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Photovoltaic Technology of Electricity Generation for Desert Camping

Shafiqur Rehman, Ali A. Shash and Omar S. Baghabra Al-Amoudi
Center for Engineering Research, Research Institute, King Fahd University of Petroleum and Minerals, KFUPM Box No. 767, Dhahran-31261, Saudi Arabia

Abstract: This study presents a case study on the utilization of global solar radiation data on horizontal surface to perform economical feasibility of using Photovoltaic (PV) panels with battery backup to meet a small load for a camping site in Saudi Arabia. The analysis considers three scenarios with daily average energy demands of: (i) full load, (ii) 75% load and (iii) half load with annual peak load of 3.84, 3.06 and 2.27 kW, respectively. Each of these loads is further studied economically to investigate the effect of battery storage for 1 to 5 days. The study also compares the cost of electricity generation in $/kWh from PV system and diesel generating systems. The lower mean temperature (~20°C) and high intensity of radiation (~ 6.3 kWh m ^{2}/day) in Abha make it a promising site for the usage of PV systems for desert camping. Analysis of the data indicates that the battery storage capacity cost plays an important role in the overall cost of the PV system. The economical indicators suggest that larger PV systems be preferred over the smaller ones with minimal storage option. The energy generation cost analysis indicated that the diesel generating cost was found to be 29, 56 and 116% higher than the PV system for full, 75% and half load systems, respectively.

Key words: Global Solar Radiation Data, Photovoltaic Systems, Battery Storage Capacity, and Cost

INTRODUCTION

Exponentially growing population and equally increasing demands of electricity are causing the burning of the fuels and addition of green house gases into the atmosphere. This concern has lead the interested researchers, engineers, environmentalists, industrialists and even the politicians to think about the conservation of reserved fossil fuels and the exploration of renewable pollution-free sources of energy. Solar energy, which is abundant in nature and free from pollution, is one of the alternative sources of energy and being explored since 1970's energy crisis. Photovoltaic (PV) technology is proven to be an easy to use source of energy to generate electricity. It is being used globally to supply power to remote communities, utility peak load shaving, cathodic protection in pipelines, remotely-located Gas Oil Separation Plants (GOSP), telecommunication towers, highway telephones and billboard, off-grid cottage/s, resorts in desert areas, water pumping for community; cattle and irrigation, municipal park lighting, street lighting, exterior home lighting and many other usages.

As an example, Libya is one of the largest oil exporting country and possesses large reserves of fossil fuel, however, it is using renewable sources of energy like wind and solar and saving its oil reserves for future use or to generate more revenues, [1]. In Libya, photovoltaic technology is being used since 1976 for cathodic protection in oil pipe lines between Dahra oil field and Sedra Port, communication towers, water pumping for irrigation at El-Agailat, street and historical site lighting, etc. [1]. The total PV-installed capacity in Libya, as of May 2003, is 633.88 kWp. Furthermore, according to El Hori [1], Libya is planning to build a grid connected PV power plant with 1 MW installed capacity in the near future. Photovoltaic is also being used in Jordan to pump water and in lighting the streets, schools and other governmental institutions located in remote areas. According to Hrayshat and Al-Soud [2], the total PV-installed capacity in Jordan is 82 kWp generating a total of 182.5 MWh of electricity each year.

The Kingdom of Saudi Arabia lies between latitudes 31 and 17.5°N and longitudes 50 and 36.6°E. The land elevation varies between 0 to 2,600 m above the mean sea level. Complex terrains are found in the southwest region of the Kingdom. The east and the west coasts of the Kingdom are located on the Arabian Gulf and Red Sea, respectively. Mainly two seasons, winter and summer, are observed during the year. The daily average bright sunshine in the Kingdom is 8.89 hrs and average global solar radiation on horizontal surfaces is 5,591 WHm ^{2}. These averages are based on the data collected at 41 solar radiation stations over a time period of approximately 10 years. The geographical locations of these solar radiation stations are shown in Fig. 1. These stations have been under the supervision of the Department of Water Resources Development and the Ministry of Agriculture and Water of Saudi Arabia since 1970 (Saudi Arabia Solar Radiation Atlas [3]).

In Saudi Arabia, there is no threat of an exponential increase in population, an energy crisis, shortage of basic supplies and lack of outpouring facilities for wastes disposal. However, in the last 25 years, the demand of electricity has grown at a rate of 10 to 15% per annum as a result of increase in population, industrialization and a subsidized tariff [4]. In a country with 21,000,000 people, the number of consumers has risen from 304,000 in 1974 to 3,372,000 in 1999 and the installed capacity has reached to 20,647 MW in 1999 compared to 1,141 MW in 1974. Moreover, the peak load demand has increased to 20,236 MW from 722 MW [4].

