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Enhancement of the characteristic of PV array under partial shading condition

A thesis

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Abstract

The photovoltaic (PV) Power generation has several merits like free fuel cost, little maintenance, cleanness and causing no noise because of the absence of moving parts. The Egyptian government moves towards encouraging the consumer to generate electricity from PV system and issues new electricity law that allows the consumer to sell the superfluous of PV array generated power to utility.

Partial shading is one of the obstacles for propagation of PV array. The photovoltaic (PV) Partial shading may occur by neighbor building, trees, dust, and clouds. The effectiveness of partial shading on the PV array performance are loss in the PV array output power, presence of multiple Maximum power peaks (MPP) that causes difficulty of tracking MPP and global MPP occurred at relative low voltage. All these effects are considered in literature review. Also, a comparative literature review and different methods for mitigating these bad effects are provided.

In this thesis, three techniques for enhancing the characteristic of photovoltaic array under partial shading are suggested:

1. A photovoltaic/battery scheme technique for boosting PV array output power is suggested. This system applied a battery connected in parallel with PV array to substitute the power loss during occurrence of partial shading.

Also, 2.a reconfiguration strategy is suggested that increases PV array output power during partial shading. This reconfiguration strategy used current sensors, controller and electronics switches. The current sensor sense occurrence of partial shading and send signal to controller to control the switches that reconfigure PV array to arrange shaded modules in same column to reduce power loss.

3. The thesis presents a technique for boosting the reconfigurable PV system output power by connecting a battery in parallel with photovoltaic. This improves PV array output power.

The study of the thesis, also covers optimizing of a rooftop PV array output power interconnected to the grid by using a cascaded DC/DC converter across each module.

In this thesis, Matlab/Simulink software package used for executing the analysis. Two models were built up for the study in this thesis:

1. A model for simulation the performance of photovoltaic array during fully illumining conditions and during partial shading.

2. A model for simulation the performance of rooftop PV array connected to grid with cascaded DC/DC converter across each PV module.

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List of symbols and abbreviations

a	Diode ideality factor
BL	Bridge linked connection
D_{scu}	Shading control unit diode
E	Terminal voltage[V]
FF	Fill Factor
$G(W/m^2)$	Irradiance
I_o	Diode reverse saturation current
I_{batt}	Battery current [A]
I_{mpp} (A)	Current at Maximum power peak
I_{ph} (A)	Photo electric current
I_{pv}	Photovoltaic module current
I_{sc} (A)	Short circuit current
K ($1.38*10^{-23}$ J/K)	Boltzmann's constant
K_i ($A/^oC$)	Short circuit current temperature coefficient
K_p	Polarization constant [Ohm]
K_t ($^oC.m^2/W$)	Cell temperature proportionality factor
K_v ($V/^oC$)	Open circuit voltage temperature coefficient
N_c	Number of cells in module
NOCT	Nominal Operating Cell Temperature
Pin	Input solar irradiation power
P_{mpp} (W)	Maximum power peak
PV	Photovoltaic
Q ($1.6*10^{-19}$ C)	Electron charge
R_b	Terminal resistor, independent on SOC[Ohm]
R_p (ohm)	Parallel resistance
R_s (ohm)	Series resistance
SCU	Shading Control unit
SOC	State of charge, number between 0 and 1[no unit]
SP	Series-parallel connection
STC	Standard test condition
T (^oC)	Ambient temperature
TCT	Total Cross Tie connection
V_O	Battery open circuit voltage [V]
V_{batt}	Battery terminal voltage [V]
V_m	Output voltage of photovoltaic module connected with shading control unit
V_{mpp} (V)	Voltage at Maximum power peak

$V_{mpp, min}$	Voltage under minimum irradiation at Maximum power peak
V_{oc} (V)	Open circuit voltage
V_{pv}	Photovoltaic module voltage
V_{scu}	Shading control unit battery's voltage
V_{th} (V)	Thermal voltage
η	Efficiency of Photovoltaic array

Publications

Ahmed M. Mahmoud , Salah M. Saafan , Ahmed M. Atallah, Hamdy El-goharey "Enhancement of PV Array Performance during Partial Shading Condition", International Journal of Advanced Research in Science, Engineering and Technology, Vol. 4, Issue 5 , May 2017, PP.3867-3875.

