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Effect of Temperature on Performance of PV Array Operating Under Concentrator

By

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A Thesis

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Abstract

The sun is the world's sole source of energy. In fact, all of the energy being used on the earth today is driven from solar energy. Because of the increase in world energy demand and the threat of global warming; there is a pressing need for the development of reliable, cost-effective sources of renewable energy. Renewable energy sources include indirect solar energy such as hydro, wind and direct solar energy conversion through thermal receivers or photovoltaic. This paper discusses the parameters that affects on the cell temperature under concentration. Comparison between fixed modules and solar cells operating under concentration to get the optimum solution. By increasing the concentration factor one minimizes the area of the cell .System uses special cell (Fresnel lens and multilayer cells).This cell has large efficiency and bear high temperature. The economic studies are necessary to calculate the cost of 1kwh for each case.

Keywords: Photovoltic (PV) system, Concentration Photovoltic (CPV) system, Multilayer cell, Economics.

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List of Abbreviations

PV	Photovoltaic
eV	Electron volt
E_λ	photon energy
EGP	Egyptian Pound
AC	Alternating Current
DC	Direct Current
UV	Ultraviolet
J	Joule
W	Watt
Wp	Watt Peak
kW	Kilo Watt
MW	Mega Watt
GW	Giga Watt
KWh	Kilo Watt hour
h	Plank’s constant
c	Speed of light
AM	Air mass
TFSC	Thin-film solar cell cell
TFPV	Thin-film photovoltaic cell
GaAs	Gallium Arsenide
CdTe	Cadmium telluride
Si	Sillcon
F_F	Fill Factor
CPV	Concentration photovoltaic solar cell
LCOE	levelized cost of electricity
C_{th}	concentration factor
DNI	Direct Normal Irradiance
HCPV	high concentration PV
LCPV	Low Concentration PV
CTJ	concentrator triple junction
MJC	multi-junction cells

List of Symbols

B	Tilt angle
T_a	Ambient temperature
T_c	Cell temperature
δ	Solar declination
Ø	Latitude angle
ω	Hour angle
Θ_i	Angle of incidence
ω_s	Sunset hour angle
I_{sc}	Short circuit current
A_c	solar cells area
A_m	module area
I	Overall current
V_{oc}	Open circuit voltage
η_m	Module efficiency
P_{max}	Maximum power
η_c	Solar cell efficiency
R_s	Series resistance
R_p	Parallel resistance
T_{sky}	sky temperature
F_p	packing factor
t_{ss}	Sunset time
t_{sr}	Sunrise time
t	Time
T_R	reference temperature
η_c	efficiency solar cell
A_1	Area of mirrors or lenses (large area)
E	Load energy
A_2	Area of cell
US $	U.S .Dollar
D	Day of the year
W	Wind speed
H_w	heat loss coefficient
F	Analysis a factor
T_G	Outer glass surface temperature
б	Stefan Boltzman constant
T_{sky}	Sky temperature

U_L	overall heat loss coefficient
U_o	annual average heat loss coefficient
α_c	solar cell absorption coefficient for incident radiation
$(Geff)_{track}$	The instantaneous irradiation under concentration with tracking.
P_{el}	electrical output power under concentration with tracking
A_{hs}	Area of heat sink
F_f	fins factor
T_{co}	Temperature of the cell at room temperature
B_c	coefficient of efficiency drop per degree centigrade
K_T	clearness index
η_{co}	efficiency of the solar cell at room temperature
H_B	the global irradiance on a horizontal surface
H_d	diffuse irradiance
H_D	Direct beam irradiance on a surface perpendicular to the direct beam
$H_{D,t}$	Direct radiation on tilted surface
R_b	Ratio between direct radiations on tilted surface to on horizontal surface
H_T	The total radiation for any inclined (inclination = β) with any orientation
G_T	Instantaneous global radiation on tilted surface
I_{mp}	Max. Power current
V_{oc}	Open cicuit voltage
V_{mp}	Max. Power voltage
I_{mp}	Max. Power current
$\eta_{ctrackeff}$	efficiency of the solar cell that work under concentration with tracking

Chapter 1

Introduction

1. Introduction

Most of the energy that is used today is in the form of fossil fuels, which also originated from the Sun but has been stored in the earth for millions of years. If the current trends of global energy use and demand continue, the supply of fossil fuels are predicted to be exhausted within 50-100 years from now [1]. Burning fossil fuels releases stored carbon into the environment. This disturbs the global carbon cycle and leads to an increase in atmospheric CO2 levels.Sun beams arrives at Earth about eight minutes later. The solar energy travels to the Earth at a speed of 186,000 miles per second (3.0 x 10^8 meters per second).The speed of light. Solar energy is considered a renewable energy source. Renewable sources of energy are resources that are continually renewed by nature, and hence will never run out. Solar power is considered renewable because the nuclear (fusion) reactions that power the sun are expected to keep generating sunlight for many billions of years. [2].

