Photovoltaic module: The cost of PV module including installation has been considered as 4 USD/W for Algeria (1USD=72 DZD, 2009[21]). Life time of the modules has been taken as 25 years and these are titled like the latitude with no tracking mode.

- Wind generator: The load demand is very low for single home system and the price per kW turbine cost is very high for low capacities wind turbine compare to that of high capacity ones. Also low capacity wind turbine is not much available. Now a day, research and development are going on to improve the technology and designing low capacity turbine with low cut- in speed around 2.5 m/s So, for the Adrar site which present a high wind potential, turbine from southwest wind power (model Whisper 175; capacity 3kW) has been
- considered at the cost of 10910 USD with tower and installation.
- Diesel generator: Diesel generator supplies a significant amount of energy of 1 and 20 houses. The selected diesel generators have operating hour of 15000, minimum load ratio 30%, 0.2 kW to 5 kW of power is generated by consuming 0.25L/hr of fuel.
- Battery with controller: As the system considered the AC load only, battery and controller were also as a main part of the system. Battery from vision battery company (Model Vision 6FM200D; nominal voltage: 12V; nominal capacity: 200Ah) has been used at cost of 853 $ Battery with controller charge.
- Economics and constraints: the project life time has been considered to be 25 years and the annual interest rate has been taken 10%. As the system has designed for single and also for 20 house users but the load consumed by the user is low so operation and maintenance cost has been take 300$/year. There is no capacity shortage for the system and operating reserve is 10% of hourly load.

5. RESULTS AND DISCUSSION

In this section we present results obtained using the HOMER Software for an rural Algerian site and for system designed for single and also for 20 house users.

5.1 cost summary

Analysis shows that the cost of energy (kWh) is low for the system which is the combination of 20 homes. On the other hand it's revealed too that the energy cost depends largely on the renewable energy potential quality. Table 3 shows the load demand for each combination of homes and each site with system architecture and financial summary. A detailed analysis and system architecture for the 20 homes system and for the chosen site has been given Fig. 5.

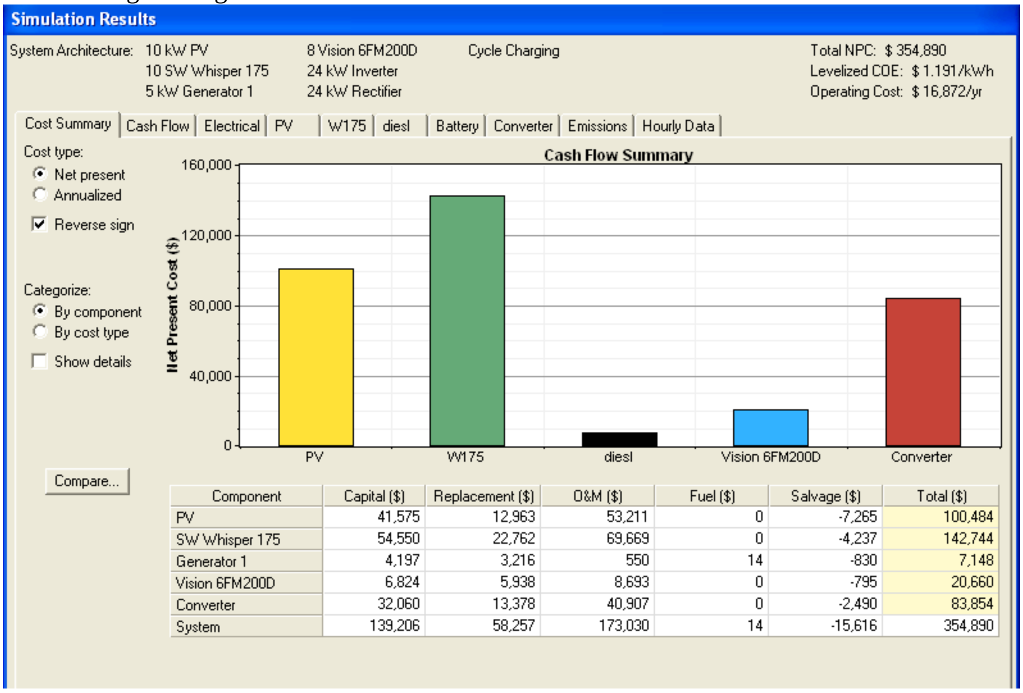

Fig.5 : Simulation results for 20 houses. Site : Adrar

Table 3
HOMER analysis and results

Site	PV module (kW)	Wind Generator (Quantity)	Diesel Generator (kW)	Battery (Quatity)	Initial cost ($)	Total NPC ($)	COE ($/kWh)	Home	Load
Adrar	0.1	1	1	1	8.5	22.3	1.49	single	3200Wh/day 628 W peak
	10	10	5	8	139.2	354.9	1.19	20	64 kWh/day 12 W peak

5.2 Emissions

Table 4 . shows the emissions of the standard diesel system (system 1) and the PV-Wind-Diesel hybrid system(system 2). As the main greenhouse gaz, the emission of carbon dioxide form system 1 is 16,086 kg/yr while the optimized system exhausts only 268 kg/yr, which means a 98 % of reduction.

Meanwhile, the sulfur dioxide and nitrogen oxide emissions of the system 2 are equal to 0.539 and 5.91 kg/yr while the emissions of system1 are equal to 32.3 and 354 kg/yr.

Table 4
. the emissions of SYSTEM1 And SYSTEM 2

Pollutant	Emissions system 1 (kg/yr)	Emissions system 2 (kg/yr)
Carbon dioxide	16,086	268
Carbon monoxide	39.7	0.662
Unburned hydocarbons	4.4	0.0733
Particulate matter	2.99	0.0499
Sulfur dioxide	32.3	0.539
Nitrogen oxides	354	5.91

6. CONCLUSION

This paper was devoted to simulating and sizing a Photovoltaic/Wind/ diesel hybrid system with battery storage for rural electrification in Algeria. Different combinations of component sizes and quantities has been compared and explored how variations in resource availability and system costs affect the cost of installing and operating different system design. on the other hand, it could be summarized from analysis that it will be better to use pv-wind combination for 20 homes instead of single home system where the per unit (kWh) cost of energy varies from 1.49 USD to 1.19 USD which agree with the result obtained by Shamim Kaiser M and al [23].

In addition, the emissions of CO2, SO2 and NOx decrease to less than 98% of the standard diesel power system.

Thus, the obtained results could be enough to take decision concerning an electrification of remote area in a developing country [24], [25]. This is tool to evaluate and validate the great renewable energy potential available in Algeria.

Finally, the overall system would be low if the turbine and battery cost decreases.

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