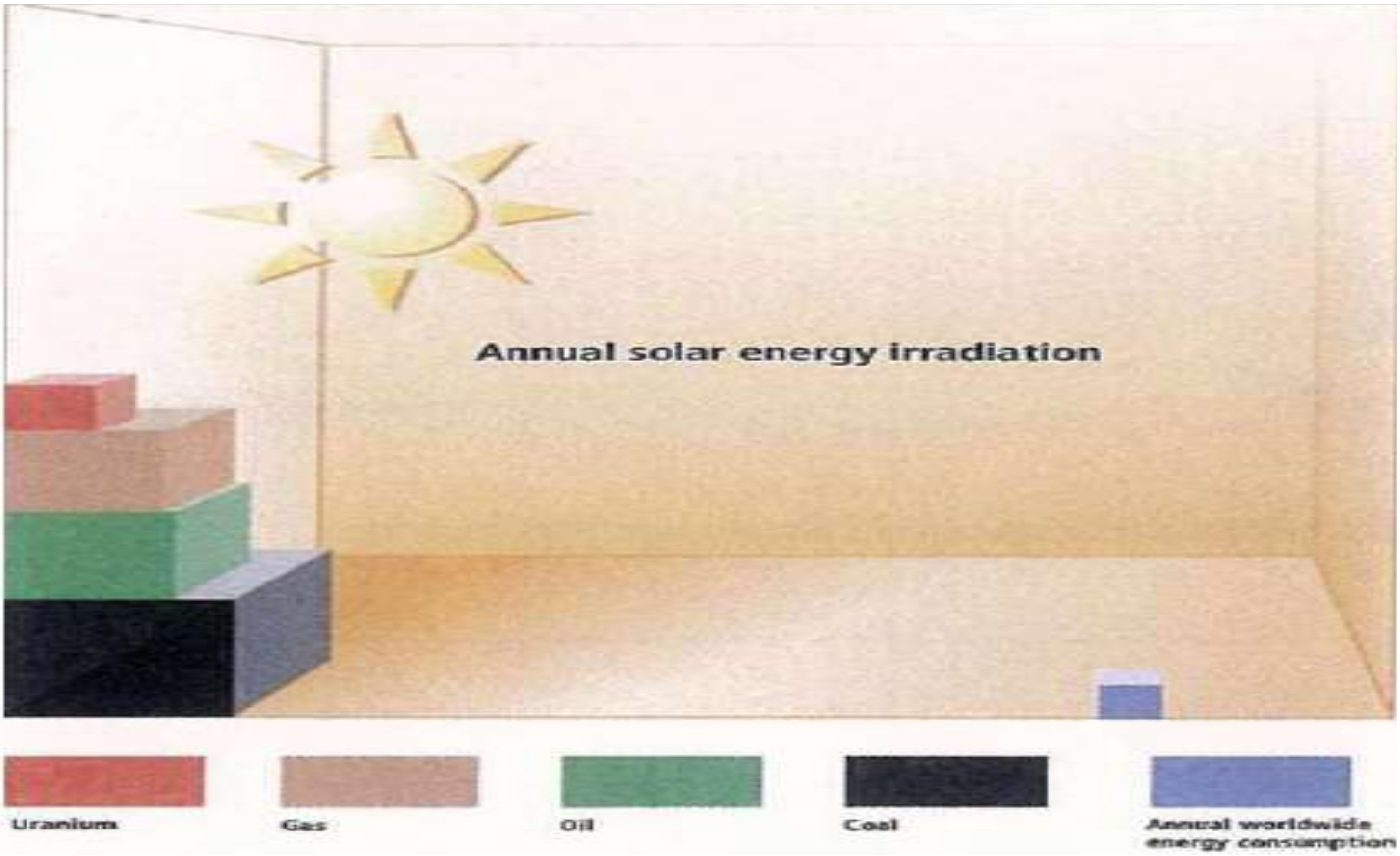
Ahmed M. Mahmoud , Salah M. Saafan , Ahmed M. Atallah, Hamdy El-goharey "Enhancement of the rooftop Photovoltaic array characteristic interconnected by the grid under partial shading condition by using cascaded DC/DC converter", International Journal of Power Systems, Volume 3, 2018, PP.42-52.

Ahmed M. Mahmoud , Salah M. Saafan , Ahmed M. Atallah, Hamdy El-goharey "Reconfiguration technique for Optimization of the Photovoltaic array output power under partial shading conditions", Trends in renewable energy,Vol. 4,Issue 2, June 2018,PP.111-124.

Chapter 1

Introduction

Photovoltaic (PV) is considered an alternative Energy source that produce electricity without burning the fuel or establishment nuclear fission reaction. Photovoltaic energy can supply the electricity to the rural areas and some areas where there some difficult geographic places. Photovoltaic Energy reduces influence of global warming and decreases harmful gases emission that produced from burning of the fuel. Photovoltaic array will help the electrical utility to satisfy its peak load on rush hour. Irradiation is a form of sun energy that is incredibly vital for the life on the world. This energy made in the sun's overturn due to hydrogen atoms fusion through helium. Only two millions of the sun radiation produces electrical energy equal to



10^{18} kWh/year.

Figure 1.1 Energy content of annual solar radiation reaches to the earth in comparison to the worldwide energy consumption and fossil and nuclear energy resource *[1]*.

The solar energy arrived to the earth appreciated 10,000 times the world's energy demand. Figure 1.1 compared the annual demand of world wide's energy exhaustion to various energy resources.

The rapidly expanding application and demand for the alternative energy resources have recently increased. Photovoltaic (PV) cell are progressively becoming more popular [2, 3] due to the availability, cleanness of the sun energy, it is considered a free fuel for the PV array, and the modern technology laid to decreasing the charge of photovoltaic cell. Egypt has a high annual average of irradiance between 2000 to 3200 kWh/m^2/year and the average brightness of the sun in Egypt between 9-11 hours/day [4].The government proceeds toward increasing the PV farms establishment to exploit high solar irradiance. The Egyptian government also issued a new electricity law that allow the consumer to generate electricity from the PV array and sell excess of the generated electricity to unity network[5] .After gradually removing of the governmental subsidies on the price of the electricity; It becomes more economical for consumer/investors to produce electricity. The consumer/investor can also sell surplus energy to the unity network.

1.1.1 Distribution of solar radiation in the world and in Egypt

The intensity of the solar radiation reach to Earth's atmosphere depends on the distance from the sun to the Earth which varies between $1.47*10^8$ Km to $1.52*10^8$Km. So, the solar radiation fluctuates between 1325 W/m^2 to 1412 W/m^2 depending up on the region. Figure 1.2 shows the annual global irradiation in kWh/m^2 and this value varies depending on the region. Some region at the equator reaches value in excess to 2300 kWh/m^2, where some region in southern Europe received 1700 kWh/m^2 and Germany gets an average of 1040 kWh/m^2 [6]. The solar radiation in Egypt varies between 2000 and 3200 kWh/m^2 [4].