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SOLAR ELECTRICITY APPLICATIONS AT MUĞLA SITKI KOÇMAN UNIVERSITY, TURKEY

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Abstract

In this paper we presented the electricity yield of photovoltaic power plant applications starting from 1996 is described and obtained results are summarized in the main campus of Muğla Sıtkı Koçman University, Turkey. There are four small scale photovoltaic power plants installed in the campus. They are installed on the top of Menteşe Library of Muğla Sıtkı Koçman University, on the roof of Turkevi Student Cafeteria, on the façade and on the east and west towers of Staff's Block of the Building of Education Faculty and two double axis tracking systems. The systems are installed in 2001, 2003, 2008 and 2009 with rated powers of 10 kWp to 40 kWp. There are also several lamp-posts at the campus in various locations. All power plants are monitored from the start up and the collected data are analysed in several conference proceedings and papers individually. This paper summarizes the electricity yield of photovoltaic power plants, after their installation and also their presentation itemized.
Keywords: Photovoltaic System, Electricity Yield

MUĞLA SITKI KOÇMAN ÜNIVERSITESI'NDEKI GÜNEŞ ENERJISI UYGULAMALARI

Özet

Bu çalışmada, Muğla Sıtkı Koçman Üniversitesi'nde merkez yerleşkedeki 1996 yılında başlayan fotovoltaik güç sistemi uygulamalarından üretilen elektrik enerjisi ve elde edilen sonuçlar aktarılmıştır. Yerleşkede 4 adet küçük ölçekli fotovoltaik güç sistemi bulunmaktadır. Bunlar; Menteşe Kütüphanesi üzerinde, Türkevi öğrenci kafeteryası üzerinde, Eğitim Fakültesi Öğretim elemanları bloğunun yüzeyi ve doğu batı kulelerinde ve iki eksende güneşi izleyen sistem şeklindedir. Bu sistemler 2001, 2003, 2008 ve 2009 yıllarında kurulmuş olup 10-40kWp arasında kurulu güçlere sahiptir. Yerleşke içerisinde farklı noktalarda güneş enerjili aydınlatma direkleri de bulunmaktadır. Tüm güç sistemleri başlangıçtan buyana izlenmekte olup elde edilen veriler değerlendirilmektedir ve bu sonuçlar zaman içerisinde çeşitli konferanslarda sunulmuştur. Bu çalışmada fotovoltaik güç sistemlerinin kurulum sonrasındaki elektrik üretimleri hesaplanmıştır.
Anahtar Kelimeler: Fotovoltaik Sistem, Elektrik Üretimi

1 Introduction

Muğla is located in south west of Turkey at 37° 13' latitude. Since 1998 solar radiation measurements has been carried out using a Kipp and Zonen (CM11) pyranometer. An average daily solar radiation is found to be over 9.5 hours during December and January and over 14 hours during June and July. Average monthly solar energy per square meter is calculated to be just above 50kWh for December and January and well over 200kWh for June and July [1]. Humidity sensor, wind speed sensor, wind direction sensor, ambient temperature sensor and air pressure sensor are form weather station which was established on the top the Menteşe Library. Performances of photovoltaic systems for different conditions are being investigated by meteorology station.

Solar Energy measurements for Turkey are carried out by Renewable Energy division of General Directorate of Renewable Energy and results are published in a Solar Map in Fig.1 [2]. Yearly average sum of solar radiation of Turkey is about 1350kWh and measured solar potential of Mugla is approximately 30% over the country's average.

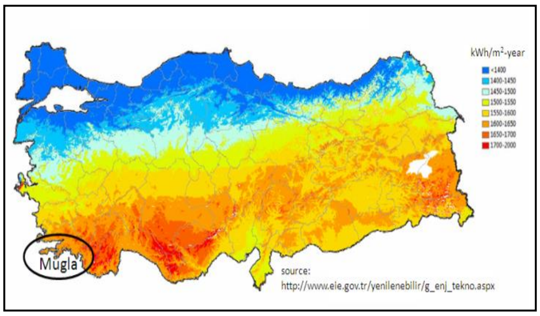

Figure 1. Solar Energy Map of Turkey (where Mugla is marked)

Photovoltaics (PV) convert solar radiation into direct current electricity by solar cell. Heaps of time solar cells have insufficient power to operate many devices alone that used in real life. PV systems may be grouped in various configurations generally; grid-connected systems and standalone systems. Sometimes the third one is called, which is composition of two systems and generator, as hybrid systems [3].

PV systems can be connected to the public electricity grid via a suitable inverter or inverter groups. Energy storage is not necessary in this case. The electricity produced by the PV system is used first to cover any electric requirements (e.g., appliances, lights) in the home. If more electricity is produced from the PV system than the user needs, the excess energy is sold back to the utility through net metering. In many countries it is possible to sell the unused electricity with agreements. But for Mugla Sıtkı Koçman University there is only 120kWp installed power and it can cover only 4% of the demand of the electricity used in the main campus.