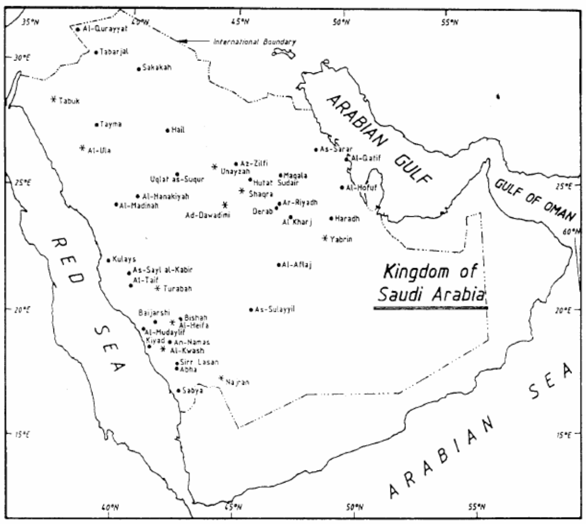

Fig. 1: Map Showing the 41 Locations of Solar Radiation Measurement Stations

Saudi Arabia has invested a good amount of funds on the development of solar energy both on experimental and theoretical investigations. Solar energy-based appliances are being used at the Royal Commission of Yanbu and Jubail, Saudi Arabia. The world's first and the largest grid-connected PV facility was developed and tested at Solar Village situated on the outskirt of Riyadh, the capital city of Saudi Arabia [5]. Rehman [6] used monthly average daily global solar radiation and developed empirical model to predict the radiation at a location where only sunshine duration is available. The author compared the proposed correlation with some of the existing correlations and found that his correlation having latitude, longitude, altitude and sunshine duration, as input was the best among those compared. Aksakal and Rehman [7] presented hourly, daily and monthly statistics of solar radiation using one-minute average recorded values for a location on the east coast near Dhahran, Saudi Arabia. The highest measured daily and monthly mean solar radiation was found to be 351 and 328 W m ^{2}, respectively.

Mohandes *et al.* [8] used radial basis for the estimation of daily solar radiation in spatial dimensions and found good agreement between the predicted values and the actual measurements. In another attempt, Rehman and Ghori [9] used geostatistical technique to estimate the global solar radiation in spatial domain and found excellent agreement between the predicted and measured values of radiation. Moreover, solar radiation data is also measured by the Research Institute at King Fahd University of Petroleum & Minerals, as reported by Bahel *et al.* [10], Kruss *et al.* [11], Bahel *et al.* [12], Srinivasan *et al.* [13], Bakhsh *et al.* [14], etc. To the best of the authors' knowledge, as seen from Rehman and Halawani [15], no attempt has been made to estimate the solar radiation behavior with respect to latitude, longitude and altitude for Saudi Arabia as a whole. Sabbagh *et al.* [16] presented an empirical formula obtained using the daily total solar radiation, sunshine duration, relative humidity, maximum temperature, latitude, altitude and the location of the place relative to the water surface.

A group of electrical engineering students developed an automated irrigation system energized by photovoltaic cells to supply the required amount of water, as part of their senior project [17]. This project shows an increasing interest on the usage of PV in Saudi Arabia. Photovoltaic is also being used in Saudi Arabia for cathodic protection of oil pipelines, communication microwave towers, remotely-located unmanned oil platforms, highway telephones, etc.

Desert camping is very popular among all classes of people including rich, high ranking government officials, families and poor too and in all parts of Saudi Arabia and persists throughout the year irrespective of weather conditions. These camps are usually located in the desert areas away from highways and whereby no source of energy exists. Hence, the occupants of these camps often utilize diesel generating sets to meet their electricity demands. These sets, in turn, create noise pollution and add a lot of green house gases into the local atmosphere. Moreover, the owner of any desert camp is always worried to maintain the continuous supply of diesel to keep the units running, which is difficult to assure.

This study utilizes solar radiation data for a typical Saudi town to study the economical feasibility of using photovoltaic panels with battery backup to generate electricity to meet the power demand of a desert camp. The town of Abha, southwest of Saudi Arabia, was selected because it has recently become a family touring destination for Arabian Gulf States, whereby camping is the frequent entertainment tourism. In addition, there are few important reasons behind the selection of Abha as the study site: (i) the mean annual temperature remains below 20°C, which means low energy demands will be required, (ii) high values of global solar radiation on horizontal surface of above 6.3 kWh/m^2/day are measured, (iii) the terrain is very rough which makes the grid extension to remotely-located camping site economically infeasible and finally (iv) the local people are very fond of desert camping in this part of Saudi Arabia.

