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Performance evaluation of hybrid Photovoltaic-Wind power systems

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Abstract

This paper presents experimental results from the operation of a test bench constituted of a PV-Wind hybrid system. This device includes photovoltaic (PV) and wind subsystems, battery energy storage, load and a hybrid system, controller for battery charging and discharging condition. The system includes a 600W PV array, 1KW wind turbine; in the day the energy produced is stored in a battery bank 24V/1600Ah and used for public lighting at night, with an average daily energy consumption of 2640 Wh. The experimental set up has been realized in the Research Unit in Renewable Energies in Saharan Medium, Adrar (South of Algeria). The photovoltaic panel group constitutes the primary energy supplier of the system; while the wind turbine is the secondary supplier since the contribution of wind turbine is small as compared to the share of the photovoltaic subsystem.

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Keywords: Hybrid energy system; phtovoltqiaue; wind; battery energy storage; electricty generation; load profile.

1. Introduction

Today, Algeria's energy needs are fulfilled exclusively thorough hydrocarbons exploitation, mainly natural gas. The level of natural gas volumes, produced of the domestic market would be 45 billions m^3 in 2020 and 55 billions m^3 in 2030. Other volumes of natural gas are intended for export to finance national economy. Electricity

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consumption is expected to reach 75 to 80 TWh in 2020 and 130 to 150 TWh in 2030 [1,2].

All these considerations justify the strong integration, right today, of renewable energies in the strategy of long-term energy offer. The strategic choice is motivated by the huge potential in solar energy. This energy is the major focus of the programme of which solar power and photovoltaic systems constitute an essential part. It is expected that in 2030, solar should cover more than 37% of national electricity production [1,2].

Despite its relatively low potential, wind energy is not excluded from the program because it constitutes the second axis of development with a share in electricity production expected to reach about 3 % in 2030. Algeria also plans to install some experimental size units to test the various technologies in renewable energies such as biomass, geothermal energy and desalination of brackish water [1,2].

In the literature, the hybrid systems are described in many studies both experimentally and numerically such as PV/Wind/Battery [3-5], PV/Wind only [6-10], PV/Wind/Battery/Diesel [11,12], wind/Diesel/battery [16-18], PV/Wind/Diesel [13-15], PV/diesel [19, 20], PV/Wind/Diesel/Microhydroelectric turbine [22], PV/Wind/micro-turbine/battery [21] and PV/Wind/Fuel cell [23,24]. The selection process for hybrid power sources at a given site is dependent on a combination of many factors, including the load demand, site topography, seasonal availability of energy sources, cost of energy storage and delivery, seasonal energy requirements, etc. [24].

The aim of this paper is to presents and discusses the results of measurements of solar radiation, wind speed, temperature, energy production data from photovoltaic modules and from wind turbine and the load during period testing of a photovoltaic-wind–battery hybrid power system used for public lighting at night, with an average daily energy consumption of 2640 Wh.

2. Potential energy of Adrar

Adrar is a province in southwestern Algeria. It is bordered to the north by the province of Bechar, El-Bayadh and Ghardaïa; to the west by the Wilaya of Tindouf; to the east by the Wilaya of Tamanrasset; to the south by Mauritania and Mali [25-28].

Its geographical coordinates are represented by a latitude of 27°52′ North of the equator and longitude of 0°17′ West of Greenwich, Adrar occupies an area of 427,368 km^2, a population of 422,331 inhabitants with very low population density estimated at 0.98 inhabitants/km^2 [25-28].

3. The hybrid PV-Wind experimental system description

The hybrid system considered in this study is a combination of photovoltaic and wind subsystems, intended for use in residential applications. Here, the amount of the electricity produced depends on the total solar radiation on tilted plan (a slope roughly equal to the latitude of the site $\beta = 28°$) and the wind speed.

The seven main components of the experimental residential power system are a PV array (UDTS50, 600 W monocrystralline silicon), wind turbine (1KW, Whisper 100), hybrid charge controller (Steca " Tarom 245 ", 24V), battery bank (SP 12V-100Ah, lead-acid type), inverter (DC/AC, CP 300), load (AC and DC) and data acquisition.

The proposed system is composed of: 3.33 m^2 photovoltaic (PV) panels and 1 kW wind turbine interconnected to a DC bus through converters. The PV-Wind hybrid system is coupled to battery storage. PV panels transform solar radiation into direct current (DC), and the electricity (AC) generated by the wind turbine transforming it to direct current (DC) by the Whisper controller. The DC voltage obtained at the output of the photovoltaic and wind subsystems are connected to the inputs of the hybrid system controller.

The system can satisfy both DC and AC loads. For the AC 220V loads a CP300 inverter is used between the hybrid charge controller and the AC loads, to convert direct current DC 24V into alternative current AC 220V.

The schematic diagram of the experimental system and all of its components are shown in Fig.1, along with photos 2 and 3 of the actual installation. The experimental set up has been realized in the Research Unit in