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# Design of Solar Power System

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**ABSTRACT**

*The population increase played a fundamental role in the use of energy to sustain the new civil life, and this led to high rates of environmental pollution through the emission of carbon dioxide and combustion products and its impact on climate change. Today, clean energy is one of the solutions that developed countries seek to reduce the emission of carbon dioxide and combustion products for industrial processes. It includes solar energy, wind energy, energy Hydroelectricity and nuclear energy.*

*During this paper, we review the calculation of solar power system as an important uses of renewable energy however the using of MatLab. Simulation to examine the best design of the solar system and provide good information for building of hybrid power system.*

## Introduction

Solar energy is a source of all types of energy except nuclear energy. Its presence is necessary for the continuation of life on Earth, and the energy it emits is almost stable, except for short intermittent periods when accidents occur. The amount of energy that the planet Earth receives is estimated at 174 petawatts, reflecting 30% of it. To space [1], solar energy is distributed between the amounts absorbed by the waters of seas and oceans and what is used by crops in photosynthesis and other things. It is possible to exploit the solar radiation falling on the Earth's surface to generate electrical energy. This is done in two direct paths, using photovoltaic panels, or by concentrating the sunlight using mirrors or lenses to focus a large area of sunlight on a small area. [6] It is possible to exploit less than 1% of the energy that falls on the ground to supply electrical energy for all life’s needs. Despite the advantages of the solar source, there are negative factors that prevent the establishment of stations with large capacities, as they require vast areas and constant maintenance in addition to being variable according to time.

**Factors that can influence the land requirements include:**

1-Panel efficiency: Higher efficiency solar panels generate more electricity per unit area, potentially reducing the amount of land needed.

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2-Type of solar mounting system: The choice between fixed-tilt or tracking systems will impact the spacing requirements between solar panels. Tracking systems typically require more space as they need to avoid shading each other as they follow the sun's path across the sky.

3-Spacing between rows: To minimize shading and improve airflow, rows of solar panels need to be spaced appropriately. More spacing might be needed in regions with lower sun angles or to accommodate maintenance and cleaning equipment.

4-Terrain and site characteristics: The land's topography, soil type, and environmental constraints, such as floodplains or protected habitats, will also influence the amount of usable space within a given area.

5-Additional infrastructure: The space needed for access roads, electrical equipment, inverters, transformers, and substations, as well as any buffer zones or setbacks required by local regulations.

Before planning a solar farm, it's essential to perform a detailed site analysis, consider local permitting requirements, and consult with an experienced solar project developer to obtain a more accurate estimate of the land area needed for our specific project.

**Calculating Array Size:**

A formula is available for calculating the size of the solar PV array. The variables are electrical energy usage, peak sun-hours (PSH), and system derate factors. The first step is to determine the average daily solar PV production in kilowatt-hours. This amount is found by taking the owner's annual energy usage and dividing the value by 365 to arrive at an average daily use. This will tell us how much energy we will need on a daily basis. To calculate the array size needed to offset annual energy consumption, divide the annual kWh consumption by 365. The result is the average daily consumption in kWh. Divide this amount by average daily peak sun hours (PSH) to get approximate array size in kW. Divide this amount by the system's efficiency derate factor [2]

$$\begin{aligned} &\textit{the array size needed to offset annual cosumption} \\ &\quad = \textit{the annual } (kWh) \textit{ consuption by } 250 \textit{ day} \\ &\quad \div \textit{Avg. peak sun hours per day} \div \textit{Temperature losses}(0.88) \\ &\quad \div \textit{Inverter efficiency}(0.96) \\ &\quad \div \textit{General system derate factor}(0.774) \qquad \ldots\ldots..(1) \end{aligned}$$

The next step is to determine the amount of solar PV energy which can be produced from a specific space (location). a general rule is one kilowatt (1 kW) of solar PV module will fit in 100 square feet (9.3 $m^2$) of space, or 10 watts per square foot(0.093 $m^2$).

**Solar Module Selection:**

Once the size of the array has been selected, determining the number of solar modules needed to produce the power is the next step. Modules are marketed by the amount of power (in watts) produced. The larger the amount of watts per module, the fewer the modules required.

