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Peak Shaving Using Grid-Connected Solar Panels Case Study: Ministry of Islamic Affairs Mosque

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ABSTRACT:
The main purpose of this paper is to introduce the application of renewable energy, namely solar energy for peak shaving during peak loads and to investigate of the feasibility of using grid-connected solar system for electricity generation in Ministry of Awqaf mosques. PVsyst software is used to find the optimal design for total connected load of 80 kW. The technical performance of 80 kWphotovoltaic (PV) solar systems grid-connected was tested. Applying renewable energy in building is required by Kuwait government, all sectors should use 30% of the consumed energy from renewable energy in year 2030. The total cost of solar system for 1400 mosques is around 145 million KD; the total cost of energy is 11 million per year according to 0.058fils which mean that the payback period within 13 years.Based on the study results, the development of grid-connected photovoltaic (PV)solar system in Awqaf mosques in Kuwait could be economically viable and provide peak shaving during peak loads.
Keywords: photovoltaic (PV), solar system, renewable energy,

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I. INTRODUCTION:

Electricity plays a significant role in the well fair development nations and it participates effectively in the history of man progress. All nations have been concerned with the production of the electrical energy and meeting its increase in industrial and residential demand.

Kuwait has an extensive development of electricity since the thirties of the past century till the present time where the installed capacity has increased many times during this period from only 60 kW in 1934 to reach 11640 MW by the end of 2008[1].

Kuwait electrical utility mainly uses thermal steam turbines for the generation of power needed to satisfy demand. However, power plantsalso include some thermal gas turbines that make up around 4% of total installed capacity and are usually used in emergencies and during the time of peak load [1].

Electricity peak demand has been moving upwards in amazing leaps. The rate of increase ranged around 32% in the fifties and 5-8% in 2008.

Because of cheap price of electricity (2 fils per kWh [1]), Kuwait suffers from the problem of the excess consumption in electricity. This has led to exhausting the non-renewable resources. In addition; the state suffers from huge expenses and tremendous efforts to meet the demand for this energy as the individual's share of it has risen from 3132 kWh in 1971, 6032 kWh in 1981, 12678 kWh in 2001 and 13142 kWh in 2008. This over consumption andincreases in the demand has made it possible that Kuwait may face an energy shortage in the coming years especially during summer where the maximum load was 9710 MW in 2008 and is expected to be more than 15000 MW in the coming years [1].

The proposed solutions for this problem focused in the following four points:

1- The construction and building of new power plants which needs huge funds and long time.

2- Linking the Gulf Council Countries (GCC) power networks together and importing the needed amount of energy from neighboring states which have abundant supply of it. However this solution is not definite in its date of application; the idea has been proposed in the 1980s. In addition; it relies on the fact that there is an abundant supply in other states. [2][3]

3- Energy Savings; it is very important to act seriously to solve this problem technically as a means to save energy taking into account the importance of increasing the people awareness in saving energy and focusing in the technical aspects.

4- Using alternative sources of energy such as solar energy.

In this paper the feasibility of the use of solar panels to produce electrical power in worship houses (Mosques) in the State of Kuwait is explored in this paper.

The use of solar energy has to be taken into account especially as Kuwait enjoys this clean source of energy all the year round.Kuwait's average solar intake is about 9-11 hours per day with an average daily solar insolation can reach more than 7.0 kWh/m^2 per day. The previous facts make us think seriously to use the solar energy to meet the increase demand for electricity during summer [4].

In the State of Kuwait where most of people are Muslims,you can see a great concern for building and maintaining of mosques. There are more than 1400 mosques in Kuwait in six governorates. These mosques vary in size from small, medium and large ones. Some of them were built by the government while others were built by people. Some of them are modern and others are old.

The Ministry of Awqaf and Islamic Affairs care for these mosques. Once the mosques come under their supervision they assign the working staff for them and they enroll them in the maintenance schedule which include civil, electrical, audio and mechanical works (air-conditioning systems) plus the cleanliness contract. The cost for the mosques is estimates to be around 30 million dollars annually. Most of the fund is spent on maintenance (salaries, water and electricity consumption is not included in this figure).

Mosques as any public facility are one of the great consumption sites for energy and therefore a potential waste area of this energy. The cost of the consumption of electricity in the previous years reached around one million dollars (Table 1) which made the ministry to try to decrease this bill and to save energy.

TABLE.1: mosque annual energy consumption and cost.

