SETSCI Conference Indexing System,
Volume 3 (2018), 1550-1553

ISAS 2018-Winter
2nd International Symposium on Innovative Approaches in Scientific Studies
November 30 – December 2, 2018, Samsun, Turkey

Shading Effect on Output Power of Gried-Tied PV Systems: A Case Study

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Presentation/Paper Type: Oral / Full Paper

In this case study, the shading effect of 480 kW Solar power plant in ilkadım-Samsun was investigated. It is well known that the power generation of photovoltaic systems is significantly influenced by the partial or complete shading of the cells. The substation of the solar power plant caused the falling energy on a directory panel to be adversely affected by the generated energy. The performance of the panels effected by the shadow on the total power generation has been monitored and analyzed. Despite of the dual MPPT tracking inverters, it was observed that the loss was up to 4.80%. The results show that the generated PV voltage has fallen due to the shade.
Keywords: Renewable energy, Photovoltaic modules, Partial shading, Power losses

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1. Introduction

Energy is a need of life. With the industrial revolution and rapid population growth, the need for energy has increased. Until the beginning of the twentieth century, the environmental pollution rose because of fossil fuels used extensively. Moreover the concern that one day will be ended, have encouraged humans to search for new energy sources. As a result of this search, renewable energy resources have become a part of our life. Solar energy, one of the renewable energy, is an alternative energy source that can be a solution to the environmental problems that today humanity is facing [1]. Many countries in the world have accelerated the use of renewable energy and have set targets for clean and safe energy. They have developed energy policies in line with these goals.

Solar power systems can be installed as small, off- grid or large scale, grid-tied. For this, photovoltaic (PV) modules formed by assembling solar cells consist of a number of cells assumed to be the same according to their electrical properties. The solar rays, which are fell on the solar panels, influence completely or partially from the shadows of the clouds, adjacent buildings, towers, trees, telephone and electric poles. So shading reduces the power which is generated by the PV array and reduces the efficiency. In addition, the shaded cells in the modules can absorb the electrical power generated by other cells, causing irreversible damage [2]. Various studies have been carried out to increase the efficiency of solar energy systems by reducing the effect of all these adverse conditions. One of these applications is to use maximum power point tracking (MPPT) algorithms to obtain the maximum power that panels can provide at certain radiation and temperature condition [3-4].

It is very valuable to observe the effect of the partial shading of the panel surface in the installed solar power plant on the performance in the outdoor condition [5]. In this context, a case study was carried out on a 480 kW power plant established in Samsun, a real production plant, in order to understand the partial shading effect on panel performance.

2. Shading effect

Shading has a great effect on the performance of solar panels. For this reason, the best solution is to avoid shadows. This is not possible in practice due to factors such as cloud and rain. The thing, we are going to notice, is to avoid being shadowed by objects. However, what most people do not realize is that even if a small part of the solar panel is shaded, it will significantly reduce the performance of the entire panel. The reason is that solar panels are actually circuits consisting of a series of interconnected solar cells. The reduction in a single cell power output means that the output power of entire module will be reduced.. For this reason, a small amount of shading can meaning reduce the performance of the entire solar panel system [6].

The impact of partial shadows on the solar energy system has been extensively studied for many years and than result of these studies, a number of methods have been used to reduce the negative effects. Nowadays, the use MPPT inverters is one of these methods.

3. How to calculate distance from panel to obstacle and panel to panel while assembling modules

For a solar power plant to run for many years without problems, the installation must be done correctly. For this reason, attention should be paid not only to the distance between panel and panel, but also to the distance between the higher objects and the panel, which may create shadow at the same time. When the solar panels are installed, the sunlight should be considered according to the seasonal arrival angle. The most oblique rays of the sun come on December 21 for Turkey. When calculating the inclination angle α, the drawing shown in fig.2a, should be used. In a power plant installed without considering this drawing, trees, poles, buildings (such as a transformer building) form a shadow on the panel.

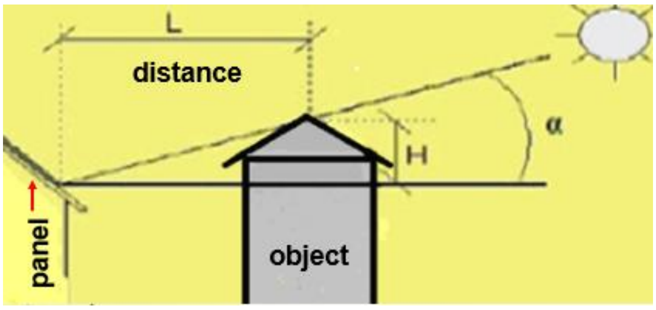

Fig.2a: formula of distance : L > H / tan α.