1.1 Sun-Earth Geometry
1.1.1 Solar Radiation

The sun is the source of energy on the earth and is a primary factor in determining the thermal environment of a locality. It is important for engineers to have a working knowledge of the earth's relationship to the sun. They should be able to make estimates of solar radiation intensity and know how to make simple solar radiation measurements.They should also understand the thermal effects of solar radiation and know how to control or utilize them.

1.2 Sun-Earth Relationships

The solar constant G_{SC} is the energy from the sun, per unit time, received on a unit area of surface perpendicular to the direction of propagation of the radiation, at mean earth-sun distance, outside of the atmosphere, as shown in figure. (1.1)
Solar constant G_{SC}(=1.35 Kw/ m^2) is given by [3]

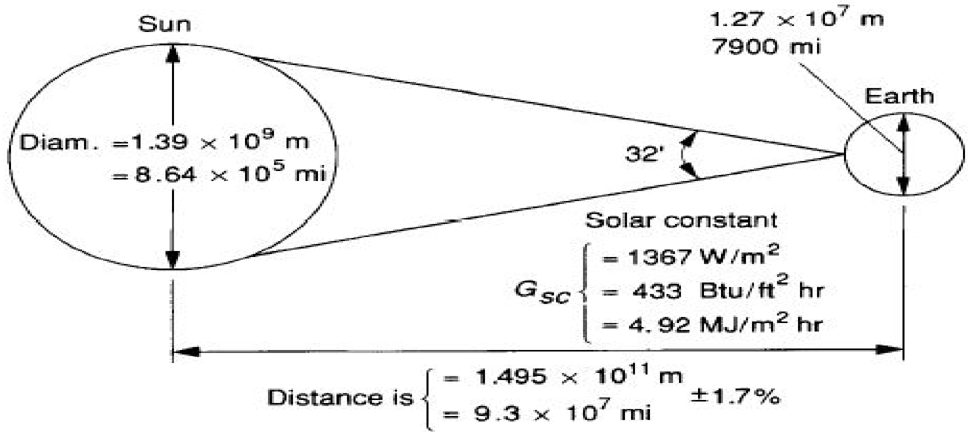

Figure: (1.1) Sun -Earth Relationships.

- **Radiation:** The transfer of energy via electromagnetic waves that travel at the speed of light. The velocity of light in a vacuum is approximately 3 x 10^8 m/s. The time it takes light from the sun to reach the Earth is 8 minutes and 20 seconds. Heat transfer by electromagnetic radiation can travel through empty space. Anybody above the temperature of absolute zero (- 273.15 º C) radiate energy to their surrounding environment.

- **Extraterrestrial Solar Radiation**

The solar radiation at the entrance into the Earth atmosphere is known as extraterrestrial radiation. The intensity of extraterrestrial solar radiation is changelle because of the change in distance between the Earth and Sun and because of the Sun activity. The value of this radiation during the course of a year changes in the range from 1307 (W/m^2) to 1393 (W/m^2) [4]

- **Terrestrial Solar Radiation**

Passing through the earth atmosphere and because of dispersing and absorption on atoms and ions of present gases (oxygen, hydrogen, nitrogen, ozone, carbon dioxide, etc.) the intensity of solar radiation reduces for 25% − 30%. Solar radiation that comes to the earth is known as terrestrial radiation [5].

- **Global Solar Radiation**

Two components of solar radiation come to the Earth surface. One component comes directly from the Sun [H_D (direct solar radiation)] and the other originates from dispersing of direct solar radiation in the atmosphere [H_d (diffuse solar radiation)]. Global solar radiation (H_B) consists of direct and diffuse solar radiation.

Photovoltaic (PV) cells are semiconductor devices that can convert sunlight into electricity. Photons below a threshold wavelength have enough energy to break an Electron-hole bond in the semiconductor crystal, which in turn can drive a current in a circuit. The solar radiation consists of photons at a range of wavelengths and corresponding energies. Photons with wavelengths above the threshold are converted into heat in the PV cells. This waste heat must be dissipated efficiently in order to avoid excessively high cell temperatures, which have an adverse effect on the electrical performance of the cells.

A solar cell is an electronic device that produces electricity when light falls on it. The light is absorbed and the cell produces dc voltage and current. The device has a positive and a negative contact between which the voltage is generated and through which the current can flow. You connect these contacts to whatever it is you want to power. Solar cells have no moving parts. Effectively they take light energy and convert it into electrical energy in an electrical circuit.

Initially solar cells were too expensive to be used in non-space (i.e. *terrestrial*) applications.They are a good idea for country areas that have no electricity supply network, of which there are many in the Developing World, and for maritime applications. If cells can be made cheap enough (and great efforts are being made to achieve this) they could even replace our normal methods of making electricity.