FEASIBILITY STUDY FOR THE PRODUCTION OF ELECTRICITY USING A HYBRID PV-WIND-GENERATOR SYSTEM IN A REMOTE AREA IN COMOROS

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ABSTRACT

We present in this work a configuration of a hybrid system for the mix energy for electrification of rural area in Comoros, with renewable energy source combined with generator energy system. The system studied is composed of photovoltaic cells, a wind coupled with a generator with batteries for the storage. The use of photovoltaic energy in rural areas is undoubtedly of great advantage, because of its ease of implementation and the little maintenance it requires. But, know that one Watt delivered by photovoltaic is quite expensive for medium and high power compared to other energy sources. Thus, engineers and experts in the field have been led to couple several energy systems (wind, solar, diesel), in order to make the input variables less a priori and to seek optimization of the storage. Such combinations of energy sources are referred to as hybrid systems. In this work, the performances of the wind-photovoltaic system are presented, as well as the complementarities of these different energy sources. This work allowed us to demonstrate that the combination of different sources of wind-photovoltaic-diesel energy generates a considerable profit, such as the reduction of capital investment on the system.

Our objective is to bring about a significant improvement in the energy system from the point of view of energy, reliability or limitation of the storage part, which is prone to inevitable problems. Indeed, the main objective of this work is to reduce the overall cost of the installations, by optimizing their operation by using possibly auxiliary generators. The results show that wind/diesel generator combination system appears as a feasible solution and is more profitable margins of economic cost with a less expensive investment than in the other cases studied. The results obtained have better optimization of the hybrid system used.

Keywords: *Photovoltaic array; wind energy; diesel generator; hybrid system; rural area; energy autonomy; meteorological data; Comoros.*

1. INTRODUCTION

The use of renewable energy resources has become essential owing to rapid population growth, global warming, increasing in soil and water pollutions, shortage of electrical power for several millions people in the world, depleting in fossil fuel resources, and increasing in oil price. Photovoltaic energy is non-deployable, no-polluting, site-dependent, and potential source for alternative energy options. Moreover, utility grid extension to remote areas is impractical owing to harsh terrain or dispersed population. Renewable energies combined such as solar and wind energy is becoming increasingly attractive and is being widely used for substitution of oil-produced energy, and eventually to reduce air pollution. Since the oil crises of the early 1970s, utilization of solar and wind power has been increasingly significant, attractive and cost-effective. Indeed, many countries, with average wind speeds in the range of (5 to 10 m/s) are pursuing the option of wind energy conversion systems, in an effort to minimize their dependence on fossil-based non-renewable fuels [1-3]. It is important to state that the use of solar energy in rural regions will protect these areas from pollution, since the use of solar home systems avoids large amounts of CO_2 emissions. In the literature several research works have been done by using computational method for the hybrid system components size and cost optimization according to the load demand and the energy resources available from the sites. Indeed, economic analysis of hybrid power system for rural electrification in Oman has been conducted by Abdullah and Hadj Bourdoucen [4]. Their paper presents a feasibility study of wind penetration into an existing diesel power plant of an isolated Duqum area in the Sultanate of Oman. Wind data from Al Duqm meteorology station and the actual load data from Duqum have been used in the simulation model. HOMER software has been used by authors to perform their study for the hybrid system with no battery storage. For Wind speed less than 5m/s the existing diesel plant seems to be the only feasible solution over the range of fuel prices used in the simulation. Their results show that, the proposed hybrid system becomes feasible at wind speeds up to 6 m/s and a diesel cost of 0.368 US $/L or more, which is the current diesel cost in Duqm. Elhadidy [5] has shown that standalone wind energy system does not produce usable energy for considerable portion of time during the year due to relatively high cut-in wind speed, which range from 3.5 to 4.5 m/s. Kanzumba and Herman [6] have proposed an approach for optimal operation control of a hybrid multisource system with the aim of meeting the load energy requirement with reliability and minimized life cycle costs. Their results were limited at the problem formulation and the development of the mathematical model for the performance of all the hybrid system's components. Theirs principal results show that the developed model's decision variables can then be optimized using any suitable advanced algorithm in such a way to minimize life-cycle costs object while satisfying demand. Simulation and optimization of stand-alone hybrid renewable energy systems was conducted by José and Rodolfo [7]. The aim of their study is to revise the simulation and optimization techniques, as well as existing tools needed to simulate and design stand-alone hybrid system for electricity generation. The authors show that the most frequent systems are those consisting of a PV generator and/or wind turbines and/or diesel generator, with energy storage in lead-acid batteries. They point out that stand-alone electric generation hybrid systems are generally more suitable then systems that only have one energy sources for the electricity supply to off-grid applications especially in remote areas with difficult access.

The combination of several renewable energy sources makes it possible to optimize of electricity production, both from a technical and an economic point of view. There are several combinations of hybrid systems, namely: wind-diesel [8-10], photovoltaic-diesel [11], and wind-photovoltaic-diesel [12-14]. These same sources of energy can be combined with other sources such as hydraulic energy [15]. Evaluation methods for hybrid systems Wind and photovoltaic systems and their advantages have developed considerably in recent years. Optimization of wind and photovoltaic energy with electrochemical storage solution, in particular the use of hydrogen [16] which gives much more autonomy of batteries), with or without diesel fuel, is highly dependent on economic models of each system taken separately (wind and photovoltaic). Software has been developed in the laboratory to evaluate the optimal dimensioning of each subsystem such as HOMER. Ajao et al. [17] has conducted a study on the cost of installation of a hybrid wind / solar PV system for power supply. There results show that the hybrid system is not economically profitable. The authors specify that the recovery time of the system was thirty-three years. If the cost of investment per kilowatt has been reduced due to the installation of several model of this hybrid system on a farm wind-solar hybrid system would be profitable. They have shown that its availability, durability and user-friendliness make it a desirable source of energy reserve. An analysis of a photovoltaic system for supplying electricity to a renewable energy laboratory was done by Salam et al. [18] using the HOMER software. The results obtained by the authors from the optimization of the system give the initial capital cost at US $ 13,500, while the operating cost is US $ 817 / year. Total NPC system is US $ 23,939, and the COE is US $ 1,354 /kWh. The authors showed that the performance of the photovoltaic system depends on the daily global radiation as well as the clearness index.

