Analysis of Wind-Diesel Hybrid Power System Integration in an Autonomous Grid

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Abstract

The electrical energy is often produced with the help of diesel generators in isolated areas in the Saharan region. While the latter requiring relatively little investment because is generally expensive to exploit due to the transportation to remote areas adds extra cost, significant fuel consumption and relatively high maintenance cost, etc. Moreover, the electricity production by the diesel is ineffective, presents significant environmental risks. But these isolated areas have significant wind energy potential; which is good position for the exploitation of clean and sustainable wind energy. The use of wind-diesel power system is widely recommended especially to reduce fuel consumption and in this way to reduce system operating costs and environmental impact.The subject of this paper is to present the simulation of a wind-diesel power system. This system has a high control strategy for the management of different power sources (wind, diesel, battery) that depending to weather conditions, especially wind speed values and the power demanded by the consumer load.

Keywords: renewable energy, isolated grid, management, simulation.

I. Introduction

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meet them. The growth of the world's human population has created several problems. One of them is global warming caused by the abundance of CO_2 in the atmosphere. Many of these gases are produced from electrical plants burning fossil fuel all over the world. To reduce these emanations out into the atmosphere alternative sources of energy must be used. In the last two decades solar energy and wind energy has become an alternative to traditional energy sources. These alternative energy sources are non-polluting, free in their availability and renewable [6].

In isolated areas such as the Algerian Sahara (Adrar, Bechar, In Salah, Timimoun, Tindouf, Amenas, etc), electrical energy is often produced with the help of diesel generators. Moreover, the electricity production by the diesel is ineffective, presents significant environmental risks (spilling), contaminates the local air and largely contributes to GHG emission. In all, we estimate at 16086 kg/year GHG emission resulting from the use of diesel generators for the subscribers of the autonomous networks in Algeria [2],[7]. But numerous isolated areas have significant wind energy potential. It is then interesting to associate with a diesel some wind generators as diesel electricity is generally more expensive than wind electricity. To reduce fuel consumption and power variations of the diesel, an energy storage system can be associated with the wind–diesel system [5].

The subject of this work is to combine these diesel generators (DG) with wind turbine generators (WTG) plant sized to the needs of consumption, while providing continuous high quality electric power. The main goal with wind diesel hybrid system (WDHS) is to reduce fuel consumption and in this way to reduce system operating costs for economic purpose and environmental impact. This system equipped with a control system, a proper control strategy has to be developed to take full advantage of the wind energy during the periods of time.

Nomenclature

WDHS	: Wind Diesel Hybrid System
DG	: Diesel Generator
WTG	: Wind Turbine Generator
GHG	: Greenhouse Gas
DCS	: Distributed Control System
ρ	: Air density (kg/m^3)
A	: Area swept by turbine blades (m^2)
C_p	: Rotor power coefficient
v_ω	: Wind speed (m/s)

II. Geographical and meteorological data of the studied site

II.1. Geographical situation

The studied site located in Adrar region with geographical coordinates (27°59'N, 0°11'W, 263 m). Adrar state situated in the extreme Algerian South-West extends over 427 968 km^2 about (1/5) of the country.

II.2. Meteorological data

The climate data of wind speed recorded at Adrar region (Algeria) for the year 2012 were measured at the weather station of the Renewable Energy Research Unit in Saharian Medium (URER-MS) Adrar. (See Table 1 below), [8].

Table 1. Wind speed data for a studied site.

Months	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
***v* (m/s)**	6,44	6,22	6,05	5,33	6,27	5,27	7,78	6,41	4,94	4,8	4,86	5,58

III. Hybrid system overview

In this study, Fig. 1 shows the configuration considered in this paper. This configuration consists of wind turbine generator (WTG), diesel generator (DG), battery bank, consumer load, power electronic converters (AC/DC rectifier, DC/AC inverter),monitoring system, distributed control system (DCS), switches and relays, controller and other accessory devices and cables [3],[4].

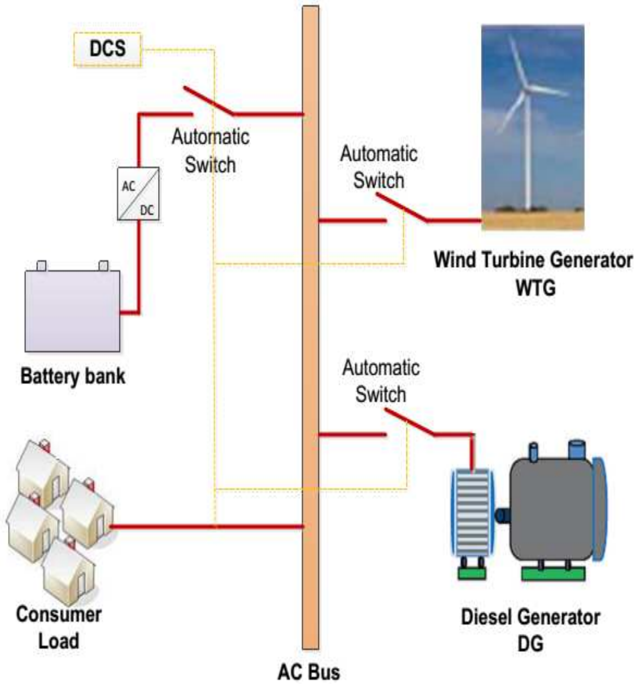

Fig. 1. Schematic diagram of the hybrid wind-diesel generation power system

IV. Operation modes of wind-diesel hybrid system

The WDHS is classified as being High Penetration (HP), [4]. HP-WDHS have three modes as follows:

