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Experimental Analysis of a Stand-alone Wind-photovoltaic Hybrid System in the Sahara Desert

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ABSTRACT

The present paper discusses the feasibility study of an autonomous hybrid PV-Wind power system used for public electrification in the city of Adrar- South of Algeria, with an average consumption of 3445 Wh/day.
The system includes a 1KW of PV arrays (78 % solar energy penetration), one wind turbine of 900 W (22 % wind energy penetration), 16 unit batteries (12V-100Ah) and 800 W sized power converters.
The main source of power to the energy system is photovoltaic panels, whereas, wind generators are the supported additional sources.

1. INTRODUCTION

The transition of the energy sector in the World towards sustainability is one of the biggest challenges of the 21st century [1]. In 2014, World production marketed energy was 13045 Mtep, with only 9 % from renewable sources [2-3]. In 2035, the primary energy demand in the world will be close to 17 billion Gtep. 18 % of this demand will be met through renewable sources [1].

Algeria is highly dependent on fossil fuels. Oil and natural gas account for more than 98% of primary energy demand. Despite that, the country has excellent solar power potential and a considerable wind resource. For that Algeria has incorporated into its energy policy issues of sustainable development and meet the national demand, through a program of development of renewable energy for the period 2011-2030, aspiring to eventually produce 40 % of the national electricity consumption from solar and wind power sectors [4-5].

To meet this program, the government has outlined the following plans for [6-8]:

Short term (2010–2013): Installation of 110 MW.
Medium term (2014–2015): Installation 650 MW.
Long term (2016–2020): Installation 2600 MW.

An additional capacity of approximately 12000 MW is planned for installation by 2030 [6-8].

This paper aims to present and to discuss the experimental results of a stand-Alone Wind- Photovoltaic Hybrid System in the city of Adrar- South of Algeria used for public electrification, with an average consumption of 3445Wh/day.

2. THE HYBRID SYSTEM DESCRIPTION

The proposed prototype in this paper consists of:

(1). 1kW photovoltaic solar panels (250 W);
(2). Wind turbine of 900W (Whisper100);
(3). 16 unit batteries (SP12V-100Ah);
(4). Battery charging and discharging controller Steca Tarom 245-24V;
(5). Victron energy 800 inverter.

The experimental prototype of PV-Wind hybrid system has been installed in the Renewable Energy Research Unit (URER-MS), Adrar [9-10].

During the testing period, from 02 to 08 March 2017, the following data were regularly measured:

(1). Solar radiation (using CM 11 pyranometer).
(2). Wind speed (at a 10 m above ground level).
(3). Photovoltaic output power.
(4). Wind turbine output power.
(5). Load profiles.

3. LOAD PROFILES ANALYSIS

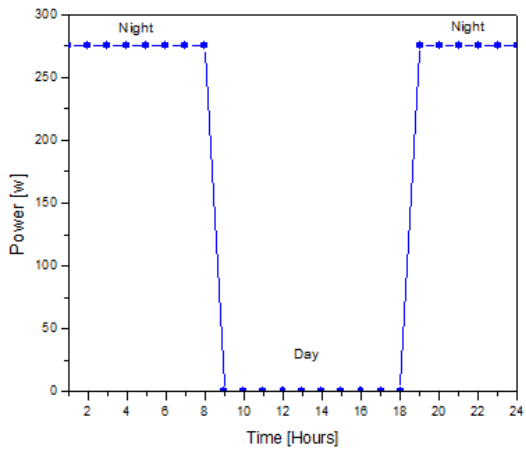

Figure 1. The Hourly profile of the considered load

Table 1. Calculated energy consumption

Appliance	Power [W]	Number of used hours/ day [hours]	Used energy /day [Wh]
Lighting	265	From 19 H to 07 H	3445

The statistical data of electricity consumption of the load charges (DC and AC) are collected every 30 second and integrated over each day [11].

$$E_d = \sum_{i=1}^{n} I_n V_n D_n \quad (1)$$

where:

Ed: total energy demand.

In: the current;

Vn: the voltage;

Dn: duty cycle of each appliance used in one day.

The average daily consumption is calculated as 3445Wh/day according to Eq. (1) and the hourly profile of the load charges is shown in Figure 1.

4. RESULTS AND DISCUSSION

The system performances were studied, from 02 to 08 March 2017. Figures 2 to 8 show the variation of the measured data for solar radiation, wind speed, voltage and state of charge SOC of the battery bank, PV and wind energy output as a function of time.

