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PAYBACK PERIODS OF THREE IDENTICAL SOLAR PHOTOVOLTAIC POWER PLANTS

ABSTRACT

Payback periods of three (I, II and III) identical solar photovoltaic power plants (SPPs) have been determined in this paper. SPPs were installed in Adıyaman location, Turkey (Latitude: 37.45°, Longitude: 38.17° and Altitude: 672m) in 2017. Date of commencement of operation is November 27, 2017, the installed power capacity is 1.025 MW, and the installation cost is $1000000 of each SPP. The supply method for installation is 100% equity capital and the sales price of the electricity to the grid is 0.133$/kWh. The results of the work showed that the average annual electricity generation was 1696665kWh of each SPP. The internal electric consumption is 10770kWh. Thus, net electricity generation was 1685895kWh. The average payback period was 5.5 years for these SPPs.

Keywords: Solar PV Plant, Payback Period, Economic Analysis, Solar Photovoltaic Power Plant, Adıyaman

1. INTRODUCTION

Increasing demand and scarcity in conventional sources have triggered the scientist to pave way for the development of research in the field of renewable energy sources especially solar energy [5 and 18]. Renewable energy sources are considered as alternative energy sources due to the cost of fossil fuels, environmental pollution, global warming and depletion of ozone layer caused by greenhouse effect. Earth receives about 3.8×10^{24} J of solar energy on an average which is 6000 times greater than the world consumption. Solar energy is most readily available source of the renewable energy. Solar energy is Non-polluting and maintenance free. Solar energy is becoming more and more attractive especially with the constant fluctuation in supply of grid electricity. Solar power plant is commonly based on the conversion of sunlight into electricity directly using photovoltaic (PV) panel [17 and 18]. In current era, the use of renewable technology for energy generation is growing at a faster rate. Considering the low stock of conventional fuels and consistent price rise the use of solar energy at places where solar radiations are available throughout the year must be utilized to its maximum. At the same time as the efficiency of the solar systems is low a real time financial analysis must be done to identify the conditions in which it will be most economical. The use of energy for the production and installation of the renewable system must be taken into account to calculate their energy payback time or payback period [1, 6, and 8]. Therefore, payback periods of three identical solar photovoltaic power plants (SPPs) that located in Adıyaman city, Turkey has been

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determined in this paper. The results of the work showed us that the first year average electric energy production is 1696665kWh, internal consumption is 10770kWh, net generation is 1685895kWh and average payback period is 5.5 years for these SPPs.

2. RESEARCH SIGNIFICANCE

Turkey is a poor and foreign-dependent country in regard to fossil energy resources. However, the country, which is located in the solar belt, is very rich in terms of solar energy. Therefore, one of the important steps that can be taken to reverse our foreign dependence in terms of fossil fuels is to invest in solar power plants and to encourage this by the public. In addition, these investments are still important for the earth life due to global warming. In this study, it has been evaluated how long the three identical solar power plants in Adıyaman Province repay the initial investment cost. The calculations were carried out by taking into account the annual electricity generation data of three solar power plants which were considered in this research. In order to be freed from the foreign dependency of Turkey, the investments of solar power plants need to increase. Therefore, this study is important in terms of guiding the investors who want to invest in this field.

3. ANALYTICAL STUDY

Three identical solar photovoltaic power plants (SPPs) that named as I, II and III has been selected for this work. These SPPs were installed in location of AdIyaman City, Turkey (Latitude: 37.45°, Longitude: 38.17° and Altitude: 672m) in 2017. Date of commencement of operation was on November 27, 2017.

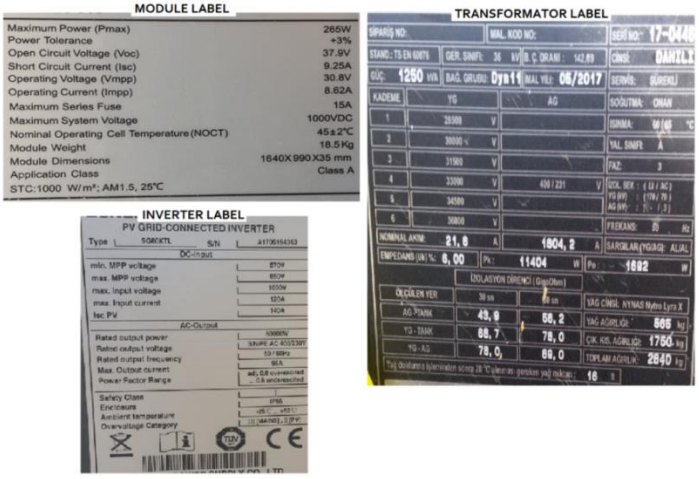

Figure 1. A view from module, inverter and transformer label of the system

The installed power capacity is 1.025MW, and installation cost is $1000000 of each SPP. The supply method for installation is 100% equity capital and sales price of the electricity to the grid is 0.133$/kWh. The each selected solar photovoltaic power plant (SPP) mainly has steel frame constructions for panel placing, polycrystalline silicon type solar PV (photovoltaic) panels, combinations of MPPT (maximum power point tracker) + inverter boxes, collecting busbar, transformer boxes, distributor busbar, kWh meter (output counter), underground cable line and mechanical components for external grid connection, control building, lighting and camera monitoring system (Figure 1 and Figure 2).

