Investigation and Design of Solar Cell System for Households in Gulf Cooperation Council (GCC) Countries: Qatar, Saudi Arabia

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Abstract

The Gulf Cooperation Council (GCC) countries are blessed with several natural resources, such as oil and natural gas. Currently, 17% of these countries oil and gas production is being used to produce electricity. Now, the GCC countries have the opportunity to decrease their CO_2 emissions by using renewable energies, including solar energy. Using solar energy could be a possible alternative to reduce the oil consumption and reduce some sources of CO_2 emission, thus decreasing global warming. The objective of this paper is to equip a house in residential areas with solar cells system in the GCC countries, therefore substituting its energy source with solar energy. The household design includes designing of a DC/DC converter with a specific output voltage. The design will also include a DC/AC inverter that produces a high power AC output to operate the appliances and Heat, Ventilation, and Air Conditions (HVAC). A charge controller and batteries functioning as a backup power supply will be designed and installed as well.

1. Introduction

Solar energy is one type of a renewable energy that can be converted easily and directly to electric energy by using photovoltaic converters, without any environmental effects. In addition, solar system has long life time, and it can produce small power (watt) to large power (Mega-watt) scales [1]. In fact, a photovoltaic converter is an energy converter with advantageous features such as relevant design and installation, silent energy conversion, long life time with less maintenance requirements, easy transportation and light weight. Nonetheless, in comparison with other types of energy converters like diesel generators, photovoltaic converters are not expensive.

The process of non-movable mechanisms converting solar energy into electric energy is called photovoltaic (PV) phenomena whereas the conversion device is called solar cell [2]. Solar cells convert the energy of light's photons to electric energy with efficiency between 5 to 25 percent, without using thermodynamic cycle or active fluid. "The maximum efficiency of a solar cell made from a single material can achieve in converting light to electrical power is about 30 percent; the best efficiency actually achieved is about 25 percent"[1-3] [11]. Solar cells can be direct light collectors or can use light concentrators, like mirrors or convex lenses that can help highlight the aesthetic features of the design.

It would be better to install them in a movable manner since the solar arrays have low efficiency. The movable installation of the solar arrays will help absorb the maximum electric energy from the PV-array and will add an inventive value to the design of the building. [5]

2. Environmental concerns about using solar energy

Since the GCC countries, in general, and Qatar in especial are going through a vast development in terms of producing gas and oil products, it has been brought to their concern that those products are affecting their environment. Therefore, a great deal of research is currently underway in the topic of renewable energies that are not only environmental friendly but also provide a longer lasting energy resource.

Solar cells have been proven to be clean energy sources, as they produce fewer pollutants than conventional fossil fuel technologies. There are concerns that producing solar cells would add to the region some serious pollutants like lead, mercury and cadmiums producing carbon dioxide which contributes to global warming. However, a study conducted and published by the ACS (American Chemical Society) Environmental Science & Technology showed that air emissions data from 13 solar cell manufacturers in Europe and the United States from 2004-2006 were collected, and it was found that "producing electricity from solar cells reduces air pollutants by about 90 percent compare to using conventional fossil fuel technologies" [12].

3. Design of a solar system for solar household

3.1. Block diagram of system design

In this paper, it is suggested to operate the household on solar energy during the day. Then at night, the house will start operating on the energy that has been stored in the batteries during the day. When there is energy shortage in the batteries at night and in the emergency cases, a backup generator system will operate automatically to supply the house with the necessary energy.

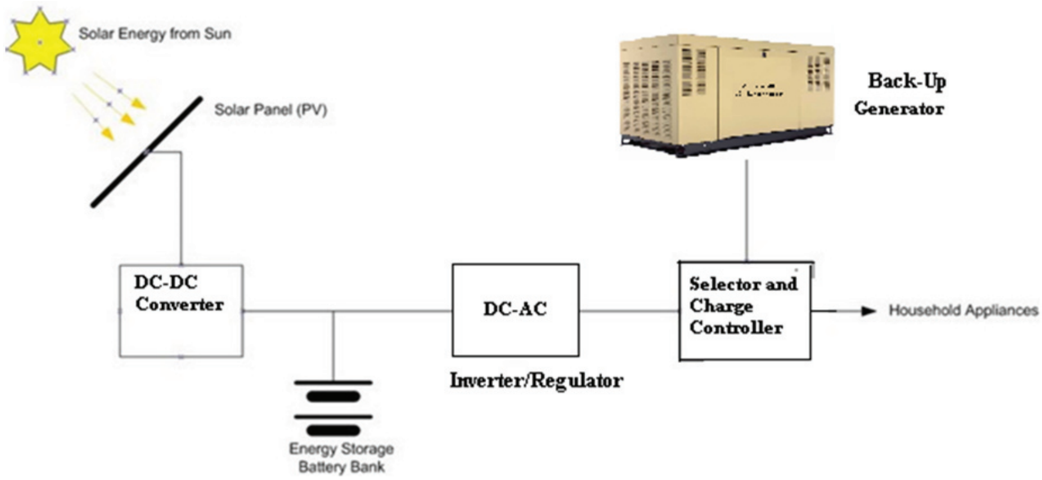

Figure 1: Proposed Energy Flow for the Household

For further energy savings, the whole heating system in the house will depend on solar water heater that only will save around 5000 Watts for a single house in the GCC countries; since it has the bless of having sunny days all over the year. In addition, the household will be connected to an UPS system that will manage to switch between the different energy sources that are available in the design.