The hourly variation of solar radiation and PV output powers are shown respectively in Figure 2 and 5, it can be observed that a distinct increase of PV output powers has been observed since 9:00h with the increase of solar radiation.

The hourly variation of the wind speed as well as the wind turbine output powers are shown respectively in Figure 3 and 6. It can be observed that average wind speed is higher between 10:00H and 16:00H, while lower values are obtained during the rest of the day.

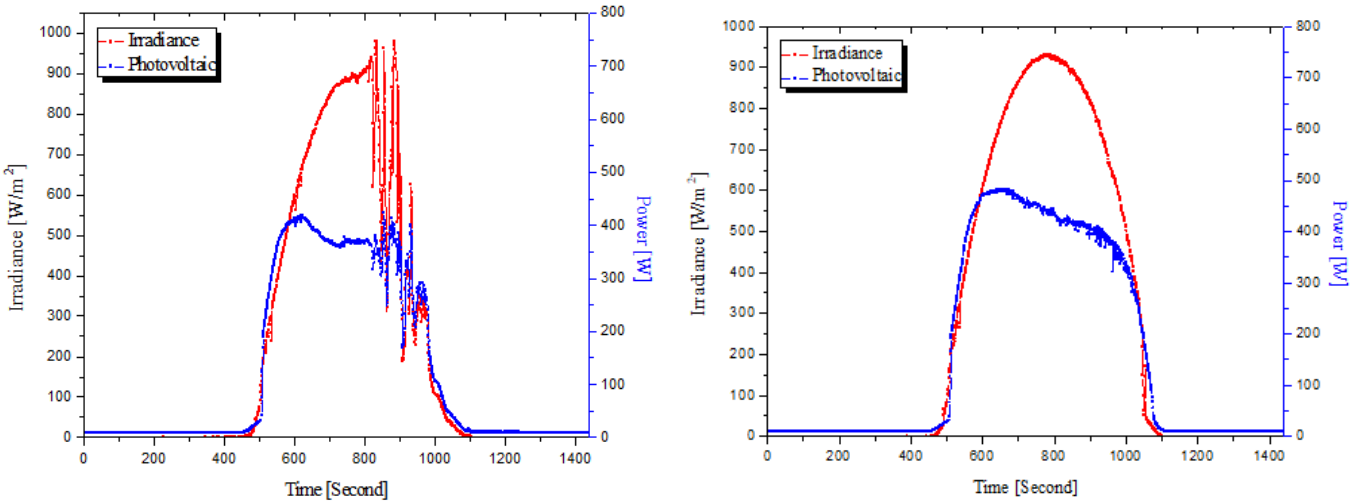

Figure 2. Variation of solar radiation and PV output power: a) 02 March 2017; b) 08 March 2017

