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OPTIMIZATION AND SENSITIVITY ANALYSIS OF HYBRID ENERGY SYSTEMS FOR RURAL ELECTRIFICATION: A CASE STUDY OF THE CENTERS OF TELECOMMUNICATION MOBILE (MOBILIS) IN ADRAR, ALGERIA

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A B S T R A C T

The demand for power generation of the world is increasing day by day so the use of hybrid systems become an important solution. The hybrid systems are used for supplying power in different areas to overcome the intermittence of solar and wind resources. The hybrid system incorporate two or more renewable energy sources so techno economics analysis of different combinations of hybrid systems is necessary for efficient utilization of renewable energy resources. In this study an extensive review of power generation from different hybrid systems are carried out and research gaps are identified. To conduct our studies different hybrid systems PV-Wind-Diesel-Battery, PV-Diesel-Battery, Wind-Diesel-Battery investigated for different cities, ouled said, Talmine and Timiaouine in Adrar ,Algeria . The telecommunication load demand is used in HOMER simulation. The results show that the PV-Wind-Diesel-Battery produce more power in comparison to PV-Diesel-Battery, Wind-Diesel-Battery system. The cost of energy (COE) is found to be 0.468 $/kW h, 0.4689 $/kW h, 0.4914$/kW h, respective cities for load 1.3 kW peak, providing best combination PV-Wind-Diesel-Battery system are useful for generation of power.

Keywords: Telecommunication load , Cost of energy, Battery, Diesel, Power PV and Wind.

1. INTRODUCTION

The demand for energy is increasing at an escalating pace and cannot be fulfilled entirely by conventional energy systems, due to their limited supplies. As fossil fuels are depleting and energy demands are increasing so power generation by renewable energy sources has drawn attentions worldwide. The single source of renewable energy sources are not able to provide power continuously to the load, therefore hybrid based energy systems become an important option for maintaining feasibility between power and telecommunication load. The hybrid based system incorporate more than one renewable energy sources increasing the feasibility of power to load. Most of the researcher has described the cost analysis of hybrid energy system [1-2]. And also a review about design and analysis of the context of renewable energy sources power generations [3-4]. In Algeria, industrial load consumed more power followed by commercial, domestic and agriculture. The telecommunication is one of the fastest growing industries in Algeria. In every month millions of mobiles subscribers are added in Algeria. It is a big challenge to meet regular power supply to telecommunication loads with fuel which is expensive. The telecommunication tower is mostly equipped with only diesel generator for power supply when there is no electric power. Due to this carbon emissions and cost get increases so it is necessary for the industry to use green energy for power sources. Algeria has the highest potentials for exploiting the renewable energy resources. Renewable energy (RE) is clean and inexhaustible. RE systems especially hybrid systems provide more power with increased efficiency and greater balance in energy supply. Thus, Algeria's growing telecommunication tower industry can attain considerable cost savings by reducing fossil-fuel dependence and carbon emission by using hybrid renewable power generated electricity supply. In this study, different types of Hybrid Renewable Energy Sources (HRES) are compared for power generation and optimum sizing in different cities of Adrar ,Algeria . For all combinations of HRES the meteorological data of solar radiation and wind speed is taken for Ouled said (Latitude 27.7°N and Longitude 26.7°E),Talmine (Latitude 8.2°N and Longitude 26.7°E) and Timiaouine (Latitude 10.2°N and Longitude 22.4°E) . The prototype of consumption load of the typical load profile of telecom is duly modeled . The Hybrid Optimization Model Electric Renewable (HOMER) software is used for analysis of hybrid power generation system. This software compares the broad range of equipment with distinct sensitivities and constrains for optimization of the design system. The technical properties and Life Cycle Cost (LCC) of the system are used for analysis of the system. The LCC consists of operation cost, installation cost and initial capital cost over the duration of system life. HOMER software provides simulations to satisfy of demand using resources availability and alternate technology options. This paper is organized as follows: Literature review on hybrid systems, The methodology, the results and discussions Finally, conclusions.

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2. LITERATURE REVIEW ON HYBRID SYSTEM