1. Weak winds ($v_\omega \le 3m/s$): Diesel Only (DO).
2. Moderate winds ($3m/s < v_\omega \le 10m/s$): Wind and Diesel (WD) in service.
3. Strong winds ($v_\omega > 10m/s$): Wind Only (WO).

V. The proposed control system strategy

For a multi-source energy system, a power flow management strategy is needed. According to wind speed values and the power demanded by the consumer load. The power management strategy used in this study is according to the flow chart shown in Fig. 2. [1].

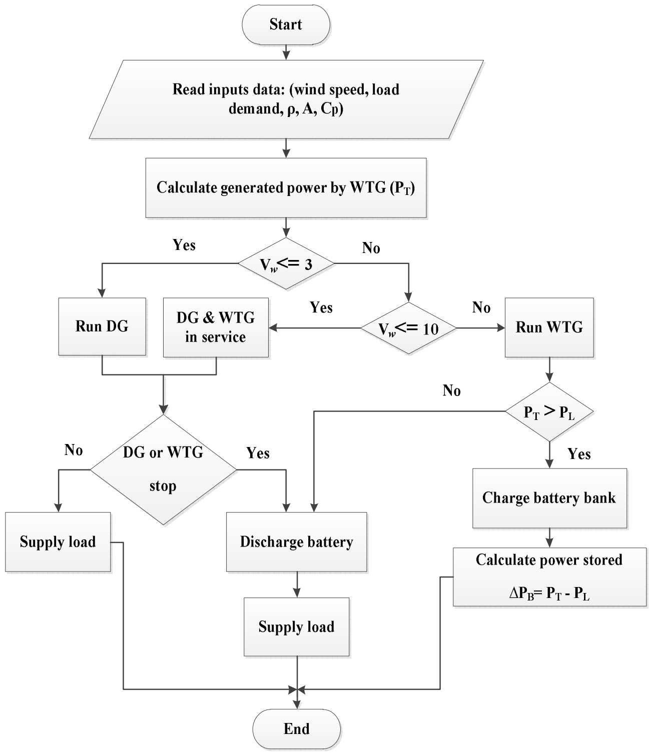

Fig. 2. Main flow chart

VI. Simulation results and discussions

From Table .1, the highest wind speed was in July (7.78 m/s). Fig. 3 shows the average daily wind speed for the considered site in July.

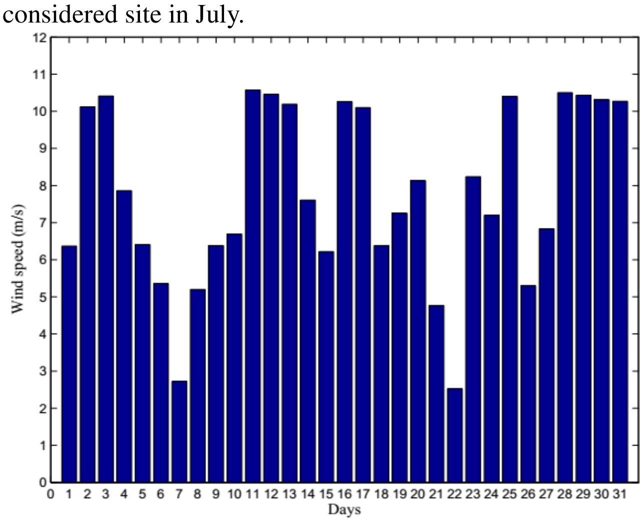

Fig. 3. The average daily wind speed in July

The load detail for the hybrid system is shown in Fig. 4 shows the load profile adopted in this study. This profile is considered to be the same for all the days of the year with peak load as 98 kW.

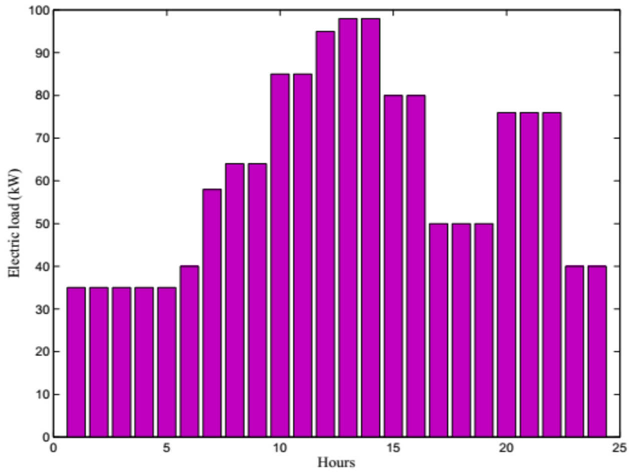

Fig. 4. The daily profile load

Fig. 5 shows electricity produced by wind turbine generator and diesel generator. The wind turbine generator only supplies energy during 12th days; in these cases the generated power (P_T) is greater than the require power by the consumer load (P_L). So, the surplus wind energy will be stored in battery bank. But, on July 7th and 22nd the supply power is ensured by diesel generator only because the wind speed is less than 3m/s. The battery bank is used only when the renewable source and/or the conventional diesel power system are not able to satisfy the load demand, also when the DG or WTG broke down.