Year	Cost (KD) in thousands	Energy consumed(Kwh)
2005	194	96,958
2006	199	99,696
2007	186	92,833
2008	205	102,696
2009	209	104,324
2010	231	115,703
2011	239	119,529

The reduction in energy consumption during year 2007 in Table.1 according to the maintenance of many building.

Energy saving is very important. Generally energy saving will decrease the abuse of the petroleum wealth and consequently eliminate pollution of the environment. Funds will be saved for other vital projects. More specifically the saving of the energy will help in decreasing the annual bill of electricity, prolong the life duration of equipments as long as possible and save the necessary funds for maintenance.

II. OBJECTIVES:

The problem of wasting electrical energy in buildings is due to several reasons. One of these reasons is the designing mistakes during specifying the equipments or the materials used. Another reason there, the continuous use of electrical even if is no body is using the mosque. The dependence on only one source for energy makes things even worse.

Grid-connected solar system without battery will be used on the rooftop of the mosques to supply power to the connected loads during day time. This will help in peak shaving of the total energy consumed.

The expected results in this paper can be applied to other facilities whether public such as schools, hospitals, etc. and private such as houses which will lead to saving the electrical energy and will delay the need of build a new power plant.

III. LITERATURE SURVEY:

After discussing the problem and possible suggested solution for it we will now go through the previous works, articles, studies and researches related to the topic.

In a study carried out by Kuwait Institute for Scientific researcher [5] to check the cost benefit of implementing solar system in Kuwait, the researchers concluded that applying solar system have economic and environmental benefit . Cost estimated for generating one watt of electricityis 5 dollars per watt. The researchers also concluded that using solar system in Kuwait is viable.

Another project was carried out in east of the Kingdom of Saudi Arabia near AL Dhahran [6]. The solar energy in the area and the relationship between solar radiation and heat were studied. After collecting the data for a whole year (1995) it was discovered that the area enjoys huge solar energy which encourage the constructing of similar projects.

In [7], Al-Qahtani has suggested building a solar plant capable of generating 10 M.W. to help with the peak load during day. He pointed that the plant can recover all its cost (pay back) in 12 years time. He also suggested adding solar cells to houses to generate 1 K.W. funded by the government.

Lighting is one of major sources of energy consumption and therefore offers some of the biggest saving potential [8] so that many studies have discussed lights and its effect in energy consumption. One study [8] has indicated that 88% of the lighting cost goes to energy. Where many studies [6][9] have suggested substituting the incandescent light with the fluorescent bulb. The study [9] has proved that using the fluorescent bulb type will consumes 70% of the incandescent light energy which loses most of its power in the heat it produces. One of studies [8] claimed that changing lighting from T12 to T8 will save up to 38% of the energy expenses.

In another study [10] carried by Kaygusuz concerning the energy status in Turkey, the researcher has pointed to the continuous need for energy there. He discussed the use of alternative sources of energy such as wind and solar energy which are available that country. However the use is very limited and in certain areas which generates only 0.040 million ton of oil equivalent. He also discussed the energy policy and the role of the private sector in generating electricity. He also discussed the status of the energy consumption in the residential sector which consumes up to 35% of the total national energy at present and is the biggest energy-consuming sector in Turkey. A recent survey [10] indicated that as an average, 40% of the annual fuel consumption could be saved in this sector by using proper conservation techniques (improvement of insulation and building materials, double glass use, and new building design based on optimum orientation for direct solar gain). The study further goes through the consumption energy of the industrial sector and the possibility of saving.

IV. ENERGY AUDIT :

The electrical equipment in the mosque has various rating power and different function as well as different operational time. It has been observed from monitoring the building that all equipment'sare being used for different period of time(Fig.1).

For example; the interior lights are used during the five times of prayers, the exterior lights are used during the night time. The remaining loads of the mosque are estimated through two methods. The first method is based on the equipment rated power operational time duration. Table2 presents a list of all electrical equipment used in the mosque and their rated power. The table shows the maximum total installed power equivalent to 82.5kw.The second method is based on a determination procedure by calculating the difference obtained from the summation of the measured energy consumption. The air-conditioning loads are not included in this study due to high cost of using solar energy.

