Khalifa University of Science, Technology and Research
Electronics Engineering Department

ELCE 340: Electromechanical Systems

Solar panel system design

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Solar panel system design

Whenever the sun is shining, you will know you are doing your part to improve the environment and reduce your electricity bill. This report discusses revolves around designing a sun power Solar panel system for our house. The electrical load of our house appliances was analyzed in this report and the design process was is illustrated from A to Z.

This report is divided into six sections. The first one is about finding the power consumption of the appliances, the second sections covers the power consumption cost calculations. The third section investigates the power consummation of ACs only and highlights their contribution to your bill. After that we start considering the hardware implantation of the system and discussing the cost of constructing it. The last section gives an overview about the whole costs and compares between solar and electrical systems from a cost point of view.

The obtained results and calculations were fully discussed in the report.

Introduction

AIMS OF THIS PROJECT :

- Savings On Your Electricity Bill:
  Your home will consume the energy that comes from your solar system to reduce the energy you take from the utility grid.

- Clean Power Generation:
  Your SunPower system produces clean, emission-free solar electricity that helps to reduce air pollution.

HOW YOUR SOLAR SYSTEM WORKS?

From sunrise to sunset, the solar system is converting sunlight into electricity. The system turns on automatically in the morning and turns off automatically at night. Solar cells within the panels produce direct current (DC) electricity that flows to an inverter. After that, an inverter converts the DC electricity being produced by your panels into alternating current (AC), which is required for household use. The converted solar electricity is delivered directly to your home's main electrical service panel.

Is Solar a New Technology?

Modern solar cells were invented in the early 1950s and were used to power satellites. In the 1970s, they were used for remote telecommunications and navigational aids. In the 1980s, they were used for roadside emergency telephones and traffic signs. Now in the 21st century, they help power your home. Currently, over 100,000 homeowners worldwide enjoy a SunPower solar system.

What Are Solar Cells and Solar Panels?

A solar, or photovoltaic (PV), cell is the smallest element of a system that converts sunlight into electricity. Each cell is made of silicon, the same material found in computer chips. Silicon in photovoltaic cells is treated so that it generates a flow of electricity whenever it is exposed to light. A series of solar cells are wired together to form solar panels.

Will My System Work at Night?

No. Sunlight must be present for the system to generate electricity. At night the inverter displays a blank screen.

❖ Power Consumption

We started the designing process by calculating how much power will be consumed at our home; this was achieved finding out each electrical appliance's consumption of power separately.

The appliances of the house are mentioned and their power consumption is calculated as well in the provided table below.

Calculations:

In order to find the yearly power consumption of each appliance; you take the number that indicates the yearly consumption of the chosen appliance (each appliance is labeled with this number once they are bought). Then, in order to find their daily consumption, they were divided by "365" which is the number of days in a standard year. After that we divide the result by 24 to find the power consumption per hour.

Example:

Let's take O-General air conditioner as an example; it is known that its power consumption per year is 3150 kwh/year, so it is divided by 365 to get the power consumption per day.

$$\text{Power consumption per day} = \frac{3150\ \text{KWh/year}}{365\ \text{day}} = 8.6\ \text{KWh/day}$$

After that, we divide by 24 to find the power consumption per hour.

$$\text{Power consumption per hour} = \frac{8.6\ \text{KWh/day}}{24\ \text{hour}} = 0.359\ \text{KWh/day}$$

In order to find the total consumption per day, we start by multiplying the result by the average number of hours the appliance is used per day.

$$0.36\frac{\text{KWh}}{\text{day}} * 8\ \text{h} = 2.88\ \text{KWh/day}$$

In order to find the total consumption per month, we multiply the result by 30

$$2.88\frac{\text{KWh}}{\text{day}} * 30\text{days} = 86.4\ \text{Kwh/month}$$

The same previous steps were used again to calculate the total power consumption of each appliance at the house.