3.2. Solar cell design and simulation

Implementing solar panels on building requires finding fixed solar arrays. There are several types of these arrays: flush mounts, universal roof/ground, and pole mounts. Those mounts are used to support the solar panels to be installed almost everywhere, finding the best angle of installation. For maximum design strength, Aluminum could be considered as an element to be used in manufacturing the frames of the solar panels. Also, there are several parameters that should be considered for designing the mounts of the solar panels [1-3] [13]. These parameters are as follows:

Weight and height of the solar panels;

Air resistance;

Humidity and temperature of the region;

Stress on the solar mount support;

The flush mount can be implemented on buildings; however it requires a space underneath it to keep it cool. The minimum required space would be between 2 to 4 inches and if this space is eliminated, then the life time of the solar panel will be greatly affected due to overheating.

The floor-roof mount is a type of mount that provides more flexibility during the installation process. The system can be placed higher by adding poles or concrete blocks at the ground of the mounts. Moreover, the height can be placed at any desired inclination by adding screws to support the beams at any desired position [14].

Pole mounts can be easily installed. It requires a pole to be fitted on and it can be installed on the top of the pole or on the side of the pole. It might require, though, some physical stress depending on the size, and weight of the solar panel. Table 1 shows the specification of solar cell model ND-216u1F [14] used for this research.

Table 1: Specifications of Solar Cell ND-216u1F [14]

Maximum Power (Pmax)	216 W	Series Fuse Rating	15 A
Tolerance of Pmax	+10%/-5%	NOCT	47.5°C
Type of Cell	Polycrystalline silicon	Temperature Coefficient (Pmax)	-0.485%/°C
Cell Configuration	60 in series	Temperature Coefficient (Voc)	-0.36%/°C
Open Circuit Voltage (Voc)	36.5 V	Temperature Coefficient (lsc)	0.053%/°C
Maximum Power Voltage (Vpm)	28.9 V	Maximum System(DC) Voltage	600V
Short Circuit Current (Isc)	8.10 A	Maximum Power (Pmax)	216Watt
Maximum Power Current (Ipm)	7.48 A	Module Effi ciency (%)	13.3%

Regarding the simulation, Figure 3 simulates the equivalent circuit of the solar cell and the following formula (1) measures the total current I in the simulated circuit:

$$I = qA\left(\frac{D_h}{L_h}P_{N0} + \frac{D_e}{L_e}n_{P0}\right)\left(e^{\frac{qV}{K_BT}} - 1\right) - qAG(L_{h+}L_e) \qquad (1)$$

Formula (1) shows I which is the load current (amperes), q is the charge of the electron (coulombs), A is the area of the diode (cm^2), D_h is the diffusion constant for the hole, L_h is the diffusion length for the hole (cm), P_{N0} is the density of holes (g/cm^3), D_e is the diffusion constant for the electrons, L_e is the diffusion length for the electrons (cm), n_{P0} is the density of electrons (g/cm^3), V is the voltage (volts), K_B is Boltzmann's constant, T is the transmission coefficient of coupler in coherent receiver, and G is the generation rate for carriers. The output voltage of the solar cell can be calculated using:

$$V_{oc} = \frac{k_B T}{q} \ln \left[\frac{L_h + L_e}{\frac{D_h}{L_h} P_{N0} + \frac{D_e}{L_e} n_{P0}} G + 1 \right] \tag{2}$$

Formula (2) shows V_{oc} which is the maximum voltage obtainable at the load under open-circuit conditions of the household (volts) [4].

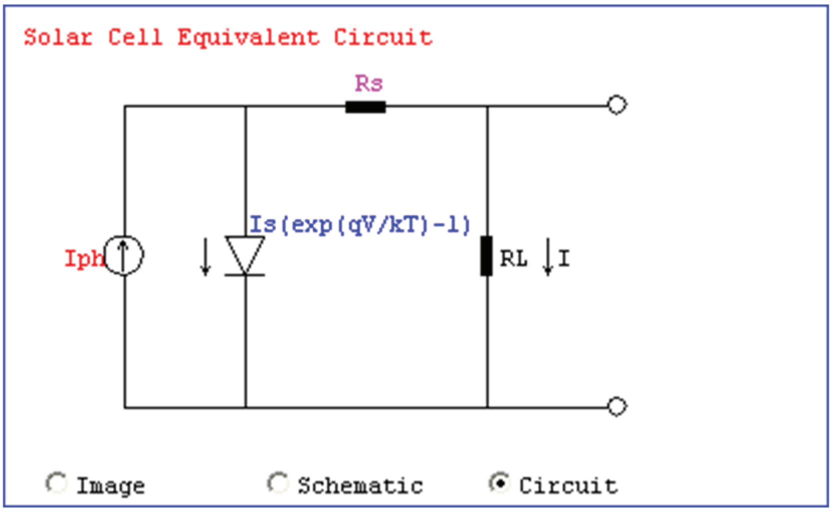

Figure 2: Equivalent Circuit of the Solar Panel

3.3. DC/DC converter design and simulation

A DC/DC converter will be used in the design. Since the input would be changed accordingly with the intensity of the sun light, a DC/DC converter will supply electric energy to the load, and also it will be used to charge the batteries from the output voltage of the photovoltaic arrays which will help maintain a constant DC output voltage.

There are three main types of converters that could be used in solar panels: buck, boost, and buck-boost converters. The main advantage of the Step Up (boost) converter is that the output voltage will be higher than the input voltage. On the other hand, the Step Down (buck) converter will have a lower voltage for the output compared with the input voltage. However, the buck-boost converter has the flexibility of working as a Step Up or a Step Down converter. Therefore, preferably the Buck-Boost converter will be used since the sun intensity is not constant over the year.

