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An experimental intelligent simulator of a single household: Wind energy application

Djohra Saheb* and Mustapha Koussa

Centre de Développement des Energies Renouvelables, CDER
16340, Bouzaréah, Algiers, Algeria

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Abstract - *In the present study, an experimental real domestic electrical load simulator containing the set of lighting equipment as well as equipment simulating all those of primary necessity is elaborated. Therefore, the energy consumption of each equipment was adjusted according to the geographical location of the site in which the installation is planned and the season of the year in question. Because of its small size, the simulator can be connected to the system of production of wind electric energy by a simple connection. Furthermore, the energy consumption of all the electrical equipment is read and recorded on a computer by voltage and current measuring.*

Résumé - *Dans la présente étude, un simulateur expérimental de charge électrique domestique réel contenant l'ensemble des équipements d'éclairage, ainsi que les équipements simulant tous ceux de première nécessité est élaboré. Par conséquent, la consommation d'énergie de chacun des équipements a été ajustée en fonction de la localisation géographique du site dans lequel l'installation est prévue et de la saison de l'année en question. En raison de sa petite taille, le simulateur peut être connecté au système de production d'énergie éolienne par une simple connexion. De plus, la consommation d'énergie de tous les équipements électriques est lue et enregistrée sur un ordinateur pour la mesure de la tension et du courant.*

Keywords: Experimental - Intelligent - Simulator - Household, Wind energy.

1. INTRODUCTION

Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human times scale, such as sunlight, wind, tides waves, and geothermal heat [1]. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural energy services [2, 3].

Based on REN21s 2016 report, renewable contributed 19.2 % to human's global energy consumption and 23.7 % to their generation of electricity in 2014 and 2015, respectively.

This energy consumption is divided as 8.9 % coming from traditional biomass, 4.2 % as heat energy, 3.9 % of hydro electricity and 2.2 % from wind, solar, geothermal and biomass. Worldwide investments in renewable technologies amounted to more than US$ 286 billion in 2015, with countries like China and the United States heavily investing in wind, hydro, solar and biofuels [4].

Globally, there are an estimated 7.7 million jobs associated with the renewable industries, with solar photovoltaic being the largest renewable employer [5]. As of 2015 world, more than half of all new electricity capacity installed was renewable [6].

Renewable energy systems are rapidly becoming more efficient and cheaper. Their share of total energy consumption is increasing. Growth in consumption of coal and oil could end by 2020 due to increased uptake of renewable and natural gas [7, 8].

* d.saheb@cder.dz

Algeria has created a green momentum by launching an ambitious program to develop renewable energies (RE) and promote energy efficiency. This program leans on a strategy focused on developing and expanding the use of inexhaustible resources, such as solar energy in order to diversify energy sources and prepares Algeria of tomorrow. Through combining initiatives and the acquisition of knowledge, Algeria is engaged in a new age of sustainable energy use. [9].

Indeed, in the field of solar energy, conversion systems such as systems for the production of electrical energy from solar or wind power sources are designed to materialize these programs. Only the performance of a photovoltaic system or a wind turbine must be evaluated for reliability and performance by using real-time simulations of these systems and for an electrical load representative of the actual load should be used [10]. This is what our paper represents.

2. THE SYSTEM CONFIGURATION

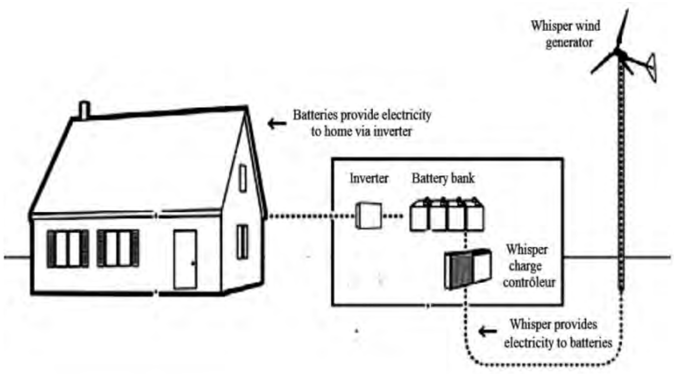

Fig. 1: The off grid wind energy system

The studied energy system consists of small wind generator, inverter and batteries considering residential wind power for energy self-sufficiency. The principal advantages of the off grid wind energy system are as follow [11].