2.Literature review on hybrid system

In recent years, much research has been done on the sizing, optimization, control and operation of hybrid energy systems Renewable. Research and development efforts in technology renewable energy sources such as solar, wind and other energy sources .Renewable energy must continue in order to improve their performance and reliability. A review of hybrid systems is classified into three sections a review of sizing method ,a review of optimizing methods ,a review of control methods ,a review of some management methods .The first a review of sizing , Sizing of the hybrid system is an important step in defining the capacity of each system generator. There is a big risk in sizing under-sized or over-sized systems considering the difficulties in the evaluation of real load time of many fluctuations (in time and use), however, most researchers take average hours, days or months as time of use [5]. Of sizing the hybrid system ; can be using software or using traditional method. [5].Bentouba and al. use HOMER software for size hybrid system based on solar photovoltaic, wind turbine and diesel generator in Timiaouine (Algeria). The objective of this study is cover consumption of this rural village using hybrid system. After simulation, the best economic result is 0,176 $/kWh. [6] , also Ekren, O and all use HOMER for Size hybrid (solar-wind) electric vehicle charging station[7],with that Guerello, A and all done a study for Reducing costs through joint hybrid system and energy efficiency optimization. Energy and Buildings for the sake of Energy for off-grid homes[8]; and Li, J work on the sizing and techno-economic analysis of a solar-wind-biomass off-grid hybrid power system for remote rural electrification: A case study of west China[9]. Using the stochastic programming by Li, R.and all for Optimize and sizing the wind concentrated solar plant electric heater hybrid [10]. Alberizzi, J and all use Mixed Integer Linear Programming (MILP) for Optimal sizing of a Hybrid Renewable Energy System Focused on importance of data selection with highly variable renewable energy sources [11]. The researchers are interested in studying the Fuzzy logic, Like : Dhunny, A and all They did a study for identification the optimal wind, solar and hybrid wind-solar farming sites[12]; Xie, Y and all are based on Fuzzy logic for equivalent consumption optimization of a hybrid electric propulsion system for unmanned aerial vehicles [13]. There's someone who's hired the algorithm genetic for Sizing the hybrid system as Xie, Y and all [14] do a Sizing of hybrid electric propulsion system for retrofitting a mid-scale aircraft using non-dominated sorting genetic algorithm; Yang, H and all use the method of sizing the for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm [15]. Zhang, W and all using the weather forecasting and a hybrid search optimization algorithm for Sizing a stand-alone solar-wind-hydrogen energy system[16]. The Performance improvement of off-grid hybrid renewable energy system using dynamic voltage restorer is study by Hassanein, W. S and all [17]. The optimization of hybrid system is a point interest for the members researchers . Someone used HOMER PRO for optimize hybrid system, Khalil, L and all [18] ; Khare, V and all studied the optimization of hydrogen based hybrid renewable energy system using HOMER, BB-BC and GAMBIT[19]. The PV-biomass-diesel and grid base hybrid energy systems for rural electrification is optimize by Rajbongshi , R and all used HOMER [20] . The another one use the particle swarm optimization ,Kharrich, Mand all have studied Design of Hybrid Microgrid PV/Wind/Diesel/Battery System for Rabat and Baghdad [21]. Singh, S. and all used hybrid ABC-PSO algorithm for optimize the grid connected solar/fuel cell energy system [22], for stand-alone PV systems. Farajdadian, S and all Count on of fuzzy logic for optimize this system [23]. Zahedi, R and all study the Power management for storage mechanisms including battery, supercapacitor, and hydrogen of autonomous hybrid green power system utilizing multiple optimally-designed fuzzy logic controllers [24].

The number researchers take into account the process of optimizing the control, size and choice of components of such hybrid energy systems like Suresh, V [25], a study for a off-grid hybrid renewable energy system in three villages the Kollegal block of Chamarajanagar district, Karnataka State, India, The objectives is to reduce the Total System Net Preset Cost (TNPC), Cost of Energy (COE), unmet load, CO2 emissions using Genetic Algorithm (GA) and HOMER Pro Software. The results of both methods are compared with four combinations of hybrid renewable energy systems (HRES). Sensitivity analysis is also carried out on the best possible solution for the study of changes in annual wind speed and biomass fuel prices. The obtained results after Compared to HOMER, GA-based HRES of combination (biogas/biomass/solar/wind/fuel cell and battery) is found to be the optimal energy-supply solution with 0 percent unmet load at the lowest energy cost of $0.163 per kWh. As a result, PV saturation in GA is more cost-effective than HOMER. Zhao, P and all [26] proposes a stand-alone photovoltaic / wind turbine / adiabatic compressed air energy storage hybrid energy supply system for rural mobile base stations. Energy from renewable sunlight and wind is the primary source of energy, and the adiabatic compressed air storage system acts as an energy buffer to manage fluctuations on both demand and generation sides. The hybrid cooling strategy is also being adopted, consisting of air conditioner, fan assistant natural ventilation and turbine exhaust from adiabatic compressed air energy storage during discharge. The simulation results under design conditions show that the likelihood of power supply failure is 0.988 per cent, and that the monthly load and individual power consumption, the monthly cooling energy demand and supply, and the monthly generation and consumption of energy are all well matched. The effect of the design of the photovoltaic-wind turbine, the volume of the air tank and the storage pressure of adiabatic compressed air energy storage on system output was then implemented .However, the loss of power supply probability analysis shows that the necessary number of photovoltaic panels increases with the reduced volume of the air tank under conditions of fixed wind power and a set threshold of 1% maximum loss of power supply probability, while the dump load rate decreases.

With a certain amount of air tanks and a maximum loss of power supply likelihood level, the dump load rate decreases first and then increases with the number of wind turbines.

3. METHODOLOGY

3.1 Simulation tool HOMER

The Hybrid Optimization Model for Electric Renewables (HOMER), originally developed by the National Renewable Energy Laboratory, United States, is the world's leading microgrid simulation model for optimal planning and design of energy systems in off-grid or and on-grid modes. HOMER assesses the technical and economic performances of energy systems [27]. HOMER offers various energy sources and storage such as PV arrays, wind turbines, hydropower dams, hydrokinetic turbines, grid, generators, batteries, fuel cells, supercapacitors, etc. The software simulates different system configurations and finds the optimal system combination based on the lowest net present cost. Moreover, a sensitivity analysis can be carried out in HOMER to investigate the impact on the optimization results of changing the input parameters [28].