This study presents a pilot study on the possibility of using PV technology for a Saudi town. Therefore, all the necessary data were retrieved including annual and seasonal variation of global solar radiation on horizontal surface, temperature and relative humidity to understand the climatic conditions and availability of solar radiation for Abha city in the southwest region of Saudi Arabia. Thereafter, the study presents an economical feasibility study on the usage of photovoltaic panels to generate electricity for a desert camping site having three tents, two toilets, one watchman room and the fencing covering a 100 X 100 m^2 area.

SITE AND DATA DESCRIPTION

The generic desert camp is located on a hill top consisting of three living tents, two toilets, one watchman room and the fencing. The various lights and appliances used in this camping area are described in Table 1. This table also gives details of various electrical loads required to energize the camp at large. As seen from this table, the daily average DC and AC energy demands are 8.16 and 21 kWh, respectively, while the annual peak load is 3.84 kW. The global solar radiation, temperature and relative humidity data collected at Abha covered a period of five years between 1998 and 2002.

BEHAVIOR OF METEOROLOGICAL PARAMETERS

For a successful development of any solar radiation-based application, detailed, long-term and thorough understanding of the meteorology of the anticipated site is very important. In the present case, the meteorological data was available only for five years. The yearly and monthly mean values were calculated using five minutes average values. The yearly variation of global solar radiation in Abha is shown in Fig. 2. An increasing trend was observed in the values of solar radiation from 1998 to 2001, as seen from Fig. 2. The maximum annual mean value of solar radiation was observed in the 2001 while the minimum was in 1998.

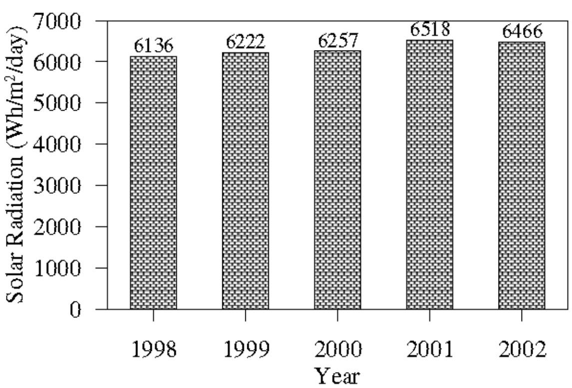

Fig. 2: Yearly Variation of Global Solar Radiation in Abha, Saudi Arabia

The variation of annual mean values of temperature reached in different years is shown in Fig. 3. It is evident from this Figure that the maximum mean temperature of 19.10°C occurred in the year 2000 while the minimum of 18.88°C in the year 1999. This Figure also shows the yearly maximum and minimum values of temperature in the different years. During entire data collection period, as evidenced in Fig. 3, the maximum temperature was found to be 35.96°C, which is relatively low compared to the maximum temperatures reached in other areas of Saudi Arabia. The annual minimum temperature of 1.2°C was noticed in the year 1998 and it remained less than 5°C in most of the year analyzed here. The mean relative humidity was found to remain between 58 and 65% during the entire data collection period, as depicted in Fig. 4.

