DESIGN AND IMPLEMENTATION OF A SOLAR THERMAL / PHOTOVOLTAIC ENERGY SYSTEM

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ABSTRACT

Toward go green, the main aim of this paper is presentation of a proposal for the integration and implementation of photovoltaic(PV) technologies in buildings considering aesthetic effects, particularized for the Iran through a case study. Our main objective is the selection of the most appropriate technical solution (PV and thermal) for the integration of renewable energy in buildings and electricity grid interconnection in near future.

The proposed energy system is employed for energy supply in a residential building for different end uses such as hot water and electricity, a major part of electricity required for lighting, domestic appliances (elevator and electric garage door) that is generated through a PV system. Both the solar thermal and PV systems are installed on the building roof.

INTRODUCTION

One of the most important ways to offer electrical energy to residential and commercial building is to install photovoltaic systems. Using solar energy, it would be possible for utilities to buy a certain amount of electricity from these independent entities. Such small-scale Distributed Generation (DG) also helps create local jobs installing system, instead of just in one centralized area, as is done with large-scale power plants.

Buildings are generally one of the main energy consumers in the urban context. Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning [1].

In Iran, total energy consumption in residential sector was 185.58 million BOE in 1998 and increased to 333.39 million BOE in 2008. The building sector has the highest rate of energy consumption before the transport sector in Iran. According to recent data from Iran energy balances of the institute for international energy study, residential buildings account for about 28.1% of final energy consumption [2]. Such a huge consumption shows the significant necessity for an appropriate design or use of renewable and low energy technologies. Among various renewable and low energy technologies, solar solutions like photovoltaic (PV) and thermal collectors are gaining a rapid growth in the world.

This necessity is driven due to not only energy crisis over the world but also to making the traditional buildings green is one of the best solutions to overcome concerns about the urbanization and environmental serious problems, climatic changes. Furthermore, for residential and small buildings applications, solar energy holds a high potential. Solar energy is an extremely abundant resource also it is reliable and non- depletable.

Photovoltaic systems convert solar energy into electrical energy. A beneficial characteristic of photovoltaic for residential applications is its modularity. This means that they can be constructed in any size to fit specific energy needs. Such modularity allows for various-sized PV systems to be installed on the rooftops of houses.

Mashhad is the second largest city in north east of Iran (36°27′N, 59°37′E and 985 m above mean sea level) with about 3 million populations and with a relatively high amount of mean solar irradiation (~200W/m2).

As it can be seen in figure 1, Mashhad is well-suited for the application of solar energy technology. So in an effort to go green and because of Mashhad city importance as a first holy city in Iran and according to rapid growing energy demand and also decreasing pollutions, MEEDC was commissioned for a green building feasibility study considering aesthetic effects in city.

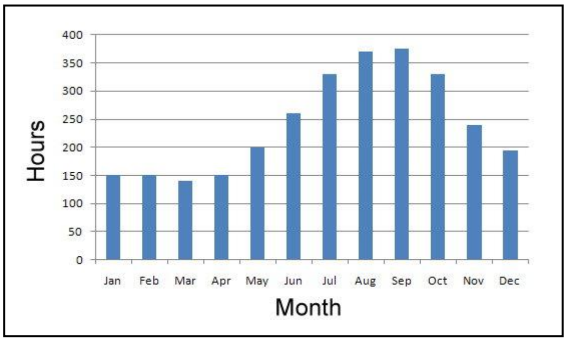

Figure 1. Average insolation (last 20 years of Mashhad)

For this purpose a residential unit with 4 flats (each flat $120m^2$) was selected. This paper presents our commission toward go green in Mashhad.

METHODOLOGY

To meet the energy demand for domestic appliance and hot water, a solar thermal system and photovoltaic system was designed. At first step, the building energy demand for lighting, elevator, electric garage door was estimated .In second step a suitable PV system and solar water heater regarding our needs was found.
In third step we used PVsyst software, powerful software for photovoltaic system design, in order to simulate performance of the system to investigate energy production of the system in each month based on parameters include zone and PV system. Finally, we selected case study and analyzed condition and begun to implement.

BUILDING DESCRIPTION

The building is a new residential unit, located in Mashhad. It consists of four flats, one elevator and an electric garage door. Total surface area for each flat is 120 square meters and a flat roof with an available area of 150 square meters, where PV panels and solar water heater can be installed.

ESTIMATED ENERGY DEMAND

We obtained past electric bills same as our case study and audit building to determine what can be done to reduce electricity usage. Consequently, we found that if we can use solar energy to provide energy for lighting, elevator and electric garage door, we can reduce electricity usage. As a result, total amount of energy demand for building for this purpose was estimated about 13kWh during a day shows in table1.
To be certain, we studied same building's bill again compare it's consumption with our estimated energy demand. As can be seen in table 2 building energy consumption in one month is less than our estimated energy demand so our estimated energy demand was exactly true and meets our needs. The second way to reduce energy usage in building is supplying hot water by solar heater water so we calculated energy consumption before and after the installing solar water heater and our result showed more than 53% energy saving. Finally, four solar water heaters were selected to be installed for each flat on roof.

Table1. The building energy demand

	Power	Use (hour)	Energy kWh
Lighting includes (lamps:27×23w, 8×9w,24×3w)	900w	2h	1.6
Elevator	5500w	2h	11
Electrical door(2 jack)	400w	0.5h	0.2
Total			13

Table2. Building energy consumption in months(Kw)

Jan	Feb	Mar	Apr	May	Jun
252.02	245.90	281.23	348.48	304.23	250.50
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
255.37	261.29	259.13	262.76	251.38	246.50

ANALYSIS AND DESIGN

Our needed components

Solar photovoltaic system mainly includes three parts: solar components; power electronic equipment such as charge-discharge controller, inverter; battery or other energy storage and auxiliary power generation equipment.

