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Sizing and Optimization for Hybrid Central in South Algeria Based on Three Different Generators

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ABSTRACT. In this paper, we will size an optimum hybrid central content three different generators, two on renewable energy (solar photovoltaic and wind power) and two nonrenewable (diesel generator and storage system) because the new central generator has started to consider the green power technology in order for best future to the world, this central will use all the green power resource available and distributes energy to a small isolated village in southwest of Algeria named "Timiaouine". The consumption of this village estimated with dWetailed in two season; season low consumption (winter) and high consumption (summer), the hybrid central will be optimized by program Hybrid Optimization Model for Electric Renewable (HOMER PRO), this program will simulate in two configuration, the first with storage system, the second without storage system and in the end the program HOMER PRO will choose the best configuration which is the mixture of both economic and ecologic configurations, this central warrants the energetic continuity of village.

Keywords: : hybrid system, HOMER PRO, renewable energy, solar energy, wind energy, diesel generator.

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1. Introduction

The World Bank and International Energy Agency (IEA) estimated that the world will require a doubling in installed energy capacity over the next 25 years to meet the anticipated demands of developing countries (IEA 2015). In other part, the IEA informed that 1.3 billion people in the world live without access to electricity (IEA 2012), the challenge of reliable and cost-effective services remains one of the major global challenges facing the world in this century. Although grid extension is still the preferred mode of rural electrification (Bhattacharyya 2012), the new technological solutions offered by hybrids generators, even they are very complex compared to current solutions however, they propose considerable interest with their flexible operation and minimize disturbances of the environment and attractive price (Rekioua and al. 2008).

Hybrid Renewable Energy Systems (HRES) are composed of one or more renewable source with or without conventional energy sources, they can work in either stand-alone or grid connected mode (Lazarov VD et al. 2005). Different types of hybrid system combinations are feasible, depending on the need and resource availability at a particular location; however, in the present study, we have focused only on PV–wind based hybrid systems as solar and wind sources are most promising power generating sources due to their complementary nature advantage (Sunanda and Chandel 2015), We can classify HRES by capacity installed, These systems vary form few kW to hundreds of kW, with a capacity less than 5 kW can be treated as the small systems, this kind of systems is generally used to serve the loads of a remotely located home or a telecommunication relay system. Then the systems with the capacity more than 5 kW and less than 100 kW can be treated as the medium systems, these are used to power remotely located

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community which contains several homes and other required amenities. The medium systems in most cases work in stand-alone mode and sometimes may be connected to utility grid, if it is nearby. The other type of the system is able to cover the energy of a region, with the capability of more than 100 kW can be called as the large system. These systems are generally connected to grid, to enable the power exchange between the grid and the system in case of surplus or deficiency (Aeidapu and Kanwarjit 2015).

While HRES use PV and wind energy in stand-alone mode, they can meet the load demand just for the time during which sunshine or cut-in wind speeds are available. Hence, HRES invariably includes backup energy storage systems to meet the load demand at any point of time. The elements of backup energy storage systems are either fuel cell (FC), battery, diesel generator (DG), ultra-capacitor (UC), or a combination of these sources sources (Prabodh and Vaishalee 2012). While batteries are most commonly used for this purpose, they typically lose 1–5% of their energy content per hour and thus can store energy only for short period of time (Nayar 1997). The various possible hybrid system configurations can be designed based on the availability of primary energy sources (PV and/or wind) on site.

Modeling software HOMER (Hybrid energy Optimization Model for Electric Renewables) is utility tool for design and analyzed energy product with hybrid system, composed a diesel generator, solar photovoltaic, wind turbines systems, hydraulic systems, batteries, of fuel cells, biomass and many other sources (Vincent 2011).

The objective of this study is select the best configuration for hybrid central uses all available resources in rural village location to meet the electricity demand. To achieve this objective, on use an example of an rural village in southwest Algeria, estimate the electrical consumption, identify the available renewable resources, size hybrid system and optimized it using HOMER PRO software, select the best option based on the economic and ecologic parameter (initial investment, levilized cost, dioxide carbon, fuel consumption) and technical parameter (annual production, renewable penetration, unmet energy, etc.).

2. System description

HRES are designed by the interconnection of many generators units such as; AC (wind turbine) and DC (solar photovoltaic) energy sources, Storage (battery), AC and DC loads, AC/DC, DC/DC or DC/AC converters. The choice of any configuration depends on technical and economical factors at that location (Mohd et al. 2009, Hossan et al. 2011). In this study hybrid central is composed from: Solar photovoltaic, wind turbine, diesel generator and storage device.

The generators connecting between them are described in Figure 1. Generally, generator of HRES classified on two categories, generator with AC output and generator with DC output (Fig1). In this study, wind turbine and diesel generator classified in AC output and in other side solar photovoltaic and battery put in DC output, the rural village consume just AC output energy, for this an converter reversible has installed to convert DC energy to AC energy, the excess energy produced from renewable source uses for charging battery in case battery has low capacity.

In this work, strategy uses in hybrid central is uses renewable resource to produce energy and cover consumption, when this resource cannot cover consumption, a storage systems (battery) and diesel generator was added to combined with renewable resource and meet energy demand.