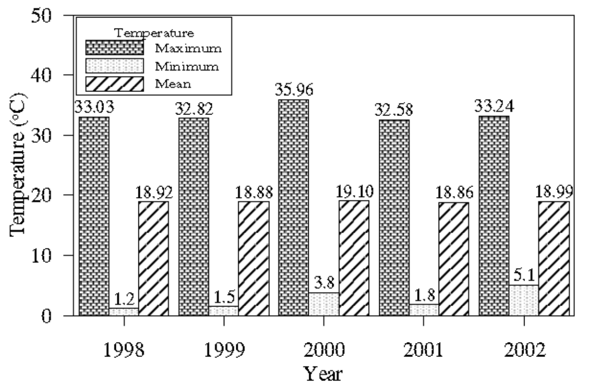

Fig. 3: Annual Variation of Temperature in Abha, Saudi Arabia

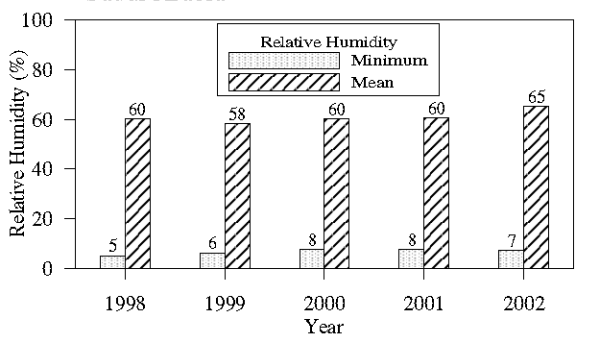

Fig. 4: Annual Variation of Relative Humidity in Abha, Saudi Arabia

The understanding of the seasonal variation of the global solar radiation data is important for the design and development of a solar-based electricity generating system. Figure 5 shows the variation of monthly mean values of global solar radiation during different months of the five years analyzed in Abha. As expected, higher values of global solar radiation were observed during summer months, particularly during the months of April and May as against in July and August and lower values during winter months. The seasonal trend of temperature is shown in Fig. 6. Higher values of temperature are seen during April to October and comparatively lower values during the rest of the

Table 1: Daily Load Demand Details for a Remote Desert Camp in Abha

Description	AC/DC	Load (kW)	Hours of use per day	Days of use per week
Tent Lights 40 W*12	AC	0.48	8	7
Fence Lights (Type 1) 40W*16	AC	0.64	4	7
Fence Lights (Type 2) 25W*24	AC	0.6	10	7
Other Lights (Type 3) 10W*10	AC	0.1	6	7
Fan Ceiling 25W*6	DC	0.15	12	7
Fan 15W*4	DC	0.06	18	7
TV 330W*3	AC	0.99	6	7
Refrigerators 3*65W	DC	0.195	24	7
Telephone, Radio	DC	0.025	24	7
VCR	AC	0.03	6	7
Vacuum Cleaner	AC	0.8	2	3
Computer	AC	0.2	6	7
			Daily average	*Annual*
DC energy demand	kWh (DC)		8.16	2,978.40
AC energy demand	kWh (AC)		21.006	7,667.10
AC peak load	kW (AC)			3.84

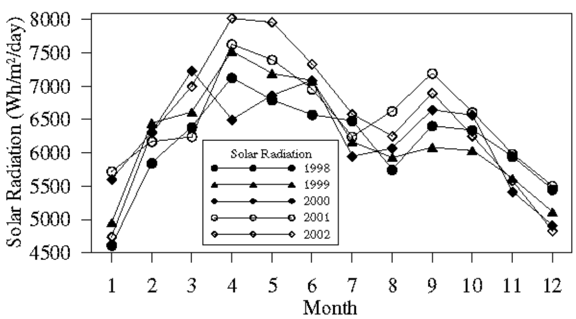

Fig. 5: Seasonal Variation of Global Solar Radiation on Horizontal Surface in Abha, Saudi Arabia

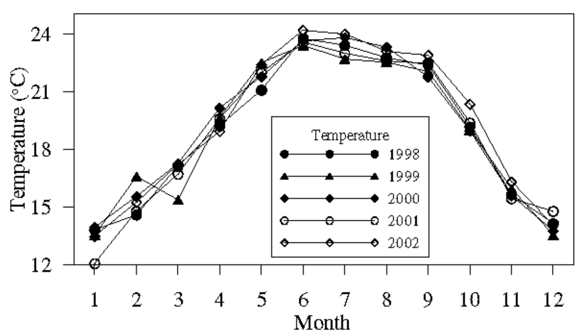

Fig. 6: Seasonal Variation of Temperature in Abha, Saudi Arabia

months. Higher values of relative humidity were observed in wintertime and lower during rest of the period, as shown in Fig. 7.

Since the temperature at Abha remains relatively on the lower side compared to other cities in Saudi Arabia, hence lower electricity demands persist. Moreover, the peak load demands occur during daylight hours during which higher values of solar radiation are available and

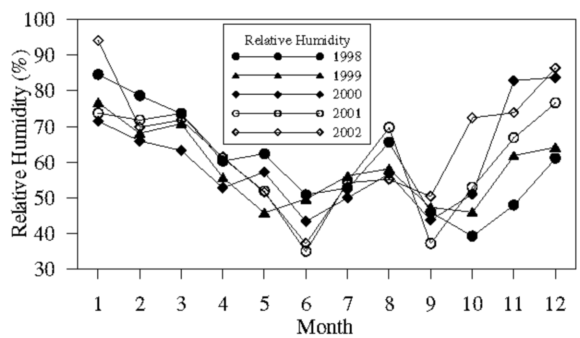

Fig. 7: Seasonal Variation of Relative Humidity in Abha, Saudi Arabia

this makes the usage of solar energy viable for the generation of electricity in Abha.