Appliances and their brand name		Yearly power rating (Kwh/year)	power consumption (Kwh/day)	Using (Hr/Day)	P_{total} consumption	
					(KWatt.Hr./Day)	(KWatt.Hr./ Month)
AC	Westpoint	3000	0.3424	10	3.425	102.73
	Whitewestinghouse	2900	0.332	10	3.32	99.31
	Panasonic	3200	0.37	10	3.65	109.6
	O- General	3150	0.36	8	2.88	86.4
	Hitachi	2865	0.327	4	1.31	39.25
Kitchen Appliances	LG Refrigerator	570	0.065	24	1.56	46.8
	Duper General Freezer	420	0.48	24	1.15	34.52
	SuperGeneral cooler	570	0.065	24	1.56	46.8
	LG Microwave Grill	1100	0.1255	4	0.502	15.06
TV	Samsung	1700	0.19	13	2.47	74.1
	Afrnon	700	0.0799	12	0.959	28.767
Washing machine	Samsung	36	0.0046	5	0.023	0.69
Light Bulb	Incedescent (12 pieces)	110(x24)	0.30	13	3.92	117.5
Total					26.729	801.52

Table 1 Electrical load analysis

As it can be seen from the table above, we have analyzed the Electrical load of machines that exist at our house. The covered appliances were; air conditioners, refrigerator, freezer, washing machine, televisions and light bulbs.
It is concluded that the total power consumption per month is 801.52 kwh/month, and it is It is important to note that the main portion of the daily power is consumed by the air conditions (ACs) which is about is 437.29 kwh/month which is more than the half of the total power consumption in this house per month.

❖ Power Cost

In this part we were asked to calculate the cost based on the total power consumption for each appliance. Many online software websites offers doing these calculations; there is “EvoEnergy”,”Energy cost” and "Dewa". We used DEWA sinceour project analyzes our house which exists in UAE. [2]

DEWA charges a standard rate 20 fils per unit for electricity, 3 fils per unit for water, and 0.5fils per unit for sewerage. If you are found using excess water or electricity than normal, DEWA will increase your rates.

For instance, if the electricity consumption goes to more than 2000kWh in a month, the rate increases to 24 fils per unit.

The table below shows the cost of each appliance. .

Appliances and their brand name		P_{total} consumption (KWatt.Hr./Month)	Cost (AED/month)
AC	Westpoint	102.73	30.39
	Whitewestinghouse	99.31	29.21
	Panasonic	109.6	32.45
	O- General	86.4	25.37
	Hitachi	39.25	11.51
Kitchen Appliances	LG Refrigerator	46.8	13.87
	Duper General Freezer	34.52	10.03
	SuperGeneral cooler	46.8	13.87
	LG Microwave Grill	15.06	4.43
TV	Samsung	74.1	21.38
	Afrnon	28.767	8.65
Washing machine	Samsung	0.69	0.075
Light Bulb	Incedescent (12 pieces)	117.5	34.52
Total			235.755

Table3: power consumption and its cost.

Comment: From the table above we can notice that the total cost of the house is 235.755 AED, and this make sense if we compare this number with the actual power consumption of our home which cost 400 AED, This difference is a result of ignoring the other electrical

appliances like Vacuum Cleaner, Iron, computers and other devices that we use everyday but we considered the major appliances only.

❖ Power consumption of the ACs (only)

Since the ACs consume a huge portion of the total power, in this part we isolate them in order to analyze their power consumption separately from the other home appliances. The table below shows the power consumption of ACs only:

ACs and their brand name	P_{total} consumption (KWatt.Hr./Month)	Cost (AED/month)
Westpoint	102.73	30.39
Whitewestinghouse	99.31	29.21
Panasonic	109.6	32.45
O- General	86.4	25.37
Hitachi	39.25	11.51
Total	437.3	128.93

Table 4: power consumption of ACs

Comment: As it can be seen from table 3, it is very clear that ACs consume approximately 60.7% of the total consumption power. From the table we can see that the total power consumed by the ACs is equal to 437.3 KWh/month, on the other hand the other electronics devices power consumption is equal to 282.7 KWh/month. Additionally, the power consumption by the ACs costs 128.93 AED, however the power consumption by the other devises costs 106.825 AED. Obviously, ACs are the primary contributors to the bill since they consume 60.7% of the total power.

