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Design and Analysis of Off -Grid PV/Diesel System for Small Scale Factory Located in Wadi Rum, Jordan Using Homer software

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Abstract: The fuel prices are increasing nowadays, causing a burden on the power system. From this, diesel generators that are still in use, must be hybridized with renewable energy (RE) to levelized the overall projects costs. This study aims to schedule an operation of a hybrid system photovoltaic (PV)/ diesel in a remote area which located in Wadi Rum district in Jordan to serve factory load in addition to obtain the best economical system combination that can serve the needs of a continuous electrical load without any interruption. Based on the results of the analysis using HOMER software, the configuration in the system will be a combination between PV modules, and diesel generator. The hybrid system has met the target for electricity production which is documented in upcoming sections.

Keywords: Renewable energy; Hybrid system; photovoltaic; diesel generator; HOMER

I. Introduction

This type of research is required across all energy sectors due to a major increase in electricity prices locally and globally in addition to the high cost of fossil fuels [1]. Also, exploring environmentally friendly alternative energy sources is crucial to face the high carbon emissions that cause a harmful effect alongside changing weather conditions. Using several models, the development of eco-friendly energy sources has been developed during the past fifteen years. By utilizing reliable energy sources, such as the creation of cheap, easily accessible, flexible, and ecologically friendly alternative energy, we may reduce our dependence on fossil fuels [2]. A hybrid renewable energy system (HRES), which consists of multiple renewable energy suppliers, is required for the best possible use of renewable energy. Both on and off the grid, hybrid power plant optimization is still being developed, primarily to address the need for electricity in remote location. The operation of a generator and storage system is the largest expense components with delivering an electric power system; thus, a dependable and effective system is required so, finding the best power flow from the available renewable energy sources will enhance the way for energy producers to cut- in the operating costs. The process of scheduling the operation of generating units involves figuring out how to combine objective and constraint functions in the form of linear equations to solve optimization issues. This process can be used to the problem of scheduling power producing units.

II. HOMER Software

HOMER (Hybrid Optimization Model for Multiple Energy Resources) is an effective and useful tool for engineers to initiate and design microgrid projects in an innovative way. The reason behind choosing this software is that it enables us to study and analyse various configurations of renewable energy sources integrated with traditional power sources [3]. The number of its users is increasing day by day as we are facing a rapid expansion in renewable energy developments. It is also able to conduct short- and long-term evaluations of electrical, environmental, and economic outcomes. A

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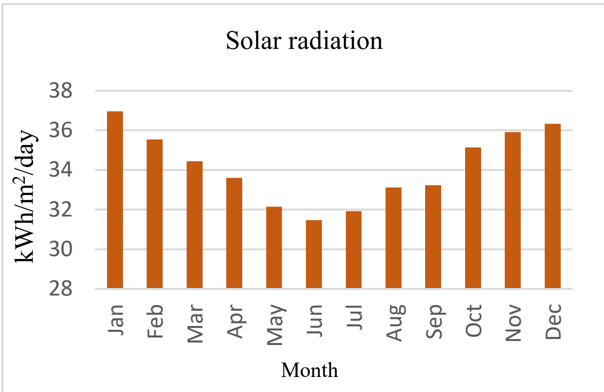
comparative study for PV/ Diesel case will explain in terms of meeting the electricity demand, cost-effectiveness, and greenhouse gas emissions reduction.

III. Configuration Methodology

Although renewable energy sources like wind and solar are abundant and eco-friendly, they cannot be relied upon to supply energy demands because of their fluctuation nature. Since the characteristics of the power produced by wind and photovoltaic (PV) systems depend on the weather conditions and temperature rate, backup systems like conventional engine generators or batteries are needed as storage devices [4]. When two power sources are hybridized and storage system is existing, the system's reliability increases significantly, especially during cloudy days or deficit time from RES. Therefore, the optimal size of system components is an important part of a hybrid power system. The use of HRES is becoming more widespread in the current energy and climate conditions also, artificial intelligence can offer good system optimization even in the absence of substantial long-term meteorological data, according to recent developments in the optimization of hybrid renewable energy systems. This case study was conducted in Wadi Rum district as shown in figure below:

Figure 1. study's location [5].

In addition to selecting the project location, renewable resources must be considered like temperature, daily solar radiation, and average wind speed. All resources have been downloaded from NASA's prediction of worldwide energy resource database in the selected area as shown in figure (2) [6].



