

Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software

Ali Al-Karaghoul, L.L. Kazmerski *

National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401, USA

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Abstract

This paper addresses the need for electricity of rural areas in southern Iraq and proposes a photovoltaic (PV) solar system to power a health clinic in that region. The total daily health clinic load is 31.6 kW h and detailed loads are listed. The National Renewable Energy Laboratory (NREL) optimization computer model for distributed power, “HOMER,” is used to estimate the system size and its life-cycle cost. The analysis shows that the optimal system’s initial cost, net present cost, and electricity cost is US\$ 50,700, US\$ 60,375, and US\$ 0.238/kW h, respectively. These values for the PV system are compared with those of a generator alone used to supply the load. We found that the initial cost, net present cost of the generator system, and electricity cost are US\$ 4500, US\$ 352,303, and US\$ 1.332/kW h, respectively. We conclude that using the PV system is justified on humanitarian, technical, and economic grounds.

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Keywords: Photovoltaics (PV); Stand-alone system; Rural electrification; Rural area in Iraq; System; Design

1. Introduction

Most of the rural areas in southern Iraq are still undeveloped and in a chaotic state after the invasion, and there is a need to provide these areas with electricity. Small stand-alone photovoltaic (PV) electrification systems can play a strategic role in the region’s development. The region enjoys a huge amount of solar radiation during the entire year. Although capable of providing plentiful and reliable electricity, this resource is largely untapped. The solar systems can satisfy the electrical needs of clinics, schools, and other social places in a way that can positively affect healthcare and education, ensuring adequate services for the population. An excellent use of these systems is in health clinics. The relation between health and energy is compelling, and as interdependent factors, they largely determine the progress of rural development. Reliable elec-

tricity produced on site has proven capable of delivering high-quality electricity for vaccine refrigeration, lighting, communication, medical appliances, clean water supply, and sanitation ([World Health Organization, 1996](#)).

2. Feasibility of the proposed system

The design of the proposed system used to power the health clinic was done according to the solar international design manual ([Solar Energy International, 2004](#)). The load total capacity was found to be 31.6 kW h/day. The system consists of PV modules, batteries, charge controller, inverter, and the necessary wiring and safety devices. The system layout diagram is shown in [Fig. 1](#).

The system feasibility analysis was performed using the HOMER software developed by the National Renewable Energy Laboratory (NREL) to assist the design of micro-power systems. HOMER is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and

* Corresponding author. Tel.: +1 303 384 6600; fax: +1 303 384 6481.
E-mail address: kaz@nrel.gov (L.L. Kazmerski).

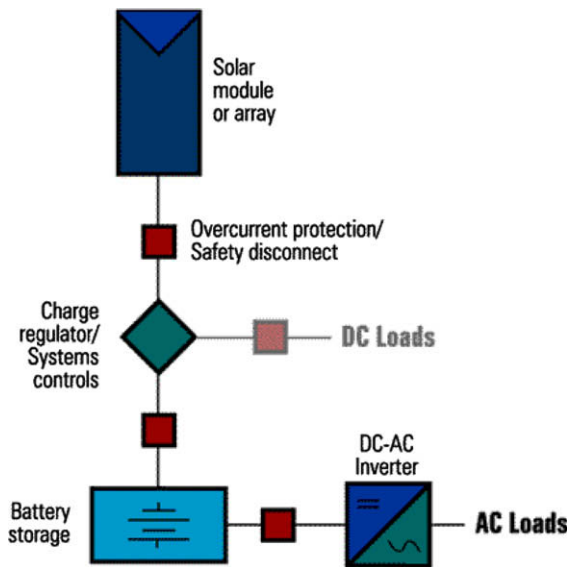


Fig. 1. Block diagram of photovoltaic system.

distributed-generation (DG) applications. HOMER's optimization and sensitivity analysis algorithms allow one to evaluate the economic and technical feasibility of a large number of technology options and to account for variation in technology costs and energy resource availability. HOMER models both conventional and renewable-energy technologies.

HOMER models a power system's physical behavior and its life-cycle cost, which is the total cost of installing and operating the system over its life span. HOMER allows the modeler to compare many different design options based on their technical and economic merits. It also assists in understanding and quantifying the effects of uncertainty or changes in the inputs.

3. Assumptions and HOMER model inputs

3.1. Clinic load analysis

The clinic building comprises the following rooms: administration room, doctor room, nurses' room, waiting

room, two treatment rooms, small pharmacy, and two restrooms. The medical equipment, lighting, and other devices used in this clinic are the following: refrigerator (80 W), freezer (80 W), vaporizer (50 W), oxygen concentrator (300 W), electric sterilizer (1500 W), water pump (100 W), color TV set (130 W), 15 florescent lamps (20 W each), seven ceiling fans (60 W each), and three evaporative coolers (500 W each).

The estimated daily working hours of the medical equipment and other devices are as follows: fluorescent lamps (exteriors and interiors), 12 h/day; TV set, 6 h/day; refrigerator and freezers, 14 h/day; ceiling fans, 12 h/day; vaporizer, 3 h/day; oxygen concentrator, 2 h/day; electric sterilizer, 3 h/day; and water pump, 6 h/day. The system is assumed to work for 6 days a week. Our analysis found that the total connected wattage is 4460 W and the total average daily load is 31.6 kW h. The load analysis calculation is listed in Table 1.

A small base load of 0.18 kW occurs from 5 pm until 7 am. This load is for outside lighting and some inside lighting, whereas the majority of the load occurs during the day time (8 am to 5 pm). Fig. 2 illustrates the load profile. The scaled data for simulation is shown in Table 2.

The solar resource was used for the site of the Al-Hammam lagoon in southern Iraq, located at 30°57' North latitude and 46°51' East longitude. Solar radiation data for this region were obtained from the NASA surface meteorology and solar energy Web site. (NASA Surface Meteorology and Solar Energy, 2004). Table 3 shows the monthly average of solar radiation for this area. The annual average solar radiation is 5.65 kW h/m²/day. Fig. 3 shows the solar resource profile over a 1-year period.

4. System components and estimated prices

The proposed system consists of PV modules, batteries, charge controller, inverter, auxiliary diesel generator, and the rest of the balance-of-systems, which includes modules structure, wiring, fuses, and other system safety devices. The prices for the PV system devices were taken from the

Table 1
Stand-alone electric load worksheet (abbreviated).

Individual load	Qty	×	Volt	×	Amps	=	Watts AC	Watts DC	×	Use h/d	×	Use d/week	÷	7 days	=	W h AC	W h DC
Lamps	13		220		0.1		260			12		6		7		2675	
Lamps (out)	2		220		0.1		40			2		7		7		792	
Refrigerator	1		220		0.364		80			14		7		7		1120	
Freezer	1		220		0.36		80			14		7		7		1120	
Vaporizer	1		220		0.23		50			3		6		7		129	
Oxygen conc.	1		220		1.37		300			2		6		7		515	
Elec. steril.	1		220		6.82		1500			3		6		7		3858	
Water pump	1		220		0.46		100			6		6		7		515	
TV set	1		220		0.59		130			12		6		7		1338	
Ceiling fan	7		220		0.273		420			12		6		7		4320	
Evap. cooler	3		220		2.27		1500			12		6		7		15,428	

AC total connected watts: 4460 W
DC total connected watts

AC average daily load: 31,600 W h
DC average daily load

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