**Inverter Sizing:**

The next step in grid-connected system sizing is determining the size of the inverter. The role of the inverter is to convert DC electricity produced by the solar array to AC electricity used by the residence. Selection of the inverter is based on: PV array capacity the inverter can handle (in watts), output voltage, and the DC input voltage range. An inverter has a DC input voltage window. The goal is to design a system where the DC voltage produced remains within the voltage range.

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**Methodology:**

Our study to dealing with small factory to replace 25% of the required electric power from the national grid to solar power energy.

The small factory is Maysan company for paper production located at Maysan Provence at the east of Iraq, it consumed 20 MW of electric power, so our work to design 5MW solar power system.

Maysan company for Paper production (25 km south of the city of Amara, N $31^{0}$ 38′ 19.36″, E $47^{0}$ 11′ 31.01″ ) was established in 1979 by a German company to produce paper of various types based on cane plant, which is abundant in the region.

The annual energy consumption of the factory is 5 MW for 2000h (250 working days) [3].

= 5000000W * 2000h /year

= 10GWh/year

The daily energy consumption

= 10GWh/250 day = 40 MWh/day

The average peak sun hours per day =8 h

Temperature losses =0.88

Inverter efficiency = 0.96

General system derate factor =0.774

Substitution in eq.(1) we can find the array size, as follow:

The array size = 10 GWh/year ÷ 250 day /year ÷ 8h/day ÷ 0.88 ÷ 0.96 ÷ 0.774

= 7.6 MW

To produce 7.6 MW power capacity in the PV system, a series and parallel of PV module will be used. Our design consists of 5 Series-connected modules per string, we will choose the module Sun Power SPR 445 NJ-WHT-D [4], to calculate the number of parallel strings:

Maximum Power (w): 444.86

Cell per Module (Ncell): 128

Voltage at maximum power point $V_{mp}$ (V): 76.7

Current at maximum power point Imp (A): 5.8

Length (mm): 2067.0

Width (mm): 1046.0

Module area ($m^2$): 2.16

$V_o = 5 * V_{mp} = 5*76.7(V)$

=383.5 V

P = V*I= 5*76.7(V)*5.8(A)*(parallel string)

7600000= 5*76.7*5.8*(parallel string)

Parallel String No.=3417

The total number of the module = 5*3417= 17085

The parallel and series connection will be as in fig(1).

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The required area for the PV array is the area of one module multiply by the total number of the modules plus 20%.

Total Required Area= 2.16 $m^2$* 17058 *1.2

= 44500 $m^2$

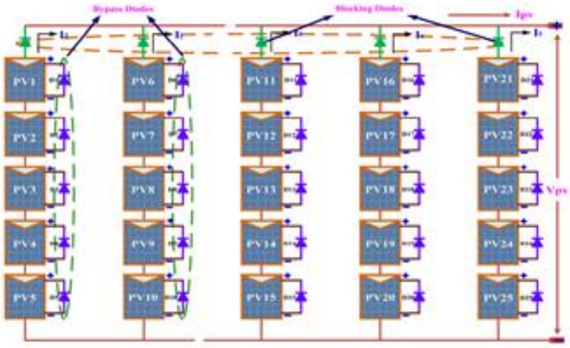


**Fig (1) the series –parallel connection of the PV array[5]**

➢ PV MATLAB

To design the 7.6MW PV MATLAB. Simulation we will evaluate the inductance, capacitance and resistance for the equivalent circuit for our efficient PV array 3417 parallel string ,5 series per string, the module Sun Power SPR 445 NJ-WHT-D, the main component of the simulation:

- ✓ PV solar array (Number of series and parallel module).
- ✓ PV solar converter (Boost converter).
- ✓ T-he controller (MPPT).

*Design specifications of the PV solar System:*

The main important electrical parameter of our system is:

Input Voltage $V_{in}$ = 383.5 V

Output Voltage $V_o$ = 600 V

Rated Power =7600000 W

Switching Frequency $f_s$ = 10kHz

Voltage ripple (ΔV) = 1%

Current ripple (ΔI) =1%

**1. Design Photovoltaic array**

To produce high power capacity in the PV system , a series and parallel combination a PV module will be used.