DESCRIPTION OF PV SYSTEM AND ENERGY PRODUCTION

The proposed full load system is comprised of 8 arrays and each array has 15 PV modules capable of producing approximately 75 to 120 Watts peak (Wp). These modules are made up of mono-Si cells from BP Solarex model # BP590F with a rated efficiency of 14.3%. An angle equal to the site latitude to maximize the energy output of the PV system will tilt these arrays. Most PV modules deliver Direct Current (DC) electricity at 12 Volts (V), whereas most common household appliances run off Alternating Current (AC) at 120 or 230 V. Inverters are used to convert the low voltage DC to higher voltage AC. Other components in a typical PV system are the array mounting structure and the various cables and switches needed to ensure that the PV generator can be isolated from the camp and the mains. In the present case, the photovoltaic modules

Table 2: Summary of Various RetScreen Simulation Output Parameters

Load	Nominal PV Size (kWp)	Area (m^2)	Specific Yield (kWh m^{-2})	Overall Efficiency (%)
Full	8.75	61.2	174-182	7.9-8.4
75%	6.5	45.5	180-186	8.2-8.4
Half	4.4	30.8	180-182	8.2

can be placed on the sloping part of the tent if this side is facing south otherwise in the premises of the camping area.

Based on the load demand, the RetScreen software calculates the nominal PV size, the required area to install the modules, specific yield, overall cell efficiency, etc. [18]. Table 2 shows that for the full load of 8.2 DC + 21.0 AC kWh with 3.84 kW AC equivalent peak load, the nominal size of PV panels will be 8.75 kWp, which will require approximately 62 m^2 of area and will produce the energy with specific yield of around 180 kWh/m^2 at an overall PV cell efficiency of about 8.2%. For the 75% of full load, the nominal PV size will be reduced to 6.50 kWp and will require around 45 m^2 of area. For the full load demand, the system is capable of delivering about 11.12 MWh electricity during the 12 months analyzed. The system produces 8.265 MWh in a year for 75% of the full load and 5.606 MWh of electricity for half of the full load in the same period.

ECONOMICAL FEASIBILITY PARAMETERS

The economical feasibility was performed using the RetScreen software in terms of the Internal Rate of Return (IRR), Profitability Index (PI), Simple Payback Period (SPP) and Years to Positive Cash Flow (YPCF). Lastly, the reduction in Greenhouse Gases (GHG) in tons per year of CO_2 and its annual cost per year is presented. The details of these calculations and various mathematical equations can be found elsewhere [17].

RetScreen Input Parameters: The energy cost escalation rate, inflation, discount rate and project lifetime used in this study are summarized in Table 3. The various cost items used in the feasibility study like development, engineering, renewable energy equipment including the photovoltaic panels, balance of plant, miscellaneous and operation and maintenance costs are given in Table 4. The costs of lead acid battery (48 V, 80% efficiency, 50% maximum depth of discharge, 95% charge controller efficiency and 10 years life), PV modules, module support structure, miscellaneous electrical equipment, installation and inverter (90% average efficiency, 0% conditioning losses and 5 years life span), were taken from literature as $125/kWh, $ 5000/kWp, $ 50/m^2, $ 250/kWp, $ 1500/kWp and $ 800/kW, respectively.

It is to be noted that the cost items like feasibility study; development and engineering remained constant for all the simulation runs, while RE equipment and balance of plant costs varied with the size of Photovoltaic (PV) panels and battery storage capacity. The PV panel and battery sizes are calculated based on the daily load demands and the number of days for which the storage was sought, i.e. anticipated days without solar radiation. In the present work, battery storage is considered for 1, 2, 3, 4 and 5 days without solar radiation and the PV panel sizes for full load, 75 and 50% of the full load, as given in Table 1.

Table 3: Various Input Interest Rates for all Load Demands Considered

Item	Amount
Energy cost escalation rate (%)	4.0
Inflation rate (%)	2.5
Discount rate (%)	5.0
Project life (Years)	25.0

Table 4: Summary of Costs (US$) of Various Major Heads of a PV System

Items	%	Amount (US$)
Feasibility study	2.8	4,000
Development	3.1	4,500
Engineering	3.1	4,500
RE equipment	30.9	44,550
Balance of equipment	50.8	73,347
Miscellaneous	9.3	13,480
Initial Costs – Total	100.0	144,377

Total Initial Cost of a PV System: As seen from Table 4, the major component of the cost $73,347 (50.8%) corresponds to the balance of the plant while 30.9% (i.e. $44,550) accounts for the PV panels. The total development, equipment and installation cost for a PV system to meet the full load, given in Table 1 and five days of battery storage capacity comes out to be $144,377, as given in Table 4. The total cost of the PV systems with 75 and 50% of the full load are shown in Fig. 8. The effect of load on the total initial cost of the whole PV system is clearly dictated by Fig. 8. A 25% decrease in the load results into 21% decrease in the initial cost of the plant and a further decrease of 25% in load results into a total decrease of 40% compared to full load system cost.