3.2. Telecom load

Adrar has 75 telecom central moblis, this study we selects for three cities :Ouled said ,Talmine and Timiaouine , Adrar ,Algeria (Figures.1-3). The Base Transceiver Station (BTS) consists a primary load of telecom. The Telecom infrastructure of BTS provides wireless communication facility between operator network of telecoms and subscriber devices. Increasing global development of BTS is a delightful place in those regions. After that often power distribution of grid is break down for long time or no access to the power distribution grid. This type of regions required diesel generator with batteries is provided back-up to grid for supplying electricity and network availability. But in this type of requirement has high level maintenance and high amount of diesel fuel to low level output. The cost of energy (COE) is high due to diesel price increasing and also rising greenhouse emissions.

All the BTS that installed in Adrar of type ZTE, it contains a part of Radio, part climatization , part Redresser and part Microwaves (Figure. 4) [29]. The BTS load has two types firstly outdoor BTS and secondly indoor BTS. Most indoor BTS required AC and no requirement of AC in outdoor BTS. In this paper, the analysis of minimum-size 1.3 kW is of 1.3 kW is taken. There are two types of BTS load. One is indoor BTS and the other is outdoor BTS. Most indoor BTS require air conditioning. For outdoor applications, there is no requirement for air conditioning. The types of BTS in communication tower first 2/2/2 type required typical power consumption is 1.3 kW, second 4/4/4 type required typical power consumption is 2 kW and third 6/6/6 type required power consumption is 3.5 kW. Considered a Daily load profile of telecom is shown in Figure.3. The data measured for the total hourly basis daily load requirement of a telecom. The HOMER software is used for simulation using telecom load. The details of hybrid system used in the simulation are shown in Table.1

PONTE
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Fig.1. Location of study area Ouled said

Fig. 2. Location of study area Talmine

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Fig. 3. Location of study area Timiaouine

Fig .4. the BTS load.

PONTE

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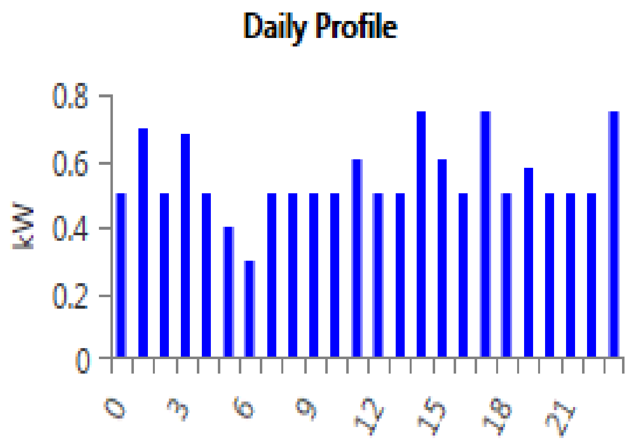

Fig.5. Daily load profile of telecom

Table.1. Data for sizing and cost analysis of hybrid system.

Description	Details
Type of Solar Module	Multi crystalline
PV System life time (N)	25 years
Cost of PV module	US $ 0.25–0.35/Wp
Cell Efficienc	13%
Module Efficiency	> 11%
Power Conversion Efficiency	90%
Temperature Correction Factor	0.9
Inverter Rating	4 kW
Efficiency of Inverter	90%
Type of Wind Turbine Generic	1 kW
Cost of Wind module	US $ 0.125–0.135/Wp
Life Time of Wind Turbine	15 year
Hub Height	50 m
Real Interest Rate	2.01

3.3. Climatic data

a. Solar radiation and temperature

The amount of solar radiation falling on PV panels play a very important role in the estimation of the output power of PV. Consequently, for this case study, the monthly average solar radiation are usedas input parameters in HOMER. The solar radiation profiles, clearness index for Ouled said , Talmine and Timiaouine are shown in Figures.6-8

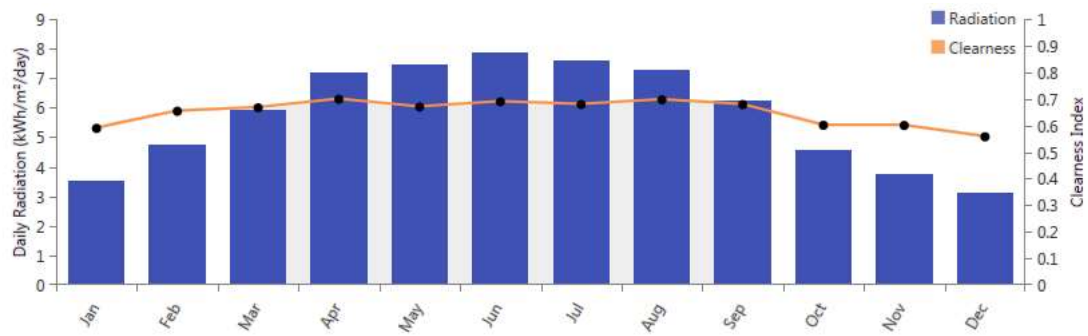

Fig.6. Monthly average daily global solar radiation for Ould said.