This strategy applied by sizing renewable generator (solar photovoltaic and wind turbine) to cover consumption during sunrise to sun set for solar photovoltaic and from wind speed star to wind speed cut for wind turbine with considering an acceptable levilized cost, that mean on use diesel generator just in following cases:

- In the night when no renewable resource or battery can cover consumption.
- In time when we have pic consumption and this happen just in season high consumption, (massive uses of air-conditioner in summer and exactly in the middle of day (11h to 13h) create big pic in load profile).
- Maintenance or system breakdown (solar photovoltaic, wind turbine, battery or converter).

The technical data of HRES is listed in Table 1.

Table1
Description of Timiaouine city

PV array parameter	
Technology	Condor polycrystalline
Capital cost	1100 €/kW
Efficiency	13%
Life time	25 years
Wind turbine	
Technology	GAMESA G52
Capital cost	1.8 M€
Power	850 kW
Hub height	74m
Life time	20 years
Diesel generator	
Capital cost	500 €/kW
Power	1400 kW
Life time	15000 Hours
Battery	
Capital cost	300 €
Capacity	1kWh LA
Nominal voltage	12V
Efficiency	80%
Life time	10 years

Fig 1 describe schematic system configuration uses in this study, system contains from two renewable sources (solar photovoltaic and wind turbine) which are connected with a reserve secondary sources (diesel generator and batteries), a converter is comprised in the hybrid system to connect between DC and AC bus.

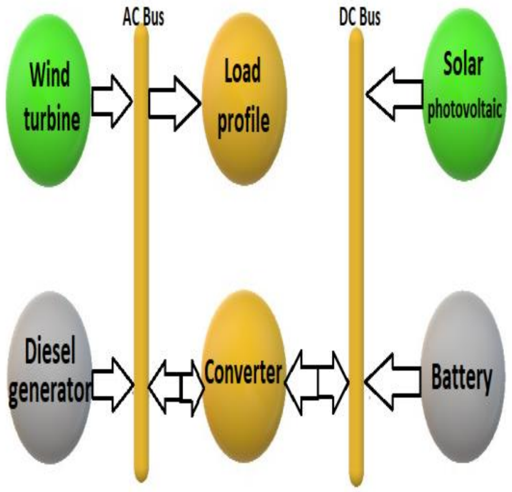

Fig. 1 Hybrid system connection

3. Hybrid central sizing

Luna et al. (2012) presented the correct size method to determine the number of wind turbines, PV panels, number and capacity of battery banks needed for the stand-alone system. If the size of HRES is over loaded the system cost will increase. On the other hand, when HRES are under sizing, the latter can lead to failure in power supply to cover the load requirements. It is important to maintain optimum resource management in a hybrid generation system in order to avoid wrong sizing.

To size a hybrid system in HOMER PRO, we have to follow these steps:

3.1 Load consumption

It's the first step to design and optimized the HRES and it's difficult to doing real analyzed load demand in all minute, at that point hourly or daily averages demand is one from the best generally technique (Sunanda and Chandel 2015).

The HOMER PRO program filed loads according to their type (home, commercial, industrial or city) and proposed model for each type. In our case, the load is consumption of Timiaouine city as detailed in Table 2.

Table2
Description of Timiaouine city

	Numbers installed in the city
House	450
Primary school	4
Secondary School	1
Masjid	1
administrative Centre	3
Polyclinic	1

We will describe in this part just the consumption for houses and schools, because it presents 98% from global consumption of Timiaouine city.

A- Housing consumption

We classified the consumption in two season; a season when consumption is low (winter), and a season when consumption is high (summer). In winter season, we note the most consumption of house is in the refrigerator and light and present 45% from global feeding, the other consumption repartee between the rest devices, the consumption rest low and equal 16.17 kWh (Fig 2.), but in the season high consumption we have the air- conditioner present more than 60% from the global house load, this last added to the daily consumption 46.9 kWh and this what represent in the Fig 3.