Table2: Typical one day loads in kwh (Data were sampled every one hour).

time	Light	External light	Power	Fan	Exhust Fan	Water Cooler	Total power
1	0					2	2
2	0					2	2
3	58.5		5	3.7	3.2	2	72.4
4	58.5		5	3.7	3.2	2	72.4
5	0					2	2
6	0					2	2
7	0					2	2
8	0					2	2
9	0					2	2
10	0					2	2
11	58.5		5	3.7	3.2	2	72.4
12	58.5		5	3.7	3.2	2	72.4
13	58.5		5	3.7	3.2	2	72.4
14	0					2	2
15	58.5		5	3.7	3.2	2	72.4
16	58.5		5	3.7	3.2	2	72.4
17	0					2	2
18	58.5	10.4	5	3.7	3.2	2	82.8
19	58.5	10.4	5	3.7	3.2	2	82.8
20	58.5	10.4	5	3.7	3.2	2	82.8
21	58.5	10.4	5	3.7	3.2	2	82.8
22	0	10.4				2	12.4
23	0	10.4				2	12.4
24	0	10.4				2	12.4

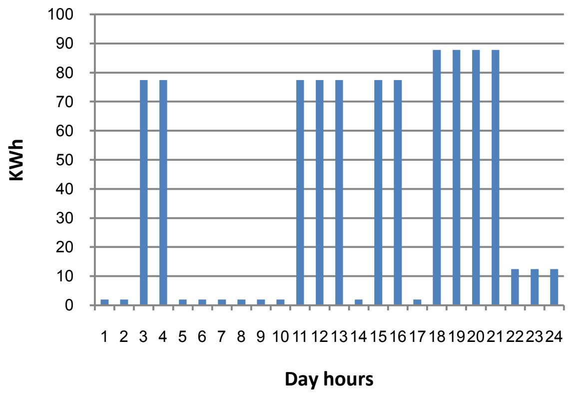


Fig.1 daily energy consumption

V. PHOTOVOLTAIC CELL

Theoretically is a semiconductor, where the material is composed mainly of silicon (Si), with ratios of impurity elements, and summed up her job in converting solar radiation to the voltage / electric current, the intensity depends on several factors. It composed of Gaps, Holes and free electrons in doped elements that disturbed energy when exposed to solar rays of light (photons), causing its transition towards other atoms, leaving (positive holes), with the continuation of the process that generated the current / voltage [11].

5.1 Types of solar cells:

Solar cells are classified into several types according to materials and manufacturing methods:

1-Crystalline silicon: Made of silicon tinged with elements such as phosphorus and Baron, it's a high efficiency and high reliability due to the purity of its raw materials and free of defects, but the cost is relatively higher. Based on purity it can be classified into two types:

1.1-Mono-crystalline silicon (highest purity)

1.2- Polycrystalline Silicon (Multi-Si)

The average cell diameter is 150mm and the average thickness is 0.18 mm, the voltage generated equals almost 0.5v, consists board assembly Module / Panel of several cells, often at a rate of 35 cell, and relate to each other in a row or connect the joint by the design of the effort and ability

2-Thin-Film: Cells are made mostly of silicon, or other materials, thickness of very thin where the average thickness of the slide around 30 micrometer, and a few percent of the raw materials, which reduces the cost by up to 40% less than the cost of (Crystalline) but less efficiently and is characterized by flexibility and lightness weight, and are available with high transparency.

3-Concentrated PV Cells: A system that supports the use of lenses to collect and focus solar radiation needed to generate the voltage on the cells for a very high efficiency up to 40%.

5.2 Solar Cell Efficiency:

Since the Sun has intermittent sunlight, photovoltaic cells would be unable to generate constant electrical energy. PV cell efficiency depends on several factors, such as solar radiation, temperature, wind speed, rainfall and other weather data. The open circuit voltage, Voc, is the maximum voltage from the solar cell and occurs when the net current through the cell is zero and the short circuit current, Isc, is the maximum current from the solar cell and occurs when the voltage across the cell is zero.However, at both of these operating points, the power from the solar cell is zero. Open circuit voltage and short circuit current depend on solar irradiance andtemperature as shown in Equation (1&2) [11]. WhereIo is the saturation current, q is the electronic charge, K is the Boltzmann constant, T is the absolutetemperature,H is the incident light intensity and b constantdepending on the properties of the semiconductor junction, the geometry of the detector and the size of the collector.

$$V_{oc} = \frac{KT}{q}\ln\left(\frac{I_{sc}}{I_o}\right) \qquad (1)$$

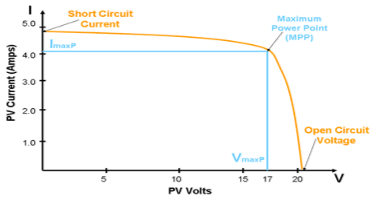
$$I_{sc} = bH \qquad (2)$$

The current and voltage (I-V) characteristics, Fig(2), of a particular photovoltaic cell give a detailed description of its solar energy conversion ability and efficiency which is critical in determining the device's output performance and solar cell efficiency.