The Sun Power SPR 445 NJ-WHT-D will be used in this work. This module has the specifications as presented in table(1)

**Tab. (1) the specification of Sun Power SPR 445 NJ-WHT-D**

| | |
|---|---|
| STC Power Rating $P_{mp}$ (W) | 444.86 |
| Open Circuit Voltage $V_{oc}$ (V) | 90.5 |
| Short Circuit Current $I_{sc}$ (A) | 6.21 |
| Voltage at Maximum Power $V_{mp}$ (V) | 76.7 |
| Current at Maximum Power $I_{mp}$ (A) | 5.8 |

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To produce 7600000 W power capacity, 3417 series and 5 parallel module will be required

Rated Power (PV array) = P= 3417 * 5* Pmp= 3417*5*444.86 = 7600433=7.6 MW

Input Voltage (PV array) $V_{in}$ = Vmp *Number of series module =76.7*5=383.5 V

2. Design the PV Solar Converter (Boost converter)

To evaluate the inductance and capacitance of the equivalent circuit:

$$Output\ current\ = I_o = \frac{P}{V_o} = \frac{7600433W}{600V} = 12666A$$

$$current\ ripple\ = \Delta I = 0.01 * I_o * \frac{V_o}{V_{in}} = 0.01 * 12666A * \frac{600V}{383.5V} = 198A$$

$$Voltage\ ripple\ = \Delta V_o = 0.01 * V_o = 0.01 * 600V = 6V$$

$$Inductance\ = L = \frac{V_{in}(V_o - V_{in})}{\Delta I * f_s * V_o} = \frac{383.5V(600V - 383.5V)}{198A * 10000Hz * 600V} = 7.0032e - 06\ H$$

$$Capacitor\ = C = \frac{I_o(V_o - V_{in})}{\Delta V_o * f_s * V_o} = \frac{12666A(600V - 383.5V)}{6V * 10000Hz * 600V} = 0.0741\ F$$

$$Resistance = R = \frac{V_o}{I_o} = \frac{600V}{12666A} = 0.047\ \Omega$$

So will build our PV array system according above information, first of all we examine the output of the PV array for 1000W/m$^2$, 500 W/m$^2$ and 100 W/m$^2$ , for 25 and 45 C$^0$ and examine the behavior of solar power production by PV array through deferent mode as in fig (2)

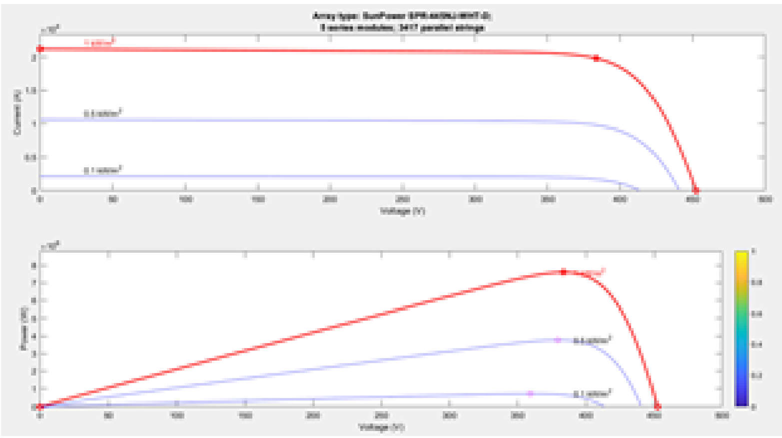

**Fig (2) the output of the PV array system**

The final system design for the Matlab simulation of the equivalent circuit will be as fig (3).