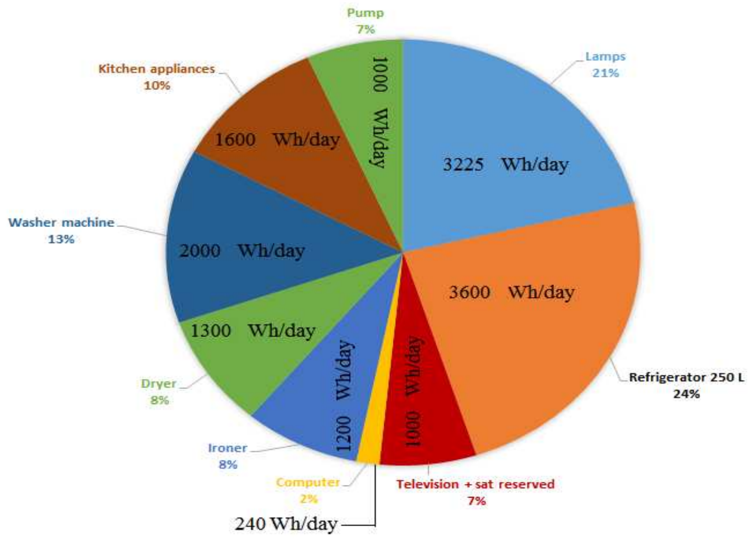

Fig 2. consumption of house in winter

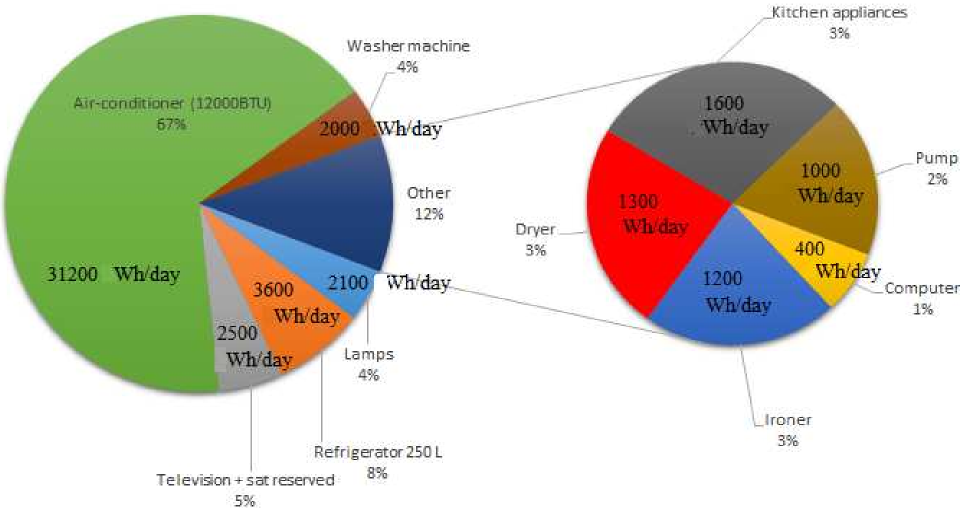

Fig 3: consumption of house in summer

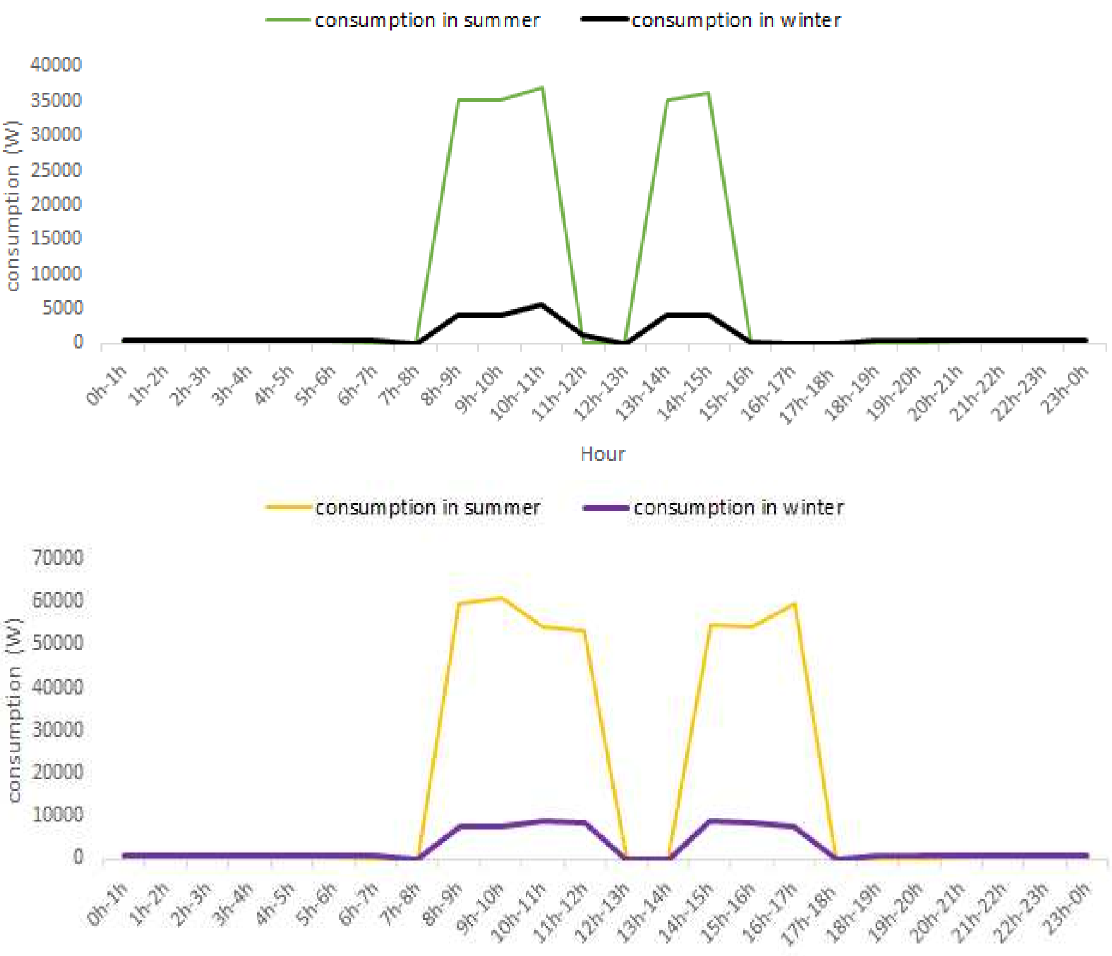

Fig 4. Consumption of primary and secondary school in two season

Table3
Total village consumption

	Number	Winter			Summer			The percentage (%)
		Consumption (Wh)	Global Consumption (Wh)	Global Power (W)	Consumption (Wh)	Global Consumption (Wh)	Global power (W)	
Housing	450	16,165	7,274,250	3,813,750	46,900	21,105,000	4,983,750	93%
Primary school	4	28,230	112,920	27,960	182,625	730,500	152,760	3%
Secondary School	1	67,350	67,350	10,800	403,900	403,900	62,800	2%
Mosque	1	42,225	42,225	5,325	281,225	281,225	44,825	1%
Administrative Centre	3	8,010	24,030	9,990	53,510	160,530	29,490	0.5%
Polyclinic	1	6,405	6,405	1,435	80,040	80,040	10,535	0.5%

B- Primary and secondary school

The figure 4 represents the consumption of primary school with 400 students, the school construct from:
- 20 classroom
- 1 teacher class
- 2 office
- 1 bathroom

The capacity of secondary school is over 900 students, it is composed of:
- 30 classes
- 1 class teachers
- 4 offices
- 2 bathrooms
- 2 laboratories
- computer lab.

The consumption of primary and secondary school concentration in two periods, the first star 8h to 12h and the second between 14h-17h, in this two period the most load consumption is the light in winter season and the air- conditioner in season high consumption.

C- Total consumption

Timiaouine city consumes 7.52 MWh/day in winter (season low consumption) and 23 MWh/day in summer (Table3), We note the communities is representing the greatest consumption in Timiaouine with 93%, the second most consumption is the schools by 5% (secondary and primary), for this reason, we concentrate our load profile for two this highest eating and we don't entre the public light installation because will use the solar light

3.2 Generator sizing

First, we need chose the product generator conventional or renewable and isolated system or connected to the grid. Our system composed from 2 generator renewable (solar and wind turbine) and 2 nonrenewable (diesel generator, battery).

A- Solar photovoltaic:

Meteorological data indicates that Timiaouine city is the most favorable area in the solar number of days, in the light of this information, we size photovoltaic generator for captured the maximum energy also cover the energy demand, the price of 1 kWh, replacement and the cost of maintenance is takes approximately 1100 €, 1100 € and 10 € respectively, the lifetime system is 25 years. Photovoltaic generator is