Figure 4 shows a graph that summarizes the performance of the three different types of DC/DC converters, where a linear relationship has been monitored between the three types. This proportional relationship helps provide a Step Up and Step Down conversions in the buck-boost converter, making it the most suitable converter for the household design.

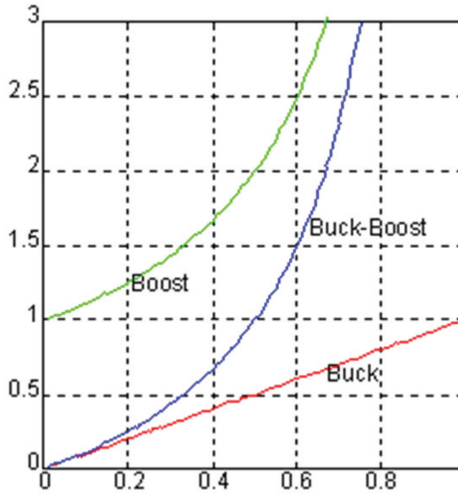

Figure 4: Comparison of Voltage Ratio for DC Converter

Figure 5 illustrates an equivalent circuit of the buck-boost converter.

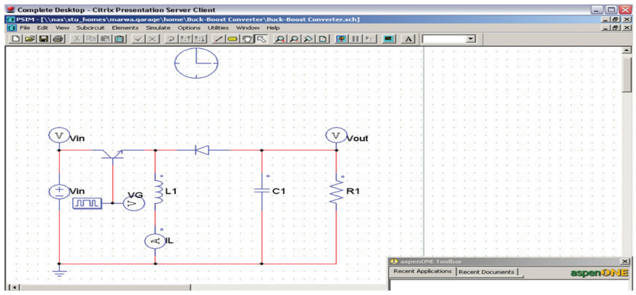

Figure 5: Buck-Boost Converter Circuit

Figure 6 shows a simulation indicating how a buck-boost converter can maintain the same pattern of voltage output.

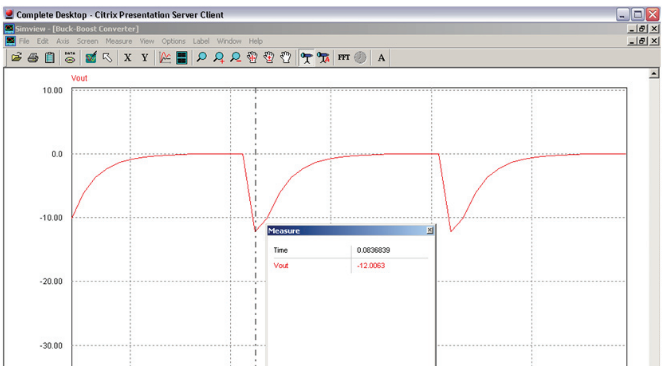

Figure 6: Voltage versus Time across DC/DC Converter Using PSim

After doing this simulation, the study was directed towards using technology and according to the available solar cell specifications; a DC/DC converter with digital or analog control of a custom fit for the designed circuits will be used. This converter was chosen because it allows us to control the power, current and most importantly the voltage. It can also maintain a constant voltage which is just what is needed to stabilize the input voltage entering the inverter. The input voltage is intended to be 12 V.

The specifications of the DC/DC converter for this design are as follows:

Input voltage: 0-24 V

Output Voltage: 12 V

Output Power: Depending on the design of loads

Since the DC converter chosen is very flexible and supports a wide range of input voltages, 0 to 24 input voltages is chosen. Because the open circuit voltage (Voc), the solar cell model has a maximum voltage of 36.5 V with full efficiency.

3.4. DC/AC inverter and simulation

DC/AC Inverter is crucial for having a solar household. DC to AC inverters converts the DC current generated by a solar panel into AC current that can be used to supply power to different appliances and HVAC.

The proposed design would be including a single-phase bridge voltage source inverter (VSI). The DC/AC inverter circuit is shown in Figure 7.

The output voltage of the inverter is:

$$Vo = [\left(\frac{2}{To}\right)\int_0^{\frac{To}{2}} V_s^2\, dt]^2 \quad (3)$$

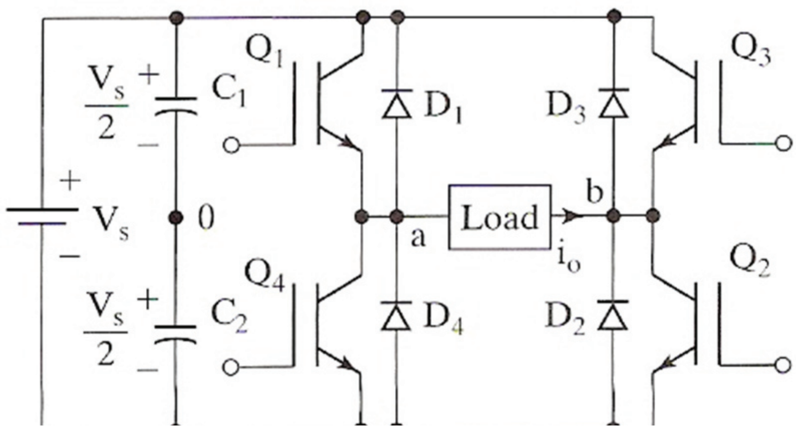

Figure 7: 12V DC-240 AC Single Phased Inverter [15]

An inverter produces a pure sine wave which helps the appliances run efficiently and protects their circuit. Figure 8 shows simulation of input voltage vs. the output voltage of the inverter.

According to output voltage from the converter, the inverter will function on 12 V DC with a 5000/10000 Watt Power Inverter [19]. This DC/AC inverter can convert 12V DC into 220/240V AC. It has a maximum continuous power of 5000 Watt and a peak power of 10000 W and it has can function on 50 Hz frequency.