Recently, Waeli et al. [19] conducted a study on the use of a PV / Generator hybrid system for the pumping of water from remote areas to farmers in the Sultanate of Oman. A comparative study between PV and generator presents a techno-economic solution in environmental for the two sources of energies. Their results show that pumping water with PV as an energy source is more cost effective for Oman than for the diesel generator with a very high system lifetime with o carbon emission. They subsequently showed an optimization of the cost of electricity which is $ 0.4743 / kWh for a PV system while it is $ 0.6092 / kWh for a diesel generator.

The main purpose of this study is to analyze the economic feasibility of a hybrid diesel/PV/wind power plant supplying energy system to a remote area in order to reduce fuel consumption and environmental pollution. Village requirements are filled with diesel power system load. The focus was on saving and reducing the percentage of fuel carbon emissions for reduction in greenhouse gas emissions to fight against climate change but also reduce electricity cost system for energy autonomy.

2. ANALYSIS AND MODELLING

2.1. Hybrid energy system component

Hybrid system energy system consists of a primary renewable resource energy working in parallel with a non-renewable energy sources like diesel generator or others. In fact, figure 1 presents a general scheme of a stand-alone power generation system. In the other hand, we have presented in the figure 2 the equivalent circuit diagram of hybrid system while in the figure 3 we show the scheme established by MOHER software tool. Our proposed hybrid system is composed of a diesel generator, a solar PV system array, a wind energy resource, a battery storage system, an inverter on which will convert the DC power stored in the battery tank to AC at a standard level of voltage and frequency and then supply it to the load. A configuration with a parallel hybrid system (Figure 3) composed by the diesel generator and renewable energy system supply a portion of the load demand directly. In fact, this type of system uses generally a bi-directional inverter, which is operated in parallel with the diesel generator and can act as an inverter and rectifier/battery charger. The parallel hybrid power system as shown in figure 3 is a DC coupling configuration where the renewable energy and generator are connected to a battery bank through the DC bus and supply AC load through the bi-directional inverter. The functional schemes of the system's different components in terms of energy are presented below [20]:

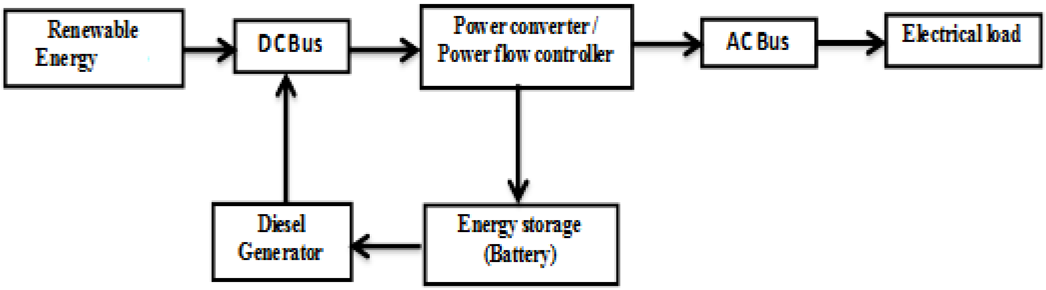

Figure 1. General diagram of a stand power system -alone hybrid

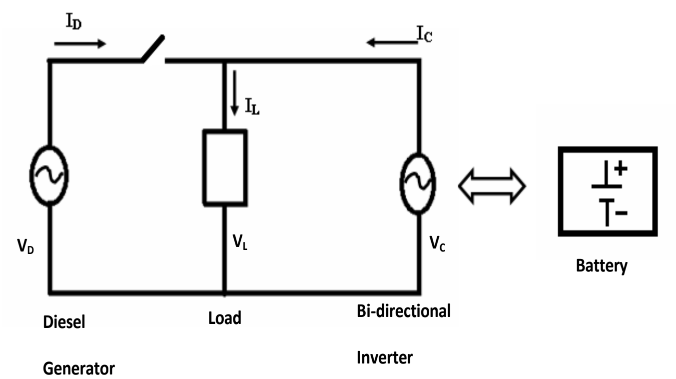

Figure 2. Equivalent circuit diagram of hybrid system

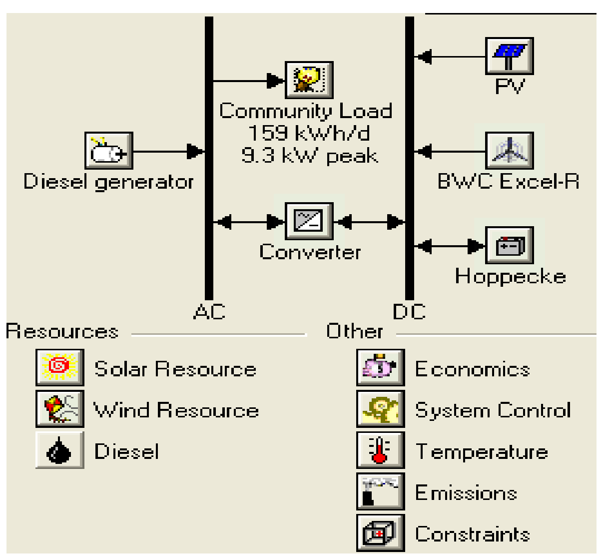

Figure 3. Homer implementation of the hybrid energy system

2.2. Location of study

The rural village where this study was conducted is Koua Mitsamiouli, a small area located in the Northern of Ngazidja in the -11°40' South latitude and 43°33' EST Longitude, an area in the *Mayor of Sada Djoulamlima*.

Villagers consume water tanks and have no permanent access of electrical energy caused by le problem of electricity in the national society producer of energy said (MAMWE). Indeed, in remote rural village, the electricity demand use is not the same as in urban areas. Electricity in rural village is demanded for domestic activities as (refrigerator, radio, television, computer, charging phone, compact fluorescent lamps, ceiling fans, table fans…etc.), community activities (marriage, agriculture activities, schools, mosques, radiao centers and television, youth hostels and cultural complex, pumping of water in tanks and medical center). It's used again for rural commercial and small-scale industrial activities (such as fish and meat cold storage, food products and cottage industries).