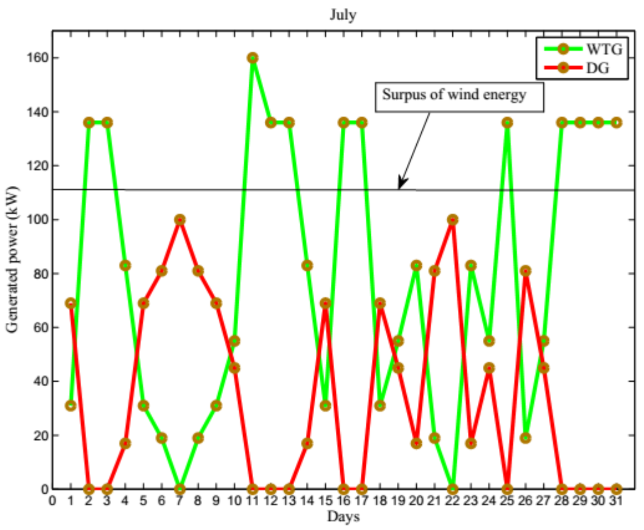

Fig. 5. The daily energy production by wind-diesel hybrid system

The summary of various costs related to the hybrid wind-diesel power system is summarized in Table 2: the energy cost of WTG is greater than DG this is due to the number of operation of each system. While the latter has the effect of fuel consumption and its impact on CO_2 emissions. Moreover, cost of fuel consumption.

VII. Conclusions

This paper presents a techno-economic analysis and the design of a complete hybrid system, consisting of wind turbine generator, a diesel generator and a battery system as a backup power source for a typical isolated area situated in Adrar region. We have demonstrated the electricity produced with the help of diesel generators is relatively inefficient, very expensive and responsible for the emission of Greenhouse Gas (GHG). The WDHS has a great potential technical, economical and ecological very promoter and very cost-effective compared to the traditional diesel system. This system has a good control strategy for the management of different power sources (wind, diesel, battery) that allowing to optimize the operation of the hybrid system, to take full advantage of the wind energy during the periods of time and to minimize diesel fuel consumption, in this way to reduce system operating costs and environmental benefits. Therefore, the wind-diesel power system is widely recommended especially for isolated sites that have significant wind energy potential.

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Table 2. Summary of various costs related to the hybrid wind-diesel power system.

Days	Energy Cost WTG (**DA**) **(5.958 DA/kWh)**	Energy Cost DG (**DA**) **(5.958 DA/kWh)**	Fuel consumption (***l*****/day**)	Fuel cost (**DA**) **(13.7 DA/*****l*****)**	CO_2emission **(kg/day)** **(2.6kg/*****l*****)**
1	180,42	411,102	25,119	344,1303	65,3094
2	791,52	0	0	0	0
3	791,52	0	0	0	0
4	483,06	101,286	12,327	168,8799	32,0502
5	180,42	411,102	25,119	344,1303	65,3094
6	110,58	482,598	28,071	384,5727	72,9846
7	0	595,8	32,745	448,6065	85,137
8	110,58	482,598	28,071	384,5727	72,9846
9	180,42	411,102	25,119	344,1303	65,3094
10	320,1	268,11	19,215	263,2455	49,959
11	931,2	0	0	0	0
12	791,52	0	0	0	0
13	791,52	0	0	0	0
14	483,06	101,286	12,327	168,8799	32,0502
15	180,42	411,102	25,119	344,1303	65,3094
16	791,52	0	0	0	0
17	791,52	0	0	0	0
18	180,42	411,102	25,119	344,1303	65,3094
19	320,1	268,11	19,215	263,2455	49,959
20	483,06	101,286	12,327	168,8799	32,0502
21	110,58	482,598	28,071	384,5727	72,9846
22	0	595,8	32,745	448,6065	85,137
23	483,06	101,286	12,327	168,8799	32,0502
24	320,1	268,11	19,215	263,2455	49,959
25	791,52	0	8,145	111,5865	21,177
26	110,58	482,598	28,071	384,5727	72,9846
27	320,1	268,11	19,215	263,2455	49,959
28	791,52	0	0	0	0
29	791,52	0	0	0	0
30	791,52	0	0	0	0
31	791,52	0	0	0	0
Total	**14194,98**	**6655,086**	**429,537**	**5884,6569**	**1116,7962**