size with 2500 kW capacity, sizing strategy for HOMER PRO required to minimum capacity equal to or less than the peak load. Figures 5 represent the production of annual photovoltaic. We note in Fig. 5 that the solar energy is powerful and can cover some consumption of course in the morning, with a storage system we can supplies the charge in all the time but it is very expensive (27 M€ and 0.413 €/kWh).

B- Wind turbine

In our system, we use two wind turbines of GAMESA mark, type G52 with 850 kW capacity, the cost of this type is 1, 8 M€ and is same for replacement, the maintenance costed 18333 €, Simulation results is present in the Figures 6. The electrical production from wind turbine is not stable and stay low than solar photovoltaic, but it used for minimized carbon dioxide emission.

C- Diesel generator

Generator diesel is used like support in peak load or absence in the renewable generators production (solar or wind). The initial cost to produce 1 kWh is 500 € and the same price for replacement, the maintenance cost is 0.03 €, Finally HOMER PRO size the generator capacity to 1400 kW, lifetime is 15000 hours. Figure7 present the result of this simulation.
Diesel group is used as emergency protection, because it is very hard to make a central totally based on renewable sources, but the usage of batteries and more green energy can reduce emissions when we use the group diesel.

D- Battery

We choose plumb batteries for storage system with 2400 kWh capacity, the power for one battery is 12V, nominal capacity is 83 Ah. Price of 1kWh is the same for replacement 300 € and 10 € for maintenance. Usage of storage system in this central gives two advantages, the first is ecological for reducing the operating time of the diesel generator and it minimizes CO_2 emissions, the second advantage is economic, because we will reduce hydrocarbon consumption and limit the usage of the diesel generator; lifetime extended.

E- Bidirectional converter

Bidirectional Converter takes the role of rectifier and converts alternative current to continue current for charging the battery, and takes the role of inverter when convert current continues (produced from solar panels and battery) to alternative current to feed the load, the capacity of converter is 1650 kW, the cost to product 1 kW is 300 € and the same for replacement, 15 years is your lifetime. We note that the converter works as invertor, because the battery discharges several times, with a performance of 90%, we note the energy loss in both cases (either AC-DC or DC-AC) but it remains low (710 kW/day compared what he produces 6,388 kW/day).