A large number of photovoltaic systems installed in industrial nations today are grid-connected. The most significant problems in PV industry are installation costs and efficiency. When we incorporate efficiency with costs, Building Integrated Photo Voltaic systems (BIPV) begin important for consumers. BIPV means photovoltaic systems integrated in the building skin, i.e. roof top and façade [4-6].

It is widely recognized that integration of PV modules into buildings (roof or façade) can effectively decrease the cost of the installation of systems. In other words, building aesthetics or architect designer must take into account PV covering.

Solar tracker, a device that keeps photovoltaic panels in an optimum position perpendicular to the solar radiation during daylight hours, consequently increases the collected energy. Solar tracking could be performing by one-axis and double-axis tracking systems (Fig.2). Tracking systems are generally classified into two group; passive and active [7]-[11]. Passive solar trackers are based on thermal expansion of a matter. Active trackers can be as microprocessor and electro-optical sensor based, computer controlled date and time based, auxiliary bifacial solar cell based and a combination of these three. Double axis sun tracking systems types are polar (equatorial) tracking and azimuth/elevation (altitude-azimuth) tracking.

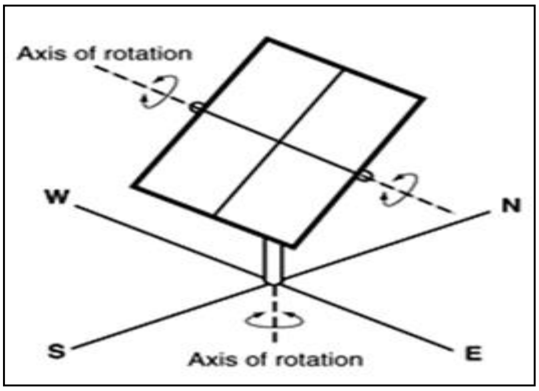

Figure 2. Double-axis tracking system.

For this trend in the world grid connected PV forms the main part of the total installed capacity. PV installation types differ country by country with varying support schemes and climate. The world's cumulative PV capacity surpassed the impressive 100-gigawatt (GW) installed electrical power mark, achieving just over 102 GW in 2012 and 2013 was a record year for PV installations with at least 38.4 GW of newly-added capacity around the world. The most important fact from 2013 is a rapid development of PV in Asia combined with a sharp drop of installations in Europe. The latest statistics show that cumulative yearly newly-installed PV capacity is about 30GW and the total PV capacity on all over the world is about 140GW at the first quarter of 2015 [12]. 100GW capacity is capable of producing as much annual electrical energy as 16 coal power plants or nuclear reactors of 1 GW each and an amount capable of producing at least 110 TWh of electricity every year [13].

2 Descriptions of Photovoltaic Systems

Muğla Sıtkı Koçman University has four grid-connected photovoltaic systems. There are four small scale photovoltaic power plants installed in the campus. They are as follows: on the top of Menteşe Library of Muğla Sıtkı Koçman University, on the roof of Turkevi Student Cafeteria, on the façade and on the east and west towers of Staffs' Block of the Building of Education Faculty and two double axes tracking systems. The systems are installed in 2001, 2003, 2008 and 2009 with rated powers of 10 kW_p to 40 kW_p. And there are two standalone photovoltaic system applications. One is more than 50 lamp posts and the other is a hybrid car boot system 15kWp which is powering the pumps of the pools located in the entrance of the University.

2.1 PV Systems on the Top of Menteşe Library and PV Outdoor Test Site

Total installed power of the PV systems is about 10kWp and there are 4 sub-systems (Fig.3). Sub-arrays are; 20 single crystal silicon photovoltaic modules, 27 multi-crystal silicon photovoltaic modules, 45 amorphous silicon thin film photovoltaic modules and 60 CdTe thin film photovoltaic modules. For obtaining optimum seasonal efficiency and comparing the electricity yield PV modules are installed on adjustable metal plates. In the control room of the PV Outdoor test site there is a solar measuring system is which has a sensitivity of 0.025 A and 0.02 V for 0-10 A and 0-240 V range, respectively for current and voltage [14]. Short circuit current, open circuit voltage and maximum power point are measured at the beginning of measurement then sketching the voltage-current graph on monitor. Also fill factor and efficiency is calculated.

Figure 3. PV Outdoor Test Site.

2.2 The BIPV System on the Roof of Turkevi Student Cafeteria

Installed power of the BIPV system is 25.6kWp and it is on the roof of the Turkevi student cafeteria in Mugla Sıtkı Koçman University campus, Turkey (Fig.4). It consists of 214 multi crystalline silicon PV modules, covering 215 m^2 areas with a slope of 18° and modules are integrated directly onto the structure of the roof [15],[16].

The modules have an efficiency of 11.94% under standard test conditions (STC: 1000W/m^2 irradiation and 25°C operating temperature). The data acquisition system consisted of a NEG-LOG data logger, PT 1000 temperature sensors, irradiation sensors and an energy meter. Irradiation sensors (high precision ESTI) were used to measure horizontal global irradiation and plane of array irradiation. Two thermocouples (Pt 1000) were used to measure ambient temperature and PV module temperature.