Figure 8 also shows the effect of battery storage capacity on the total initial cost of the entire PV system. For full load condition, if battery storage is decreased by 20%, i.e., from 5 to 4 days, the initial cost is decreased by approximately 7%. A decrease of 40, 60 and 80% in battery storage results into a decrease of about 12.3, 18.9 and 23.5% in the total initial cost of the PV system. Almost a similar type of effect of the battery storage on the initial cost is observed for the 75 and 50% load conditions. This shows that the battery storage plays an important role on the total initial cost of any PV system.

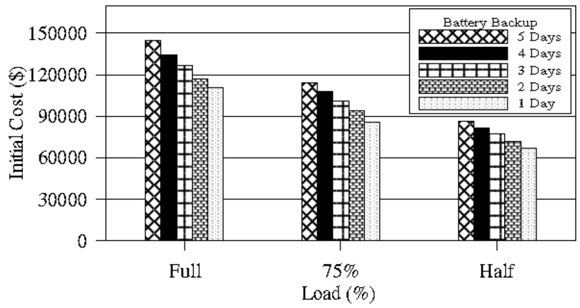

Fig. 8: Variation in Initial Cost of PV System with Load and Battery Storage

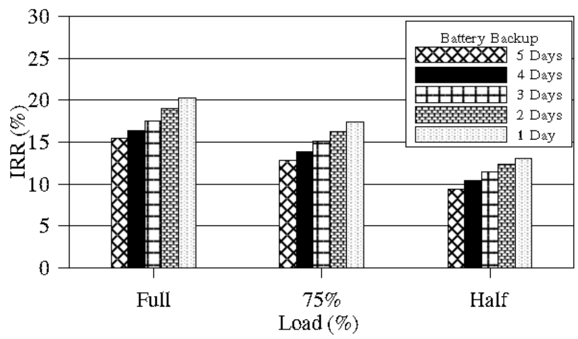

Fig. 9: Effect of Load and Battery Storage Internal Rate of Return (IRR)

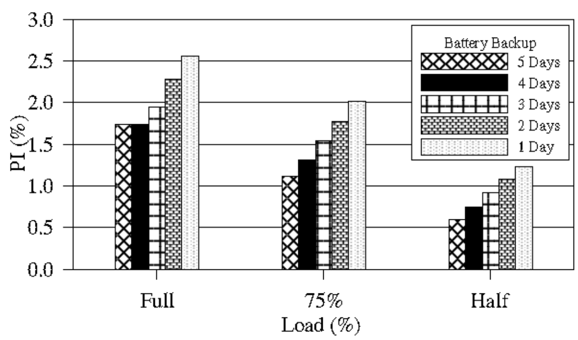

Fig. 10: Effect of Load and Battery Storage on Profitability Index (PI)

Economical Feasibility Indicators: The development of a PV project would be acceptable if IRR is equal to or greater than the required rate of return. The IRR calculated for the three different loads is shown in Fig. 9. The maximum IRR of 20% was obtained for the full load with 1day battery backup system. The analysis shows that the economical performance improves with higher loads and smaller battery backup system. The Profitability Index (PI) is calculated as the ratio of the Net Present Value (NPV) over the project equity. Positive ratios are indicative of profitable projects. Figure 10 shows that the PI is positive for all the loads and battery storage options. Higher percentages of PI were obtained for larger PV system and smaller battery storage and vice versa. A maximum PI of 2.5% was found for the full load PV system with one-day battery storage.

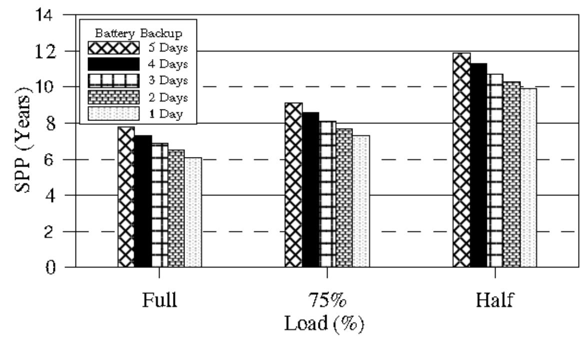

Fig. 11: Effect of Load and Battery Storage on Simple Pay Back Period (SPP)