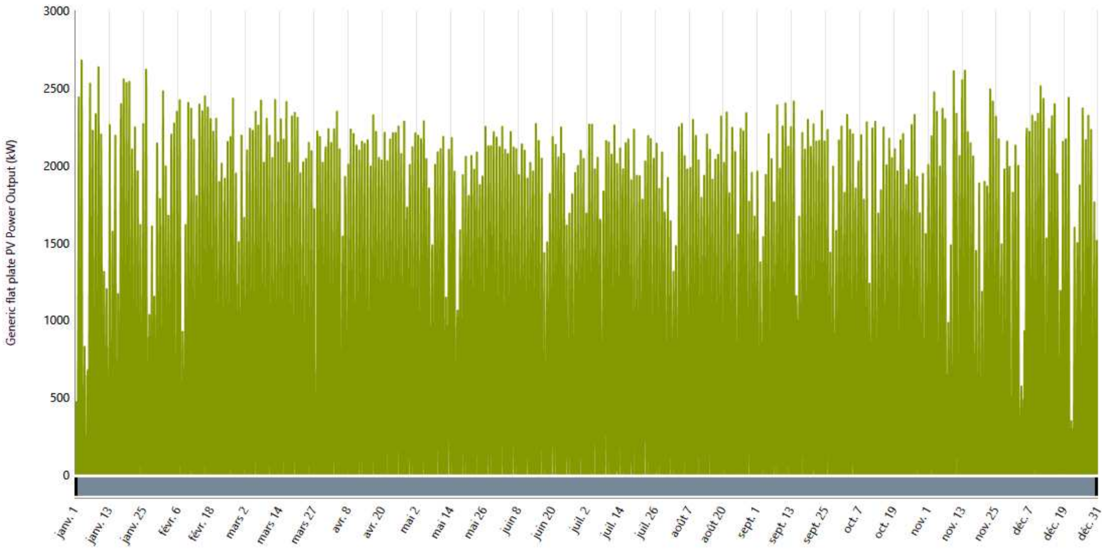

Fig 5. Solar photovoltaic yearly production

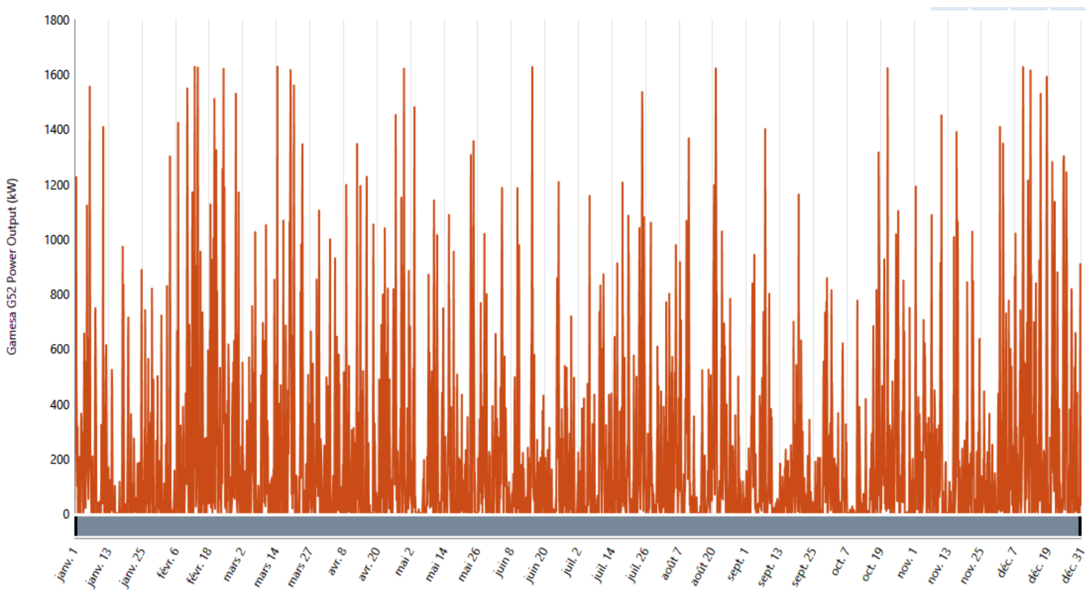

Fig 6. Wind turbine annually production

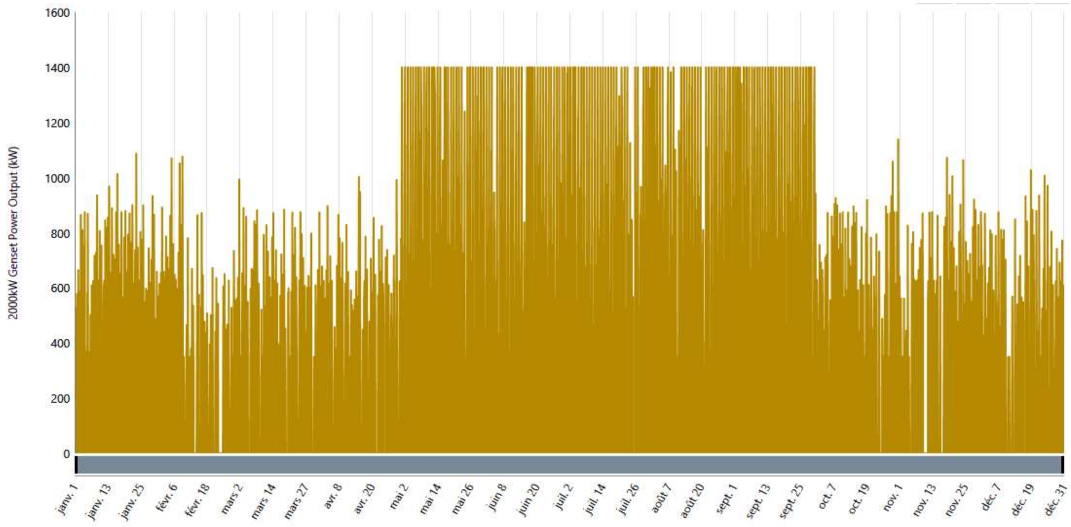

Fig. 7 Diesel generator yearly production

Table4
Weather data take from (RETScreen) program

Month	Air temperature (C°)	Relative humidity (%)	Daily solar radiation horizontal (kWh/m2/d)	Atmospheric pressure (kPa)	Wind speed (m/s)	Earth temperature (C°)
January	17.0	22.7	4.30	96.6	4.8	18.5
February	19.7	17.6	5.39	96.4	4.7	21.7
March	24.2	15.4	6.34	96.1	4.6	26.8
April	28.9	12.9	7.05	95.9	4.6	32.0
May	32.6	13.8	7.45	95.8	4.3	36.0
June	35.0	16.0	7.17	95.8	4.,1	38.7
July	34.3	23.6	7.04	95.,8	4.2	38.1
august	33.3	29.0	6.68	95.9	4.2	37.0
September	32.9	23.6	6.18	95.9	3.9	35.9
October	29.6	18.6	5.50	96.1	4.2	32.1
November	23.9	19.5	4.59	96.3	4.3	25.8
December	18.8	22.3	4.07	96.5	4.6	20.3
Annual	27.6	19.6	5.98	96.1	4.4	30.3
Measured at					10 m	0

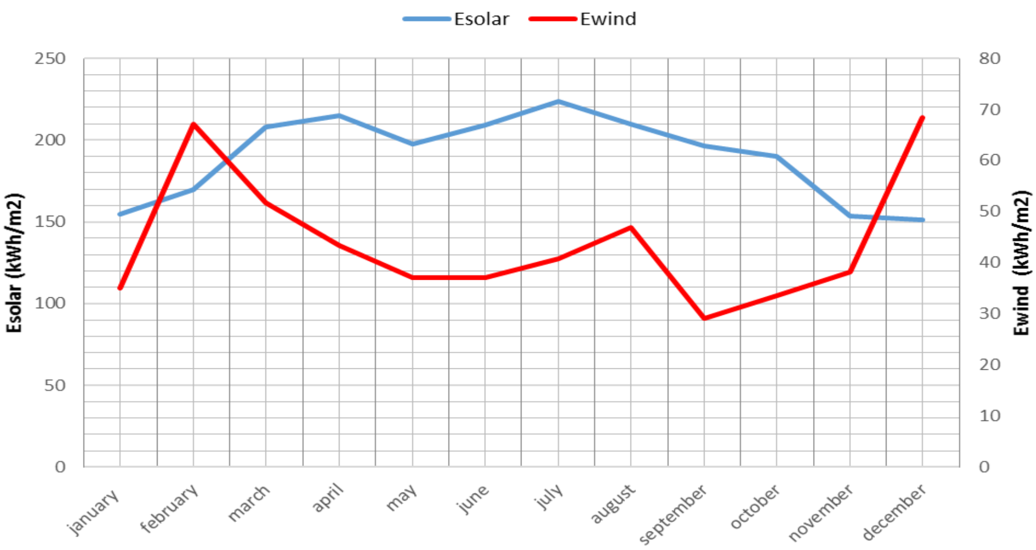

Fig 8. monthly variations for solar and wind potential

3.3 Weather data

The climatic conditions play a major role as the entire power generation is dependent on this. For every different location the weather conditions will be different. So, for a feasibility study or for optimal sizing of the hybrid systems, weather data is a very important tool for analyzing the climatic conditions thoroughly before setting up a plant. Such data is mostly available at the local meteorological stations, for some potential sites the space research agencies like national aeronautics and space administration (NASA) have made the data available through the web resources (Gansler et al. 1994)

HOMER PRO suggests choice to enter weather data, either manually or download from another source. In our case, it was noted that the best method for weather data is to use special programs like RETScreen when it gives results well-detailed compared to HOMER PRO. Table 4 illustrates the weather data taken in 2014 for Timiaouine city, On note in the above figure (Fig.8) the solar potential is more powerful and available compared to the wind energy potential, because the wind speed stays low in the whole year except some months (December, February and march); however, solar radiation takes average values between 4.8 kWh/m^2 and 7.21 kWh/m^2.

