Hybrid SOLAR / DIESEL Low Power Generation Performance System for Local House in Baghdad City

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Abstract. The national electrical energy situation report study today in Iraq represents that the value of the conventional electrical energy power is increasing day after day with increasing more demand on the electricity source in all sectors of life in Iraq. To avoid energy supply shortage, today should be using renewable energy sources with rise required management. A hybrid electrical energy system usually consists of two or more renewable energy sources used together with conventional electrical energy sources to extend increased system efficiency, but the design of hybrid power involves uneconomic and excessive capacities results in excess electric generation with increasing the initial costs. In this study, we find the optimization the best time required of sharing alternative between both of solar-diesel generator hybrid power system for 24 hours. The PV peak power was 1.3kW and diesel power 2.4kW with using both of theoretical calculation. The HOMER software was used to improve a simulation model for one day in Baghdad city in Iraq. The HOMER software is used to implement the optimization. The master objective is to optimize hybrid system component sizes, minimizing excess electricity generation, and set electric load and implement cost analysis based on life cycle price. Inputs data used for simulation consist of real solar radiation data (Averaged to monthly values), taken from the local weather station installed at Baghdad city. Based on maximum load, hybrid system parameters sizes considered and many simulation results are acquired.

Keyword: Hybrid system, Renewable energy, Homer software, solar energy, Efficiency.

1. Introduction

Hybrid renewable energy systems (HRES) is very common as stand-alone power system to provide national electric power in remote areas by reason of development in new renewable energy technology and high cost of all products produced from petroleum. The hybrid energy system typically involves two or more sources of renewable energy which were applied together to achieve high power system efficiency along with better balance in powered supply. Typically the hybrid energy systems involve two or more energy source; solar, wind, and hydro energy sources. Most of the renewable energy can be found including different forms of solar energy as photo voltage and thermal energy techniques [1-3].

A system that has all these types of energy sources have the advantage of the constancy and balance. The present study was performed by applying HOMER software which has been developed by the National Renewable Energy Laboratory (NREL). This software performs economic analysis of hybrid power systems [4]. Inputs to HOMER will provide an hourly simulation for each possible combination of components which were entered and the obtained results according to the system according to total Net Present Cost.[9-5]

In this paper, the simulation of a hybrid power generation system consists of DC electric power from PV panels and AC electric power from Diesel generator with Battery storage has a modeled and power management strategy. The system was designed and simulated by using two methods, PVGIS website
and HOMER software simulation with comparison in the theoretical equation to check and prove the output data is the same for all in the same condition with our facts [10-11].

2. System Description

The hybrid power system was designed based on required peak load of present location in Baghdad city and to optimize the size and cost of components effectively. While the designing of power system solar radiation, load profile, size and cost considered components of the system were discussed in the next sections. The system design consists of the 2.4kW Diesel power generator (DG) and 1.3kW peak PV solar energy with charger and battery bank storage with an inverter from DC to AC power [12-15]. The block diagram of the Hybrid Solar Diesel Power System (HSDPS) as shown in figure 1.

2.1. Solar radiation Data

In this work, solar radiation was collected for two sources Davis instruments type Vantage Pro2 and PVGIS website. (Longitude 44.21° E, Latitude 33.21° N) the location from weather station installed at the ministry of science and technology, Jadryia, Baghdad of the year 2017, where data has been measured to monthly values to estimate the design of hybrid PV/Battery/DG power systems. First, we begin in Global Horizontal solar radiation for Iraq and especially in Baghdad city as shown in figure 2. Then Table 1. Shows monthly mean daily solar radiation ranges from 4.28 to 7.23 (kWh/m2/d), the total annual average radiation was 5.9kWh/m2/day and the monthly average solar radiation have maximum value in July 7.23 kWh/m2/day compared January 4.24 kWh/m2/day show in figure 3.