Fig.2 I-V characteristic curve

5.3 Tracking System:

Solar tracking systems can be one-axis or two-axis, the two-axis tracker can be polar or azimuth/elevation tracking.Tracking systemincrease the power gained over a fixed horizontal array between 30-40%.These systems can be classified



into two categories passive and active trackers [12]. The solar panels showed face the sun for higher efficiency.

5.4 Photovoltaic Technology in Kuwait

In Kuwait, only solar and wind renewable resources are available for utilization due to its location on dry hot desert land. The entire territory of Kuwait appears suitable to PV application due to high irradiation conditions. Considering harsh climate conditions in Kuwait (very high temperatures combined with significant dust occurrence and low rate of rainfall Fig.3).for successful PV development, available technologies suitable for Kuwait have to be selected carefully.

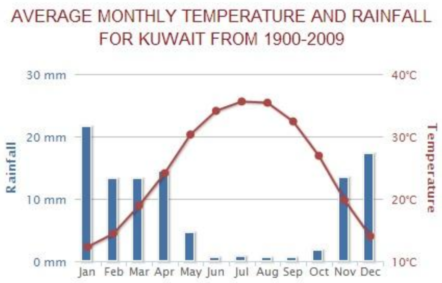


Fig.3 (source: world bank)

Most of the photovoltaic panels on the market are either mono or poly crystalline silicon; however, thin film PV technologies have been gaining a remarkable market share. Thin film technologies are expected to continue in order to gain future market share due to their potentials for low cost and advancement in technologies. This expectable low price makes thin film technologies appealing for large-scale, grid-connected PV systems. Further growth rates for thin film technologies can be expected in the near future.

Photovoltaic equipment are available in various qualities and sizes and from a number of manufacturers all over the world. The selection of PV equipment suitable for the project sites depends on several criteria as follow: environmental conditions, energy yield, transportation to the foreseen PV park site, local experience with regular operation and maintenance, technical characteristics of the components, availability of equipment and track record,maintenancerequirements,requirement of national grid connection and terrain complexity.

VI. SYSTEM DESIGN AND SIZING:

6.1 Building under study:

alhadhrami mosque is chosen as a sample for this study. The total area of the building is 3000 m^2; the Area of the free rooftop of the building is 1000 m^2. Based on data collected from site survey and technology initial review the size of the project will be 80kw for each mosque for non-air-conditioning loads. Mono crystalline PV panel with fixed tilted angle are chosen. All available PVpanels type can be considered as suitable for installation on fixed tilted mounting structure .The advantages of these structures are their compact layout such as low land requirement and their durability combined with low maintenance requirements .The main disadvantage of this technology option is the comparable low load factor. Anyhow, considering the harsh climate conditions in Kuwait, this option appears to be the most suitable.

Grid-connected system without battery to reduce the cost 40% and to reduce the maintenance since the goal for this research is to find the optimal solution for the peak shaving during day time especially between 13:00pm to 15:00pm during summer months.

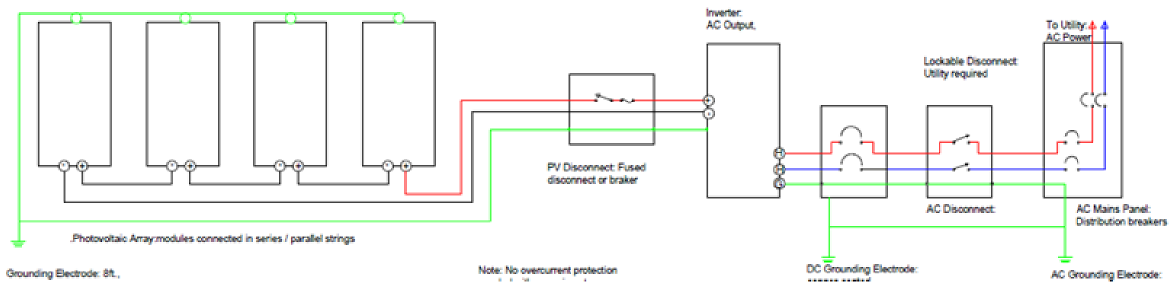


Fig.4 Grid-connected solar system

6.2 system component

Using PVsyst software to design the system (Fig.4),by interring the weather condition ,total loads, type of system ,type of photovoltaic (PV) solar panels and other information about the building we get the following design:

6.2.1 PV Panels

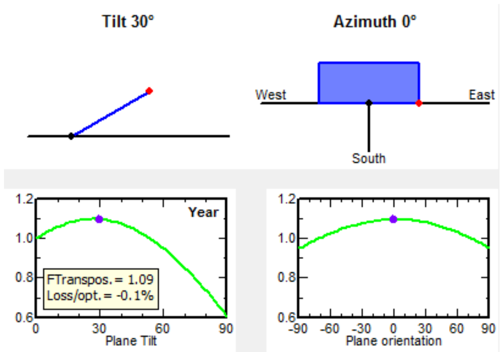


Fig.5

PV panels are optimized for the best orientation according to solar path in Kuwait Fig .5 and the result is that the tilt angle is30^{o} and Azimuth angle is 0^0. Total of 400 mono crystalline cell, 50 strings in parallel and 8 module in series to produce 80 kw_p of power. These panels fixed on the rooftop of the mosque taking into account the weight of the system and the effect of wind on the panels. The area required for fixing the panels is 498 m^2. The annual energy of the system is 144.1Mwh.

If the panels aredirected to the west this will give more energy during peak time since the sun rays will fall vertically on the solar panels, but the total energy will be reduced. Tracking system for best energy production not used since the aim of the project is to find the optimal case during peak time and to reduce the cost of the system and the maintenance.

6.2.2 Inverter

Fifteen grid-connectedinverters with rating power 5.2kWeach with total output power of 78 kWand a voltage rating 240-450 v to convert direct current into alternating current with ability to synchronize with the utility line.

The grid-connected inverter must synchronize its frequency with that of the grid using a local oscillator and limit the voltage to no higher than the grid voltageand are also designed to quickly disconnect from the grid if the utility grid goes down.

Three-phase inverters have the unique option of supplying reactive power which can be advantageous in matching load requirements.

6.2.3 Other System Devices:

Other devices such as controller, electrical panel, protectiondevices, distribution boards, metering,cables and other accessories should be selectedaccording to regulation for safe operation and to reduce the losses of the system. The metering must be able to accumulate energy units in both directions or two meters must be used. The ministry of electricity should use net metering to pay for customer who injects energy to the grid to encourage building owners to use renewable energy in their building.

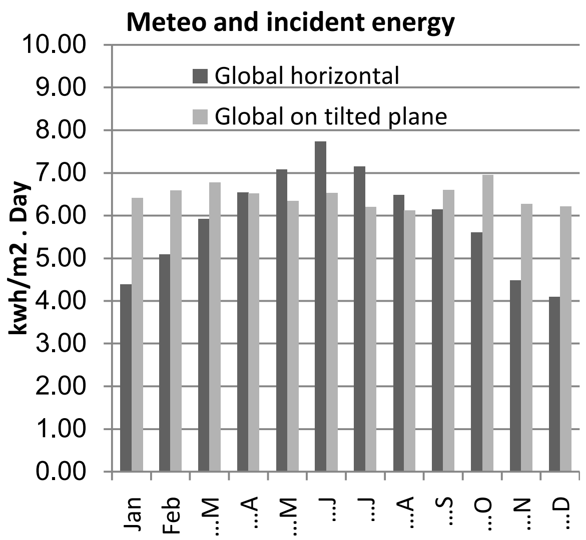


Fig.6 Meteo and incident energy from pvsyst software

6.2.4 Meteo and incident energy and system output

Using the data base of the software about the global horizon, weather data of the site,fig (6) shows that the average of global horizon irradiation is 5.9 kWh/m^{2}per day and the average of global irradiation on tilt plane is 6.5 kWh/m^{2}per day. The annual energy, table (3), from the system is144.1MWh. The monthly energy generated from the system (fig.7) shows that the maximum generated power was in March and the lowest generated power was in august. Although during summer months the sun is shiny and the wind is strong, the generated power is less during these months. The efficiency of the solar system is reduced [13].