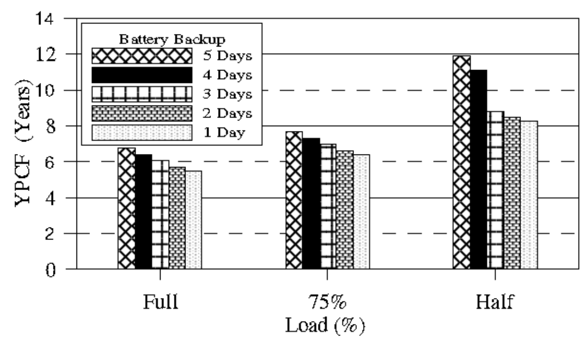

Fig. 12: Effect of Load and Battery Storage on Years to Positive Cash Flow (YPCF)

The simple payback periods and the years to positive cash flows are shown in Fig. 11 and 12, respectively. Figure 11 indicates that larger PV systems, irrespective of battery backup capacity, result into smaller simple payback periods which mean that the larger the PV system is, the better will be its economical performance. The number of Years to Positive Cash Flow (YPCF) represents the length of time that it takes for the owner of such a project to recoup its own initial investment out of the project cash flows generated. The year-to-positive cash flow considers the project cash flows following the first year as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback period. The YPCF obtained from the model for all loads indicates that the minimum YPCF was obtained for the biggest PV system and the highest for the smallest PV systems studied in this study, as seen from Fig. 12.

In Net Present Value (NPV) analysis, the present value of all cash inflows is compared with the present value of all cash outflows associated with an investment project. The difference between the present values of these cash flows, called the NPV, determines whether the project is generally an acceptable investment or not. Positive NPV values are an indicator of a potentially feasible project. In using the NPV, it is necessary to choose a rate for discounting cash flows to the present value. The NPV is found to be highest in the case of full load with one-day battery backup system and, in general, the NPV becomes higher for all battery backups compared to smaller PV systems, as seen in Fig. 13. The Annual Life Cycle Savings (ALCS) are calculated using the net present value, the discount rate and the project life. The ALCS analysis also shows that larger PV systems have higher values of ALCS and, hence, are preferred compared to small systems, as shown in Fig. 14.

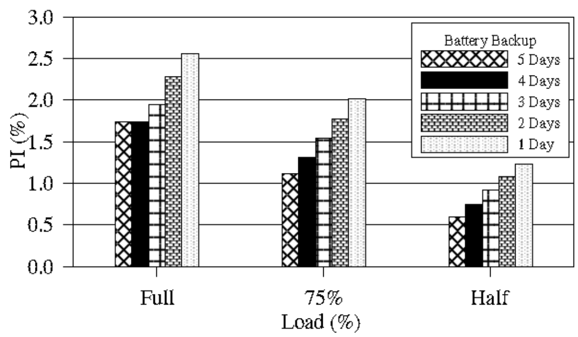

Fig. 13: Effect of Load and Battery Storage on Profitability Index (PI)

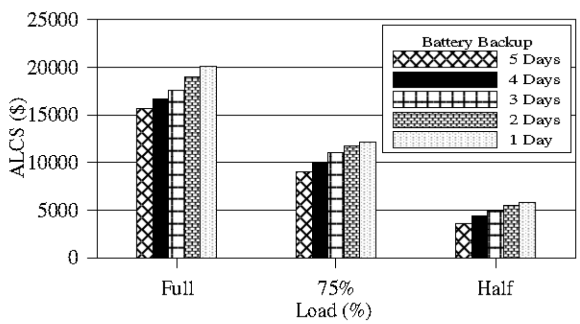

Fig. 14: Effect of Load and Battery Storage on Annual Life Cycle Savings (ALCS)

Based on the above analysis, it can be concluded that the economical feasibility indicators show that larger PV systems are more economical compared to smaller ones.

Green House Gases Reduction: The RetScreen model also has the capability of calculating the reduction in Green House Gases (GHG) as a result of using PV systems as a source of energy to generate electricity. The resulting values of GHG to be avoided from entering into the atmosphere in 25 years (i.e. during the designed life of the project) are shown in Fig. 15. The bigger the PV system is, the more electricity will be generated and, hence, it will displace more GHG. As depicted in Fig. 15, for the full load system, a total of 258 tons of green house gases can be avoided from entering into the local atmosphere over the project life time of 25 years if PV system is utilized in place of a diesel system.