Figure 1. Block Diagram of Hybrid Solar Diesel Power System (HSDPS)

Figure 2. Iraq Map of Global Horizontal Irradiation (GHI)
Figure 3. Monthly Average Solar Radiation in Baghdad city

Table 1. Annual average Radiation values in Baghdad city

| Month | Clearness Index | Average Radiation (kWh/m²/day) |
|-------|----------------|-------------------------------|
| Jan   | 0.798          | 4.24                          |
| Feb   | 0.787          | 5.24                          |
| Mar   | 0.738          | 5.7                           |
| Apr   | 0.607          | 6.1                           |
| May   | 0.586          | 6.51                          |
| Jun   | 0.617          | 7.10                          |
| Jul   | 0.641          | 7.23                          |
| Aug   | 0.687          | 7.15                          |
| Sep   | 0.715          | 6.40                          |
| Oct   | 0.843          | 6.04                          |
| Nov   | 0.920          | 5.19                          |
| Dec   | 0.868          | 4.30                          |

2.2. Load Profile

Load is an important factor for any power generation system. HOMER software optimizes the system parameters based on load information of load profile. In this research load data have been provided for a simple Iraqi house by ministry of Electricity with the department of distribution company in Baghdad by consideration through meter reading instrument (MRI), the average of each 24 hour of the day in unit of kW. So that daily measured consumption is considered as 13 kWh/d in this study. The peak load was 1.3KW utilize to design the simulation model and it decides the size of system components as shown in figure 4. Shows Daily average load profile. The annual load is also a significant condition, for that HOMER measured seasonal load variations by simulating 12 months. The season load profile for the whole year shows that the minimum and maximum monthly average load is shown in figure 5 and Table 2. Represents the daily components of load demand.
Figure 4. Daily Demand load profile

Figure 5. Annual load profile

Table 2. Daily components load demand.

| no | name       | Consumption Power W | Quantity | Load kW | Hour/ day | kWh/ day |
|----|------------|---------------------|----------|---------|-----------|----------|
| 1  | Lighting   | 40                  | 5        | 0.2     | 10        | 2        |
| 2  | Fans       | 50                  | 4        | 0.2     | 10        | 2        |
| 3  | Refrigerator | 250                | 1        | 0.25    | 24        | 6        |
| 4  | TV         | 150                 | 1        | 0.15    | 8         | 1.2      |
| 5  | cooler     | 200                 | 1        | 0.2     | 5         | 1        |
| 6  | computer   | 100                 | 1        | 0.1     | 6         | 0.6      |
| 7  | printer    | 200                 | 1        | 0.2     | 1         | 0.2      |
| total |          |                     |          |         |           | 13       |

2.3. Diesel Generator

The diesel generator has mainly been used to provide power operates at night time, is of AC type. The generator have capacity 2.4kW is used in this study (China). The capital cost was considered is $200. The lifetime of the generator is rating at 5000 operating hours and the price of diesel is 0.35 $/liter this is the price in Baghdad Iraq. In the figure 6 shows that the working time table of hybrid Solar/Battery/diesel generator power systems that each of them working every day for one year appears that generator schedule depends on daylight and night hours that’s mean working diesel 8 hours every day with PV solar 8 hours solar energy (from 8 clock morning time to 4 clock evening time) and 8 hours when used Battery bank storage.
2.4. PV Solar Generator

The photovoltaic modules type Silicon polycrystalline efficiency 17% the price here around 0.4$/W in Iraq with many companies specialize in Baghdad for solar energy components cost in the renewable energy market. That’s mean the cost of 1.3kW peak power of PV price around 500$.

2.5. Converter

The converter function is rectifying like an inverter. Since 2kW output would be generated for designing simulation model with capital cost is assumed to be $200. The lifetime of the converter is measured at around 10 years and an efficiency of 95% (inverter), 90% (rectifier).

2.6. Battery

The types of storage battery is a gel with capacity of 12V, 100Ah. Batteries used to provide about one hour of electricity, and arranged such that any string consist of two batteries, with total strings equal to six. Using 12 units of total batteries and use nominal voltage equal to 12V. This battery bank has the ability to provide about one hour of electricity.

3. Theoretical Calculations

To find the PV sizing system off-grid with peak load 1.3kW that mean the number of Module and number of Battery for 6A and three hours’ time storage with using solar module 12V and battery 12V voltage with 200Ah capacity as show in equations (1-9). The peak sun hours in Baghdad Iraq from our calculations we found the P.S.H=5.9 and the efficiency of both of inverter, charger and battery, where:

\[ \eta_{inv} = \eta_{char} = \eta_{Batt} = 0.9 \]  

The safety factor=1.3.