❖ Calculating number of solar panels needed (Including AC)

In order to reduce the bill, in this part we investigate switching to solar panels.
First, we need to calculate how many solar panels we need; we must start by determining how much energy our household uses; our roof's usable surface area; the climate and peak sunlight in our area; the wattage and relative efficiency of the photovoltaic (PV) technology of the used panels.

To find out the energy that we need the solar panels to provide us with every day, we start by considering the required energy that our house needs to run all the appliances. This was calculated previously and our results showed that the house consumes 26.729(kwh/day) which means 801.52 kWh every month.
So the plan is construct solar panels that are able to provide me with 26.729 kWh daily.

According to reality, you can't grantee the panels to provide you energy with an exact value. There will be always some difference because of the weather conditions that might night be always sunny or because some of solar panels hardware implantation issues. So you don't expect the Solar panels to operate at maximum efficiency at all times.

Experts recommend adding a 25% "cushion" to the daily energy that you need in order to offset such inefficiencies.*

Daily needed energy average = (26.729× 25%) + 26.729= 33.411 kwh/day

We have to consider the location of our house and how many hours the sun lasts high in the sky giving the maximum peak of sunlight in order to approximate how much energy our system will be producing.

So we divide the daily needed energy by the number of the daily peak sunlight hours.

Beer in mind those Sunlight Peak hours are from 10 a.m to 4 p.m which means 6 hours.

In order to find the amount of energy our panels need to produce (every hour) in kilowatt-hours the, we divide by the sunlight peak hours : 33.411 /6 = 5.57 kW/hour.

Since each type of solar panels makes a difference, at this point we needed to consider a good quality of solar panels with regard to their cost and efficiency because the whole system is based on them and their ability to provide the needed amount of daily energy.

So After reviewing many solar panel types, we concluded that there is a great difference in their capabilities and performance. So we had to be very careful before adopting a certain solar panel type to our system.

We have chosen solar panels with an excellent quality from the "Renogy" brand. The complete kit contains three solar panels. Every individual panel produces 100 w so that makes a complete kit produces a 300 watt.

We will divide our home's hourly energy requirement by the solar panels' wattage to calculate the total number of panels our need.

5.57k /300=18.56=19 solar panel

Figure 1: Module Type

figure 2 solar panels

We found those panels by $779.99 from their mother website" Renogy" besides that we have to pay extra shipping fees. While we found the same" Renogy "solar panels kit by $479.99 on Amazon website which was a great offer. So we considered it in our calculation which equals 1,761.6 AED only. [3] [4]

figure 3 renogy price label

Figure 4 amazon price label

Therefore the total cost will be = 1761.6*19= 33,470.4 AED

The dimensions of the solar panel are illustrated in the module type lable above in figure1 which says: 119.5cm, 54.1cm and 3.5cm.

So, now we reached the point where we need to calculate the occupied area by each solar panel to make sure that our roof top will be enough to cover them all.

Area of one solar panel =(hight x width) 119.5cm x 54.1cm= 6464.95 cm^2

Occupied area= 6464.95 x 19 =122834.05 cm^2= 12.3 m^2 this is good because our home roof area is about 130 m^2 so yes. There will be enough room for those panels on the roof.

And now we need to determine how many batteries we need. We start by checking the minimum AH battery bank capacity.

We take the watt-hours per day and multiply them by the number of days.

This should represent a 50% depth of discharge on our batteries. Therefore we multiply by 2 and convert the kwh result into amp hours (AH). This is done by dividing by the battery voltage.

We want the battery bank to last one day without recharging and that we use (total consumption power per day 26.729kwh per day.

As 26.729x 1 x 2 = 53.458 kwh, this is the energy we need from the batteries. Converting this to AH we have to divide by the voltage of our system.

This can be 12, 24 or 48 for commercial application. If we choose to use 12V, the minimum AH capacity is then 26729/12 = 2227.42 AH. Now if we divide by our battery's rating we will find the number of batteries we must use.

We chose a 225AH 12V DC DEEPCYCLE T6 TERMINALS SLA SOLAR ENERGY STORAGE BATTERY that was not provided with each kit we planned to buy, so we need to calculate the new cost for adding these batteries.

Total number of batteries= 2227.42 /225 = 9.899=10 batteries.