4. Optimizations results

4.1 System use battery

After sizing the hybrid central by HOMER PRO, we obtained the following results:

The initial cost for this hybrid system is over 14.4 million euro to produce 1 kWh by 0.220 €, hybrid central product 8,655,708 GWh/year with 5,077,932 GWh consumption per year, 77% produced form energy renewable and 1413.749 t/year CO_2 emissions, next two figure (Fig 9 and 10) illustrate all this result. HOMER PRO search for combinations possible of equipment can obtain for HRES due to different size of PV, diesel generator, DC-AC converter, the number of wind turbines and storage system (Nurul et all. 2010)

After simulation, the software offers many configurations possible for this system, but HOMER PRO proposed three different strategies for the optimization:

- Minimizing cost or economic choice for system economy but with ecological consequences.
- Minimizing hydrocarbons, i.e. based on the maximum renewable sources but with expensive cost.
- Minimizing emissions. This strategy, like the previous, is expensive but will reduce the usage of hydrocarbons and his emissions.

The minimum percentage for renewable energy is a condition we can add to the economic strategy for limiting the usage of hydrocarbons; in our case, we chose 60%. To secure the energy system of Timiaouine town we add another condition in sizing of the central, HOMER PRO will simulate system with a 10% increase in the load, this percentage takes space between the production and consumption, even with the additional annual energy (in our case is 3.58 GWh/year).

4.2 System without battery

The cost of investment for this system is 22 million euro with 0.336 €/kWh, the central production 10.63 GWh/year, 72% of this energy from renewable energy. To choose the best system either with or without storage, we compare between these two systems refering to three principles:

1- Economic: initial cost for investment and the price to produce 1kWh.
2- Ecological: CO_2 emissions and annual hydrocarbons consumption.
3- Energy: system security.

We summarize all these principles in Table 5.

Table 5
Comparison between system with and without battery.

	Without battery	**With battery**
Initial cost (M €)	22	14.4
price for 1 kWh (€)	0.336	0.220
Emissions CO2 (t/year)	2,226.01	1,413.74
Diesel consumption (L/year)	860,515	536,867

After this comparison, we note the system that uses battery as a storage system is more efficient and produces clean energy compared with the no storage system, even the cost of the battery is very expensive, but it minimizes the use of diesel generator when there is absence in the renewable generators production (solar and wind).

At the end, the storage system is necessary for hybrid system, either with or without the use of conventional source to guarantee feeding the charge in all situation (climatic or energetic).