Table 1. The daily load energy requirement for family in house rural area for town hall

Load type	Unit	Load power (W)	On-time (h)	Energy/day (Wh/d)
Iron	1	3000	1	3000
Lamps	5	40	6	1200
Refrigerator	1	40	24	960
Freezer	1	40	24	960
TV	1	50	8	400
DVD player	1	40	6	240
Computer	1	50	3	150
Radio	1	30	3	90
Laptop	1	20	3	60
Total energy/day(wh/d)				7060

Table 1 presents the average electricity requirements for each family in the municipality. Indeed, typical day energy consumption is higher in the evening hours. On the other hand, summer months (Jun to September) are an elevated power demand because of the wedding activities combined with holidays in Comoros. In this period one reaches the peaks of consumption of electricity.

2.3. Renewable resources

For this study, wind and solar energy resources *Sada Djoulamlima* municipality are considered. Sensitivity analysis is done to make the results suitable for other places in the municipality.

2.4. Wind speed analysis

The monthly average wind speeds for the North of Ngazidja are plotted in figure 4. Wind speeds are higher in part of the summer months as shown in this plot (April-May and August to November) and the peak is pronounced on October. This clearly reflects that turbine wind would produce appreciably more energy during the summer months as compared to other months. The overall average wind speed is 5.71 m/s. In fact, the data also show that there is considerable variation of monthly average wind speed from one month to another month. These variations demonstrate how the monthly energy output from wind energy conversion system could be subjected to considerable differences. Time step is set at 60 mn, altitude above the sea level is 60m with an anemometer height of 10 m for 15 hour of peak wind speed. Figure 5 presents the frequency distribution hourly of wind speed at Ngazidja in Comoros. The potential of the study site in rural areas was evaluated from this frequency distribution hourly wind speed. It can be seen that wind speeds are above 5m / s at around 70% of the time during the year, which shows that wind energy will produce about 70% of the total output of the hybrid system of the time. Even if the diesel generator does not work but the energy produced by the wind is largely enough to cover the power load supply of the community.

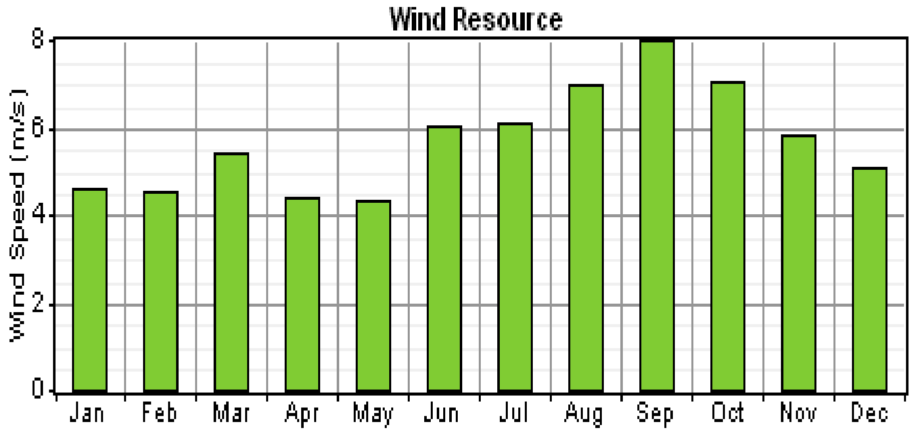

Figure 4. Average monthly wind at Ngazidja, Comoros.

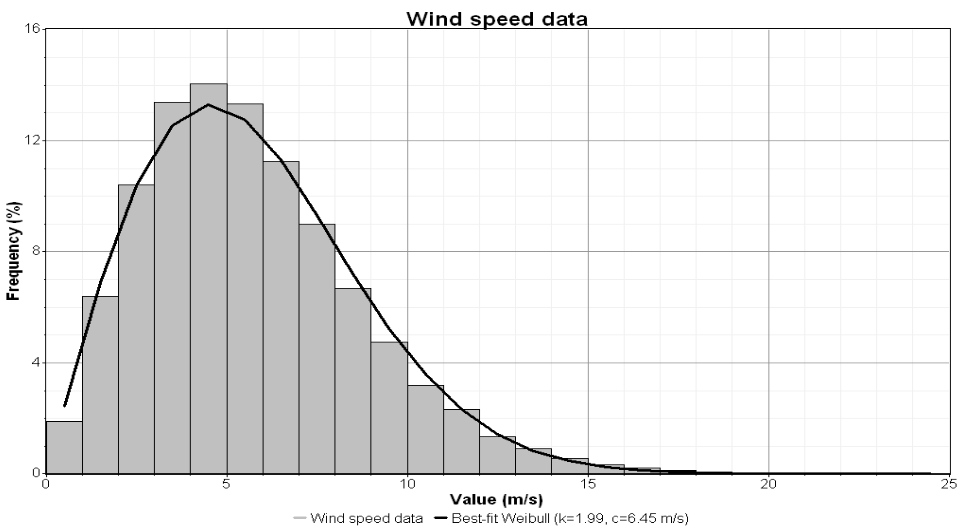

Figure 5. Frequency distribution hourly wind speed

2.5. Solar energy resources

The monthly average global solar radiation for Comoros is also presented in figure 6. It is evident that insolation level is high during five months (August to December) as compared to other months. The annual average monthly value of the solar radiation is 0.23 kWh/m^2. Previous study in the literature shows that the variation between the years is minimal [21]. In the wake of the small variations, 2014 data from meteorological agency from Comoros have been used for solar energy calculations. The energy calculations are made by combining the hourly solar radiation data with a given PV array area.