PV panels
According our requirements and considering our needs the PV system consists of multicrystalline modules of 230 Wp with a nominal efficiency of 14.3%. LG230P1C brand [3]. Based on the space availability for the correct orientation of PV modules, it was estimated that 20 modules for lighting ,elevator, electrical door and one module for emergency light in each flat with a total power of 4.83 kWp that can be installed on the building roof. Collectors will be installed on the flat roof 150 sq. meters with a capture area of 34 sq. meters and with an angle around 30º .The PV arrays are arranged as shown in figure 2 and the monthly electricity production of the PV system, estimated by the PVsyst software shows in figure 3.

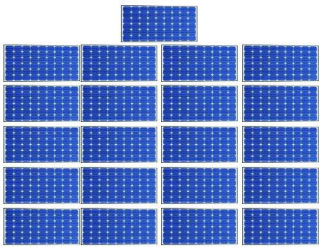

Figure 2. PV array arrangement

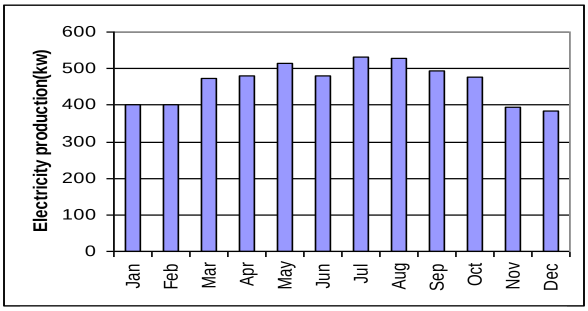

Figure3. Monthly electricity production of the PV system

DC-AC inverter

This is the device that takes the dc power from the PV array and converts it into standard ac power used by the house appliances. We need single phase voltage for lighting and electrical door and also three phase voltage to supply electricity for elevator so we applied 3 separable single phase inverter [4].

Batteries and battery charge controller

Electric energy storage for off-grid renewable energy systems is inevitable. In this project, lead acid batteries were used. Table 3 shows specifications of the battery energy storage module [5]

Table 3. Battery characteristic

Battery	
Model	Shoto 150ah
Manufacturer	Chinashoto
Battery pack characteristic	
Voltage	24 V
Nominal capacity	750 Ah
Nb. Of units	2 in series × 5 in parallel

Solar heating water

The pressurized solar water model was selected for solar heating water. Table 4 shows the characteristics of our solar water heater. This model utilizes the coating of vacuum tube to transfer absorbed sunlight radiation into heat energy, by means of copper heat pipe inside vacuum tube to transmit heat into the water tank quickly and warm up water in tank. No water inside the evacuated tubes so the solar water can still in service even with several tubes breakage. This can be used in different weather conditions even in a very cold climate [6]. Figure 4 illustrates the installed solar water heater on roof.

Table 4. Solar water heater specifications

Model	HEDUS-180L
Inner tank	Stainless steel SUS304-2B
Outer tank	Painted steel/PVDF
Frame	Coated aluminum
Heat preservation	72h
Hail resistance	30mm
The material of insulation	Polyurethane
Cold resistance	Up to -35 c
Electric heater	High grade tube with dry heating safeguard(1.5kw,220v,50Hz)

Figure4. Solar heater water

Space structure design

We need to mountain the PV modules on a roof with a tilt angle of around 30º and south oriented. Two scenarios for the space structure were suggested.

The first plan shown in figure 5, PV modules had shade effect. So this plan was omitted and the second one can be seen in figure 6 selected to install. For this purpose we used the double layer grid structure and then mountain PV modules. A "double layer grid" consists of two (nominally) parallel layers of elements that are interconnected together with 'web' elements [7].

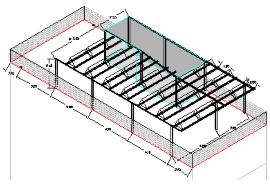

Figure 5. Plan1

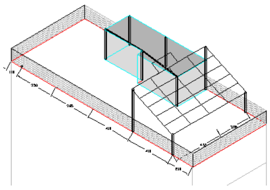

Figure 6. Plan2

INSTALLATION

In this phase, we chose roof mounting installation, the presently most successful PV products for buildings are modules for roof mounting and the wide range of products are well tested and are widely used. Roofs often offer simple surfaces for mounting PV, and traditionally with the cheaper range of mounting methods. Then, we started to install through following steps:

1-Estimate length of wire runs from PV modules to storage and inverter room.

2-Install PV panels, inverters, and associated equipment to prepare for system wiring.

3-Verify that all PV circuits are operating properly and the system is performing as expected.

Figure 7 shows workers are installing PV module.

Figure 7. PV modules mounting, total view of the PV system and water heaters on the roof

COCLUSION

In this paper we present a proposal for the integration of two solar systems in a new residential building in Mashhad city. One system is used for supplying electricity for lighting, elevator, electric garage door and thermal system supply the hot water. The first objective of this work was the selection of the most appropriate technological solution for the integration of renewable energy in this specific building. The selection of the best solution took into account the constructive aspects of the building (location, orientation, construction materials), the building's energy needs and the local availability of renewable resources and market technologies.
Despite the fact that Mashhad city has high amount of irradiation and green buildings reduce energy consumption and also pollution, still green building practices aren't significantly considered. MEEDC's commission to implement green building motivates consumers to go green. It can be notable step towards green awaking in Mashhad. It was our main objective of this commission.

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