Fig.7. Monthly average daily global solar radiation for Talmine

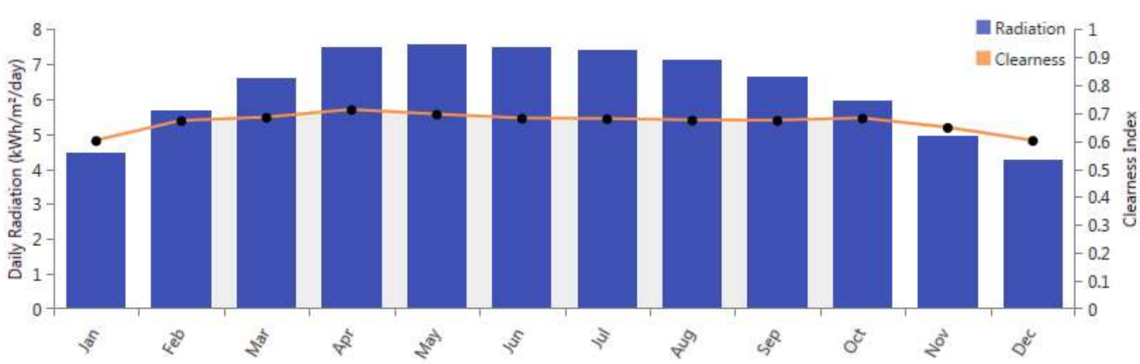

Fig.8. Monthly average daily global solar radiation for Timiaouine .

b. Wind speed

The wind speed data are also taken from NASA data base .The profiles of wind speed for three cities Ouled said ,Talmine and Timiaouine are shown in Figure .9-11

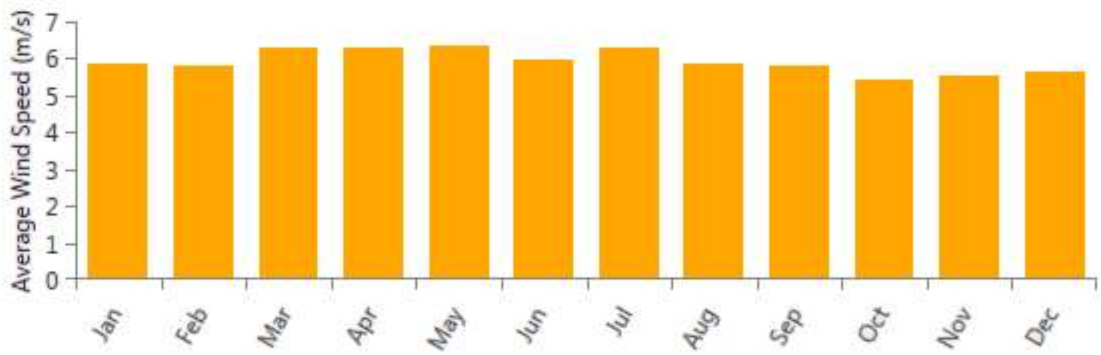

Fig.9. Wind speed data for Ouled said

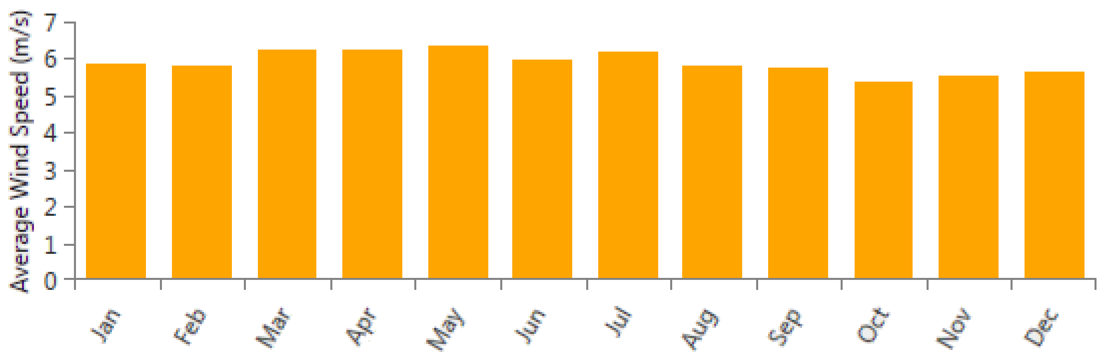

Fig.10. Wind speed data for Talmine

Fig.11. Wind speed data for Timiaouine

3.4. Proposed hybrid systems combinations

For analysis, the first combinations are PV-Wind-Diesel-Battery The second combination is PV-Diesel-Battery. The third combination is Wind-Diesel-Battery (Figure .12).

