J. Basic. Appl. Sci. Res., 2(11)11783-11788, 2012

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Study of the Power Supply for a School through Solar Energy in Hormozgan Province

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ABSTRACT

This study aimed at designing and economical analysis of the project of power supply for a school in Hormozgan Province through solar energy system. The desired pilot project to supply its electrical energy using solar energy is an educational school with an approximately 143 m^2 area. First, the amount of required energy for this educational space has been calculated using the school's map of electric utilities and then the required equipments for power supply of this school from solar energy has been estimated; and in the following the economic analysis of this project has been performed by comparing costs related to power supply and consumption through public power network and results obtained from this study

The results obtained from this study indicated that: given the evaluation of different states for power supply of the educational space; if the distance of school from power network is about 1 km and more, launching solar power system independent from the network will be cheaper than developing the power network to the project location and it's better to be used.

KEYWORDS: solar energy, photovoltaic system, power generation, economic analysis

1 INTRODUCTION

Renewable energy is a type of energy that has the capability to re-return to the nature unlike non-renewable energies. Non-renewable energies that are obtained from fossil fuels are not trustable sources either in terms of environmental damages or in terms of the probability of their existence in future; and the necessity to approach to other energies especially renewable energies is felt more than before.

Solar energy is one of free, pure and without harmful environmental impacts energy supply sources that has been used by human being in various ways since long ago.

Extensive and noticeable studies have been conducted about determining the amount of solar energy since 1970s around the world.

The received sunshine of Iran per year is about 1000 times greater than consuming and exporting energy of the country annually.[1]

Therefore, by applying methods of converting solar energy, this endless, pure and free energy source can be used to some extent and fossil fuels consumption can be saved.

One of the most important factors for designing solar energy in each location is having accurate information and statistics about the amount of sun radiation at that location.

One of the most important parameters related to the amount of sun radiation is air filter coefficient. Bahador-nejad et al. in their study have achieved a relation for this parameter based on meteorological parameters in different cities of Iran. [1]

Safaei et al. have studied the potential of sun radiation in Iran and prepared radiation atlas for various parts of this country. [2]

Mohammad Moosavi et al. identified high-radiation areas in Iran. The results obtained from this study demonstrated that first the majority of Iran's regions enjoy high capability to use the renewable solar energy and second, the sunniest days in April and May are in Jask and Minab cities form Hormozgan province. [3] Given that our project scope is also this province, it shows high capability of this province for applying solar energy.

One of the methods in which solar energy is converted into electrical energy without using stimulus and chemical mechanisms is photovoltaic system. Solar cells are semi-conductor parts that convert radiation energy of the sun into electrical energy.

The collision of the sun's light photons to solar cells causes the production of electron in the semi-conductor and electric current is flowed by connecting electric load. The following are some characteristics of solar cells:

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1. Do not occupy much room
2. No moving parts
3. Their output does not change much with the ambient temperature changes
4. Relativley easily installed and easily coordinated with other systems used in the building

Today, photovoltaic systems have been installed on the roof and exterior of many buildings, skyscrapers, public and research saloons in different parts of the world, that can refer to the building of times square 4, the biggest skyscraper in New York. [4]

Bahadori-nejad et al. have designed a solar power system connected to the network for an administrative building with 240 m^2 area in Tehran and calculated the entire costs of the generated electricity for that. [5]

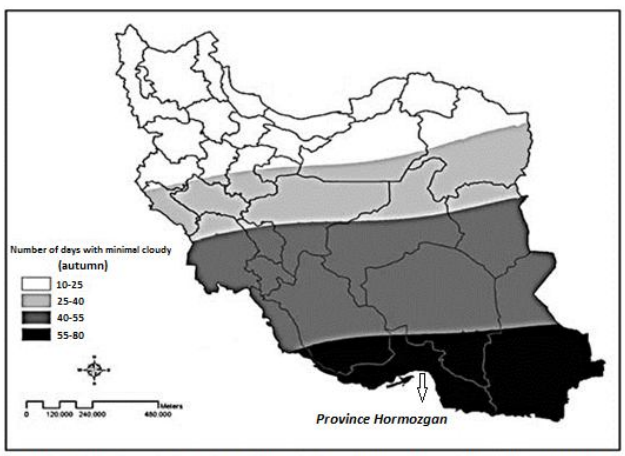
Our study aimed at designing power supply system of a school with 3 classes with 143 m^2 area in Hormozgan province using solar energy. The stages of performing this project include designing power supply system through photovoltaic system, estimating the required costs and finally economic analysis of the project.