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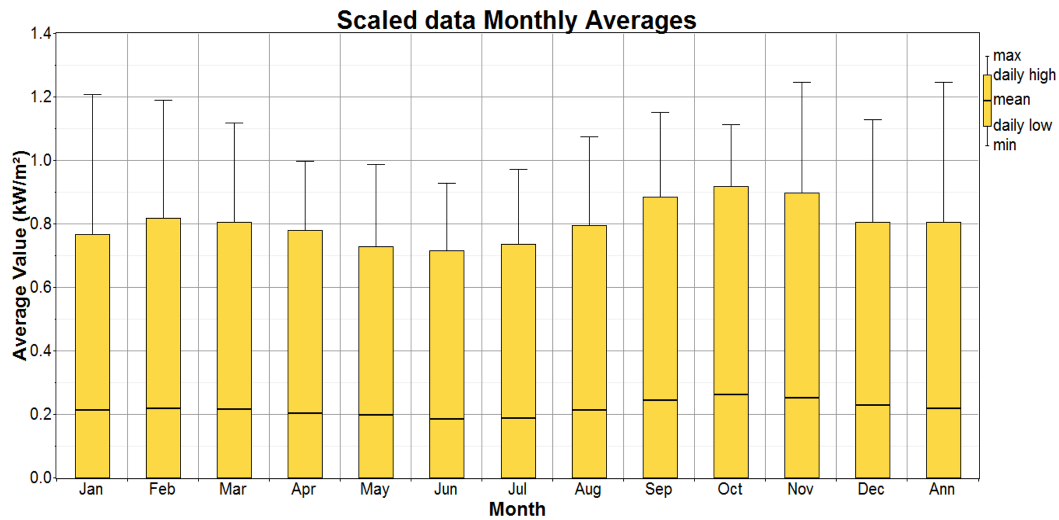


Figure 6. Monthly average global radiation at Comoros 2014

3. HYBRID SYSTEM COMPONENT

The energy system consists of a diesel generator, a wind turbine, a photovoltaic module, a storage battery and a power converter. The number of units to be taken into account, the cost, the hours of operation must be declared in the HOMER software for each of these components. In fact, the details of these components are explained in the following parts.

3.1. Diesel generator

Diesel generator cost available in the market is about \$500/kW [22]. Indeed, knowing that peak power demand is less than 10 kW, in this study, the cost of the diesel generator is taken equal to 400 \$ / kW. Replacement and maintenance costs are assumed to be \$ 450 / kW and \$ 0.50 / hr respectively (Figure 7) and were used in the HOMER simulation [23]. Diesel price is used as a sensitivity analysis for three values (0.8, 0.96, and 1.2 \$/L). In the Comoros, diesel price is around 0.96\$/L and for a very remote rural area this price could increase up to 1.2\$/L. Nine different sizes of the diesel generator (0, 5, 10, 15, 20, 25, 30, 35 and 40kW) were considered in the model.

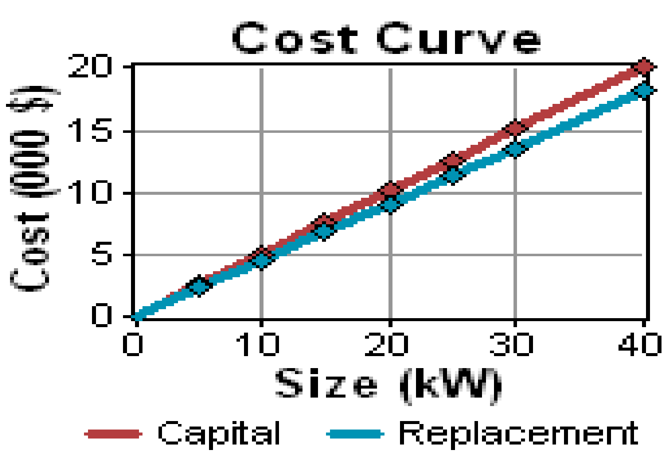


Figure 7. Diesel generator cost curves

3.2. Photovoltaic array

Nowadays, in the literature, the installation cost of PV arrays is set from $5.00 to $8.00/W [22-24]. If optimistic case is considered [25], 1kW solar energy system's installation, and replacement costs are taken as $3000 and $2900, respectively (Figure 8). Seven different sizes are considered, which are (0, no PV module, 10, 20, 30, 40, 50 and 60 kW). The lifetime of the PV arrays are taken as 20 years and no tracking system is included in the PV system.

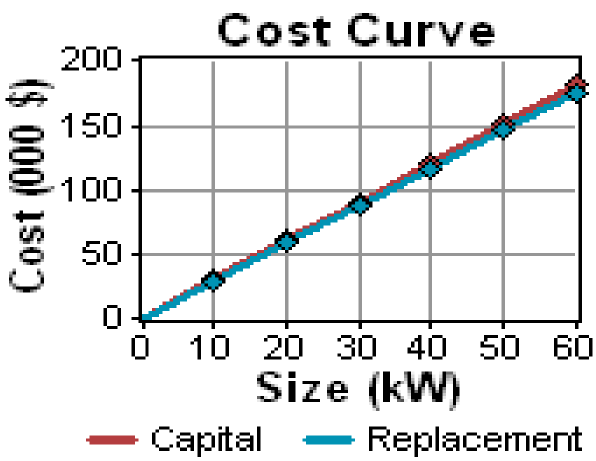
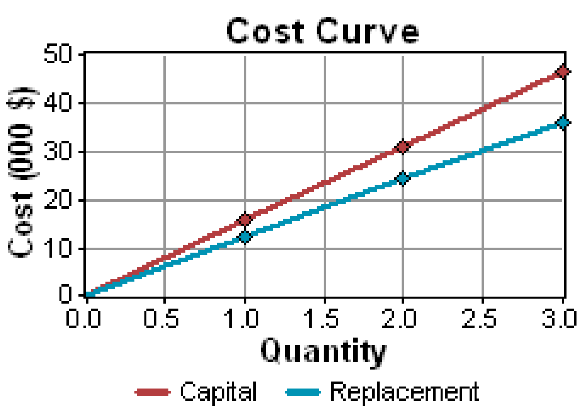


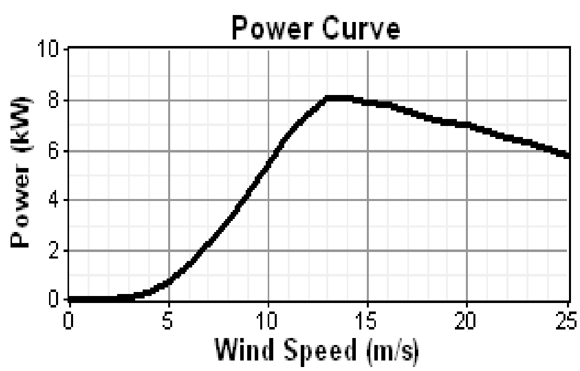
Figure 8. Cost of photovoltaic units

3.3. Wind energy conversion system

The variation of the wind speed gives us an idea about the wind turbine capacity energy that could be produced. Therefore, the wind turbine index is generally much higher compared to the average electrical load. In this study the model BWC Excel-R, was considered. It has a rated power of 7.5 kW. The cost of a unit is estimated at $ 15,500 while replacement and maintenance costs are taken in $ 12,000 and $ 70 per year. Indeed, to allow the simulation program to check optimization solution, four different sizes were considered (0, no turbine, 1, 2 or 3 units) figure 9a with a lifetime turbine wind of 20 years and hub height is 25m. In this paper, 8Kw from BWC Excel-R is used. The wind power for this turbine wind is presented in figure 9b.