• In remote locations, the off grid wind energy system systems can be more cost-effective than extending a power line to the electricity grid (the cost of which can range from $15,000 to $50,000 per mile).

• Near the grid, the off grid wind energy system permits to obtain independence from the power provider or demonstrate a commitment to non-polluting energy sources.

3. THE ELECTRIC LOAD

In this study, a household not connected to the classical energy distribution network is considered. Nonetheless, it is equipped with a number of devices to the comfort of its inhabitants. Additionally, the house is assumed to be occupied all over the year and that its devices require the standard rated voltage (220 VAC, 50 Hz). The house's characteristics are as follows [12-14].

In the present study, a typical load system for a house sites in a mountainous remote area in Algeria with *a* typical single residential load (**Table 1**) has been considered for the present case of analysis. It has been found that for this system each home user consume energy around 3.3 kWh/day and 4.9 kWh/day with a peak demand of nearly 463 W and 464 W respectively in winter and in summer.

Energy consumption

• The lighting

The lighting depends on four parameters: sunset; sunrise, the family get up and retire.

• The fridge

The number of hours a fridge runs depends on the ambient temperature, which varies with location from one season to the next. In this study, the fridge is assumed active for 8 hours per day during winter (November-April) and 12 hours per day during summer (May-October).

• The fan

This is assumed to only be used during summer (May-September), for an average of 5 hours per day.

Table 1: Estimated daily energy requirement

		Power (W)	**Duration of consumption (hour)**	**Day load (Wh)**
Lighting	Room 1	22	04	88
	Room 2	22	04	88
	Room 3	22	05	110
	Living room	22	06	132
	Corridor	22	02	44
	Bath room	22	02	44
	Kitchen	22	07	154
	Toilet	22	02	44
Subtotal 1	704			
Equipment	Fridge	225	8/12*	1800/2700
	TV	100	05	500
	Fan	100	0/5	0/600
	µ computer	100	02	200
	other	100	02	200
Subtotal 2	2600/4200			
Total	3304/4904			

*8/12: 8 hours in winter and 12 hours in summer

4. WINDGENERATOR

The considered wind turbine is the Whisper200 type designed to operate in sites with moderate wind speeds from 3.5 m/s and above. Its characteristics are given in **Table 2**.

Table 2: Whisper 200 wind turbine parameters [15, 16]

Parameters	**Values**
Rated power	1 kW at. 11.6 m/s
Monthly energy	200 kWh/mo at. 5.4 m/s
Star up wind speed	3.1 m/s
Rotor diameter	2.7 m
Voltage	12, 24, 48 Vdc
Turbine controller	Whisper controller
Blades	3
Weight	30 kg
Shipping dimensions	1295 × 508 × 330 mm
Warranty	5 year limited warranty

5. STORAGE SYSTEM

In the present study, we used the Banner Energy Bull Batteries, which are specially designed to provide long duration discharge, and are the optimum battery type for semi-traction, leisure and hobby use. Their High Cycle life, simple charging and easy maintenance make them the perfect solution for a huge variety of battery applications such as yachts, electric boats, caravans, motorhomes, canal boats, camping, wheelchairs, signaling, materials handling, solar and many more specialist applications [17].

Banner Leisure batteries are recommended for their heavy-duty construction and heavy deep cycle ability for a number of caravan clubs and associations [17]. Furthermore, **Table 3** summarizes the main batteries characteristics parameters.

Table 3: Banner energy bull 110 Ah/12 V Battery characteristics

Parameters	Values
Nominal voltage	12 V
Battery capacity	110 Ah
Cycle durability	3 to 5 years at 50 % of discharge
Self-discharge rate	Surroundings 9% par month
Discharge voltage	22.2 V
End-of- charge voltage of a battery	Whisper controller
Maximal temperature	+ 50°C
Minimal temperature	-10 °C
Recommended temperature	20°C

6. INVERTER

The AJ series sine wave inverters have been designed to meet industrial and domestic needs. They meet the highest requirements in terms of comfort, safety and reliability. Any device designed for the public electrical grid of 230 V 50 Hz can be connected to them (up to the nominal power of the inverter). The AJ series inverter is the perfect source of voltage in any place where the public grid is not available [18].