2. MATERIALS AND METHODS

2.1. **The study area**

Geographical zone to be studied in this research is Hormozgan Province. Hormozgan Province is located in south of Iran between 25° and 24´ and 28° and 57´ of the latitude and between 53° and 41´ and 59° and 15´ of the latitude from Greenwich Meridian. This province has area of 68000 sq km.

The results obtained from the study of Moosavi et al [3] indicated that this province is among high-radiation provinces, which has the least rainy days. In figure 1 you can observe zoning high-radiation regions in Iran based on the average of the least rainy days in fall, and Hormozgan province has high radiation capability in this regard.



Zoning high radiation areas of Iran based on the average number of days with minimal cloudy in autumn

Fig.1: Zoning high radiation areas of Iran based on the average number of days with minimal cloudy in autumn

2.2. **Pilot School Choice**

The desired pilot project to supply its electrical energy using solar energy is an educational space with an approximate area of 143 m^2 including 3 classes, restroom, office and pantry. Architectural plan and layout of the pilot project has been shown in figure 2:

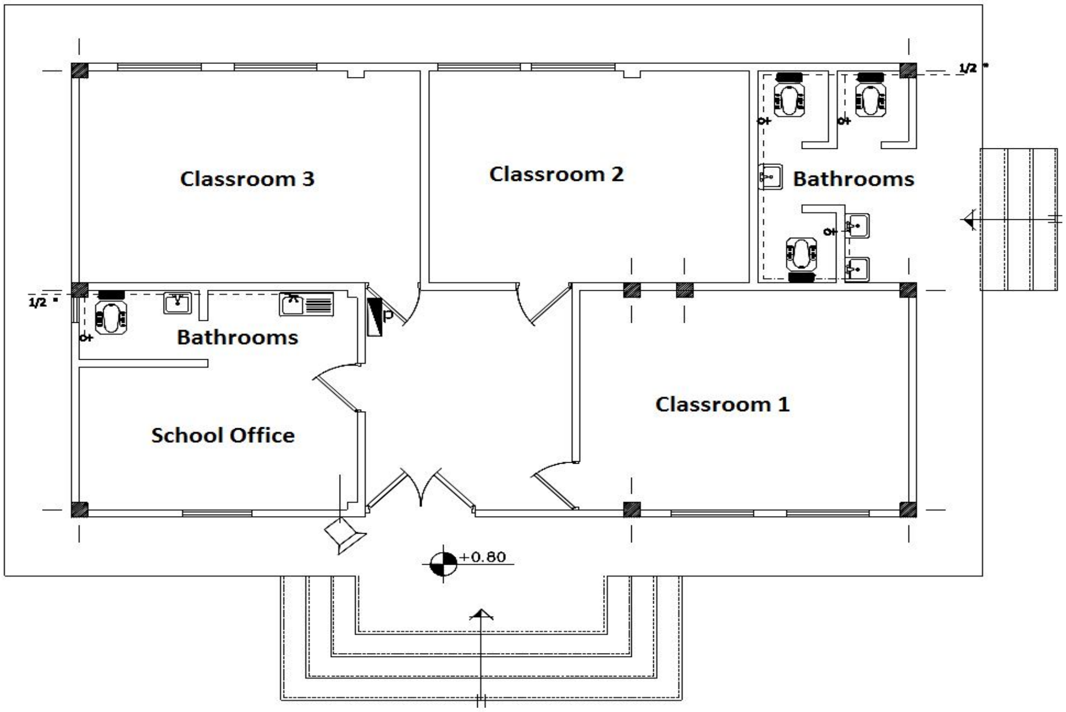


Fig.2: Architectural plan and layout of the pilot project

2.3. Estimation of Required Energy

After evaluating technical parameters related to geographical environment of the project implementation location and feasibility of using solar energy to provide electrical energy, the second stage is to estimate the amount of consumed energy required for designing solar power generation system.

Using maps of electric utilities of this school, the amount of electrical energy consumption of the school has been listed in table 1 separated by consumption type and daily, monthly and annually durations.