(a)



(b)

Figure 9. Turbine wind BWC Excel-R (a) Cost curves (b) wind power curve

3.4. Battery storage

Conventional batteries are included in this analysis. Hoppeche 10 OPzs 100 models were considered in this study (6 V, 350 Ah and 21 kW h). One battery cost is setting at $850 with a replacement cost of $840 (Figure 10). 24 strings were considered for five (0, no battery, 2, 4, 8, or 12) possibilities with 24 batteries per strings.

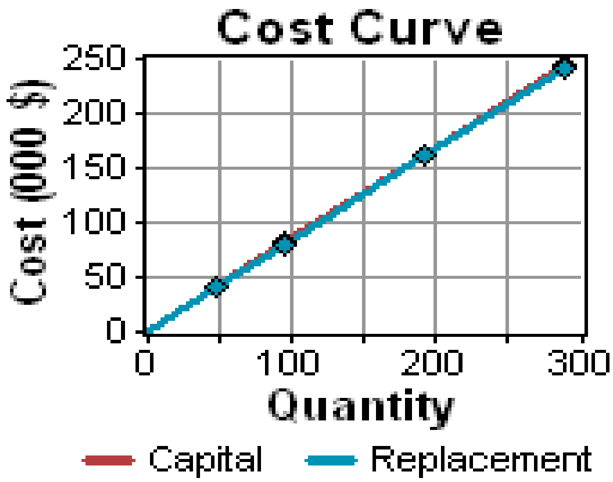


Figure 10. Cost of battery

3.5. Power converter

In order to maintain the energy flow between the AC and DC components in the system, a power converter / inverter was used. 1kW of the system requires an installation and replacement cost of $ 900 and $ 800 respectively (Figure 11). Three converter variants were considered in this model (0, 15 and 20). The lifetime of a converter is estimated at 20 years with an efficiency of 90% while the capacity relative to the inverter is 100% with an efficiency of 85%.

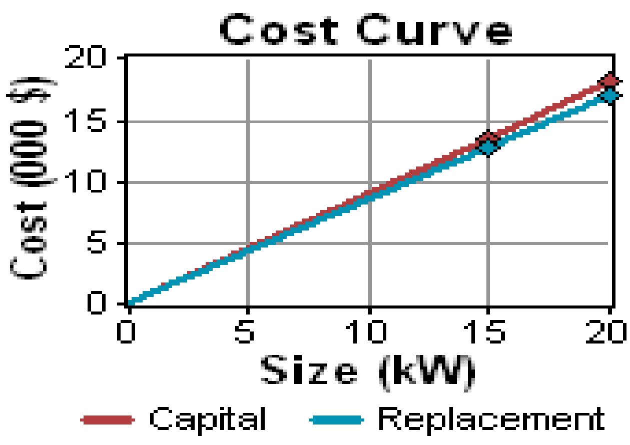


Figure 11. Converter cost curves

3.6. Economics and constraints:

The lifetime project is considering at 25 years, with an annual real interest rate of 8%, there is no capacity shortage penalty in Comoros. System fixed operations and maintenance costs is 1400$/yr. Maximum annual capacity shortage was estimated at 2%. Renewable output, is 25 and 50% respectively for solar and wind energy. We remember you that no cost subsidy available from Comoros government is considered in this present study.

4. RESULTS AND DISCUSSIONS

Three sensitivity variables (wind speed, solar irradiation and diesel price cost) are considered in this analysis. For each of the sensitivity values HOMER simulates all the systems in their respective search space. Indeed, an hourly time series simulation for every possible system type and configuration is done for one-year period. A feasible system is defined as a solution or hybrid system configuration that is capable of meeting the load. In the other hand, HOMER eliminates all infeasible combinations and ranks the feasible systems according to increasing net present cost [26-36]. It also allows a number of parameters to be displayed against the sensitivity variables for identifying an optimal system type. The HOMER software eliminates all infeasible systems and presents the results in ascending order of total net present cost (NPC). In this study, solar radiation average of (6.47 kWh/m^2/d; 7.5 kWh/m^2/d and 8 kWh/m^2/d), diesel price of (0.8$/L, 0.96.0$/L, and 1.2 $/L) and wind speed (5.71 m/s, 6.50 m/s and 7.00 m/s) were used as a sensitivity variables. A total of 27 sensitivity cases were tested with each of the system configurations. Total simulation time was 6h-18mn for an INTEL Core i3 personal computer of 1.7GHz. The optimization results show that various optimal system types (OST) are displayed as functions of different sensitivity parameters. On the other hand, wind speed and solar irradiation data are presented for identification of system configuration for various locations around Sada Djoulamlia Community. Considering diesel price (0.96$/L), a PV/wind/diesel based hybrid system is suitable for stand-alone loads around the Community. Total net present cost (NPC), Capital cost and cost of energy (COE) for such a system is $412,009; $133,000 and 0.665$/kW h, respectively. For a region with very low wind penetration, less than 5m/s a diesel generator/battery system might be suitable, this is was specify by [4-5].