Each battery costs: $125.00 = 458.75 AED

Total cost= 10 x458.75 = 4587.5 AED

To complete our system we need an inverter that converts the DC electricity being produced by **your** panels **into** alternating to determine the inverter size*. We start by finding the maximum electrical load at our home. This is found by adding up the wattage of the appliances and devices that could be run at the same time. Include everything from microwaves and lights to computers and clocks. The sum will tell us which inverter size we need.

Inverter size = power consumption = 3.5894 kw

power consumption (Kwh/day)
0.3424
0.332
0.37
0.36
0.327
0.065
0.48
0.065
0.1255
0.19
0.0799
0.0046
0.30
3.5894

We chose 4 kw / 220v inverter It costs $350=1285.60AEDx2=2571.2AED

- **Calculating number of solar panels needed (Ignoring AC)**

figure 3: invertor

Now we move to the part of taking ACs out of our calculations where we investigate how much they affect the electrical load and the whole solar system installation as well.

The same previous steps are performed once again ignoring the ACs.

So we start by calculating the number of needed solar panels (ignoring AC)

First, we need to calculate how many solar panels we need; we must start by determining how much energy our household uses; our roof's usable surface area; the climate and peak sunlight in our area; the wattage and relative efficiency of the photovoltaic (PV) technology of the used panels as we mentioned previously.

To find out the energy that we need the solar panels to provide us with every day, we start by considering the required energy that our house needs to run all the appliances. But this time we don't consider ACs in our calculations. This was calculated previously and our results showed that the house consumes 12.14 (kwh/day) which means 364.24.2 kWh every month.

So the plan is construct solar panels that are able to provide me with 12.14 kWh daily.

As we cleared out previously , you can't grantee the panels to provide you energy with an exact value. There will be always some difference because of the weather conditions that might night be always sunny or because some of solar panels hardware implantation issues. So you don't expect the Solar panels to operate at maximum efficiency at all times.

Experts recommend adding a 25% "cushion" to the daily energy that you need in order to offset such inefficiencies.*

Daily needed energy average = (**12.14** × 25%) + **12.14** = 15.175 kwh/day

We have to consider the location of our house and how many hours the sun lasts high in the sky giving the maximum peak of sunlight in order to approximate how much energy our system will be producing.

So we divide the daily needed energy by the number of the daily peak sunlight hours.

Beer in mind those Sunlight Peak hours are from 10 a.m to 4 p.m which means 6 hours.

In order to find the amount of energy our panels need to produce (every hour) in kilowatt-hours the, we divide by the sunlight peak hours : 15.175 /6 = 2.53 kW/hour.

Since each type of solar panels makes a difference, at this point we needed to consider a good quality of solar panels with regard to their cost and efficiency because the whole system is based on them and their ability to provide the needed amount of daily energy.

So After reviewing many solar panel types, we concluded that there is a great difference in their capabilities and performance. So we had to be very careful before adopting a certain solar panel type to our system.

We have chosen solar panels with an excellent quality from the "Renogy" brand. The complete kit contains three solar panels. Every individual panel produces 100 w so that makes a complete kit produces a 300 watt.

We will divide our home's hourly energy requirement by the solar panels' wattage to calculate the total number of panels our need.

2.53 k/300=8.43=9 solar panel

Figure 1: Module Type

We found those panels by $779.99 from their mother website" Renogy" besides that we have to pay extra shipping fees. While we found the same" Renogy "solar panels kit by $479.99 on Amazon website which was a great offer. So we considered it in our calculation which equals 1,761.6 AED only.

Therefore the total cost will be = 1761.6*9= 15,854.4 AED

The dimensions of the solar panel are illustrated in the module type lable above in figure1 which says: 119.5cm, 54.1cm and 3.5cm.

So, now we reached the point where we need to calculate the occupied area by each solar panel to make sure that our roof top will be enough to cover them all.

Area of one solar panel =(hight x width) 119.5cm x 54.1cm= 6464.95 cm^2

Occupied area= 6464.95 x 9= 58184.5 cm^2= 5.82 m^2 which can be coverd by our roof area since the roof area is about 130 m^2

And now we need to determine how many batteries we need. We start by checking the minimum AH battery bank capacity.