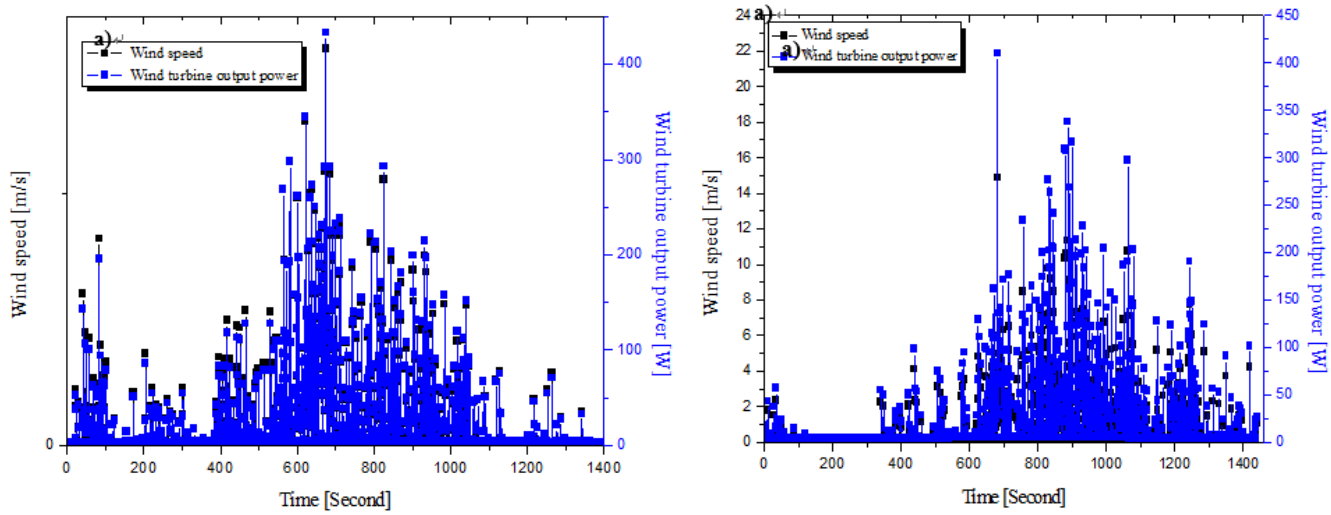

Figure 3. Variation of wind speed and wind turbine output power: a) 02 March 2017; b) 08 March 2017

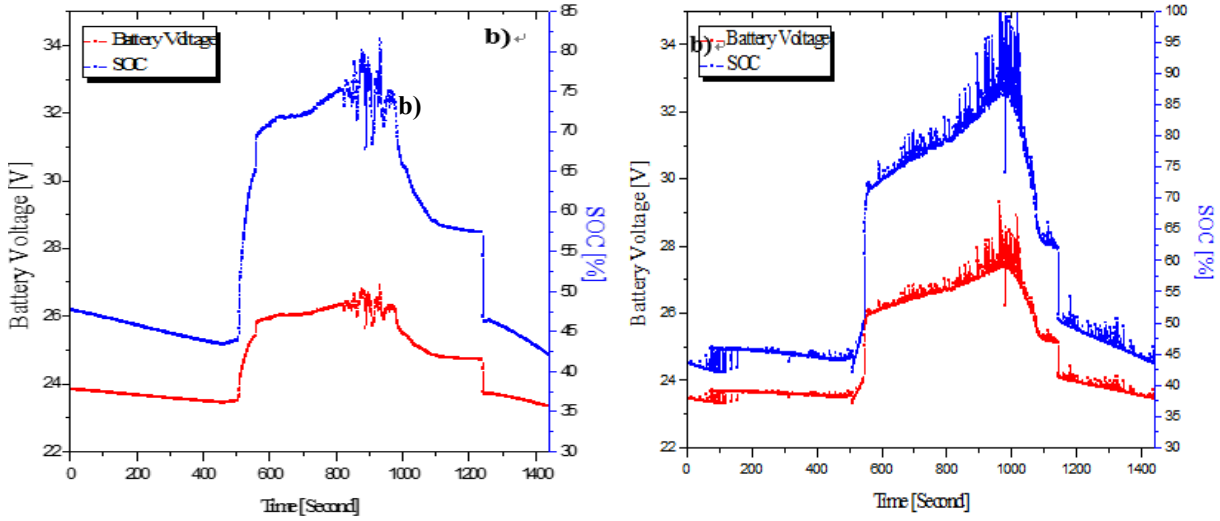

Figure 4. Variation of voltage and SOC of the battery bank during charge and discharge time: a) 02 March 2017; b) 08 March 2017