Table 1: the required consumption power of pilot school

	Device Name	Average Power Consumption of the Device(W)	Number	Useful Time of power consumption per day(h)	Daily power consumption (KWh)	Monthly power consumption (KWh)	Annual power consumption (KWh)
1	Air Conditioner(18000 btu/h)	2000	4	4	32	960	11520
2	Air Conditioner(24000 btu/h)	2500	0	0	0	0	0
3	LED Ceiling Lights 2*20W	40	17	1	0.68	20.4	244.8
4	LED Ceiling Lights 10W	10	7	1	0.07	2.1	25.2
5	LED Wall Lights 10W	10	4	8	0.32	9.6	115.2
6	Fans Ventilators	50	4	2	0.4	12	144
7	Computer	200	1	4	0.8	24	288
8	Television	100	1	4	0.4	12	144
9	Electric Water Heater	2000	0	0	0	0	0
10	Refrigerator	150	1	8	1.2	36	432
11	Electric Kettle	2000	1	0.5	1	30	360
12	Buzzer	100	1	0.1	0.01	0.3	3.6
13	Copier Device	700	1	1	0.7	21	252
14	Printer	500	1	1	0.5	15	180
15	Audio system	200	1	1	0.2	6	72
16	Washing Machine	500	0	0.5	0	0	0
17	Ironing	2000	0	0.5	0	0	0
18	Ceiling Fan	120	7	2	1.68	50.4	604.8
19	Hair Dryer	1500	0	0.2	0	0	0
Total Power Consumption Required(KWh)					39.96	1198.8	14385.6

Total power consumption for every day = 39.96KWh≈40KWh

2.4 The required equipments

The solar power supply system in photovoltaic method consists of four main parts including solar panel, battery bank, controller charger and inverter that given the required energy of the school, the calculations related to each four parts have been listed in the following:

2.4.1 Solar panel:

Given that the total net power required in a day and night is 40 kwh or 4000 wh; therefore, the average required net power per hour is equal. If the efficiency of solar panels is considered 35%; thus, nominal power of the required solar panels is calculated as follows: Solar panels needed = 1666.67W ÷ %35 ≈ 4761.91W ≈ 4.8 KW
Therefore, the total of the required nominal power of solar panels is 4.8 kwh so a total of 24 200-wh panels is needed.

2.4.2 Battery bank:

The major consumption powers is consumed during a day that include about 4 gas cooler that is about 8 kwh along with other consumption powers; and this value is consumed in 4 hours. Therefore, daily consumption power equals to:

The amount of power consumption for daytime ≈ 8 KW × 4 h = 32 KWh
The amount of power consumption for nighttime = 8 KWh
V_{OUT} = 220V
Electrical current consumption at night = 8 KWh ÷ 220 V ≈ 36.36 Ah
Voltage conversion ratio = 220 VAC ÷ 48 VDC ≈ 5
Current conversion ratio = 1÷Voltage conversion ratio ≈ 0.2
Amount of receive electrical current from the battery bank at night = 5 × 36.36 Ah ≈ 182 Ah
Capacity of the battery bank required = 182 Ah
Capacity of the battery bank required with considering the maximum 80% discharge = 182 Ah ÷ %80 ≈ 227.5 Ah
Number of batteries (48V, 200Ah) = 227.5 Ah ÷ 200 Ah ≈ 1
Number of batteries (12V, 200Ah) needed to form the battery bank = 4 × 1 = 4

2.4.3. Controller charger:

Maximum 12 pair panels can be connected to each 60-A MPPT controller charger in parallel; and given the number of solar panels is 24, a 60-A MPPT controller charger is needed that 12 pair panels are connected to it.

2.4.4. Inverter:

Given the consumption power of electrical equipment in this school, the number and type of inverter required for solar power system have been listed in table 3.

Table2: Number and type of inverters required for solar power system

Consumer	Power Consumption	Number	Type of inverter	Number
Air Conditioner(18000 btu/h)	2KW	3	2.5-3 KW	**3**
Electrical Outlets of School	3KW(Asynchronous)	1	2.5-3 KW	**1**

Therefore, in sum, 4 3-kwh inverters are required.

3. RESULTS AND DISCUSSION

3.1. Calculation of the primary investment cost of power supply from photovoltaic system

After calculating and determining the number and type of solar power system equipments independent from the network with the capacity of supplying 40 kwh consumption power in 24 hours of a day, the table2 shows the required equipment for this system.

Table3: Solar Power System Equipment List with costs

	Equipment	Number	Unit	Unit price($)	Total cost($)	Useful lifetime	Manufacturer	Sales and service representative in Iran
1	Solar Panel (200W)	24	piece	652.53	15,660.72	25 years	Aria Solar - Iran	Aria Solar - Iran
2	Deep cycle Battery (12V,200Ah)	4	piece	326.26	1,305.04	10 years	Exide - England	Sufco Co.
3	MPPT Charge Controller 16A	1	piece	1264.27	1,264.27	15 years	Xantrex - USA	Solar SanatParsian Co.
4	Sinus Inverter 3KW	4	piece	1468.19	5,872.76	15 years	HajirSanat - Iran	HajirSanat - Iran
Sum					24,102.79			
2% of the total cost for miscellaneous equipment					482.0558			
Total					24,584.85			

The amount of the initial investment cost of solar power project is 24,584.85$.