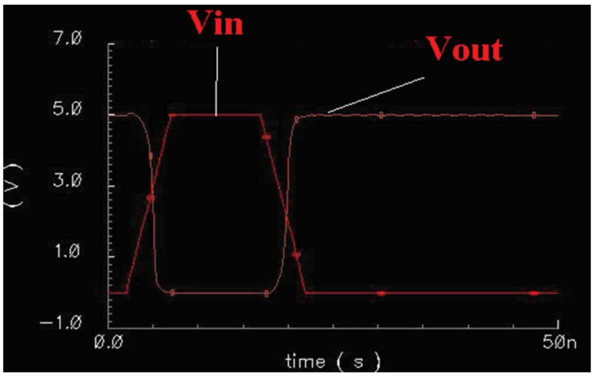

Figure 8: Comparison between the Vin (Input Voltage) and Vout (Output Voltage) for a DC/AC inverter [17]

Adding an inverter to the design of the solar household will help operate appliances much better than having only a DC-DC converter. The total load current I is:

Where$P$ is the total power in watts, V is the voltage in volts and cos θ

is the total power factor of the loads that will be taken around 0.9 with I = 40.40 A.

3.5. Charge controller design

A charge controller will be used to control the overflow of the charges in the battery. Batteries, used as a backup plan to maintain power supply, will be charged and discharged depending on the sun’s intensity. The charge controller would be installed to prevent an overcharge or unexpected discharge of these batteries.

In fact, there are two main categories for charge controllers: the stand-alone charge controllers and the integrated charge controller circuitry. The circuit of a charge controller is composed of resistors, diodes, and transistors. Each circuit element plays a different role in the functionality of the charge controllers. Resistors are used to drop the incoming voltage to suit the battery condition and diodes are used to prevent any extra charge coming from the solar panels. Figure 9 demonstrates the circuit composition of a solar charge controller.

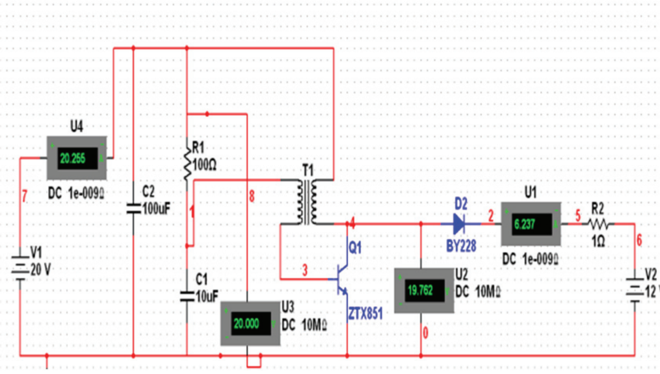

Figure 9: Solar Charge Controller Circuit

3.6. Backup batteries

Power storage batteries are essential to a renewable energy system. There should be a backup energy sources while the renewable energy system is operating. Therefore, the definition of finding a good system is that when the energy, produced from the alternative energy source, will be higher than what is needed for usage, extra power will be saved in the backup system and will be used for recharging. Battery banks can be put together to meet consumers needs. In addition, several series sets can be connected in parallel to enhance the capacity of the battery bank amp-hour. Thus, 3000 amp-hours of 12V current can be produced from two 1500 amp-hours of 12V batteries, connected in parallel. On the other hand, 1500 amp-hours of 24V power can be produced from two 1500 amp-hours batteries, connected in series. All batteries used can be arranged in a configuration that best fit the power system [18]. To support the energy flow continuously, 4 batteries of 4500 Watts PBS model are required for power supply backup.

4. Constraints of solar cells in GCC countries

Research done by Adel A. Hegazy [6] relates the dust on solar cells to their power output. In his research, the dust accumulation on glass plates with different tilt angles and associated reductions in solar power output were investigated for one year under the climate conditions of the Minia region in Egypt. This region has similar weather conditions as the GCC's [6]. The glass plates were never cleaned for one month so that dust could accumulate. The results clearly showed that the solar power strongly depends on dust deposition in conjunction with plate tilt angle, as well as on the exposure period and site climate conditions. The research recommends weekly cleaning of the glass covers of the solar panels as part of the maintenance routine and also immediately after a dust storm to retain the operating efficiency. Figure 10 shows how the dust level is related to the solar power for the days of exposure.

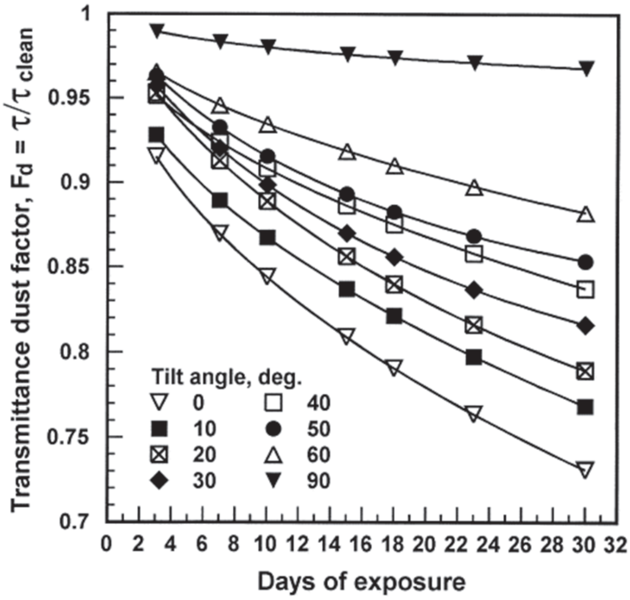

Figure 10: Dust Factor versus Days of Exposure [6]

Another factor that has to be considered is the excessive heat in GCC countries. All PV systems are affected by heat; the more heat there is, the less power produced. Reuk, a company in the UK, conducted an experiment to show the effect of heat. For this purpose, 6V, 250mA solar panels were used for simulation. In order to reproduce heat levels that solar panels experience in hot climates, a 150 Watt halogen office lamp was used at a distance of 55 mm from the solar panel as a sun substitute. This guaranteed that a constant level of light would be incident upon the solar panel, ensuring the quality of the results collected.