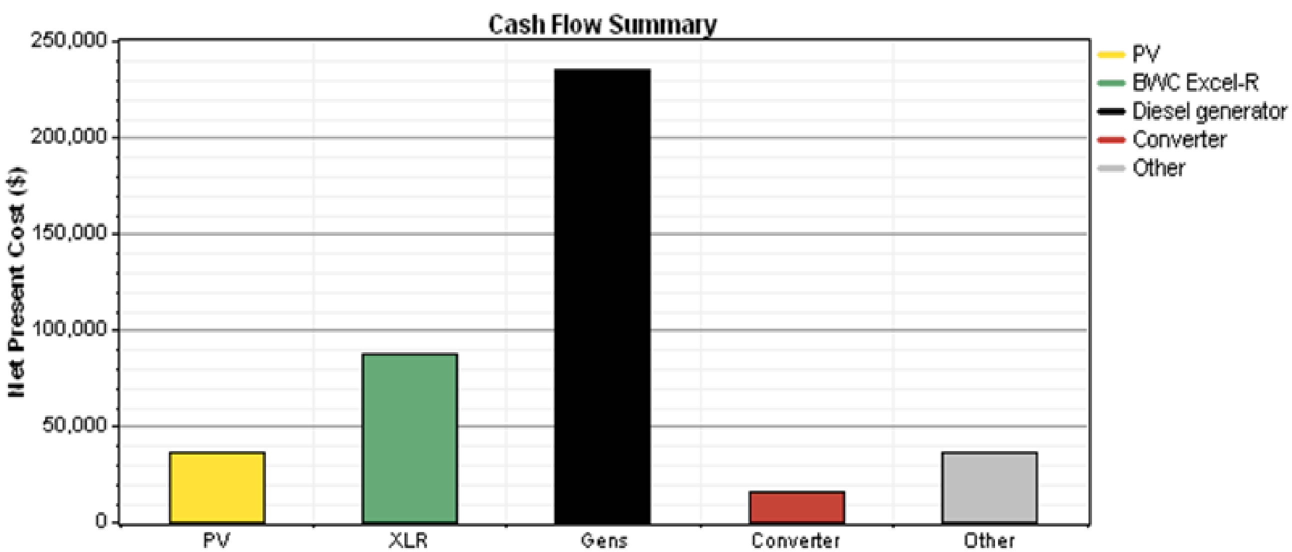


Figure 12 a. Cash flow cost summary

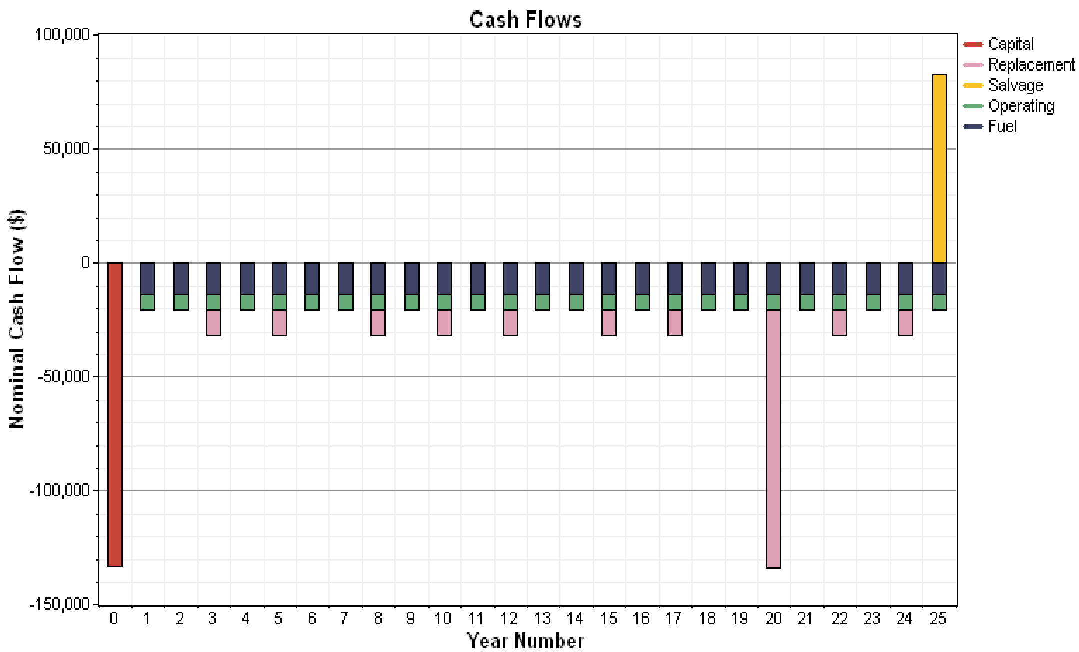


Figure 12 b. Cash flow cost summary

The figure 12 (a-b) combined with table 1 explain the global financial situation of the study. Figure 12a show that total cost for diesel generator is set at 235,701$ while for the wind it set at 87, 538$ with 36, 035 $ for PV. Converter total cost is 16, 440 $ and 36, 296 $ for other charges as explained in table 2.

Figure 12b, shows the cash flow for the system. Each bar in the graph represents either total expenditures or total revenues for a year. The first bar, of year zero, shows the investment cost of the system (133, 000$). A negative value represents an expense, such as the cost of fuel, component replacement or operation and maintenance (O & M). A positive value represents a recipe, which may be the sale of electricity or the resale of components to the dismantling of the system at the end of the life of the project. At 20 years the battery and the converter must be replaced as shown in the figure with the negative bar because both have a lifetime of 20 years. The project with a lifetime of 25 years will begin to be profitable which is explained by the positive bar (salvage) after 25 years.

Table 2. Cost summary simulated by HOMER

Component	Capital($)	Replacement($)	O&M($)	Fuel($)	Salvage($)	Total($)
PV	30, 000	6, 222	2,989	0	-3,175	36,035
Wind	77,500	12,873	3,736	0	-6,571	87,538
Diesel generator	12,000	45,721	33,407	145,486	-913	235,701
Converter	13,500	2,735	1,601	0	-1,396	16,440
Other	0	0	36,294	0	0	36,294
System	133,000	67,552	78,027	145,486	-12,056	412,009

Figure 13 shows the production details and annual electricity consumption of the system. Annual electricity production is set at 129,707 kWh/yr distributed as follow-up: 4, 821 kWh/yr for PV production, 25,403kWh/yr for diesel production and 99, 483kwh/yr for wind. As shown in the figure, wind electricity production is high than that of others 77% due to the availability of a high wind speed in the rural area that exceeds 5m / s. From Jun to November we notice a high production of electricity because of a high penetrability of wind in this period. In the other hand, we notice that community load annual consumption is 58, 036kWh/yr, the excess electricity 68, 044 kWh/yr must be storage. PV penetration in the system is 8.31% with 4,401 hr/yr of operation and a livelized cost of 0.700$/kWh (Figure 14). Wind penetration is set at 171% with 8, 205hr/yr of operation and a livelized of 0.0824$/kWh cheaper than PV system (figure 15). Figure 16 presents the diesel generator output in the system.