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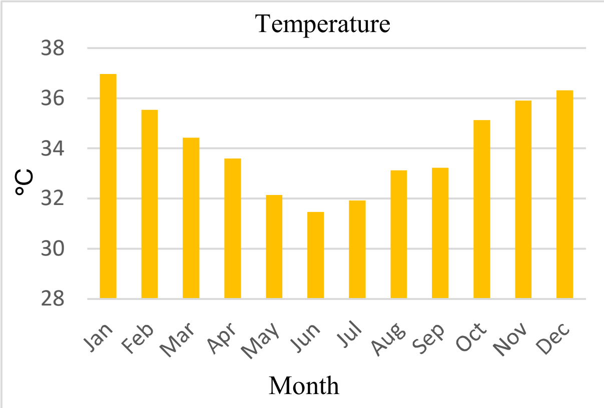

(**b**)

Figure 2. (a) Monthly average solar global horizontal irradiance GHI (kWh/m2/day). (b) Monthly average temperature data (°C).

IV. Component Selection

In this Section, each component of the project will be figured out in terms of type, manufacturer, rated capacity, lifetime, and any related power data extracted from the HOMER database [7]. The cost data that includes capital, operating and maintenance, and replacement costs were extracted regarding the attached study [8]. Solar panels and diesel generators are the main electricity sources in the system which are required to meet the desired load directly, while the excess energy will charge the batteries for later use.

1. Photovoltaic Modules

The characteristics of the selected photovoltaic panels are depicted below in Table (1).

Table 1. Properties of project PV panel [9].

Name	Trina tallmax plus
Type	flat plate
Abbreviation	PV
Rated capacity (kW)	0.345
Operating temp. (C°)	44.00
Efficiency (%)	17.8
Manufacturer	Trina Solar
Derating factor (%)	80
Lifetime (y)	25

The calculation of the PV output power is represented as follow equation (1):

$$Ppv = Ypv * fpv \, (\frac{GT}{GT.sts})$$

Where, G_T is the solar radiation incident for the PV array in the current time step in kW/m², GT_{sts} is the incident radiation at standard test conditions that is considered as 1 kW/m², Y_{PV} is the rated capacity for PV array in kW while f_{PV} is the PV derating factor in percentage that is considered at 80% [10].

2. Diesel Generator

The diesel generator used in the system as backup, whenever there is a shortage in power production by the PV, the diesel generator starts working to meet the energy demand. The excess of energy is used to charge the batteries and the diesel generator stops. Table (2) below specifies the main properties of the selected diesel generator [11].

Table 2. Diesel generator properties.

Name	Auto size genset
Abbreviation	Gen.
Manufacturer	Genset
Fuel consumption	0.236 L/h/kW
CO_2 emissions	16.5 g/L
Lifetime (y)	18000 h

3. Converter

The System converter is a bidirectional converter that converts the electrical power between DC and AC buses as an inverter and rectifier. The reliability of the conversion process depends on the power flow between the two buses and the weather conditions as well. HOMER software controller has set the capacity and other characteristics of the selected converter to make the result more flexible and efficient.

4. Storage System

The need to move away from fossil fuels and toward renewable energy sources, rising demand due to increased electrification of electric vehicles and residences, and resultant infrastructure instability are all difficulties facing today's energy grid, as global leader in the energy sector, provides the widest range of hybrid and environmentally friendly power solutions. A battery energy storage system can store energy from a variety of sources, including generators, solar panels, wind turbine and the grid. The energy can then be redistributed to a facility that demands electricity later. We chose a lead acid battery with nominal voltage 12V and nominal capacity of 1kW/h and maximum capacity of 83.4 Ah and with a minimum 5-year storage life.

5. Load Profile

The attached load profile has been extracted from U.S energy information administration (USEIA) [12], which represents a medium scale factory load for the year of 2023. A variation in energy consumption is figured out based on hourly, daily, weekly, and seasonal behaviors. Noting that the peak month in January is depicted in figure (3). The average daily load is 819.39 kWh/day.

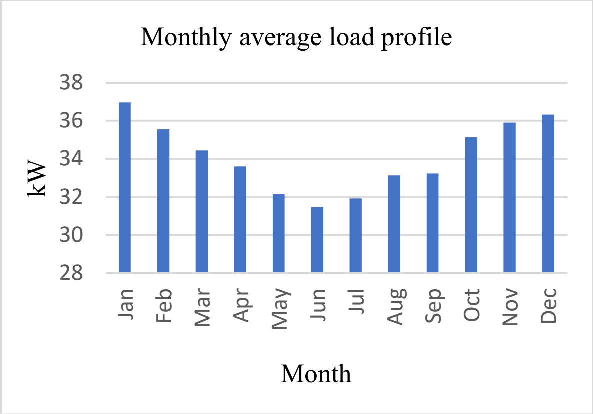

Figure 3. Monthly average load profile.