"The experiment shows relationship between temperature in degrees Celsius and the solar panel power output measured in milliwatts. Because of the way the halogen lamp took one minute to reach full brightness the results from 25-30 degrees Celsius should be ignored." [7] Figure 11 illustrates the relationship between the measured temperatures and the solar panel power output.

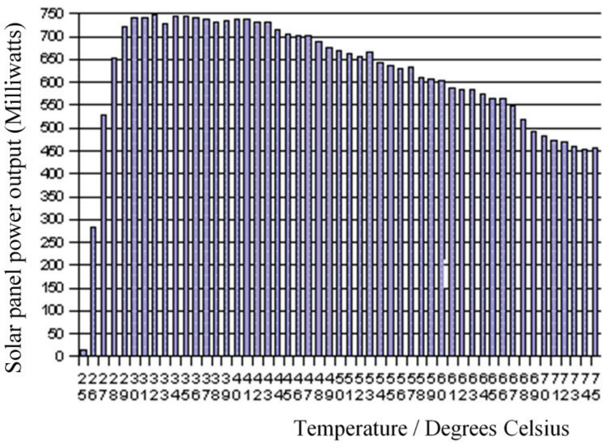

Figure 11: The Effect of Temperature on the Solar Panel Power Output

"Between 30 and 42 degrees there was only a small drop in power output from a peak of 749 mW down to 730 mW. After that there was a consistent drop in power output of around 8.3mW (1.1% of peak output) per degree rise in temperature. Voltage under load went from a peak of 6.21V at 0.12 Amps down to just below 5V at 0.09 Amps. The total power loss due to the increase in temperature was from around 750 mW down to just 458 mW - a fall of almost 40%! Had the solar panel been pre-cooled in the fridge before the experiment was started the peak power output would certainly have been even higher" [7].

These results prove that solar cells will be affected by the heat in GCC countries which can reach up to 55 degrees Celsius in summer. Therefore, the solar cells should be cooled in the summer in order to obtain maximum power output.

5. Design of solar household for energy consumption

5.1. Parameters of energy consumption for solar household

There are many parameters that need to be considered when designing a solar household. There is the question whether to use DC or AC (alternating current) equipments. If AC equipments are used throughout the whole house, it is possible to use the power grid as a backup system. However, in this case it is necessary to convert the DC voltage to AC voltage and there would be energy dissipation in this process.

On the other hand, it is possible to design the whole household for DC equipments. In this case, the energy does not need to be converted to AC voltage thus energy is conserved. Some alternatives would include a backup generator.

Since most of the equipments, in the Gulf region, work on 110 to 220 volts, this paper favored using a digital DC/DC converter with an output of 48 V. This means that the voltage is stabilized. Thus, by adding an DC/AC inverter to the whole design of the solar household, the power output will reach a value of 8 kilo-watts enabling the household users of operating many high power-consumption appliances (e.g.: Electrical oven and electrical furnace). Also, with the inverter installation, the voltage can reach a value up to 240 volts and the system can have a frequency of 50 Hz.

5.2. Estimated electrical consumption for a household

Different parts of the house consume different electric energy. Nevertheless, there is a general trend that has been recognized in most of the houses. According to a survey conducted in 2001, the following percentages have been set in Figure 12:

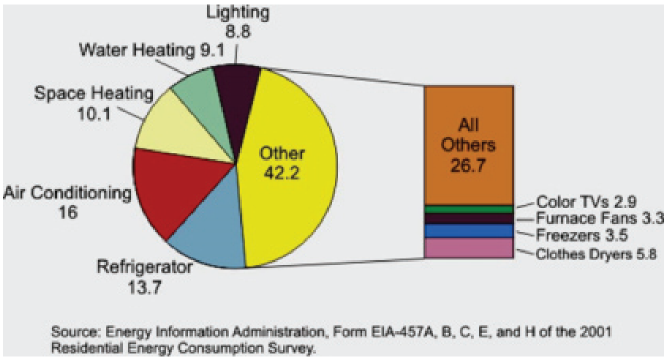

Figure 12: Percentile of Energy in Household [9]

The total estimated amount of energy consumed is 17,236 watts**.** So for the specific suggested model, ND-216u1F, 80 solar cells has to be installed to maintain the household requirements. An area of 130.367 m^2 is required to install all 80 solar cells on the house's roof.

Table 2 shows different appliances of a typical house with its relative energy consumption.