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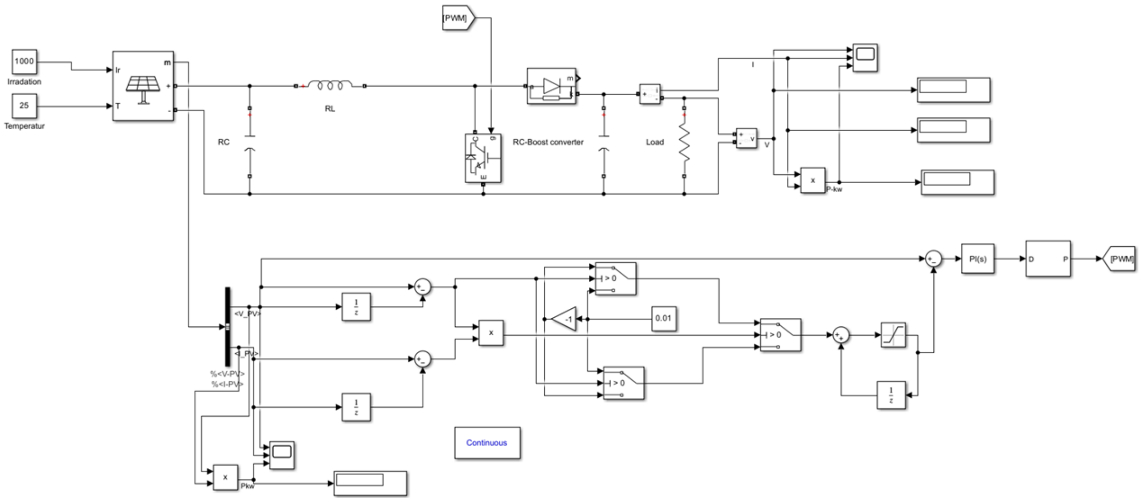


**Fig (3) the Matlab simulation of the PV array**

The running of the simulation and monitoring through the display and oscilloscope as fig(4)

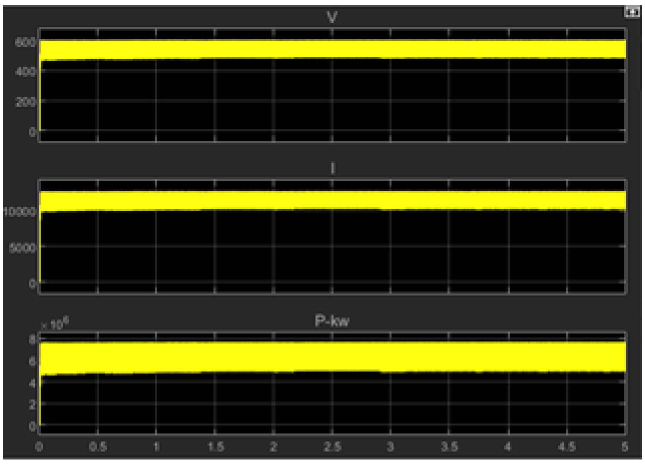


**Fig (4) PV output Voltage, Current and Power**

The simulation examine different range of irradiation and different range of temperature1000, 500, 100W/m$^2$@25C$^0$, tab. (2) and 1000,500.100W/m$^2$@45C$^0$, tab. (3)

**Tab (2) PV array output for 1000,500,100@25C$^0$**

| Irradiation W/m$^2$ | Output Voltage V | Output current A | Power W |
|---|---|---|---|
| 1000@25 | 602 | 12710 | 7.66E6 |
| 500@25 | 388.6 | 8199 | 3.186E6 |
| 100@25 | 100 | 2110 | 2.111E5 |

**Tab (3) PV array output for 1000,500,100@45 C$^0$**

| Irradiation W/m$^2$ | Output Voltage V | Output current A | Power W |
|---|---|---|---|
| 1000@45 | 570 | 12030 | 6.684E6 |
| 500@45 | 373 | 7873 | 2.96E6 |
| 100@45 | 100 | 2116 | 2.122E5 |

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The increasing temperature from 25 to 45 C causing decreasing the power about 13% but still efficient to providing a good alternative clean energy.

**Conclusion:**

The population increase played a fundamental role in the use of energy to sustain the new civil life, and this led to high rates of environmental pollution through the emission of carbon dioxide and combustion products and its impact on climate change. Today, clean energy is one of the solutions that developed countries seek to reduce the emission of carbon dioxide and combustion products for industrial processes. It includes solar energy, wind energy, energy Hydroelectricity and nuclear energy.

During this study, we review the most important uses of renewable energy and their application in maintaining a clean environment free of pollutants, in addition we work on case study for build efficient PV solar power system to feed small factory in Iraq and study.

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