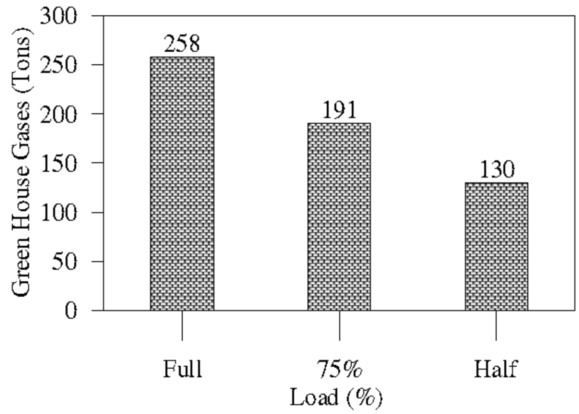

Fig. 15: Effect of Load on Green House Gases (GHG) Replacement

Cost of Using Diesel Generating Set: In this section, the cost of only diesel generating system will be calculated and thereafter compared with that of the photovoltaic system discussed in the previous sections. Since the peak load demand for full load scenario was 3.84 kW of AC equivalent, as given in Table 1, a diesel generating set of 5 kW, which is the smallest size available in the market, was chosen to meet the electricity demands of the desert camp. The capital cost of the diesel unit is taken as $1,450/kW and the replacement period is considered as 8 years. It is assumed that the unit will run on full load for 50% of the time and on half load for the remaining half of the time. Under such conditions, the unit will generate approximately 25,400kWh electricity each year with 80% efficiency, which is more than two times of the energy demands. The excess energy will be wasted or can be sold if the provision exists.

The fuel consumption will be 14,607 liters per year at an assumed specific fuel consumption rate of 0.46 l/kWh. The present fuel cost is assumed as 0.26 $/l. The details of total and energy generation costs for the two systems are given in Table 5, whereby it can be easily concluded that over a period of 25 years, the PV system-generated electricity is cheaper as compared to that of the diesel system for the entire load conditions considered in the present case. The other important aspect is that the larger the size of PV system the lesser will be the cost of electricity generation. The other economical feasibility indicators discussed in previous section also revealed this fact. Moreover, if the carbon tax cost of GHG emission is taken into consideration, the cost of PV generated electricity will further be

Table 5: Comparison Between Photovoltaic and Diesel Generated Electricity Cost

Load	Energy Demand(kWh)	Renewable Energy		Diesel Generation Electricity Cost				
		Delivered(kWh)	Cost[1]($/kWh)	Capital[2]($)	Fuel[3](L)	Fuel[3] Cost($)	Total[4]($)	Cost[5]($/kWh)
Full	11,497	11,147	0.518	96,750	14,607	3,798	191,697	0.667
75%	8,876	8,256	0.554	96,750	14,607	3,798	191,697	0.864
Half	5,783	5,606	0.615	96,750	14,607	3,798	191,697	1.326

[1]Obtained by dividing the initial cost of the PV system by total renewable energy delivered in 25 years.
[2]Capital cost includes the generator replacement cost every 8 years and the operation and maintenance cost over 25 years.
[3]Yearly fuel consumption and fuel cost
[4]Includes cost of fuel in 25 years period and the capital cost
[5]Obtained by dividing the total cost of diesel generation, given column 8, by total energy demand met in 25 years.

reduced and the PV system will become more cost competitive. The PV system also provides noise free electricity, which is a necessary factor for the inhabitants of such luxurious desert camps.

CONCLUSION

Based on the available meteorological and cost data analysis and the feasibility study on the utilization of a PV system for a camping site in Abha, Saudi Arabia, the following conclusions could be drawn:

* Due to the overall low mean temperature and high intensity of radiation, Abha is a good site for the usage of PV systems to generate electricity.
* In general, the seasonal and diurnal pattern of the global solar radiation follows almost the same trend as that of the electricity demand pattern and, hence, a PV system can provide electricity during peak demand periods.
* The battery storage capacity cost plays an important role in the overall cost of the PV system. Therefore, the battery storage for smaller time period should be considered.
* The economical indicators suggest that larger PV systems be preferred over the smaller ones.
* For full load scenario, the cost of energy from the PV system was 29% cheaper then the diesel generating set. For the 75 and 50% load systems, the cost was about 56 and 116% higher than the PV system, respectively.
* The other advantages of PV systems over diesel systems include a noise-free operation and no pollution of the local atmosphere.

The study recommends the following:

* A pilot PV system should be developed and monitored to assess the weather effect on the efficiency of the PV modules.
* A techno-economical feasibility study should be conducted for a grid connected PV system for peak load shaving to develop very large PV systems.

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