Table2: The Required Power for Different House Applications [9]

Heating		Lighting	
Elec. furnace, 2000sf, cold climate	26,500 watts	60-watt light bulb (incandescent)	60 watts
Elec. furnace, 1000sf, warm climate	7941 watts	CFL light bulb (60-watt equivalent)	18 watts
Electric space heater (high)	1440 watts	Night light	5 watts
Electric space heater (medium)	900 watts	LED night light	0.5 watts
Electric space heater (low)	600 watts	Computers	
Gas furnace (for the blower)	750 watts	Desktop Computer	150-340 watts

Cooling		17" LCD monitor	40 watts
Central Air Conditioner (2.5 tons)	3500 watts	Laptop computer	45 watts
Window unit AC, huge	1440 watts	Others	
Window unit AC, medium	900 watts	Microwave oven or 4-slot Toaster	1440 watts
Tiny-ass window unit AC	500 watts	Coffee maker	900 watts

Central AC fan (no cooling)	750 watts	Range burner	800 watts
Major appliances			
Clothes dryer (electric)	4400 watts	Refrigerator (compressor)	200-700 watts
Electric oven	4400 watts	Refrigerator (average)	57-160 watts
Water heater (electric)	3800 watts	Dishwasher (washer heats water)	3600 watts

A normal household power usage will be estimated through a design of hypothetical house supplied with the following appliances in Table 3.

Table 3: A Sample of Possible House Applications [9]

Equipments Used	Power Consumption (W)
2-Electric space heater	2x900=1800
6-Window unit AC	6x900=4500
1- Clothes dryer	1x4400=4400
1-Microwave oven	1x1440=1440
1-Coffee maker	1x900=900
2-Refrigerator (compressor)	2x550=1100
1-Dishwasher	1x3600=3600
12-CFL light bulb	12x18=216
6-60-Watt light bulb	6x60=360
3-Laptop computer	3x240=720
Total Power Usage	**17,236**

5.3. Solar heater system

Solar domestic hot water systems are cost-effective facility helps to generate hot water for houses, governmental buildings, hospitals…etc. They can be used efficiently in the G.C.C countries and there is no constrains in implementing them to the household designs, their fuel is totally free which is sunshine. Solar water heaters require a storage tank, insulated pipes, anti-freezing material, and solar collector. There are mainly two types of solar heating systems: active, which have circulating pumps, and controls, and passive which don't include that. There are mainly two types of solar heaters one is the active type and the other is the passive.

The active has two main ways of circulations of water direct and indirect. The direct one pumps the water of the household through the collectors and then directly into the home; however, the indirect active circulation mostly used in the very freezing climates which pumps inside the collectors a non-freezing heat-transfer fluid and the heat exchanger, then after that the water will be headed to the household.

The passive system is much more manageable and less expensive; however, the system is a bit less efficient but it is long lasting system. There are two main basic types of passive systems; the integral collector-storage passive systems: they function best in the houses where the temperature drop is below freezing or areas where the house would be in need for day and night hot water, and the thermosyphon systems: water starts flowing in the system when a cooler water comes into the system. Main point the collector should be installed below the storage tank so that the warm water will rise back into the tank. The reliability of this system is very high; however, the tank holder should be very strong. The passive system is highly recommended for the countries with high temperature.

There are few concerns should be looked over while designing the solar heater [21]:
-Consider the economics of a solar water heating system
-Evaluate your site's solar resource
-Determine the correct system size
-Determine the system's energy efficiency
-Estimate and compare system costs
- Investigate local codes, covenants, and regulations

6. Cooling solar cells

A very small amount of incident sunlight which strikes the solar cell gets converted into electrical energy. The reminder of the energy absorbed gets converted into thermal energy in the solar cell which can increase the cell's temperature unless the heat is efficiently dissipated to the environment.

The major factors that need to be considered to cool photovoltaic cells are:

(1) *Cell Temperature:* The efficiency of photovoltaic cells decreases as the temperature increases. If the temperature exceeds a certain level, the solar cell will show a long-term degradation. Manufacturers of solar cells specify a temperature degradation coefficient and a maximum operating temperature for the solar cell.

(2) *Uniformity of Temperature:* The solar cell efficiency decreases due to non-uniform temperatures throughout the cell. In photovoltaic panels, some cells are connected in series and some are connected in parallel. To avoid having less efficiency due to temperature rise, the cells temperature should be kept uniform.

(3) *Reliability and simplicity:* Simple cooling design should be sought

since it will minimize the cost and require less maintenance. Design simplicity also reduces the toxic materials used which endanger health and environment. Reliability is very important factor when choosing a cooling system because failure of the cooling system can destroy the PV cells.

(4) *Usability of thermal energy:* The total conversion efficiency of the solar cell can be increased by using the extracted thermal energy from the cooling system.

(5) *Material efficiency:* Materials used should be reduced for the sake of weight, cost and embodied energy consideration.

There are many methods to cool systems down. Some of these methods are passive cooling, forced air cooling, micro channel cooling and many others. However, it has been found the micro channel is an efficient way for cooling the PV arrays because of its ability to remove a large amount of heat from a small area. However, the negative side of using micro channel would be a great temperature gradient along the stream wise direction and a huge pressure drop. [22]

7. GCC countries achievements in terms of finding more sustainable architecture

Since global warming and CO_2 emission is becoming a major problem everywhere in the world, the Arabian Gulf region can play a great role in this aspect. Several studies have been done to save the region from this future environmental disaster. Most of the countries in the world are taking steps towards finding a green environment by using sustainable resources. That is why a few of GCC countries (e.g. State of Qatar and the Kingdom of Saudi Arabia) were encouraged to find a healthier living environment in the educational campuses.

7.1. Effects of modern design on culture

Considering solar power as an alternative to fossil fuel is gaining tremendous amount of attention and support all over the world. The GCC countries are considering the use of solar energy as a secondary source, if not a primary source, to derive the energy required to function distinct facilities that, nowadays, rely on gas and oil energies. However, there is a very significant element that needs to be addressed when trying to implement the solar power technology in the gulf region.