The energy demand of load every day equal power load multiple hours of operation per day: that means,

\[ El = (Energy\ of\ Load) = Power\ Load \times Operation\ hours/day \]  

\[ El = PL \times \frac{h_{day}}{day} = 220V \times 6A \times \frac{3h}{day} = 3960Wh/day \]  

\[ E_{pv} = Energy\ of\ Module = \frac{El}{(\eta_{inv} \times \eta_{char})} \]  

\[ E_{pv} = \frac{3960}{0.9 \times 0.9} = 4888Wh \]
\[ P_{pv} = \frac{\text{power of PV Module}}{\text{(Peak Sun Hour)}} = \frac{EL}{PSH} = \frac{4888}{5.9} = 828W \]  
\[ \text{Actual } P_{pv} = P_{pv} \times 1.3 \text{(safety factor)} = 828 \times 1.3 = 1077 \cong 1100 Wp \]  

That means we required number of Modules equal to around ~ 1100 W that choosing 11 modules to have power 100 watt, that means 11 Module connected in parallel or 120W, 9 panels connected in parallel depending on the designer.

The capacity battery required for storage power from the PV and diesel generator in a day when working that is:

\[ \text{Capacity Battery}(C.B) = \frac{EL}{\eta_{\text{Batt}} \times \text{DoD} \times V_{\text{batt}}} = 3960/(0.9 \times 0.7 \times 12) \]
\[ C.B = \frac{4400}{7.56} = 523 Ah \sim 600 Ah \]

That means we required about three numbers of Battery each capacity 200Ah with a total of three batteries connected in parallel each 12Volts.

4. Results and Discussion

The total price of complete PV solar / Diesel power generator system in this work consists of these items with specification as shown in table 3.

| Item, No.       | power   | price |
|-----------------|---------|-------|
| PV panels, 10pcs| 1.3KW   | 500$  |
| Gas Generator, 1| 2.4KW   | 200$  |
| Inverter, 1     | 2KW     | 200$  |
| Charger, 1      | 50A     | 100$  |
| Battery, 2      | 12V, 200Ah | 600$ |
| Cables          | 6A, 220VAC | 100$ |
| structure       | metal   | 100$  |
| total           |         | 1800$ |

The hybrid power system HOMER software which is calculates each possible design of the present local location. It compose of PV array, diesel generator, converter, and batteries which were presented in the Performed simulation. In normal operation, PV supplies the load requirement. The exceeding energy of PV is stored in the battery until the capacity of the battery is full reached. The diesel generator is used as a backup and in night day, in the case when provide from PV is unavailable. The converter is used to convert DC to AC (as an inverter) and AC to DC (as rectifier or charger). After that we have two cases for simulation of power generation of PV / Diesel 1.3 kW hybrid power generation performance system for a local house in Baghdad city.

Case 1. HOMER simulation; first of all the HOMER software working of all the scale of low, medium and large power generation scale with here used around 1-2 kW, it's difficult to make simulation analyses for low scale. So we made more suggestions to analyses with adding another generator to give our study more choosing items. The results of the cost summary as shown in figures 7, 8, 9. The cost summary represents the t
Figure 7. Cash flow analysis of NPC of the optimized hybrid energy system

Figure 8. Cash flow
Case 2. Theoretical calculation;
In the theoretical calculation, it has put the total loss factor equal to 1.3 as a safety factor and calculated the number of PV power need for a local house in Baghdad we have found we need about 1100W and three batteries to build the hybrid power generation system.
From all simulation, we have found the difference not too much because the analyses between two systems different in basic, so any designer will go directly to Homer because more accurate in calculations.

5. Conclusions
In this study optimization of sharing alternative between both of solar-diesel generator hybrid power system, the PV peak power was 1.3kW and diesel power 2.4kW with using both of theoretical calculation and HOMER software were used to develop a simulation model for Baghdad city in Iraq.
The number Module has 11 Modules connected in required about three numbers of Battery each capacity in parallel with three battery capacity has 200Ah connected in parallel each 12V. The total price of the complete PV/Diesel power generator system was 1800$ USD. The saving energy has done about 30% every day. Hybrid Optimization Model for Electric Renewable (HOMER) software is used to implement the optimization. The main goal is to optimize hybrid system component sizes, minimizing excess electricity generation, and set electric load and implement cost analysis based on life cycle cost of sharing alternative between both of solar-diesel generator hybrid power system.

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