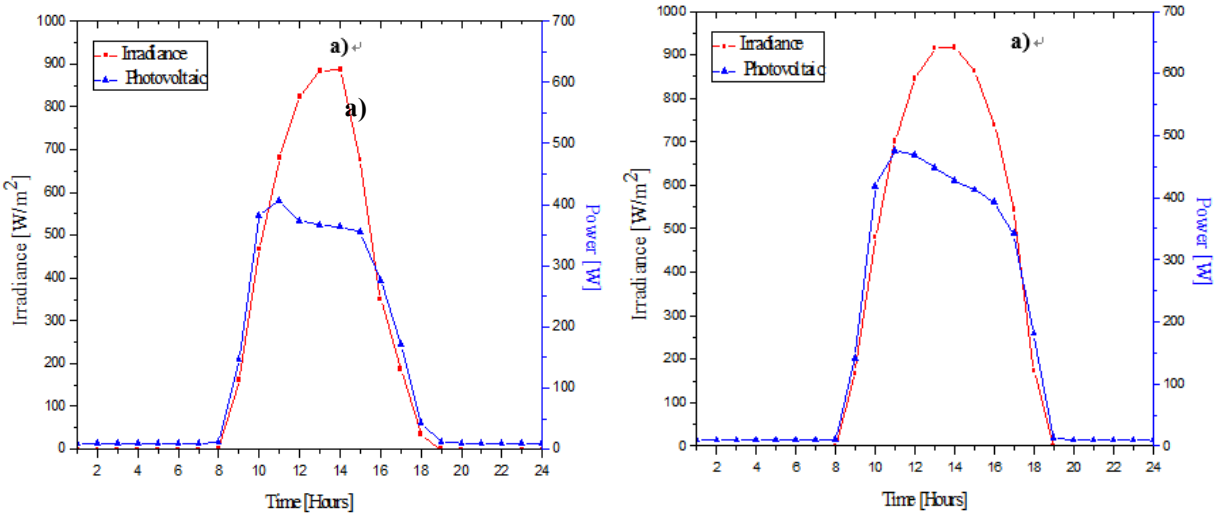

Figure 5. Global irradiance on the inclined plan and PV output power: a) 02 March 2017; b) 08 March 2017

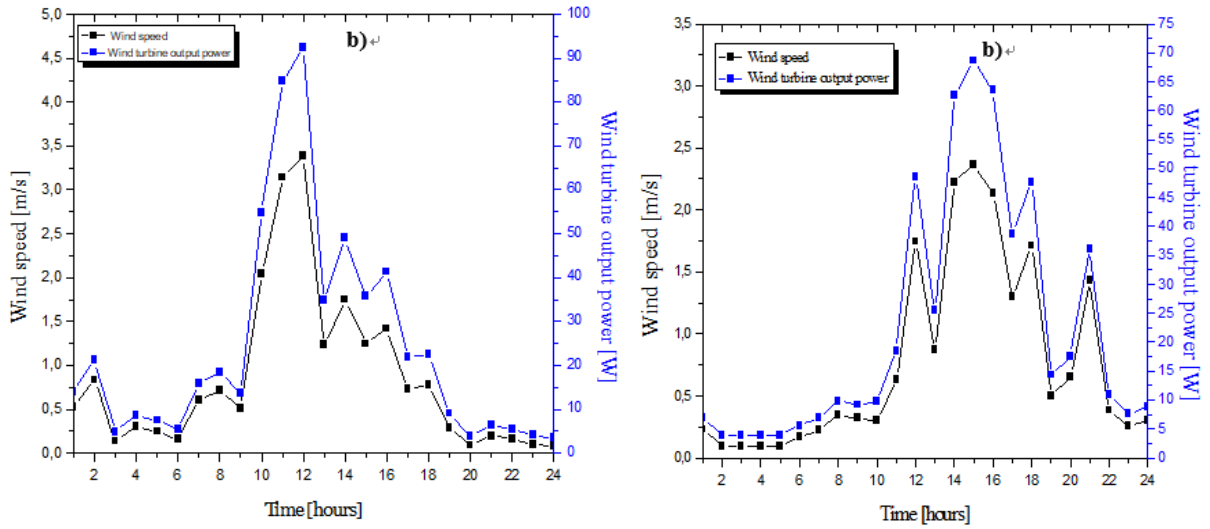

Figure 6. Variation of wind speed and wind turbine output power: a) 02 March 2017; b) 08 March 2017