Engineers should bear in mind the importance of the design on the existing culture and how implementing such technology could change the cultural aspects in the GCC countries. Implementing solar technology should not impose importing westernization in the design of the solar-energy-dependent houses. It is known that the gulf region's population is very proud of its culture and its houses' traditional look. Knowing that solar panels must be installed in a house, the traditional household design will definitely require few changes to fit such panels. Therefore, caution should be taken in terms of applying a modern household design that fits the new solar technology, since many people, especially in the GCC countries, are patriots to their culture.

Solar technology should be used as a tool to add a great modern look to the household design. This way, the nation would be a very interesting target for future non-stoppable projects and investments. In fact, having a modern design for solar cells installation and preserving the traditional design of the house can be balanced. Architects and engineers can come up with proposes that set up solar cells in a hidden approach which would not hugely alter the cultural views in the GCC countries. One technique that can be used, is installing solar panels on unoccupied spaces of the household roof. In addition, architects can avoid having sharp inclined designs to install solar panels. In order not to utterly change the house's design, solar panels can be installed on top of window shelters and garage roofs.

8. Qatar solar initiatives and parameter analysis

8.1. Qatar currently developed project

Qatar Foundation, in State of Qatar, is willing to give students the chance to live in zero-waste residence halls, offering them a great lesson in terms of responsible living by conserving the surrounding environment and utilizing the available technology. These new residential halls will maximize energy efficiency and water use by utilizing wind turbines, photovoltaic cells and a bio mass wall for filtering gray water. Figure 13 shows a design of the new residential halls in Qatar Foundation in Doha, Qatar. [8]

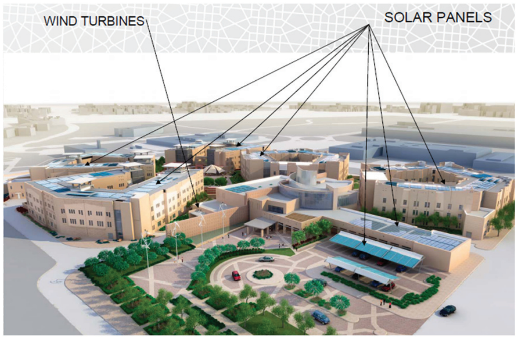

Figure 13: Design of Future Residential Halls in Qatar Foundation [8]

There would be 976 solar panels and 4 wind turbines, providing about 12.5% of the current power usage of energy per year. This would be considered a big jump towards finding a healthier environment and would give the students the chance to interact with the modern technology. All these panels would be computerized and observed by specialized staff. Access for engineering students who are willing to improve the solar system by obtaining data or studying the behavior of the solar and wind turbines systems will also be provided.

8.2. Sun intensity

“It is a known fact that the output of the pv panel is maximum under full bright sun and when the sun’s rays are perpendicular to the array. The photocurrent, which is the current generated by the solar cell, is directly proportional to the sun’s intensity. As the latter increases, the photocurrent increases in magnitude and vice versa.” [3] Figure 14 shows current variation and solar cell’s voltage in relation with the intensity of the sun.

Even if there is a variation in the sun’s intensity, the solar cell’s photo conversion efficiency remains constant. The photo conversion doesn’t change when the solar radiation crosses the 500 W/m^2 range as it is shown in Figure 15.The output power gets lowered because the amount of sunlight decreases when shade strikes the solar panel. [3]

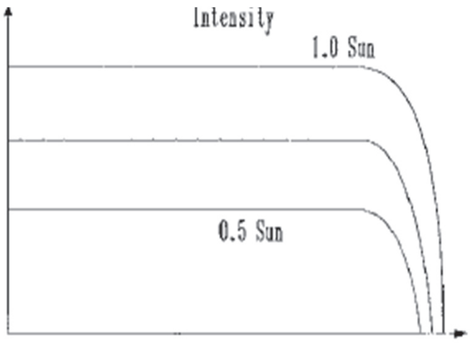

Figure 14: Current versus Voltage Graph as Sun’s Intensity Changes

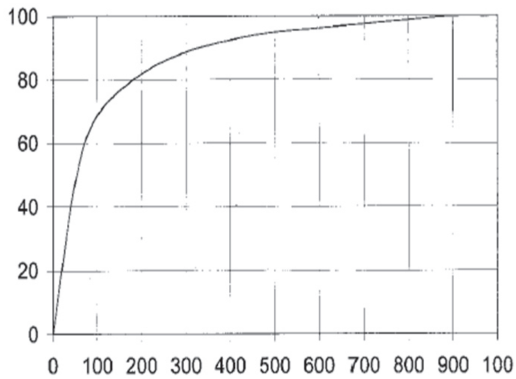

Figure 15: Photo Conversion versus Solar Radiation

8.3. Sun angle

The output current of the solar cells is given by I=I_0 cos θ, where I_0 is the current with the normal sun and θ is the angle between the normal and the sun's incident ray. The above relationship is valid for angles ranging from 0^o to 50^o. Figure 16 demostrates a graph of the relative current in relation to the incidence angle of the sun. Moreover, as the solar panel temperature increases, the short circuit current increases and the open circuit voltage decreases. [3]

9. KSA future sustainable project

Kingdom of Saudi Arabia (KSA) is implementing sustainable designs where renewable energy sources can be used. For example, in the future project of King Abdullah University of Science and Technology (KAUST), currently performed in the Red Sea area, solar panels have been installed. The KAUST campus will incorporate multiple strategies to reduce the overall energy demand for campus buildings. The strategies included both the architectural design of the buildings and the selection of the appropriate mechanical systems. There would be renewable solar photovoltaic energy and solar towers to provide natural ventilation for the pedestrian spine. The courtyard areas would use natural day-lighting strategies for outdoor spaces and select the interior space to reduce lighting demands [10].