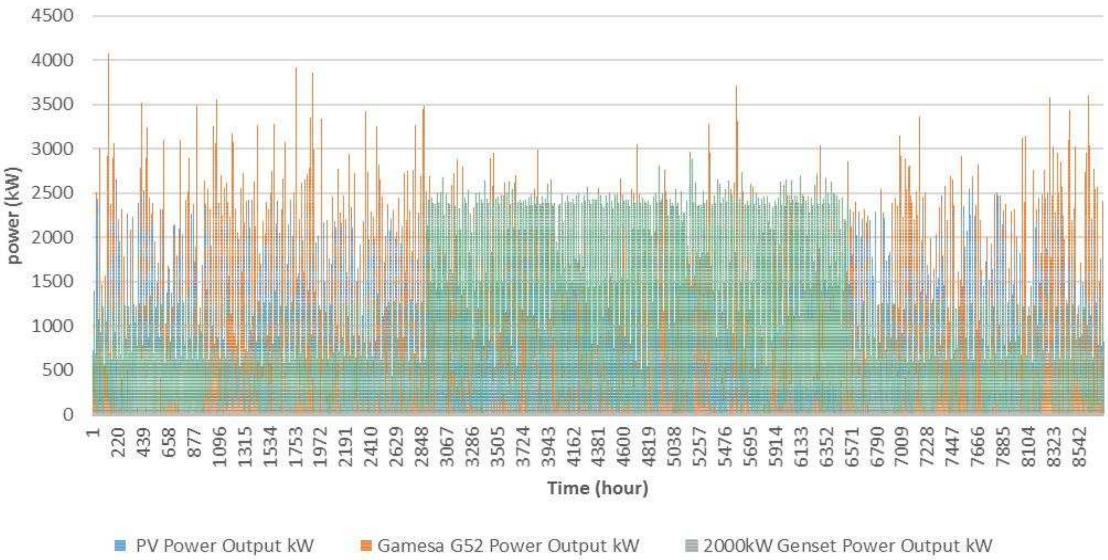

Fig 9. Annual production for hybrid central based on three generator

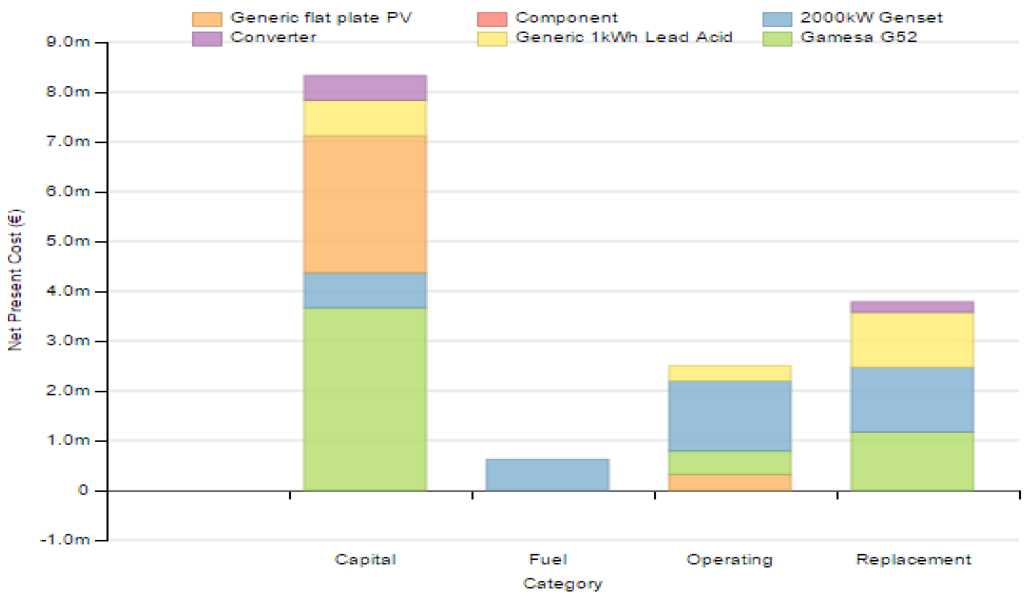

Fig 10. Cash flow summary based on the selected components

5. Conclusion

Our research has presented optimal sizing and configuration ecologic before economic for hybrid central using program HOMER PRO. This central uses all renewable resources available in southwestern Algeria.

The best configuration ecological and economical suggestion by HOMER PRO is the usage of 2,500 kW solar photovoltaic energy, two wind turbines, 1,400 kW diesel generator and 2,400 kW storage system (battery), the hybrid central based on renewable energy more than 83%, the total cost is14.4 million-euro with cost of energy (COE) 0.220 €/kWh, this result is less than (Sureshkumar et al. 2012) when he uses solar PV, wind turbine and batteries with 0.247€/kWh and fewer than (Rohit and Subhes 2014) when used solar PV, bio diesel, hydropower and batteries with 0.442 €/kWh.

From other part, we choose the system used battery because it minimizes hydrocarbon consumption and the global cost of system.

References

Aeidapu, M., Kanwarjit, S. (2015) Hybrid wind/photovoltaic energy system developments: Critical review and findings. Renewable and Sustainable Energy Reviews, 52, 1135–1147

Bhattacharyya, S.C. (2012). Energy access programs and sustainable development: a critical review andSS analysis. Energy for Sustainable Development 16(3),260e71.

Gansler R. A, Klein S.A, Beckman, W.A. (1994). Assessment of the accuracy of generated meteorological data for use in solar energy simulation studies. Sol Energy,53(3),279–87.

Hossan, M.S., Hossain, M.M., A.Haque,A. (2011). Optimization and modeling of a hybrid energy system for off-grid electrification. IEEE International Conference on Environment and Electrical Engineering, pp.1-4, 2011.

IEA International Energy Agency (2012) World Energy Outlook Executive Summary English version ⟨http://www.iea.org/publications/freepublications/publication/name,33339⟩; 2012.

IEA International Energy Agency (2015) World Energy Outlook Executive Summary English version (https://www.iea.org/Textbase/npsum/WEO2015SUM.pdf)

Lazarov, V.D., Notton, G., Zarkov, Z., Bochev, I. (2005). Hybrid power systems with renewable energy sources types, structures, trends for research and development.In: Proc of International Conference ELMA. p. 515–20.

Luna-Rubio, R., Trejo-Pereab, M., Vargas-Vázquez, D., Ríos-Moreno, G.J. (2012) Optimal sizing of renewable hybrids energy systems: a review of methodologies. Solar Energy 86,1077–88

Mohd.A, Ortjohann.E, W.Sinsukthavorn (2009). Supervisory control and energy management of an inverter-based modular smart grid. IEEE PES Power Systems Conference and Exposition, pp.1-6, 2009.

Nayar CV (1997) Standalone wind/diesel/battery hybrid energy systems. Wind Energy, 21(1),13–9.

Nurul, A.,A.R., Murtadha, M,O, Musir, I. (2010). Optimal Sizing and Operational Strategy of Hybrid Renewable Energy System Using HOMER, The 4th International Power Engineering and Optimization Conférence/ MALAYSIA: 23-24 June 2010

Prabodh, B., Vaishalee, D. (2012) Hybrid renewable energy systems for power generation in stand-alone applications: A review. Renewable and Sustainable Energy Reviews,16, 2926–2939

Rekioua, D., Roumila, Z., Rekioua, T. (2008) Etude d'une centrale hybride photovoltaïque- éolien – diesel Revue des Energies Renouvelables, 11 N°4

Sen, R., Bhattacharyya,S.C. (2014). Off-grid electricity generation with renewable energy technologies in India: An application of HOMER, Renewable Energy, 62, 388e398

Sunanda, S., Chandel, S.S. (2015) Review of recent trends in optimization techniques for solar photovoltaic–wind based hybrid energy systems. Renewable and Sustainable Energy Reviews, 50, 755–769

Sureshkumar, U., Manoharan, A., Ramalakshmi, A.P.S. (2012). Economic Cost Analysis of Hybrid Renewable Energy System using HOMER, IEEE- International Conference On Advances In Engineering, Science And Management (ICAESM -2012) March 30, 31, 2012

Vincent, D.(2011). Dimensionnement d'un système hybride photovoltaïque,groupe électrogène avec le logiciel HOMER