International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Output Power Optimization Strategies for Solar Photovoltaic Power Plant

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Received 20 Nov 2022, Accepted 26 Dec 2022, Available online 03 Jan 2023, **Vol.13, No.1 (Jan/Feb 2023)**

Abstract

Photovoltaic (PV) materials and devices convert sunlight into electrical energy. A single PV device is known as a cell. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. These cells are made of different semiconductor materials. In order to withstand the outdoors for many years, cells are sandwiched between protective materials in a combination of glass and/or plastics. To boost the power output of PV cells, they are connected together in chains to form larger units known as panels. Solar PV power plant comprises of large number of solar PV panels installed in tandem to each other. This paper discusses the various optimization strategies to boost the Output Power from a Solar PV Power plant. The optimization strategies are classified on the basis of technological complexities and ease of Knowledge management as intrinsic parameters, extrinsic parameters, and operational parameters

Keywords: *Solar PV power plant; Output power; optimization strategies; Group Technology; Intrinsic parameters; Extrinsic parameters; Operational parameters*

1. Introduction

Photovoltaic (PV) materials and devices convert sunlight into electrical energy. A single PV device is known as a cell. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. These cells are made of different semiconductor materials. In order to withstand the outdoors for many years, cells are sandwiched between protective materials in a combination of glass and/or plastics. To boost the power output of PV cells, they are connected together in chains to form larger units known as panels. Solar PV power plant comprises of large number of solar PV panels installed in tandem to each other.

Modules can be used individually, or several can be connected to form arrays. One or more arrays is then connected to the electrical grid as part of a complete PV system. Because of this modular structure, PV systems can be built to meet almost any electric power need, small or large. PV systems also include mounting structures that support the panels and point them towards the sun. PV systems also include electrical hardware that takes the direct-current (DC) electricity produced by modules and convert it to the alternating-current (AC) electricity so that electricity can be fed to the grid or used to power all of the appliances in a home.

Output power of a Solar PV plant is an important for profitable operations. In this paper we are concerned with the strategies to enhance and optimize the output power. Conversion efficiency of a solar panel is given as

$$\eta = \frac{\text{Power Output}}{\text{Power Input}}$$

$$\therefore \text{Power Output} = \eta \times \text{Power Input}$$

This paper deals with the strategies to increase the Power Output. Hence the focus is not just on the conversion efficiency rather the focus is on the Power Output.

While working on the various strategies with group technology approach the strategies were classified on as follows.

- Intrinsic parameters
- Extrinsic parameters
- Operational parameters

2. Intrinsic Parameters

Intrinsic parameters are related to Solid state physics and electronics. Intrinsic parameters refer to the essential nature of the Solar Panels. This refers to the design and construction of Solar Panels.

Solar Cells are the building blocks of Solar Panels. Hence performances of Solar Panels depend upon the type of Solar Cells used.

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DOI: https://doi.org/10.14741/ijcet/v.13.1.2

Solar Cell classification, with respect to the Intrinsic Parameters, is done on the basis of the following attributes.

(a) Thickness of active material
(b) Type of junction structure
(c) The type of active material used in its fabrication.

2.a Thickness of active material

Depending on the thickness of the active material Solar Cells are of two types

1) *Bulk material cell*
2) *Thin film cell*

2.b Type of junction structure

On the basis of junction structure Solar Cells are classified as

1) pn homojunction cell
2) pn heterojunction cell
3) pn multijunction cell
4) P-i-n semiconductor junction

2.c The type of active material used in its fabrication.

Type of active material used in its fabrication

1) Single crystal silicon cell
2) Polycrystalline silicon cell
3) Amorphous silicon cell
4) Copper indium (gallium) diselenide cell
5) Cadmium Telluride cell (CdTe)
6) Organic PV cell

3. Extrinsic parameters

Extrinsic parameters are not part of the inherent nature of the Solar Panels. Extrinsic parameters come from outside.

(a) Site Selection
(b) Orientation of Solar Panels- Direction
(c) Orientation of Solar Panels- Tilt angle (Solar Panel Angle)

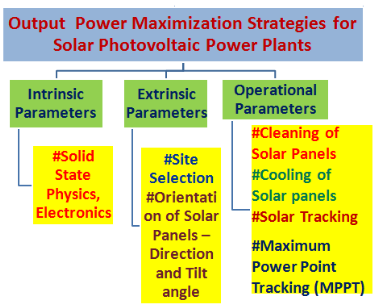

Fig.1: Classification of Output Power Maximization strategies for Solar PV Power plant

3.a Site Selection

1) Abundant Solar Irradiation (Minimum 1100 kWh/sq-m per year)
2) Transmission lines located nearby (35 kW line within 600 m)
3) Land Cover; free of mountains, forests, water bodies, buildings, wetlands, floodplains
4) preferably low and medium grassy vegetation, shrub-lands, barren lands, closed landfills, abandoned mine lands

3.b Orientation of Solar Panels- Direction and Orientation of Solar Panels- Tilt angle (Solar Panel Angle)

Orientation of Solar Panels - Direction

The *optimum* direction is taken as towards the South in the northern hemisphere and towards the north in the Southern hemisphere.

Orientation of Solar Panels- Tilt angle (Solar Panel Angle)

The *optimum* value is taken for a particular location.