3-2- Calculation of Power Supply and Consumption Expenses through the Network

Power supply and consumption expenses through the network are classified into two major groups which include 1- power network and main development cost and 2- power consumption expense or the current expenses

3-2-1-Power Network and Main Development Cost

Considering the distance between school and power network, one can consider different states for the network development expenses and we study 8 different states in this research:

- First state: power supply without need for development of network and with subsidized power tarrif
- Second state: power supply without need for development of the network and with free power expense
- Third state: need for development of medium pressure network with length of 500 m to supply power and with subsidized power tariff
- Fourth state: need for development of medium pressure network with length of 500 m to supply power and with free power tariff
- Fifth state: need for development of medium pressure network with length of 1km to supply power and with subsidized power tariff
- Sixth state: need for development of medium pressure network with length of 1km to supply power and with free power tariff
- Seventh state: need for development of medium pressure network with length of 2km to supply power and with subsidized power tariff
- Eighth state: need for development of medium pressure network with length of 2km to supply power and with free power tariff

In order to supply the consumable power, this project needs a 20 KVA power main which includes the following expenses:

1-expense of a 25 KVA transformator with installation cost, 7341 $

2-subscription fee and it connection cost, 244.7 $

Development of the medium pressure power network for each meter costs averagely 24.47$. Considering the information, primary cost of each of the above states is observed in table 3:

Table4: Electricity Network Development Costs and subscription according to the 8 scenarios

row	State No	Initial costs($)
1	state 1	7,585.65
2	state 2	7,585.65
3	state 3	19,820.55
4	state 4	19,820.55
5	state 5	32,055.46
6	state 6	32,055.46
7	state 7	56,525.29
8	state 8	56,525.29

3.2.2 The primary and current expenses of urban power use

You can find in table 5 the Electricity tariffs with subsidy in 2012 in Hormozgan Province

Table5: Electricity tariffs with subsidy in 2012

Consumption 30 days per KWh	Cost per KWh ($)
Less than 1000	0.0082
1001 to 2000	0.00897
2001 to 3000	0.0098
3001 to 3500	0.0408
3501 to 4500	0.0775
4501 to 6000	0.0938
More than 6000	0.11011

Considering the daily consumption rate of this project which has been estimated to be 40 kw/h at night and day, monthly consumption rate equals to 1200 kw/h of which subsidized power rate is 0.009$ for each kw. Free tariff of the consumable power in 2012 is 0.1101$ for each kw/h of the consumable power. In calculation of the current expenses, 20% of the annual inflation rate will be added to the expenses. It is necessary to note that expenses of environmental pollution have not been considered to calculate the primary and current expenses of urban power use.

3.3. Economic analysis and capital return

From the economic analysis of the above scenarios, the following results are obtained:

-if the monthly power consumption cost is paid with subsidized or free rates, for distances less than 1 km to power network, it's not affordable to use solar power system and it's better to use AC power split.

-generally, if the project distance to AC power network is about 1 km and more, the cost of launching solar power system is less than the cost of network development and connecting to AC power split. For example, in conditions where network development of 2 km is needed to use the AC power and the monthly power consumption cost is calculated with subsidized or free rate; if solar power system is used, the primary investment cost of solar power is far less than AC power network development and solar power system will be beneficial for 16 years.

4. Conclusion

In this study, we compared the entire costs of applying solar power using photovoltaic system with consumption power supply costs of public power network. The pilot project is an educational space with 143 m^2 area including 3 classes, restroom, office and pantry. First, given the map of electric utilities of the school, the amount of the required energy of this educational space was calculated. Then, the equipments required for solar power system has been calculated. In the following given the price of the day of the required equipments, the estimation of the entire costs was performed that totally, the primary investment cost of the project is about 28923$.

In the following, costs related to power supply and consumption through public network was calculated given the 8 different states; and finally a comparison was performed between the entire costs of power supply and generation through solar energy with the entire costs of power supply and consumption through public power network.

The results obtained from this study indicated that: given the various states of power supply of the educational space, if the distance of the school to power network is about 1 km and more, launching solar power system independent from the network will be cheaper than developing power network to the project location and it's better to be used.

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