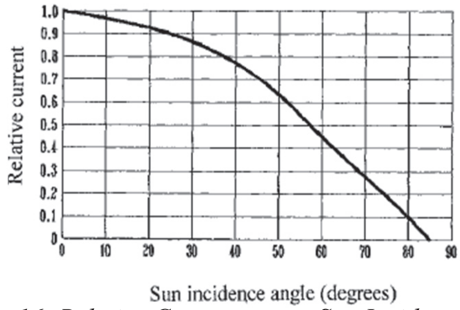

Figure 16: Relative Current versus Sun Incidence Angle

10. Comparison between Qatar and KSA in implementing solar panels

A study has been done by KAUST which shows that solar panels play a great role in terms of providing energy to buildings. Figure 17 and 18 show how successful was the implementation of the solar panels in the GCC region. This would help the rest GCC countries start implementing the solar panels' strategies.

As it can be seen, the two graphs are very similar. This shows that the photovoltaic solar panels installed in Qatar and KSA undergo similar weather conditions.

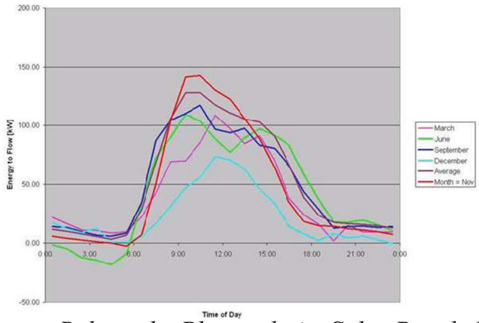

Figure 17: Potential Energy Release by Photovoltaic Solar Panels Located at KAUST [10]

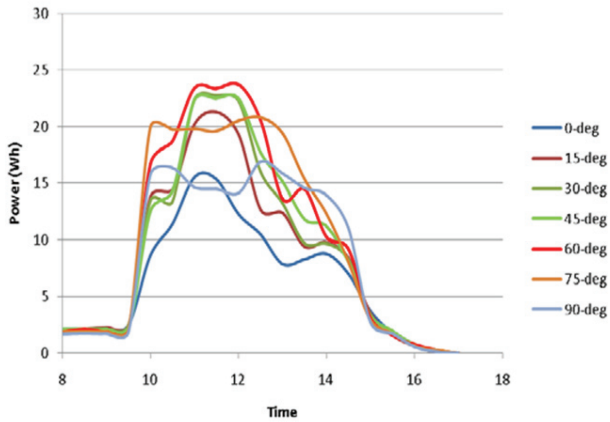

Figure 18: Solar Panel Power versus Time at Different Angles for November 8 in Qatar [1]

Conclusion

Although oil and gas are common energy resources in GCC countries, they are not renewable and they are limited to a certain period of time. Many efforts have been taken to find alternative resources that are renewable, long-lasting and environmental friendly. Solar energy can become the most reliable clean energy source. Since the GCC countries have hot and sunny weather, this qualifies them to greatly seize the opportunity and efficiently use solar energy. Heat, humidity level and dust intensity are factors that affect the study and application of solar energy. Due to various constraints that should be considered, a lot of research has been conducted in Europe and America and less in the Middle East.

In this paper, it has been found that the most suitable design for a solar household consist of a DC/DC converter, DC/AC inverter, charge controller and backup batteries. The DC/DC converter has an input voltage range of 0 to 24 V, an output voltage of 12 V and the output power depends on loads. The DC/AC inverter is used in the solar household design to generate high power output between 5000 to 10000 watts. According to the calculations, the DC/AC inverter will function on 12 V DC generated by the DC/DC converter. Furthermore, the charge controller will be used to prevent any overflow of the charges or any sudden discharge of the battery.

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دراسة وتصميم أنظمة الخلايا الشمسية للمساكن بدول مجلس التعاون الخليجي: قطر والمملكة العربية السعودية

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الملخص:

دول مجلس التعاون الخليجي من البلدان الغنية بالثروات الطبيعية مثل النفط والغاز الطبيعي. حيث ان ١٧ بالمئة من انتاجات هـذه البـلاد من النفط الخام والغاز الطبيعـي تستهلك من اجل اصدار الطاقة الكهربائيـة. الأن ، قد وجب على دول مجلس التعـاون الخليجـي تقليـل اشعاعات الغازات ومنها غـاز ثنائي اوكسيد الكاربـون وذلك من خلال استعمـال مصارد الطاقة المتجـددة ومنهـا الطاقة الشمسية. حيث ان الطاقة الشمسية ممكن ان تستعمـل كبديل اساسي لتقليل من معدلات استهلاك النفـط لتحد من مصادر بعـث غاز ثنائي اوكسيد الكاربون وذلك بالتالي سوف يحد تدريجا من ظاهرة الأنحباس الحراري. الهـدف الأساســي من البحـث هو دراسة امكانية تزويـد بيت في المناطق السكنيـة بأنظمة الخلايـا الشمسية في دول مجلس التعاون الخليجي وذلك لتزود المنزل بالطاقة الكهربائية من الشمس بدلا من مصـادر الطاقة المعتادة. البيت المعد سوف يلحق بأجهـزة تحويـل التيار المستمر مع فولتيات متغيرة ضمن نطاق محدد. بالأضافة التصميم سوف يحتوي على محولات للطاقة من التيار المستمر الى التيار المتناوب و ذلك للحصول على تيار متناوب عالي الفولتية لتشغيل مختلف الأدوات المنزلية ونظام التدفئـة والتبريد والتهوية. منظـم الشحنات مع البطاريات سوف تلحق بالتصميم و ذلك لجعل النظام المقترح في حالة امنه خلال فتره استعماله.