Electrical production is 25,403kWh/yr with 6, 259 hr/yr of operation hour. Fuel consumption is set at 11, 357 L/yr and specific fuel consumption is 0.447 L/kWh. We notice that a mean electrical output of 4.06 W is used.

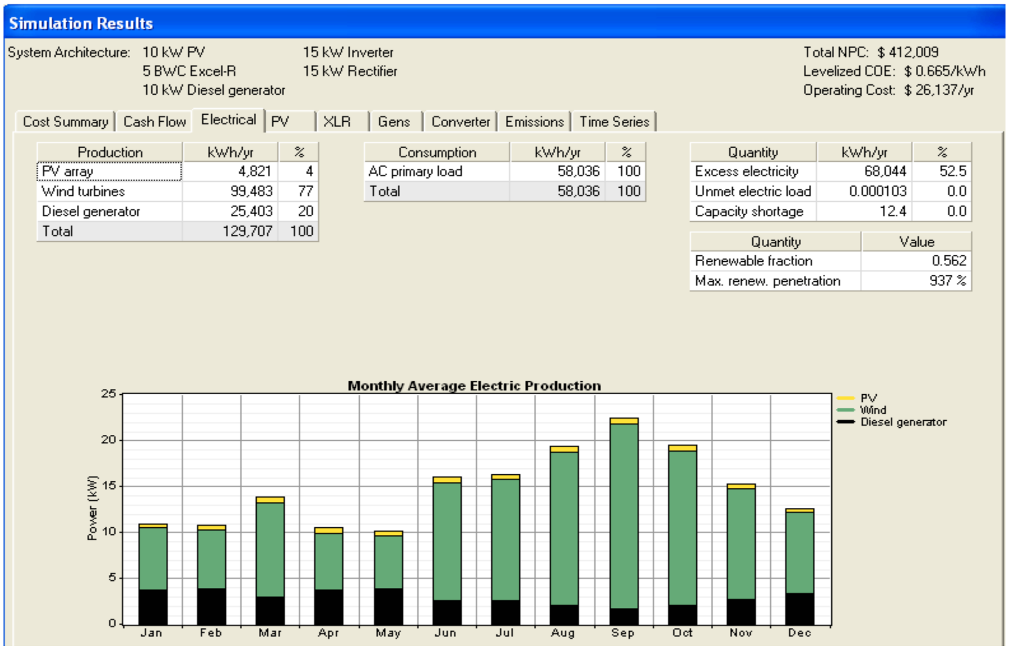


Figure 13. Monthly average electric productions

Quantity	Value	Units
Rated capacity	10.0	kW
Mean output	0.55	kW
Mean output	13.2	kWh/d
Capacity factor	5.50	%
Total production	4,821	kWh/yr

Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	2.24	kW
PV penetration	8.31	%
Hours of operation	4,401	hr/yr
Levelized cost	0.700	$/kWh

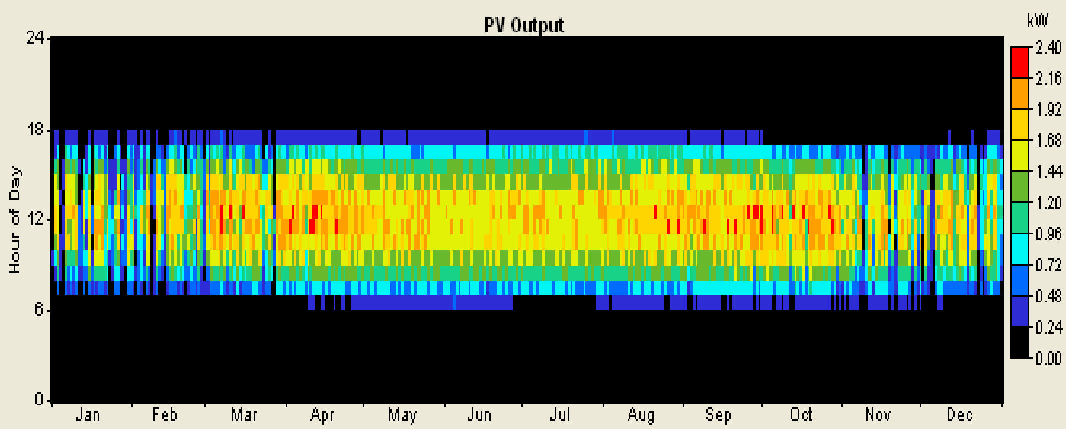


Figure 14. Photovoltaic output in the system

Quantity	Value	Units
Total rated capacity	37.5	kW
Mean output	11.4	kW
Capacity factor	30.3	%
Total production	99,483	kWh/yr

Quantity	Value	Units
Minimum output	0.0	kW
Maximum output	40.2	kW
Wind penetration	171	%
Hours of operation	8,205	hr/yr
Levelized cost	0.0824	$/kWh