Figure 4. BIPV System.

An energy meter was used to measure the 3 phase output of the system. The data logger was configured for storing the collected data in ten minute intervals and it was connected to a display for showing some of the actual measured values and the calculated energy values to the people in the cafeteria. The BIPV system has been monitored from May 2003.

2.3 The BIPV System On the Staffs' Block of the Education Faculty Building

Two different types of PV modules with different technologies are used on the towers and on the façade of the building to form a 40kWp installed power of a BIPV application (*Eke et. al.* 2010). Triple junction amorphous silicon modules were used on the façade of the five floors. Totally 405 m^2 of the façade is covered. The orientation of building is 30° southeast. The 30.15 kWp PVPS on the façade was connected to the campus grid. Single junction amorphous silicon modules were installed vertically and 10 cm apart from the walls of the east and west towers of the building to form 10.24 kWp PVPS cover 136 m^2 surface area on the two towers. Cumulative electricity yield of the system is over 300.000kWh at the end of 2014.

Figure 5. BIPV System on Façade.

2.4 Double Axis Solar Tracking PV Systems

Another PV application installed in the main Campus is double axis solar tracking systems (Fig.6). Back contact single crystalline silicon modules are used in each tracking PV system and 84 modules are used to form 15.6kWp installed power (*Eke et. al.* 2007). It is the first installation of back contact mono crystalline silicon PV modules in Turkey. One module is under test in Mugla University PV outdoor test site to monitor the outdoor performance.

There are two identical PV systems, one set in a fixed tilt angle and the other is working in double axis tracking mode. The PV systems are installed at the end of 2008 and the cumulative electricity produced and fed to grid is about 100.000kWh at the end of 2014.

Figure 6. PV arrays on trackers and control room with displays.

2.5 Hybrid PV System and Lamp posts

A specially designed hybrid inverter is used for the hybrid PV system on the car boot. The total installed power is about 15kW. The system has one hour storage for running the pumps for ornamental pools located in the entrance of the University. Multi crystalline silicon solar cell based PV modules are used to form the PV array (Fig. 7). The control unit of the system checks the PV power, storage level and run the pumps, if the power of the PV is not covering the need it takes up the necessary electricity from the power and if the storage level is below the critical level it gets electricity from grid and charges the batteries.

There are more than 50 lamp posts all over the campus. All of them has two led lamps each consists 40-60 LED units. Lamp posts are located on Sıtkı Koçman Bridge (Fig7), on water depots, racetrack (Fig. 8) and many other locations in the campus area as a standalone lighting application. Total PV power on these applications is about 3kWp. The latest solar applications are thin film test applications over 2kWp and 1kWp Photovoltaic and thermal (PVT) application which are installed in 2013 and 2014 respectively.

Figure 7. The hybrid car boot system (installed power is 15kWp) and lamp posts on Bridge.

Figure 8. Lamp posts on the top of water depots.

3 Cumulative Electricity Yields

Mugla Sıtkı Koçman University has 120kWp installed PV power and 84% of it is grid connected. Whole grid connected systems and their yield from start-up was summarized in Table I. This values show that over 85000kWh annual electricity can be produced from PV in Mugla Sıtkı Koçman University from the installed several PV systems and over 700,000 kWh of electricity is produced from PV since the installations has started.

Although there is only 120kWp installed power at Mugla Sıtkı Koçman University, it can cover 4% of the demand of the electricity used in the main campus. Besides this, PV now covers 2.6% of the electricity demand in Europe (*Eke et. al.* 2007). This is a good ratio compared with the results obtained for Europe. The target of the covering ratio is 5% in 2020.

Table 1. Annual *Electricity Yield of PV Power Plant Applications in MWh*

Systems Year	10 kWp Test site	25.6 kWp Roof-BIPV	40 kWp Façade-BIPV	15.6 kWp Double-axis Tracking
2003*		18.53		
2004		35.98		
2005	6.09	31.26		
2006	11.13	29.24		
2007	12.23	28.04		
2008	10.06	28.74		
2009	6.00	28.88	26.94	32.38
2010	5.30	24.99	35.20	24.53
2011	6.00	24.46	26.50	14.35
2012	6.00	20.06	11.90	28.65
2013	6.00	24.46	34.12	26.52
2014	Not worked	23.85	35.10	27.21
2015*	1.80	9.02	12.50	9.52
TOTAL	**70.61**	**327.51**	**182.26**	**163.16**

*Only results of first 4 months

4 Conclusions

In this study, monitoring results of the grid connected PV systems installed at Mugla Sıtkı Koçman University is presented. There are four different application types, ground mounted test systems, BIPV systems and two double axis tracking systems with all different types of PV module technologies.

Although there is only 120kWp installed power it can cover 4% of the demand of the electricity used in the main campus. The overall cumulative produced electricity is more than 700,000kWh from the start-up of the installations. Annual energy rating (electricity produced per installed power) of the PV systems varies between 850kWh and 2050kWh.

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