Figure 2. A view from module, MPPT + inverter and transformer of the system

Technical specifications of polycrystalline silicon PV module is given in Table 1. As seen in Table 1 that each PV module has 60 cells, 16.32% peak efficiency (under STC: Standard Test Conditions: irradiance @ 1000W/m^2 with an air mass 1.5, module temperature @ 25°C and @ 0m/s wind speed), 1.6236m^2 area, 18.5kg mass, 45±2°C nominal operating cell temperature and 97.5%, 90.0%, 80.0% of overall efficiency for first year, 10 years and 25 years, respectively (Table 2). The efficiency of solar PV panels is affected by environmental and climatic conditions, temperature, dust and using time [2, 3, 7, 13, 15, and 16]. In addition to this, other components of the SPPs such as MPPT, inverter, and transformer has efficiencies that commonly changing between 95%…99% [9]. The maximum efficiency of solar panels can also be gathered in first year.

Table 1. Technical specifications of polycrystalline silicon PV module

Type	Polycrystalline Silicon
The Total Panel Number of SPPs	3864
Peak Efficiency (%)	16.32
Module Mass (kg)	18.5
STC Power Rating (Pmax) (W)	265
Power Tolerance	+3%
Operating Temperature (°C)	-40… +85
Front Glass	3.2mm High Transmission Tempered Glass
Frame	Anodized Aluminum Alloy
Installation Method	Rack-Mounted
97.5% Power Output Warranty Period(Year)	First Year
90% Power Output Warranty Period(Year)	10
80% Power Output Warranty Period(Year)	25

Table 2. Some technical features regarding three identical solar photovoltaic power plants

Module Power Output Warranty for First Years	0.975x0.1632=0.15912=15.912%
Module Power Output Warranty for 10 Years	0.90x0.1632=0.14688=14.688%
MPPT and Inverter Numbers Per SPP	17
Estimated Lifetime of MPPT, Inverter and Transformer	10 Years
Estimated Total Efficiency of MPPT, Inverter and Transformer	0.98x0.98x0.97=0.9316=93.160%
Estimated Average Losses of Power Cut	0.274%
Estimated Average Losses of Dust (Assume That Panels are Periodically Cleaned)	0.5%
Estimated System Total Efficiency for First Year	0.15912x0.9316x0.99726=0.14783=14.783%
Estimated System Total Efficiency for 10 Years	0.14688x0.9316x0.99726x0.9950=0.13577=13.577%
Overall Cost of Operation, Maintenance and Cleaning (Twice a Year) per SPP and Per Year	2000$/Year (May, 2019, Turkey)
Sales Price of The Electricity to The Grid	0.133$/kWh
Personal Expenses for Each SPP	2558$/Year (May, 2019, Turkey)
Interest Income of Capital	21000$/Year (May, 2019, Turkey)

Table 3. Description and rate of budget distribution of SPPs

Description	
Location	Adıyaman City Turkey (Latitude:37.45° Longitude:38.17° Altitude :672m)
Date of Commencement of Operation	November 27, 2017
Installed Power Capacity Per SPP	1.025MW
Installation Cost Per SPP	$1000000
Supply Method for Installation	100% Equity Capital
Budget Distribution	
Solar Panels (45%)	$450000
MPPTs+Inverters (11%)	$110000
Steel Frame Constructions for Panel Placing (11%)	$110000
Solar Cables (7%)	$70000
All Other Underground Cable Line and Mechanical Components for External Grid Connection (13%)	$130000
Transformer Boxes (4%)	$40000
Cost of land (or Field), Control Building, Project, Lighting, Camera Monitoring System, Administrative or Governmental Permits, Licenses And Formalities (9%)	$90000

Payback period of a solar photovoltaic power plant can simply be calculated by using Equations 1, 2, 3, 4. This easiest calculation is the initial (or installation) cost divided by cost displaced per year (CDP). Here, the CDP is equal to the difference between annual net energy income and annual total of operation, maintenance cleaning cost, personnel expenses and interest income of capital per SPP (Table 3) [4, 10, 11, 12, 14 and 19].

$$\text{PBP (Years)} = \frac{\text{ICS}}{\text{CDP}} \quad (1)$$

$$\text{CDP (\$/kWh)} = \text{EPA x COE} - (\text{AOM} + \text{PER} + \text{INT}) \quad (2)$$

$$\text{PBP (Years)} = \frac{\text{ICS}}{\text{EPA x COE} - (\text{AOM}+\text{PER}+\text{INT})} \quad (3)$$

$$\text{PBP (Years)} = \frac{\text{ICS (\$)}}{\text{EPA(kWh/Year)xCOE(\$/kWh)} - (\text{AOM(\$/Year)}+\text{PER(\$/Year)}+\text{INT(\$/Year)})} \quad (4)$$