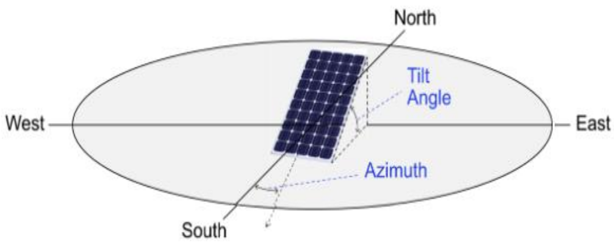

Fig.2: Azimuth Angle (Direction) & Tilt Angle for Solar PV panel

For maximum power output the orientation of the solar panel should be such that the face of the solar panel aligns with the sun. Such condition is function of **f(ϕ, δ, γ, ω)**
ϕ : Latitude
δ : Declination
γ : Surface azimuth angle
ω : Hour angle

The optimum (condition that the solar panel aligns with the sun) value the function f(ϕ, δ, γ, ω) depends on location as well as time. Hence it is not economically viable to follow the ideal orientation of the solar panel. *Hence it is prudent to have the orientation of solar panel at optimum value. Good amount of research is directed at finding the optimum values for a particular location.*

4 Operational parameters

Operational parameters are other than Intrinsic and Extrinsic parameters.

Operational parameters are the *favorable operating conditions* which lead to increase in the Output power of the Solar Panels.

(a) Cleaning of Solar Panels
(b) Cooling of Solar Panels
(c) Solar Tracking
(d) Maximum Power Point Tracking (MPPT)

4a Cleaning of Solar Panels

It is very important to clean the Solar Panels. Dirt and dust on the Solar Panels prevents the entry of light which eventually leads to less energy production (Output Power)

4b Cooling of Solar Panels

Efficiency of Solar cell varies with panel temperature
The efficiency is the maximum at 36°C panel temperature. After that it decreases at the rate of 0.4% per °C. Therefore it is beneficial to apply artificial cooling to Solar Panels for the improvement in power output and optimum performance parameters

Various methods have been applied for the cooling of Solar Panels viz. Hybrid PV/T system, Micro-channel cooling system, Thermo-electric cooling system, Heat pipe cooling system, Mist water cooling system, Water film cooling system, use of Phase Change Materials (PCM).

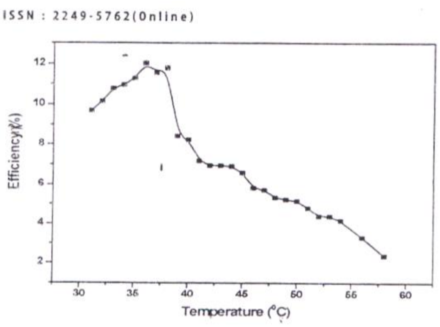

Fig.3: Variation of efficiency vs. Temperature of a solar panel

4c Solar Tracking of Solar Panels

Solar tracking of solar panels on real time is not viable. But solar tracking can be done as hourly (once or twice a day) or monthly schedule.

There is huge difference between the desired Tilt angles for different months. If solar tracking is done monthly then there is no need for automation. It can be done manually using properly designed fixtures.

4d Maximum Power Point Tracking (MPPT)

An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid.

Power depends on the product of the voltage and the current. Therefore, when the product is maximum power transmitted is the maximum. MPPT system tracks this point and thus ensures maximum power transmission on real time basis.
Power = V x I

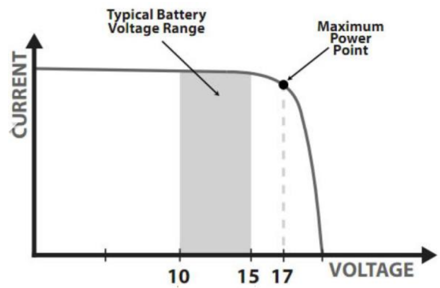

Fig.4: Current-voltage (I-V) curve showing Maximum Power Point

An MPPT system increases the Output Power in the following ways.

- It increases the running time of the appliances
- It helps in generating greater power from solar panels
- It reduces power wastage by directing extra power to the grid in a grid-tied solar system
- It uses excess power to charge the battery in case of an off-grid solar system
- Even if there's any inefficiency in the appliance connected to the inverter, MPPT doesn't let it affect the efficiency of the solar panels.
- Either way, whether for an off-grid system or an on-grid system, the MPPT technology minimizes power wastage and maximizes the power generation from solar panels.

Conclusions

This paper discusses the various optimization strategies to boost the Output Power from a Solar PV Power plant. This is directed at profitable running of a Solar PV Power plant.

The optimization strategies are classified on the basis of technological complexities and ease of Knowledge management. The strategies are grouped into three distinct categories viz. intrinsic parameters, extrinsic parameters, and operational parameters. The grouping of strategies helps in better planning for increasing profitability by way of increasing Output Power in the following ways.

- The strategies can be implemented by applying the correct technology required.
- The strategies can be implemented by the specialists of that particular technology.
- It gives a road map how and when to apply the various strategies. Some strategies are to be implemented while selecting the hardware, some while developing the infrastructure and others while the plant is in operation.

Table 1: Distinguishing features of the Output Power maximization strategies types

Type of strategy	Basic attributes
Intrinsic Parameters	*Intrinsic parameters are related the active material which make the Solar Cells and assembly of Solar Cells in a Solar Panel.*
Extrinsic Parameters	Extrinsic parameters *come from outside* viz. Site Selection, Orientation of Solar Panels- Direction, Orientation of Solar Panels- Tilt angle (Solar Panel Angle)
Operational Parameters	Operational parameters are the *favorable operating conditions* which lead to increase in the Output power of the Solar Panels viz.Cleaning of Solar Panels, Cooling of Solar Panels, Solar Tracking,, Maximum Power Point Tracking (MPPT)

Table 2: Nomenclature

Symbols
^oC : Degree centigrade
I: Current
kW: Kilo watt
kWh/Sq-m: Kilo watt hour per square meter
V: Voltage
P: Power
η: Conversion efficiency
ϕ : Latitude
δ : Declination
γ : Surface azimuth angle
ω : Hour angle

Abbreviations
DC: Direct Current
I-V: Current Voltage
MPPT: Maximum Power Point Tracking
PV : Photovoltaic

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