The system configuration for this study consists of PV panels and diesel generator in addition to LA batteries as a backup component. Since the characteristics of the power produced by photovoltaic (PV) systems depend on the weather conditions and temperature rate, backup systems like conventional diesel generator should exists in addition to batteries as storage. Figure (4) below shows the schematic diagram for our system based on HOMER interface.

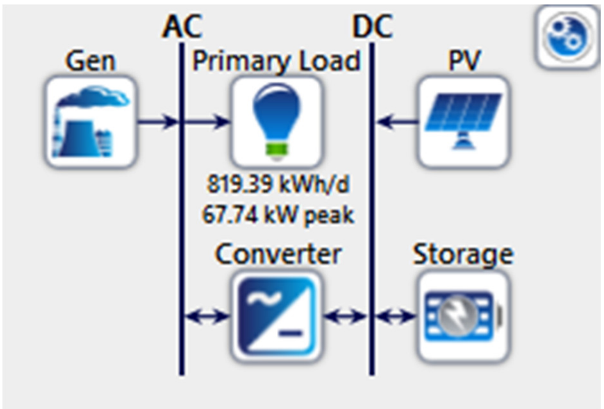

Figure 4. Project schematic diagram.

V. Simulation Results

The proposed system has been simulated to find the optimal approach for each component in terms of size, capital cost, operational and maintenance (O&M) cost and replacement cost, which is represented in table (3). This microgrid requires 820 kWh/day and has a peak of 68 kW. PV array was responsible for 477,339 kWh/y annual power production (89.5%) while the diesel generator is 21,581 kWh/y (10.5%). The total fuel consumed by the diesel generator is 7,967 L with average of 21.8 L/day. Figure (5) summarizes the total monthly energy production during project life. The overall net present cost (NPC) is 814,740 $, while the levelized cost of energy (LCOE) is 0.2107 $/kWh.

Monthly average energy production

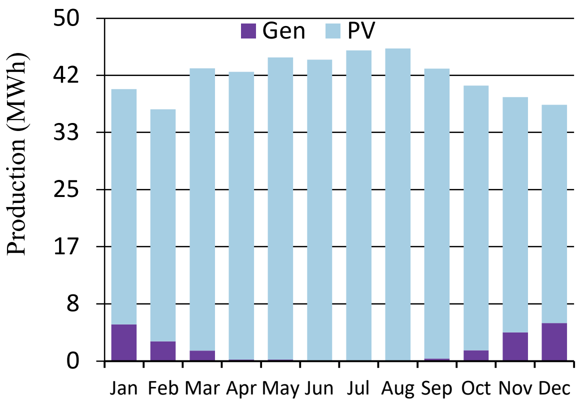

Figure 5. Monthly average load profile.

VI. Conclusion

This study aims to schedule an operation of a hybrid system PV/ diesel in a remote area which located in Wadi Rum district in Jordan to serve factory load in addition to obtain the best economical system combination without any interruption. The sensitivity analysis has been calculated which is a useful tool to measure how the system outcomes will be affected if one or more variables change during the project lifetime in terms of financial and performance results. Solar radiation has been selected as a sensitivity variable to make a sensitivity analysis study by reducing the base case of (2%), (3%), and (5%). The based scale average is 5.59 kWh/m2/day. Net present cost (NPC) has ranged from 814,740$ for the base case to 832,157$ and the levelized cost of energy (LCOE) has ranged from 0.211$/kWh to 0.215 $/kWh depending on sensitivity analysis results. The total fuel consumed is 7,967 L, with average of 21.8 L/day. This approach transforms the way we use and store RES's, making it a reliable source for the required load and energy storage regardless of the weather or time of the day which reflecting in increase the overall of the system efficiency and decreasing the carbon emissions as well.

Table 3. Simulation Results for each component.

Component	Capital ($)	O&M ($)	Replacement ($)	Fuel ($)	Size
PV	175,770	34,904	0.00	0.00	270 kW
Diesel Generator	37,500	26,265.48	12,000.77	102,988	75 kW
Storage	119,400	102,903	214,070	0.00	796 qty.
Converter	22,312	0.00	0.00	0.00	75 kW
System	354,982	164,072	226,072	102,988	-

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