We take the watt-hours per day and multiply them by the number of days.

This should represent a 50% depth of discharge on our batteries. Therefore we multiply by 2 and convert the kwh result into amp hours (AH). This is done by dividing by the battery voltage.

We want the battery bank to last one day without recharging and that we use (total consumption power per day **12.14** kwh per day.

As **12.14 x** 1 x 2 =24.28 kwh, this is the energy we need from the batteries. Converting this to AH we have to divide by the voltage of our system.

Again ,This can be 12, 24 or 48 for commercial application. If we choose to use 12V, the minimum AH capacity is then 12140/12 = 1011.67 AH. Now if we divide by our battery's rating we will find the number of batteries we must use.

We chose a 225AH 12V DC DEEPCYCLE T6 TERMINALS SLA SOLAR ENERGY STORAGE BATTERY that was not provided with each kit we planned to buy, so we need to calculate the new cost for adding these batteries.

Total number of batteries= 1011.67 /225 = 4.496=5 batteries.

Each battery costs: $125.00 = 458.75 AED

Total cost= 5 x458.75 = 2293.75 AED

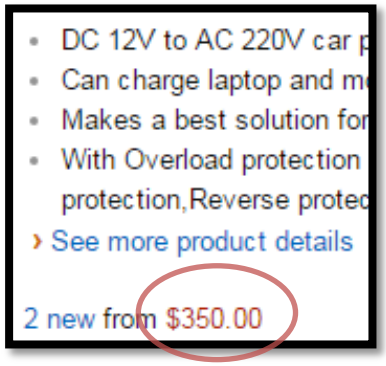
To complete our system we need to determine the inverter size*. We start by finding the maximum electrical load at our home. This is found by adding up the wattage of the appliances and devices that could be run at the same time. Include everything from microwaves and lights to computers and clocks but not ACs. The sum will tell us which inverter size we need.

Inverter size = power consumption = 1.245 kw

We chose 2 kw / 220v inverter

It costs $350 = 1285.60AED

figure 3: invertor



power consumption (Kwh/day)
0.065
0.48
0.065
0.1255
0.19
0.0799
0.0046
0.30
1.245

❖ Comparing the solar power system to the total cost of the house.

Table 4: costs comparison

Total power consumption of the house per month.	Total solar panel cost (Solar panels+ batteries + invertor)	
	Including ACs	Ignoring ACs
235.755 AED	33,470.4 + 4587.5 + 2571.2 = 40,628.7	15,854.4+2293.75+ 1285.60 = 19,433.75

Determining whether to install a PV solar system may seem like a daunting task, but it is important to remember that such a system is a longterm investment.

In many locations, solar power is a good choice from a financial perspective. Even if the cost of solar power is found to be marginally more expensive than electricity purchased from a utility, homeowners may wish to install solar power to avoid future potential fluctuations in energy costs, or may simply wish to look beyond their personal financial motivations and use solar for "green" living.

Conclusion

To conclude, the aim and the objectives of the assignment have been achieved. The electrical load of our home appliances was studied thoughtfully within the required tasks. The first section made us understand how we were being charged for the electricity we use at home. we have been shocked when we noticed that the water cooler consumes the same power that the refrigerator needs. Also, one hour of using microwave equals about 27 hours of using the washing machine. Those results shocked us a lot, so we really need to consider the yearly power rating of any device before buying it and use it at our homes.

In the next sections, we have separated the ACs from the other appliances in our calculations in order to highlight how they affect the bill. We ended up by figuring out that they contribute to more than 60% of the bill cost. The problem is that we cannot reduce the using hours since the UAE has a very hot weather most of the year days. So we started considering the solar panels as a solution to overcome the electricity consumption costs. So we calculated how many solar panels we need; we started by determining how much energy our household uses; our roof's usable surface area; the climate and peak sunlight in our area; the wattage and relative efficiency of the photovoltaic (PV) technology of the used panels.

The results were interesting and considered the solar panels as a long term investment.

All in All, this assignment benefited us a lot, it increased our fascination in many electricity aspects,. Finally, our assignment has been completed successfully and its main aim which is relating what we study in this course with our real life has been accomplished.

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Yearly power consumption of some of our house appliances