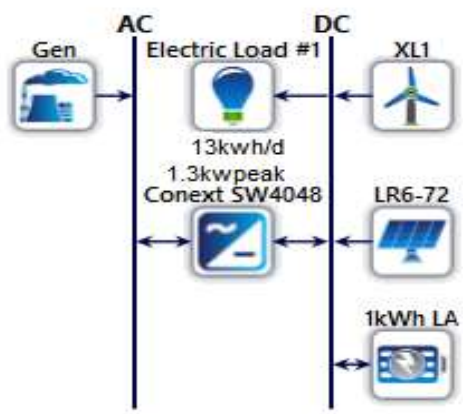

Fig.12. Homer simulation model of hybrid energy system

4. Results and discussion

The simulation is performed using hybrid optimization model electric renewable (HOMER) software and annual power production for different hybrid system combinations are shown in figures .13-15 for Ouled said city ,figures.16-18 for Talmine and figures.19-21 for Timiaouine . The cost of energy (COE) and total power generation for different combinations are shown in Table 2.
The daily average power production at AC primary load by best hybrid system combinations i.e. PV-Wind-Diesel-Battery in Ouled said ,Talmine and Timiaouine shown in Figures .22-24 .It is found that COE of PV-Wind-Diesel-Battery is very less as compared to PV-Diesel-Battery,Wind-Diesel-Battery for selected cities . Therefore integration of PV, Wind, Diesel and Battery are very important for Ouled said citie.The Power generationfrom PV-Wind-Diesel-Battery is more as compared PV-Diesel-Battery and Wind-Diesel-Battery.

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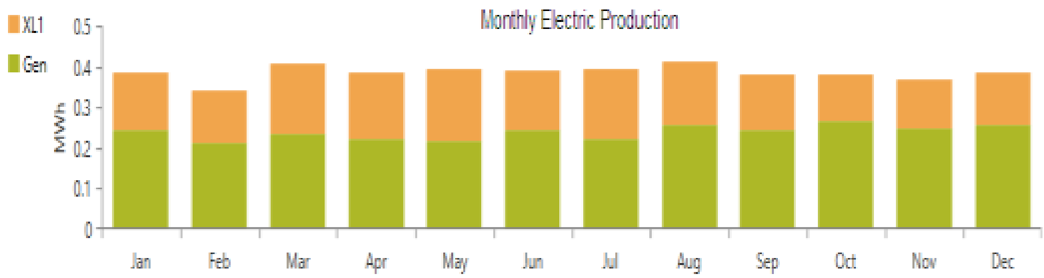

Fig.13. Annual power production by Wind-Diesel-Battery for Ouled said .

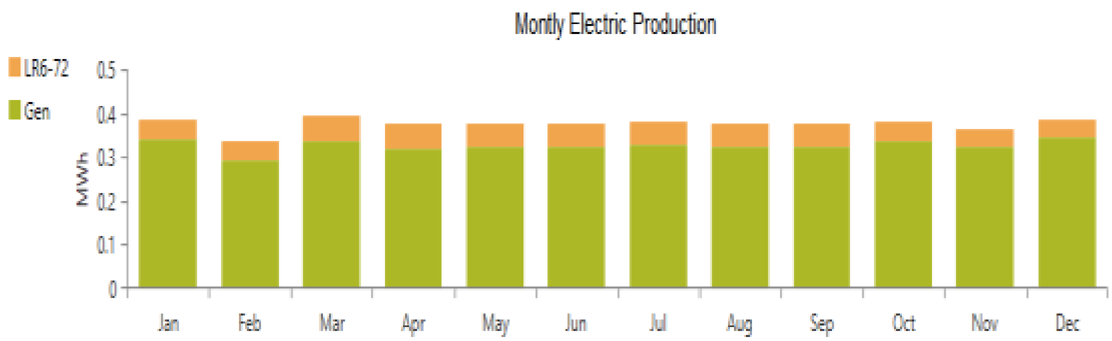

Fig14. Annual power production by PV- Diesel-Battery Ouled said .

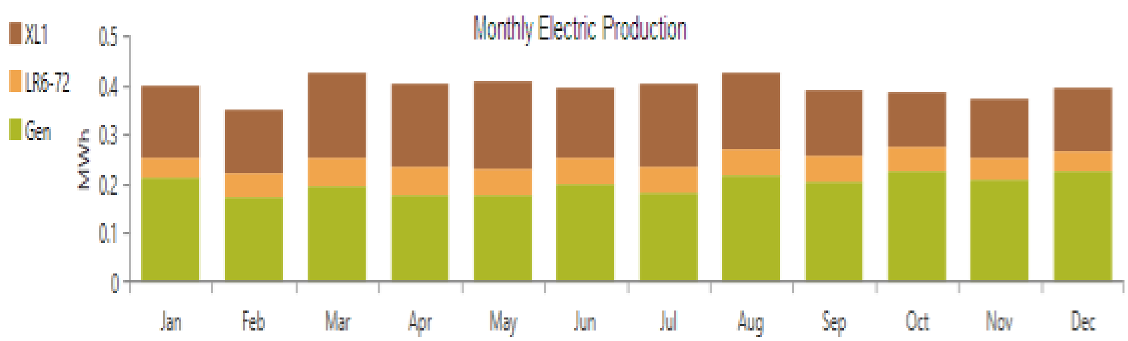

Fig.15. Annual power production by PV-Wind-Diesel-Battery Ouled said.