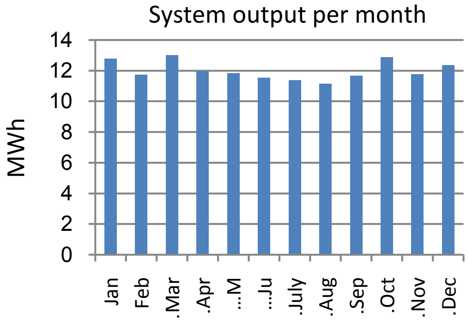


Fig.7 System output from pvsyst software

Table.3: System output.

Month	Gl.horiz. kwh/m2	Coll. Plane kwh/m2	System output Mwh
Jan	136.1	194.9	12.8
Feb	142.4	181.8	11.73
Mar.	183.7	206.8	13.00
Apr.	196.5	195.5	11.97
May.	219.5	198.4	11.85
June.	231.8	197.6	11.55
July.	221.7	194.6	11.36
Aug.	200.9	191.2	11.14
Sep.	184.3	197.4	11.69
Oct.	174.1	212.7	12.88
Nov.	134.6	185.0	11.76
Dec.	127.2	189.5	12.35
Year	2153	2345.4	144.08

6.2.5 Losses

The loss diagram over the whole year fig.8 shows that the largest losses come from the temperature loss around 13.7% and the inverter loss reach 3.6%. The horizontal global irradiance is 2153 kw/m^2 and the effective irradiance on collectors is 2281 kwh/m^2 which mean the total energy for the area of 498 m^{2}is 1136Mwh. With the efficiency of the system equal to 16.12%, the array nominal energy at standard test condition (STC) is 183 Mwh.

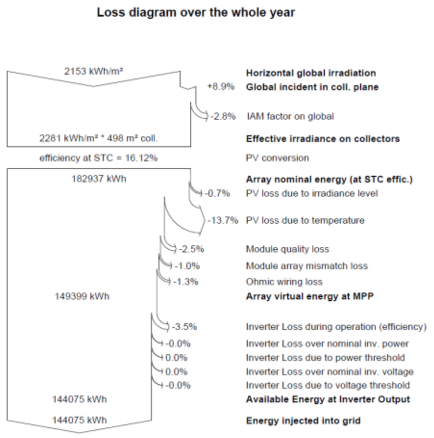


Fig.8

The available energy at inverter output is 144 Mwh which mean that 12.68% of energy. The normalized system production compared to reference incident energy in collector plane give performance ratio of 77%.

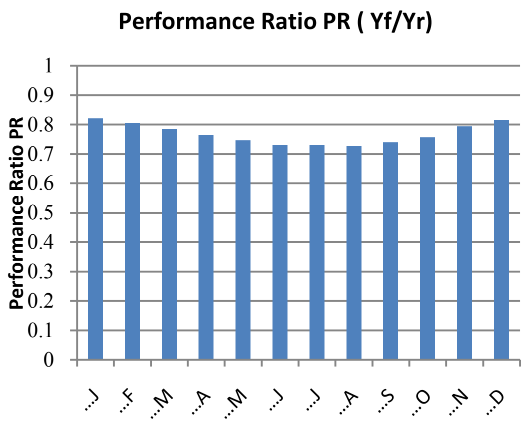


Fig.9 Performance Ratio.

Table.4: Performance ratio.

	Yr	Lc	Ya	Ls	Yf	Lcr	Lsr	PR
Jan	6.29	0.946	5.34	0.182	5.16	0.15	0.029	0.821
Feb	6.49	1.066	5.43	0.189	5.24	0.164	0.029	0.807
Mar	6.67	1.236	5.44	0.195	5.24	0.185	0.029	0.785
Apr	6.52	1.343	5.17	0.185	4.99	0.206	0.028	0.765
May	6.4	1.442	4.96	0.18	4.78	0.225	0.028	0.747
June	6.59	1.59	5	0.185	4.81	0.241	0.028	0.73
July	6.28	1.518	4.76	0.177	4.58	0.242	0.028	0.73
Aug	6.17	1.508	4.66	0.167	4.49	0.244	0.027	0.728
Sept	6.58	1.533	5.05	0.178	4.87	0.233	0.027	0.74
Oct	6.86	1.48	5.38	0.187	5.2	0.216	0.027	0.757
Nov	6.17	1.089	5.08	0.179	4.9	0.177	0.029	0.794
Dec	6.11	0.957	5.16	0.175	4.98	0.157	0.029	0.815
Year	6.43	1.31	5.12	0.181	4.93	0.204	0.028	0.768

Legends: Yr Reference incident energy in coll. Plane
Lc Normalized Array Losses.
Ya Normalized Array Production.
Ls Normalized System Losses.
Yf Normalized System Production.
Lcr Array Loss / Incident Energy Ratio.
Lsr System Loss / Incident Energy Ratio.
PR Performance Ratio.