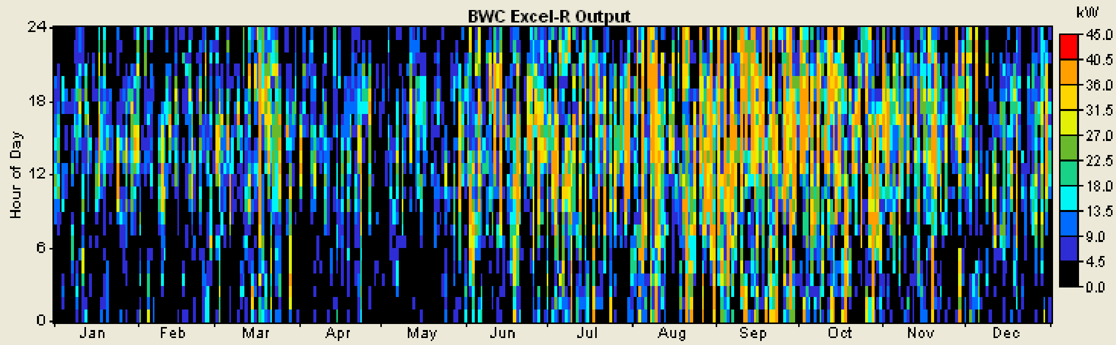


Figure 15. Wind output in the system

Quantity	Value	Units
Hours of operation	6,259	hr/yr
Number of starts	572	starts/yr
Operational life	2.40	yr
Capacity factor	29.0	%
Fixed generation cost	2.19	$/hr
Marginal generation cost	0.300	$/kWh

Quantity	Value	Units
Electrical production	25,403	kWh/yr
Mean electrical output	4.06	kW
Min. electrical output	3.00	kW
Max. electrical output	9.33	kW

Quantity	Value	Units
Fuel consumption	11,357	L/yr
Specific fuel consumption	0.447	L/kWh
Fuel energy input	111,757	kWh/yr
Mean electrical efficiency	22.7	%

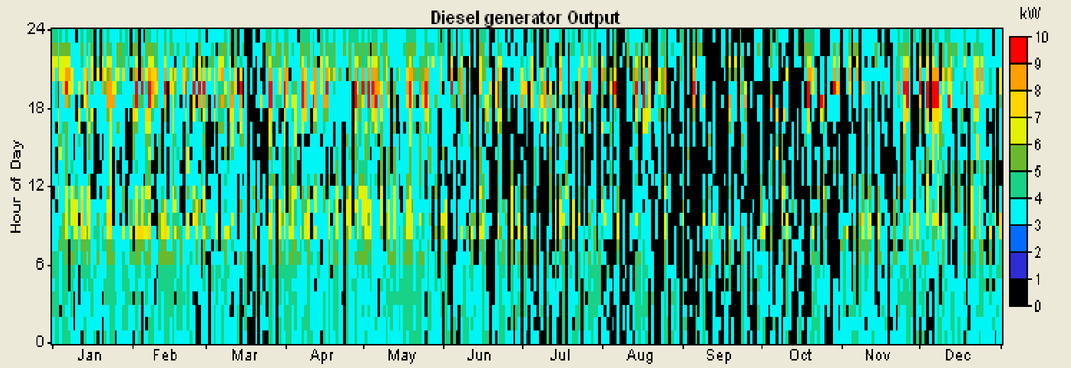


Figure 16. Diesel generator output in the system

The optimization results could be categorized for a particular set of sensitivity parameters in HOMER modelization. Considering the diesel price fixed at 0.96$/L, the system can be varied to identify an optimal system type (OST) for Sada Djoulamlima (wind speed of 5.71 m/s and solar irradiation 6.49 kW h/m ^{2} /d). This is, somehow, implies an optimistic case where the system is expected to reduce. At present, a PV/wind/diesel generator system is the most suitable solution. For a remote home (159kW h/d, 9.3 kW peak), this system might consist copy of generic model wind turbine of 5kW, one 10 kW diesel generator, 10kW of PV and a 5 kW power converter. In the other hand, excess electricity has been reported whenever available might be injected in to the national electricity network or used for agriculture and other activities.

5. CONCLUSIONS

In the present study, design of hybrid power system for a power supply in rural areas in Comoros was conducted using HOMER software tool. The hybrid system composed by PV/wind /diesel generator has been studied with sensitivity parameters for oil price, wind speed and global solar irradiation in order to optimize the system. Taking into account of the changes of the sensitivity parameters, hybrid system shows that a wind/diesel generator/battery system appears as a feasible solution.

Our results show that the best total Net Present Cost (NPC) of 412, 009$, initial capital of 133, 000$ and operating cost of 26, 137$/yr can be achieved by using converter size of 15kW; diesel generator size is 10kW with fuel consumption of 11,357 L/yr, a wind size of 15kW and 10kW of PV size with a total production of 4, 821kWh/yr. PV penetration is 8.31% while wind penetration is 171%. On the other hand, simulation results from HOMER software, shows that the hybrid PV/diesel/wind system is the best feasibility combination for rural area studied according to the cost of energy of 0.665$/kW h and for wind velocity equal to 5 m/s or more. Taking account of this analysis, following conclusions could be drawn:

- Wind resources in Sada Djoulamlima community area, bear excellent potential compared to solar energy and utilization of solar resources might be second choice to cover electrification.
- Indeed, we note that, a PV-wind-diesel system is the most suitable solution for stand-alone applications.
- So instead of using single stand-alone units, larger hybrid systems would be cost competitive for remote communities and the economies of scale might bring down the cost of energy towards an affordable price like this one in the national electricity society of Comoros (0.27$/kW h).

The advantage of a hybrid system over a pure wind or pure photovoltaic system depends on many fundamental factors: shape and type of load, wind regime, solar radiation, cost and availability energy, the relative cost of the wind machine, the photovoltaic field, the electrochemical storage system and other efficiency factors. Photovoltaic systems are currently economical for low-power plants. For stand-alone energy systems, the cost of storage represents the greatest constraint on the overall cost of the system for large power plants. Minimizing the cost of storage and optimizing its capacity is the main reason for the combination of wind and photovoltaic systems. Indeed, our study shows that replacing diesel generator by PV/wind, PV/battery or wind/battery system will protect the environment from greenhouse gas emissions. These emissions include 29.908 kg/yr of CO_2, 73.8 kg/year of CO, 659 kg/yr of NOx, 8.18 kg/yr of HCs, 60.1 kg/yr of SO_2, and 5.57 kg/yr of suspended particles as shown in the table 5.3 below.

Table 3. Green house gases for fuel and hybrid systems

Gas	Annual emissions kg/yr		
	PV	*Generator*	*Wind*
Carbon dioxide	0	29.908	0
Carbon monoxide	0	73.8	0
Unburned hydrocarbons	0	8.18	0
Particulate matter	0	5.57	0
Sulfur dioxide	0	60.1	0
Nitrogen oxides	0	659	0

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