Here;
PBP: Payback period, (Years)

ICS: Initial cost of the system (installation cost per SPP), (ICS=$1000000)
CDP: Cost displaced per year, (kWh/Year)
EPA: Annual net produced or generated energy per SPP, (EPA=1685939, 1683408, 1688337kWh/Year)
COE: Sales price of the electricity to the grid, (COE=0.133$/kWh)
AOM: Annual operation, maintenance and cleaning cost per SPP, (AOM=2000$/Year)
PER: Annual personal expenses per SPP, (2558$/Year)
INT: Annual interest income of capital per SPP, (21000$/Year)

4. RESULTS AND DISCUSSIONS

Electricity generation of three identical solar photovoltaic power plant (SPPs), their internal electricity consumption and net generated electric energy for sale are given in Table 4 and Table 5.

Table 4. Electricity generation of three identical solar photovoltaic power plants

Months	Monthly Generation for First Year (kWh/Month) Three Identical Solar Photovoltaic Power Plants		
	I	II	III
December 2017	94829	90358	96645
January 2018	82465	82490	83399
February 2018	88189	88468	88920
March 2018	144146	144555	144588
April 2018	173645	173650	174368
May 2018	164956	164898	165997
June 2018	183538	184100	184900
July 2018	198025	198826	199000
August 2018	193807	194158	192533
September 2018	165230	164841	162898
October 2018	120409	120596	116897
November 2018	88250	86770	88650
Measured Value (From kWh Meter) for First Year			
Total Gen.(kWh/Year)	1697489	1693711	1698794
Inter. Con.(kWh/Year)	11550	10303	10457
Net Gen.(kWh/Year)	1685939	1683408	1688337
Estimated Annual Average Value for 10 Years			
Total Gen.(kWh/Year)	1558974	1555504	1560172
Inter. Con.(kWh/Year)	11550	10303	10457
Net Gen.(kWh/Year)	1547424	1545201	1549715

All these monthly data are related to annual operation of SPPs for first year. As seen from these tables that the total generated electric energies were 1697489kWh, 1693711kWh and 1698794kWh and the total internal consumptions were 11550kWh, 10303kWh and 10457kWh, for I, II and III SPPs, respectively. The average annual electricity generation was 1696665kWh, internal consumption was 10770 kWh and net generation was 1685895kWh. In addition, the payback period of three SPPs is given in Figure 3. As seen from this figure that the payback period of SPPs are about same and there is very less and negligible differences between them. The average payback period is 5.5 Years.

Table 5. Internal electricity consumption of three identical solar photovoltaic power plants

Months	Monthly Internal Consumption (kWh/Month) Three Identical Solar Photovoltaic Power Plants		
	I	II	III
December 2017	1304	1263	1359
January 2018	1491	1219	1042
February 2018	1159	861	965
March 2018	1083	862	933
April 2018	820	704	754
May 2018	819	702	753
June 2018	677	570	606
July 2018	720	716	725
August 2018	750	676	799
September 2018	822	811	773
October 2018	947	950	869
November 2018	958	969	879
Total (kWh/Year)	11550	10303	10457

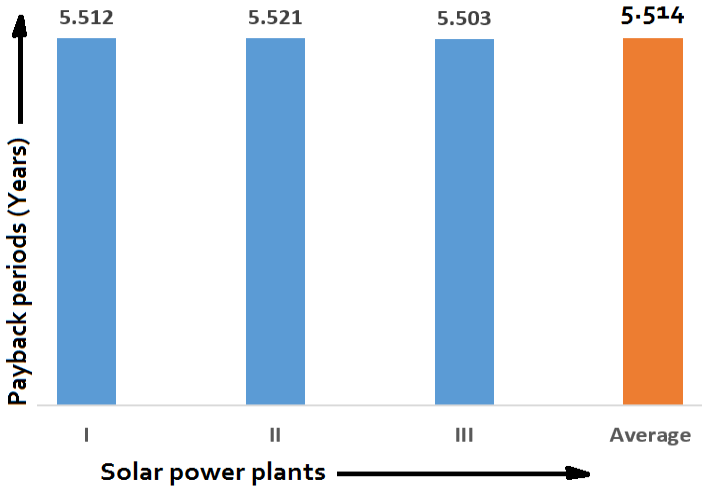

Figure 3. Estimated payback periods of three identical solar photovoltaic power plants

5. CONCLUSION AND RECOMMENDATIONS

In this study, the payback periods of three identical PV plants installed in Adıyaman province with an initial investment cost of $1 million were calculated. As a result of the calculations, the average payback period was determined as 5.5 years. These results show that investors can invest in solar power plants despite the high initial investment costs.

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