Performance ratio is important in determining the quality of the systems, during winter the performance ratio reach 83% and 73% in summer (Fig 9).The Performance Ratio is the ratio between actual yield (i.e. annual production of electricity delivered at AC) and the target yield (Eq.3):

$$\mathrm{PR} = \frac{\text{Normalized System Production}}{\text{Reference incidenct energy in coll. Plane}}$$

$$\mathrm{PR} = \frac{Yf}{Yr} \qquad (3)$$

The performance ratio, often called "Quality Factor", is independent from the irradiation and therefore useful to compare systems. It takes into account all pre-conversion losses, inverter losses, thermal losses and conduction losses (Table.4). It is useful to measure the performance ratio throughout the operation of the system, as a deterioration could help pinpoint causes of yield losses. Three performance parameters may be used to define the performance of grid-connected PV systems: final PV system yield Yf, reference yield Yr and performance ratio PR[14].Solar Cell tend to produce higher voltage as the temperature drop and, conversely, to lose voltage in high temperature. The temperature affects the system efficiency and this can be modified using cooling system for the panels[15]. The system performance degrades 1% per year and for 20 years the performance ratio will reach 61.6%. This reduction in system performance will affect the payback period, although this topic will not covered in this paper.

6.2.6 Analysis and payback period

From Fig(10) we notice that the solar panel will cover the loads from 10:00am to 17:00pm and will feed energy to the grid between 4:00am to 18:00pm .The day loads connected to the system is 378 kwh /day and the output of the system is 431.3 kwh /day. Since the Sun radiation from 5am – 5 pm for a chosen day .the cost of the system is 1.3 kd /w_p ,which mean the cost of system is 104,000 kd and for 1400 buildings 145 million kd since the loads in allthe building is uniform. The cost of energy of thebuildings from table 4 will 11 million per year, which mean the payback period is 13 years. Solar system will feed the grid by the excess power 31.5 Mwh which save 1.8 million kd and help in shaving the energy consumption during the peak loads of the grid.

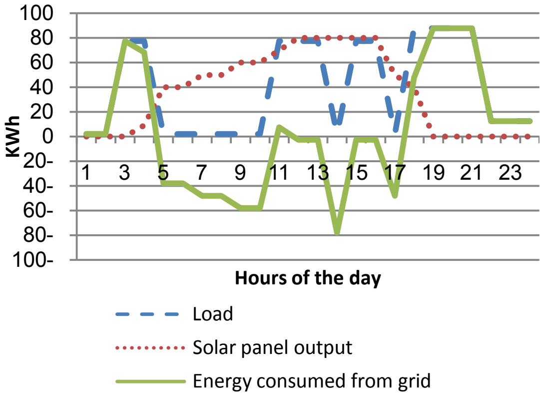


Fig.10: Solar system output, load and net energy consumed from grid

There are many factors affect the energy consumption like building structure, lighting units used , walls, windows ,…. The main problem is the dust, the cost of maintenance and dust cleaning is 0.5kd for each kw_p, which mean 40 kd for each system and 56,000 kd for 1400 system.

VII. CONCLUSION

Fossil fuel is quickly being used up faster than it can be produced and the effects of fossil fuel production on the environment are extremely damaging. This project plays very important role in increasing people awareness using building rooftop to install solar system to generate electricity. Using solar system help reducing the environmental pollution. With increasing of local market of solar system, the price of solar system is getting reasonable. Tilt angle and azimuth is optimized to reach the best output energy from the PV panel during the year and it was 30 tilt angle and azimuth 0, with these angles the total energy generated increased 9%.During summer, the performance ratio decreases because of high temperature. Although the generated power from solar system is high during sunny days, but high temperature reduces the system performance. Temperature effects are result of an inherent characteristic of solar cell. They tend to produce higher voltage as the temperature drop and, conversely, to lose voltage in high temperature .Performance ratio can be used to find the best type of solar system. The goal of this paper is to use PV solar grid-connected system and find the payback period of the system. Comparing different system to find the optimal energy generation may give better results.

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