The technical data of the inverter are summarized in the **Table 4**.

The AJ inverter is supplied with a 230 V cable to be connected to the consumer devices.

Figure 2 shows the performance and the Cp curves provided by the manufacture.

Table 4: Inverter AJ sine wave 1300 technical data [18]

Parameters	Values
Nominal battery voltage	24 V
Continuous pwer at 25 °C	1300 W
Maximum efficiency	94 %
Solar charger	25 A
Voltage output	230 V+/- %
Frequency	50 Hz +/- 0.05 %
Cos phi	0.1 - 1

7. EXPERIMENTAL HOUSEHOLD REALIZED IN RENEWABLE ENERGY CENTER, CDER

Based on a real daily profile of a standard house as it is depicted in figure 3, the intelligent simulator of load system was realized in Renewable Energy Center, CDER. In the present case, the system carried out consists of an electric load representing the whole of electrical equipment which can be used in a dwelling and which is intended to be supplied off a wind or solar electrical energy system employing respectively by using respectively an aerogenerator or the photovoltaic system.

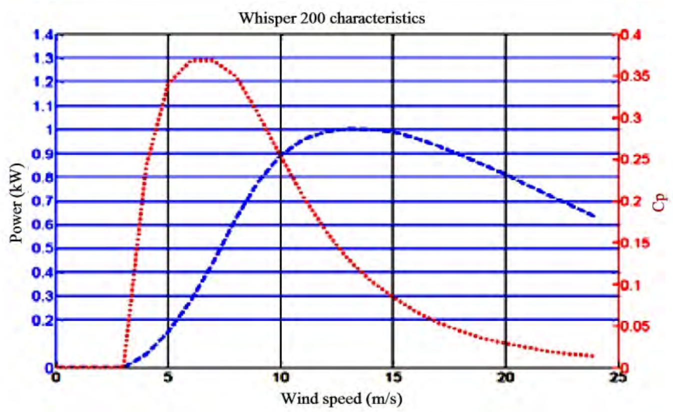

Fig. 2: Whisper 200 characteristic's [19]

Being used to simulate the performances of the system of energy production, which is of the conventional type or not and study its behavior, the C.D.E.R. consists of a metal cupboard 1 arranged various lighting device 2, 3, 4, 5, 6, 7 and 8 to light each space of the dwelling and others having the power rating representing the consumption of each one of the equipment like the fridge (9), Television (10), as well as the various equipment which can be solicited in a reduced way (11).

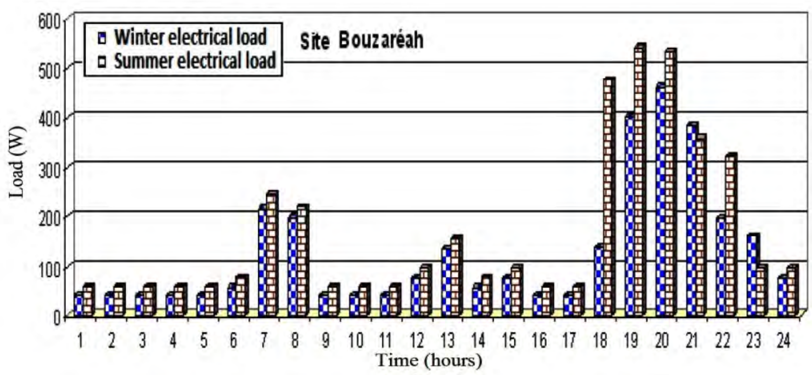

Fig. 3: A real daily profile of a standard house

All of these are run by an adjustable clock of industrial type according to the climatic characteristics of the considered site and also taking into account the effect of lasted season of lighting, the request of ventilation and the number of operating hours of the refrigerator which depends indeed on the room temperature which in turn depends on the place and season of the year.

Thus, for the simulation of energy consumption, the operation of the system is regulated according to a flow chart pre-established for each month of the year for any site located on the Algerian territory.