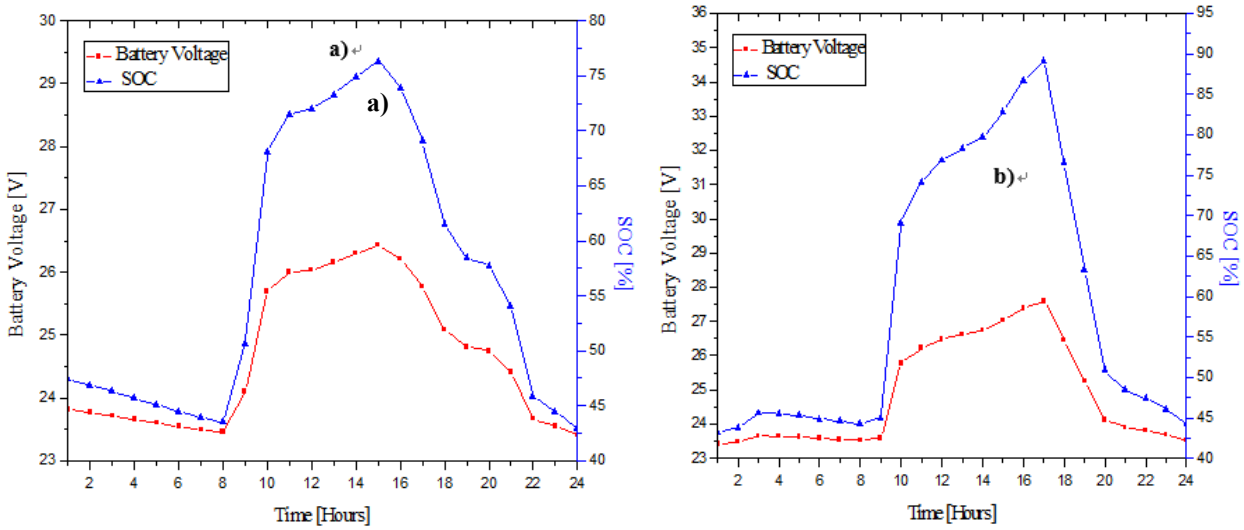

Figure 7. Variation of voltage and SOC of the battery bank: a) 02 March 2017; b) 08 March 2017

From the Figure 4 and Figure 6, the following points can be observed:

(1). The hourly-mean battery SOC is much higher during the hour's 11:00h-18:00h than the rest of the day.

(2). The peaks of the SOC (%) varied between 16:00h and 17:00h (Energy productions of the system were maximum).

(3). A distinct increase of battery SOC has been observed since 10:00h with the increase of solar radiation.

(4). For all days, the SOC varied between a SOCmax of 41% and a SOCmin of 94%.

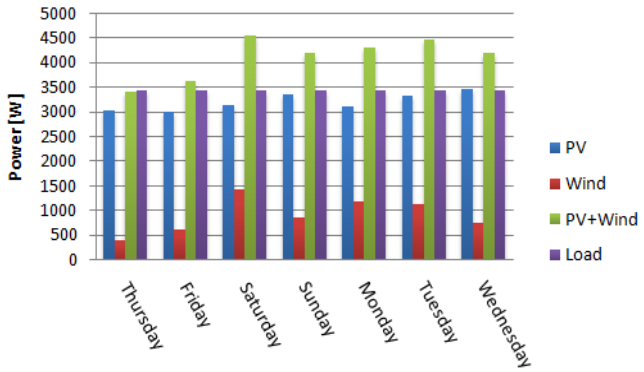

Figure 8. Daily variation of load, power contribution by wind, solar PV and hybrid power systems (From 02 to 08 March 2017)

Figure 8 shows that the total generated power by the studied system meets the load at any time of the day.

Table 2. Energy contribution by each source

	PV	Wind	PV + Wind	PV (%)	Wind (%)	Total (%)
Thursday	3015,3	386,7	3402,0	89	11	100
Friday	3013,1	613,1	3626,2	83	17	100
Saturday	3124,4	1427,8	4552,2	69	31	100
Sunday	3344,2	858,0	4202,2	80	20	100
Monday	3110,1	1191,0	4301,1	72	28	100
Tuesday	3324,3	1137,9	4462,3	74	26	100
Wednesday	3452,2	753,1	4205,3	82	18	100
Daily Moy.	3197,7	909,7	4107,4	78	22	100

The Table 2 gives the energy contribution of solar PV and wind systems of total energy production by the hybrid system. As seen in the previous table, 78 % of the energy is supplied by the PV system and 22 % is supplied by the wind turbine.

The average daily power contribution of the PV system to the hybrid power system ranges from a minimum 69 % on Saturday to maximum 89 % on Thursday.

However, the wind power contribution varied between a minimum of a maximum of 11 % on Thursday and 31 % on Saturday.

5. CONCLUSION

In this article, we present the experimental results of the operation of a hybrid PV-Wind-battery system in the city of Adrar- Sahara Desert of Algeria used for public electrification, with an average consumption of 3445Wh/day.

From the results obtained during the system operating tests, we can note that:

(1). The battery SOC is dominated by the production of the PV array.

(2). The contribution of solar photovoltaic and wind in the energy production depend to the weather conditions (the intensity and the duration of availability of this energy sources).

(3). The energy produced is sufficient to supply the load demands at all times due to the complementarities between the two renewable energy sources.

(4). At any time of the day, the SOC is superior at the permissible minimum value of the SOC (SOCmin = 20% of SOC).

(5). It is found that the use of renewable energy sources is feasible to solve the rural electricity provision in the isolated rural areas in Adrar city (South of Algeria).

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