PONTE
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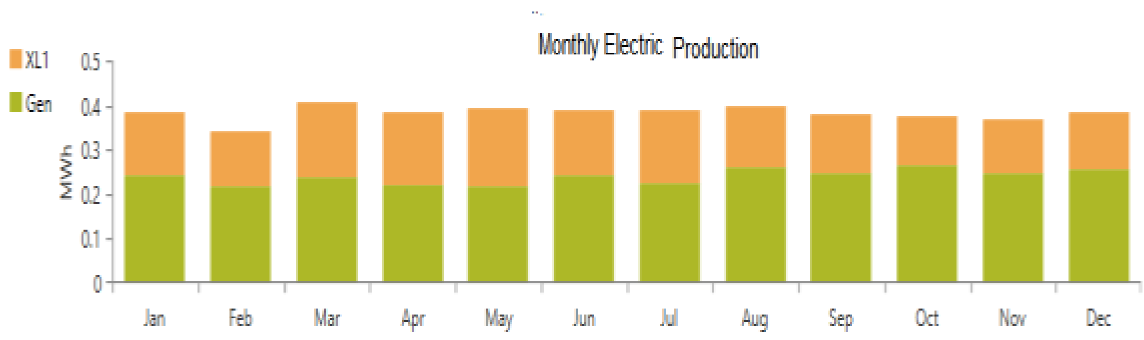

Fig.16. Annual power production by Wind-Diesel-Battery for Talmine.

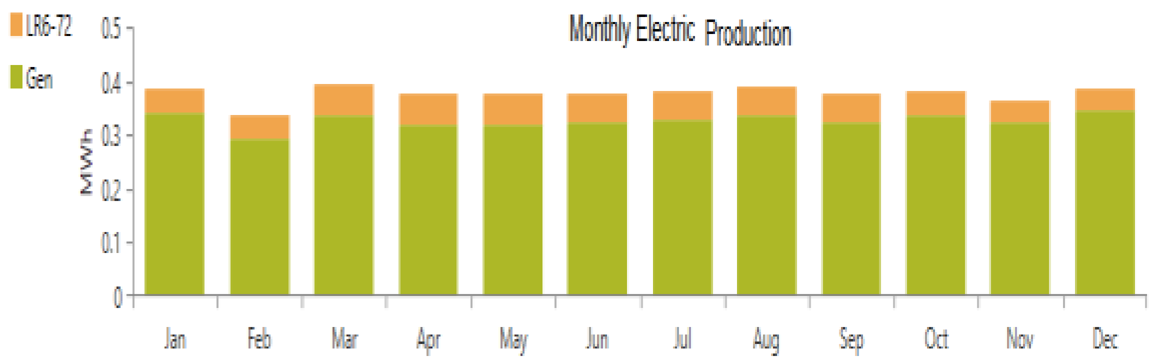

Fig.17. Annual power production by PV- Diesel-Battery Talmine.

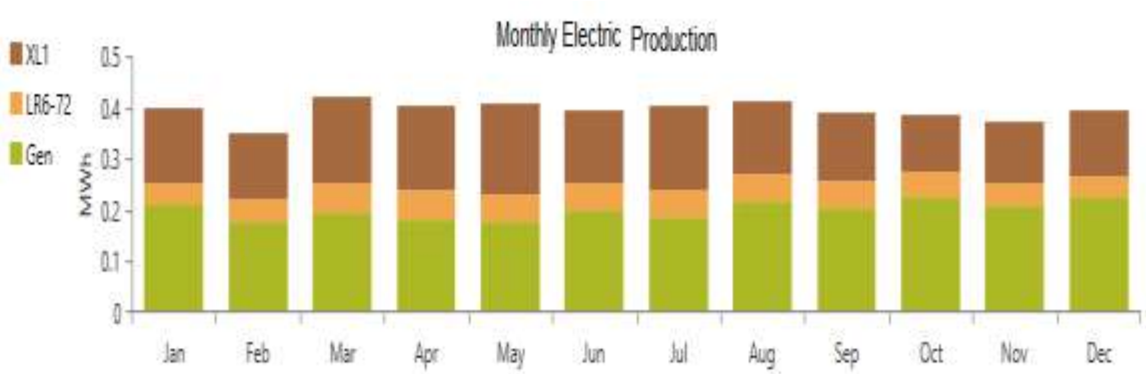

Fig.18. Annual power production by PV-Wind-Diesel-Battery Talmine .

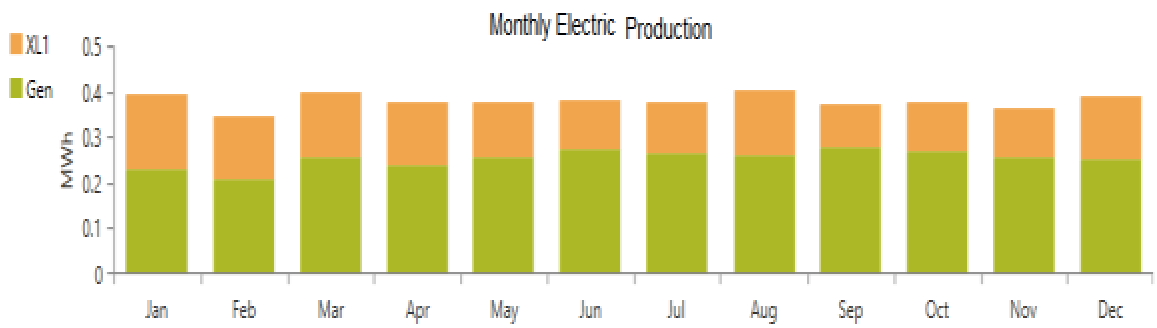

Fig.19. Annual power production by Wind-Diesel-Battery for Timiaouine.