This flow chart is defined according to real considerations of the operation of the various equipment used (fridge, television set, fan etc.) as well as the various equipment of lighting. The operation is function on the one hand, of time of sunrise and the sunset which vary from the day to day during the year, and on the other , of the wake up and sleep times of the various family members as well as their action on the various equipment related to their activities in the house.

The fan requests for operation occur only in summer and the number of running hours depends on the climatic zone it is installed. In the same way for the fridge, the number of operating hours is also related to the temperature of its environment, which also varies in a seasonal manner and depends on the climatic zone in which the considered installation is located.

In addition the measurement of consumption is ensured by measuring the input current and voltage of this load, in turn, by a digital meter (14 in figure 4) which presents the possibility of connection to a data acquisition system or to a computer through a port 432 of the energy counter.

8. THE OBTAINED RESULTS

In this section are presented the experimental results obtained by an hybrid system comprised of a windgenerator (whisper 200), batteries and genset designed to supply the household described above. Let us recall that the system is implemented in Bouzareah site which is a coastal Algerian site, and which, according to the Koppen Geiger climate classification [20], can be considered as a temperate climate with a hot and arid summer (CSA climate).The obtained results are as follows.

Fig. 4: The experimental intelligent simulator (C.D.E.R.)

- Figure 5 shows the three-phase voltage of the whisper 200;
- Figure 6 shows the batteries voltage evolution;
- Figure 7 shows ;the batteries temperature;

• Figure 8 shows the experimental daily evolution of hourly load power in winter season;

• Figure 9 shows the experimental daily evolution of hourly load power in summer season;

• Figure 10 shows the experimental daily distribution of the household current consumption in the winter season;

• Figure 11 shows The experimental daily distribution of the household current consumption in the summer season

• Figure 12 shows the experimental daily distribution of the household voltage in the winter season;

• Figure 13 shows the experimental daily The daily distribution of the household voltage in the summer season.

The data from Bouzareah site and corresponding to the 19/04/2017 were used in the present case study. The data include the output wind turbine power (figure 5) and an initial moderate voltage value of the battery (VB) of 24.6 V, (figure 7).

Therefore, the wind turbine via the batteries covers the load supply all the daytime period due to state of charge of the batteries of which the voltage is above 24.4 V for each five minutes of the day, as shown in figure 6. However, a contribution of the DG is not necessary.

Regarding the temperatures measured and shown in figure 7, it is noticed that the temperature is between 17.2 °C to 22.2 °C.

Respectively, from figures 8 and 9 it ‘s observed that the daily household Electricity consumption is 3.3 kWh/day in winter and 4.9 kWh/day in summer which confirm the required production mentioned in **Table 1** and which deals also to obtain an Annual household Electricity consumption corresponding to 39.77 kWh/yr in winter and 58.507 kWh/yr in summer.

From the same figures cited above it is seen that the maximum winter and summer power are equal respectively to 463.3428 W and 464.7552 W at 20:00 pm, where the minimum one is about 8.0892 W in winter and about 8.5386 W in summer.

From figures 10 and 11 it‘s noticed that the maximal daily household current consumption is 2.0532 A in the winter and 2.0642 A in the summer at 20:00 pm. Furthermore, the minimal daily household current consumption is 0.0359A in the winter and 0.0375A in the summer at 20:00 pm.

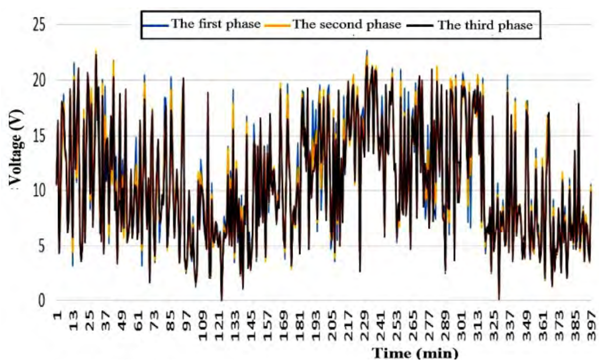

Fig. 5: Three-phase voltage of the whisper 200

Concerning the maximal winter voltage, it is equal to 229.5802 V at 2:30 pm and the summer one is equal to 228.7677 V obtained at 4:00 pm. So, the minimal winter voltage is equal to 222.3494V at 9:00 pm and the summer one is equal to 221.8868 V at 7:30 pm (figures 12 and 13).