As shown in fig.2a, the shadow size of an obstacle is formulated as follows:

$$L > \frac{H}{\tan \alpha}$$

If the distance between the obstacle and module (L) is greater than H / tan α, it does not create a shadow.

At the same time, to the distance between panel and panel should be paid attention during installation. The sun rays come to the panels must not be blocked by previous panels. The minimum distance, required for this, is calculated as shown in fig.2b [7].

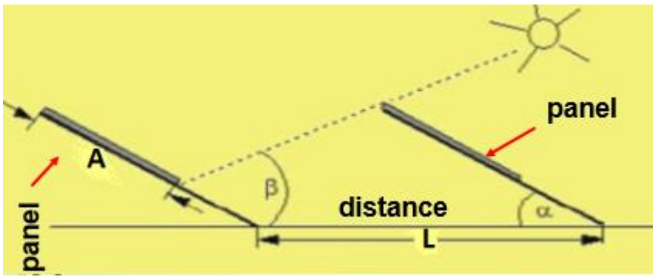

Fig.2b: formula of distance : $L = [(\sin \alpha / \tan \beta) + \cos \alpha] \times A$.

4. Case study details

4.1. Details of the installed solar power plant

The general layout of the power plant, block diagram, geographical coordinates and general information about the plant are shown in fig.1a, 1b and given in table 1. There were 16 units of 30 kW inverters used and each inverter was connected with 6 arrays, 20 modules were used in each array which some up to 1920 modules. All arrays were fixed on stands with angle of 23 degrees facing South.

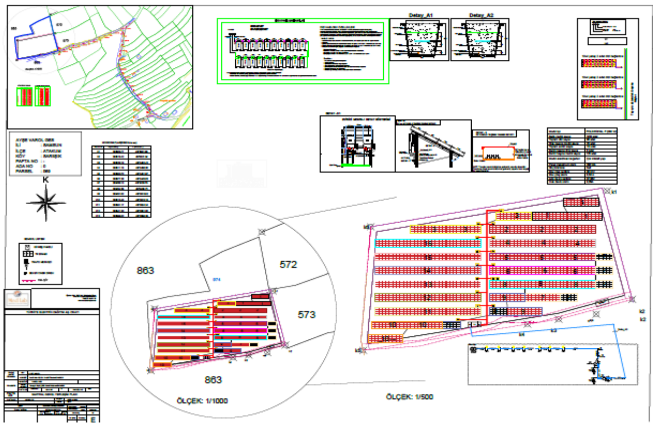

Fig.1a: The general layout of the power plant.

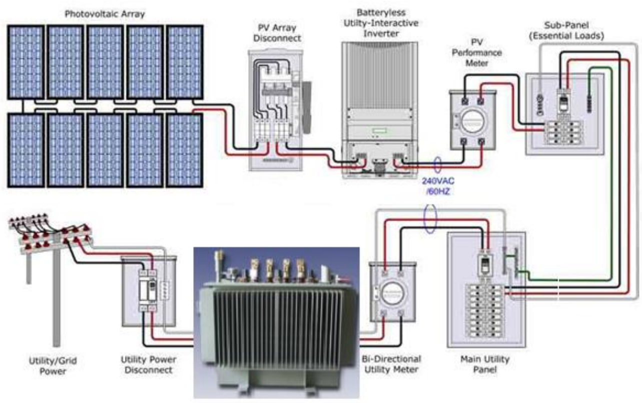

Fig.1b: Block Diagram.

Table 1: Geographical coordinates and general information.

1	**Geographical Coordinates**	SAMSUN / İlkadım Latitude : 41,292782N Longitude: 36,333128E
2	**Plant Capacity**	480 kW
3	**Technology**	Photovoltaic
4	**System Type**	Grid-Tied
5	**Module Type/Quantity**	Polycrystalline/1920
6	**Inverter Type**	String Inverter (3 Phases, 2 MPPT Tracking)
7	**Total Inverter&Capacity**	16 Unites, Each 30kW
8	**One Module Output Power**	260 Watts

The geographical coordinates of the plant are latitude 41.292782 N and longitude 36.333128 E. The plant coordinates were determined using the European solar radiation database Photovoltaic Geographic Information System (PVGIS), which is an integrated solar radiation model using climate data [8].