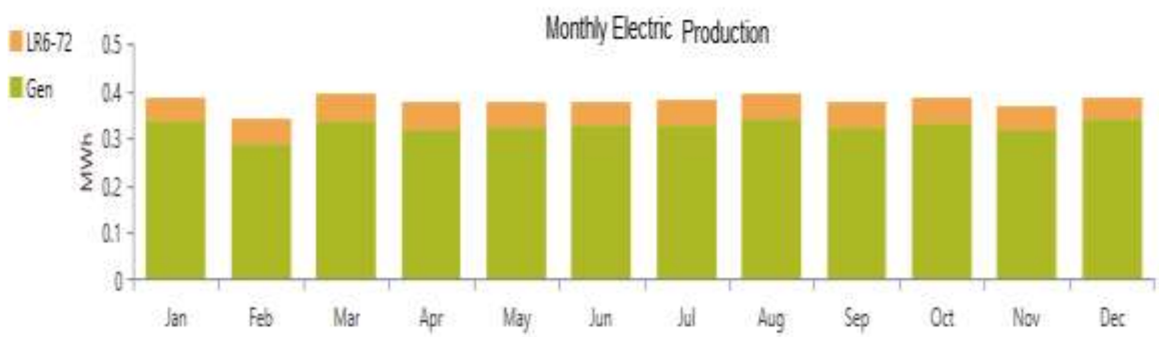

Fig.20. Annual power production by PV- Diesel-Battery Timiaouine.

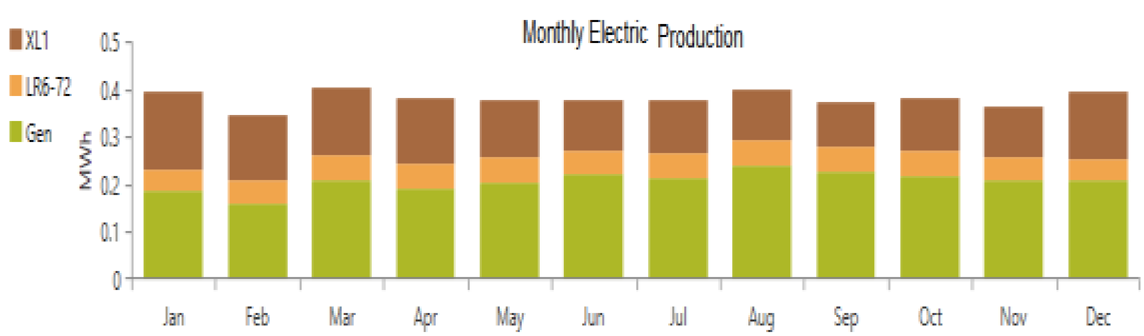

Fig.21. Annual power production by PV-Wind-Diesel-Battery Timiaouine .

Table .2. Comparison of COE and power generation for different Hybrid System

Systems	Total Power Generation(kW h/year)	COE ($/kW h)	City Name
Pv -wind-diesel-battery	4731	0.468	Ouled said
Wind-diesel-battery	4517	0.622	
Pv -diesel-battery	4605	0.640	
Pv -wind-diesel-battery	4721	0.4689	Talmine
Wind-diesel-battery	4600	0.5151	
Pv -diesel-battery	4518	0.6202	
Pv -wind-diesel-battery	4551	0.4914	Timiaouine
Wind-diesel-battery	4537	0.5397	
Pv -diesel-battery	4521	0.6195	