9. CONCLUSIONS

In this paper, an experimental intelligent simulator of a single household appliqued to Wind Energy was presented. This single household contains the set of the device lighting equipment as well as equipment simulating all of the necessities. From the obtained results, the conclusion can be drawn as follows.

◆ The energy consumption of each equipment respect the programmed adjustment according to the geographical location of the site in which the installation is planned and the season of the year is determined employing the designed simulator.

◆ The daily household Electricity consumption in winter and summer, respectively, is evaluated confirms meeting the production requirement.

◆ The built system and sustainable development of the renewable energy sector has to be considered in a wider green growth context, including the relation to technological progresses made in the energy efficiency sector, and in relation to energy legislative frameworks and electricity tariff systems.

◆ The use of the built system contributes in energy efficiency products, systems and mechanisms reduces energy consumption and has thereby an indirect impact on the national energy market and energy governance.

◆ Invest in innovative scientific and technical research.

The simplicity and dimensions of the built system promotes it to be a very effective experimental tool.

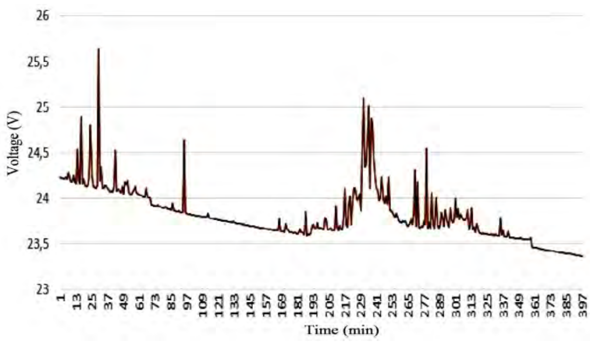

Fig. 6: Batteries voltage curve

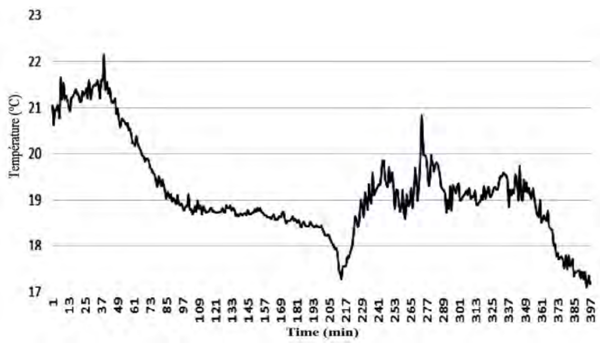

Fig.7 The batteries temperature curve

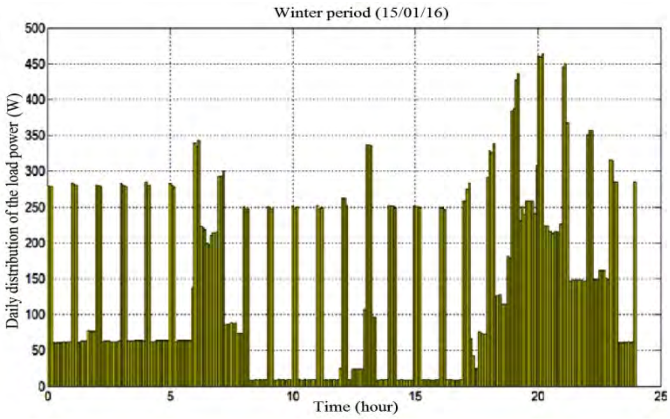

Fig. 8: The experimental daily distribution of the load power in the winter

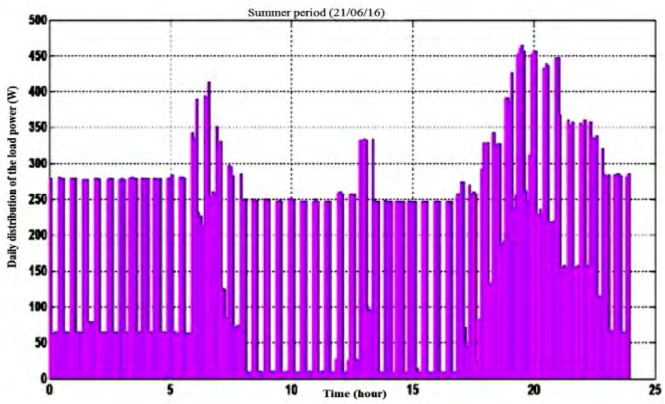

Fig. 9: The experimental daily distribution of the load power in the summer

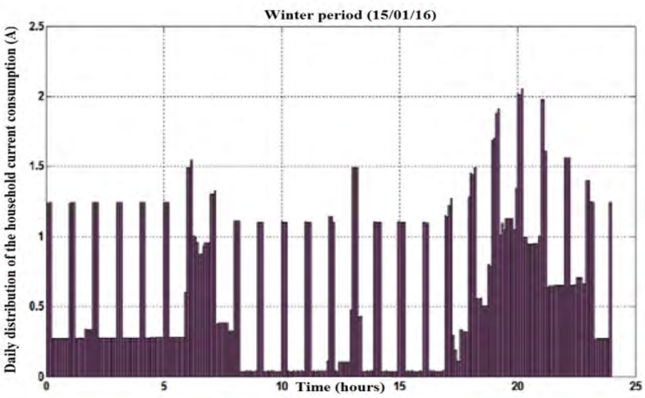

Fig. 10: The experimental daily distribution of the household current consumption in the winter

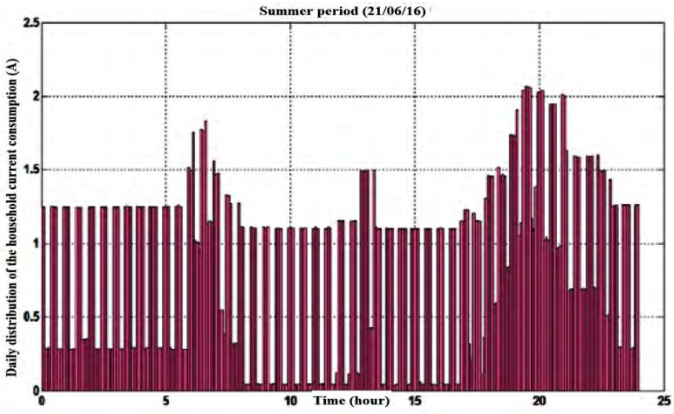

Fig. 11: The experimental daily distribution of the household current consumption in the summer

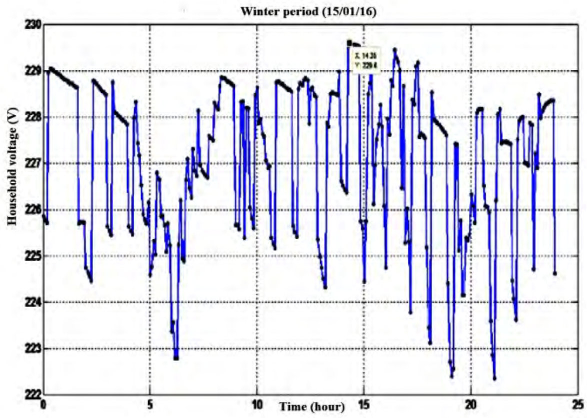

Fig. 12: The experimental daily distribution of the household voltage in the winter

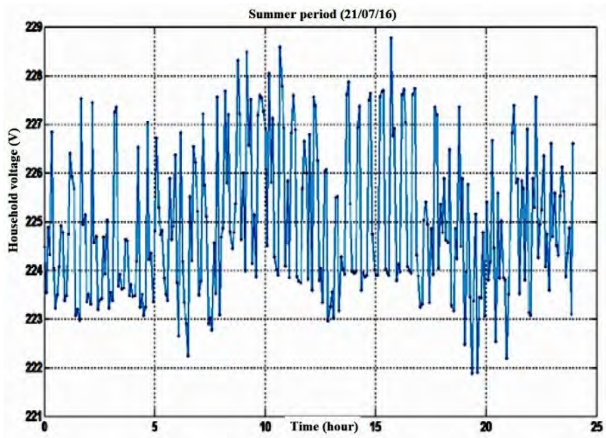

Fig. 13: The experimental daily distribution of the household voltage in the summer

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