4.2. Working Details

As shown in fig.2c, in this case study, the transformer building is placed very close to one of the panel arrays in the solar power plant. During the power plant design, it is necessary to calculate the distance between the transformer building and the panel correctly.

Fig.2c: The shading of the transformer building is on the Panels

It seems that the formula for calculating the distance in the solar power plant is not taken into consideration. As a result, a study has been carried out to see to what extent the efficiency of the array located near the shadow of the transformer building is affected. In this case study, values, read from inverters, were recorded for 10 minutes intervals between 06:40 and 08:40 in the morning for 3 months, when the shadow of the transformer building fell on the panels in the cloudless and clear weather.

5. Results and discussion

It was seen on the charts which formed by entering these values that there was a value difference of 4.8% among between the ones exposed to the shade and the ones not exposed to the shade in table 2 and fig.3. This difference occurred despite the use of dual MPPT inverters in the system.

Table 2: İnstant Production & Difference between 13 and 16 inverters

Time İnterval	İnverter-13 (unshaded) (kW)	İnverter-16 (shaded) (kW)	Diff.13-16 (%)
06:40	5.000	4.900	2.00
06:50	5.476	5.327	2.72
07:00	5.881	5.763	2.00
07:10	6.844	6.557	4.19
07:20	7.925	7.635	3.66
07:30	9.140	8.701	4.80
07:40	11.790	11.480	2.63
07:50	12.750	12.370	2.98
08:00	13.760	13.530	1.67
08:10	14.650	14.110	3.68
08:20	15.550	15.220	2.10
08:30	16.030	15.820	1.30
08:40	16.530	16.240	1.75

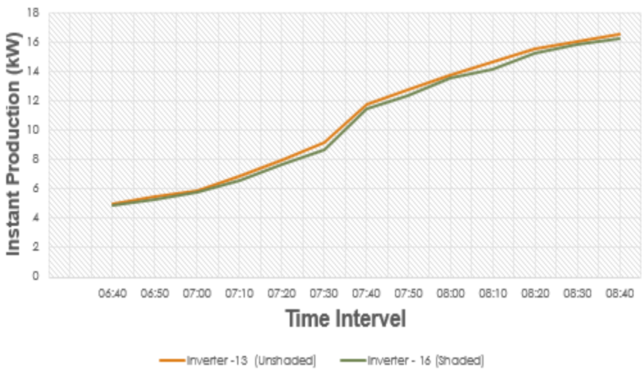

Fig.3: Instant production for 13 and 16 inverters.

When we record cumulatively the productions in both inverters, we see that the difference increases in a direct proportion. As in table 3 and fig.4.

Table 3: Difference between 13 and 16 inverters

Months	İnverter-13 Unshaded (kW)	İnverter-16 shaded (kW)	Diff.13-16 (kW)
June	17,808	17,760	48
July	22,829	22,772	57
August	28,224	28,158	66

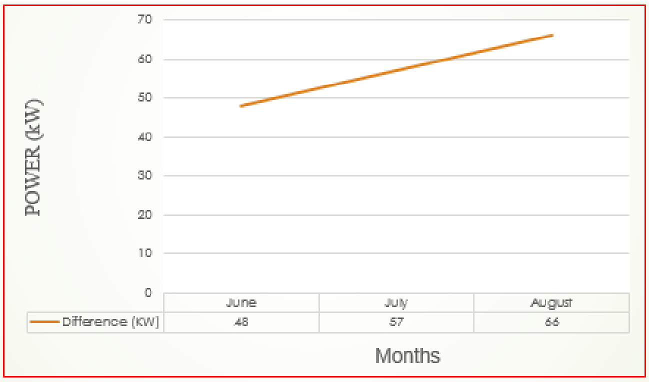

Fig.4: Difference between 13 *and* 16 *inverters as kW.*

Conclusions

In this study, solar energy production losses were carried on a 480 kW installed solar power plant in Samsun province, which is a real production power plant. When we examined the solar power plant, it was seen that the transformer building had a shading effect on a panel array. Substation building is not a natural elevation. For this reason, it is necessary to correct the settlement plan while a solar power plant is being built. Despite of used dual MPPT inverters in this solar power plant, it was seen that losses were between 1.3% and 4.8%. on shaded array. If the life of a solar power plant is thought to be long, this loss should be considered. Because loss is loss of both the investor and national wealth.

Another consequence of this study is that the business community and the academic community always act together when such an investment is done. It was concluded that for the investment of solar power plant is important, not only engineering and technical knowledge, but also scientific works.

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