Fig.22. Annual power production by PV-Wind-Diesel-Battery for Ouled said

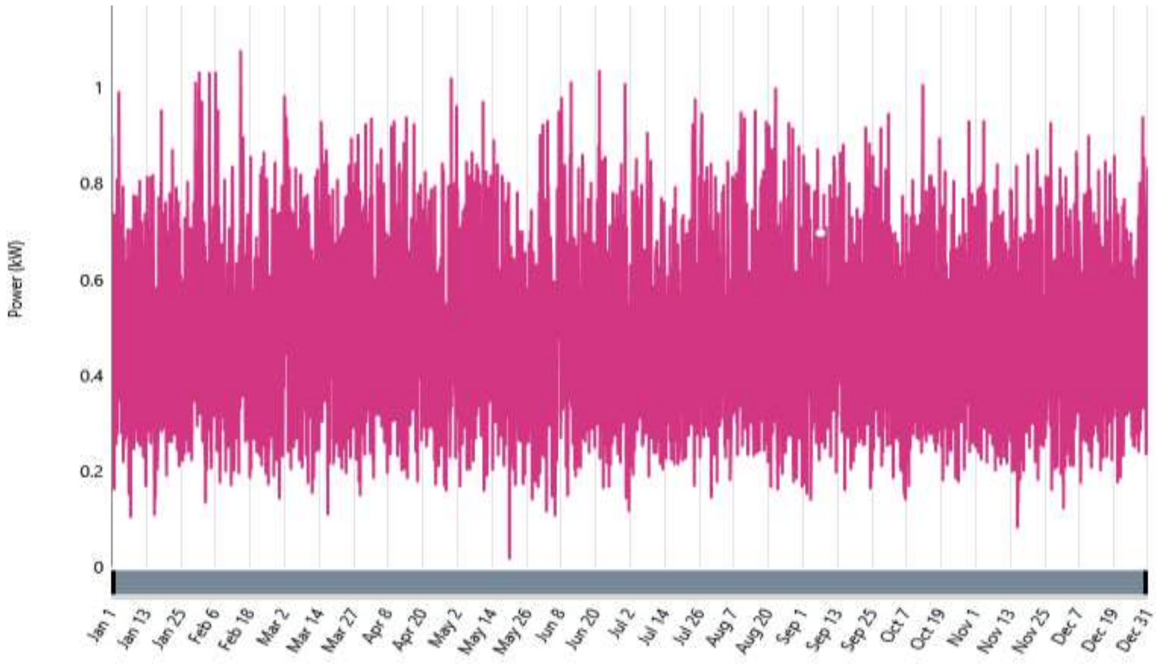

Fig.23. Annual power production by PV-Wind-Diesel-Battery for Talmine

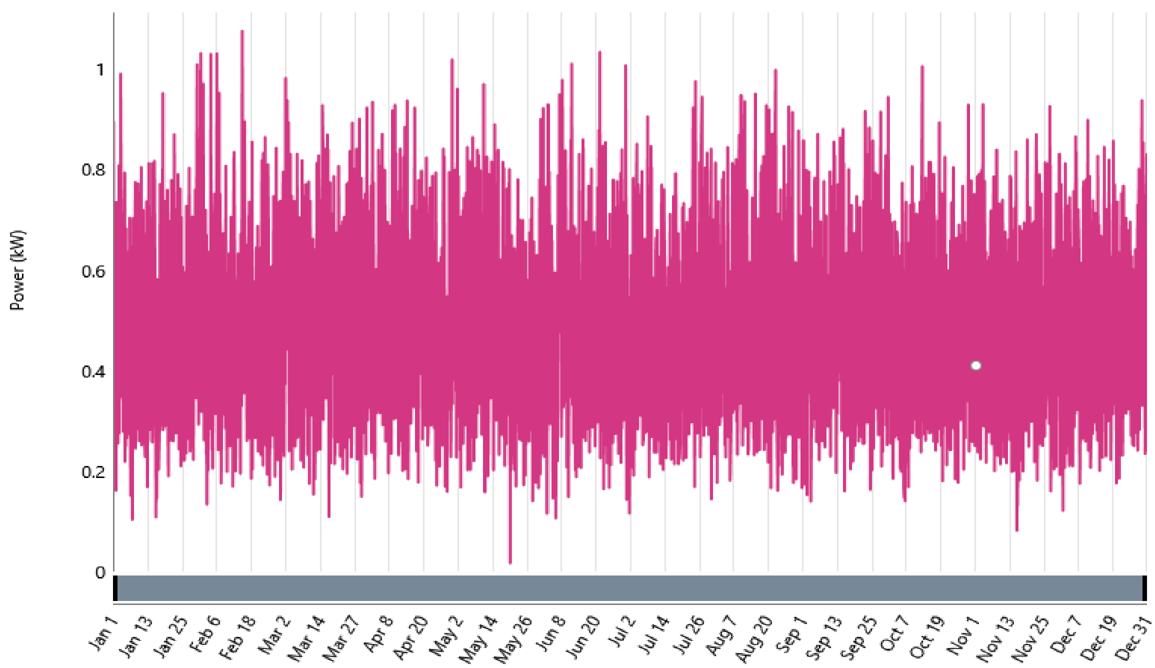

Fig.23. Annual power production by PV-Wind-Diesel-Battery for Timiaouine

5. CONCLUSIONS

In this study different combinations of hybrid systems such as PV-Wind-Diesel-Battery, PV-Diesel-Battery, Wind-Diesel-Battery are used to find most feasible combinations for Ouled said, Talmine and Timiaouine cities of Adrar in Algren . It is found that COE are 0.468 $/kW h for PV-Wind-Diesel-Battery, 0.622 $/kW h for Wind-Diesel-Battery and 0.640 $/kW h for PV-Diesel-Battery in Ouled said ,0.4689$/kW h for PV-Wind-Diesel-Battery, 0.5151 $/kW h for Wind-Diesel-Battery and 0.6202 $/kW h for PV-Diesel-Battery in Talmine and ,0.4914 $/kW h for PV-Wind-Diesel-Battery, 0.5397 $/kW h for Wind-Diesel-Battery and 0.6195 $/kW h for PV-Diesel-Battery in Timiaouine. The COE of PV-Wind-Diesel- Battery is also coming out to be minimum showing this combination can provide the required power. Therefore PV-Wind- Diesel-Battery is found to be most feasible combinations for maximum power generation.

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