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Solar Power Optimization

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Abstract--- An adequate supply of electricity is critical to the functioning of modern societies. To meet the electrical needs of an expanding global population it is of vital importance to incorporate solar energy as a source of electrical production. In a solar photovoltaic power system the solar light energy is directly converted into electrical energy. In this project solar power is generated from the solar PV array. The obtained dc power is controlled and stored in battery. This stored dc power is given to the dc load. This project monitors the voltage and current of the PV system. There is a single axis tracker to position the solar panel in correct position to obtain maximum power from the solar panel. A maximum power point tracker circuit is introduced along with the battery charging circuit to optimize the power from the V-I curve. The MPPT circuit tracks the maximum power at the knee of the V-I curve.

Key Words: Maximum power point tracking, PV array.

I. INTRODUCTION

Renewable energy sources play an important role in electric power generation. Many renewable energy technologies today are well developed, reliable, and cost competitive with the conventional fuel generators. The cost of renewable energy technologies is on a falling trend and is expected to fall further as demand and production increases.

There are many renewable energy sources (RES) such as biomass, solar, wind, mini hydro and tidal power. However, solar and wind energy systems make use of advanced power electronics technologies. In comparison to the non-renewable energies such as coal, gasoline and oil, solar power is becoming increasingly popular as an environment friendly renewable energy source that produces no pollution and requires minimal maintenance. Furthermore, the energy from the sun is free. It also has the advantage of reducing the power losses when converting the energy. Solar Energy is a good choice for electric power generation. Solar energy is directly converted into electrical energy by solar photovoltaic module.

Today, the solar energy covers only 0.5% of the world’s energy consumption, but will become one of the most important renewable energy sources in the future. In 2050, it has been estimated that about 30 to 60Terawatt energy per year being needed and solar system is the biggest contributor.

The major problem with solar panel technology is that the efficiencies for solar power systems are still poor and the costs per kilo-watt-hour (kwh). This system has two major disadvantages, which include the law conversion efficiency of electric power generation (9 to 16%), especially under low irradiation conditions and the amount of electric power generated by solar array changes continuously with the weather conditions. Solar cell is a non-linear device and it changes with the solar irradiation and temperature. Solar panels themselves are quite inefficient (approximately 30%) in their ability to convert sunlight to energy. However, the charge controllers and other devices that make up the solar power system are also somewhat inefficient and costly. To overcome this problem, maximum power point tracking (MPPT) technique will be used. Basically optimized photovoltaic array design is chosen using the software PVsyst V5.21 (Demo mode). The optimized solar panel design itself will produce optimized power output amongst the other panel materials.

II. BLOCK DIAGRAM

To obtain maximum power from the array, the output of the array is given to the maximum power point tracker circuit. When the maximum power of the circuit is traced, it can be given to the rest of the circuit. The maximum power is given to the inverter circuit. The obtained ac power from the inverter is given to the power grid. And then the ac supply is given to the three phase ac load. A part of the dc obtained power is given to a battery charging circuit. The battery charging circuit is nothing but the dc-dc converter or the chopper. Boost converter can be used to obtain maximum dc power.

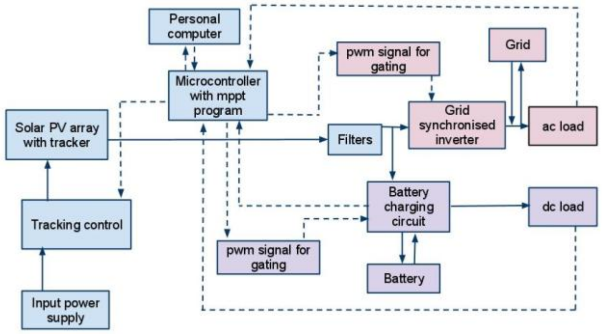

Fig. 1. Block Diagram

But buck boost converter is preferable. It is because at the time of charging or discharging, corresponding suitable operation can be done using buck boost converter.

IV. CHARACTERISTICS CURVES

The characteristic curves are drawn for the voltage-current parameters and for power-voltage parameters. The curves given below are the ideal characteristic curves of KC200GT model solar panel. These curves belong to optimized design of the high efficiency multicrystal photovoltaic module plotted using PVsyst V5.21 software.

A. Voltage-current (V-I) curve

Curves are plotted between the voltage on the X axis and current on the Y axis. By these curve we can find out the maximum power at maximum current and voltage.

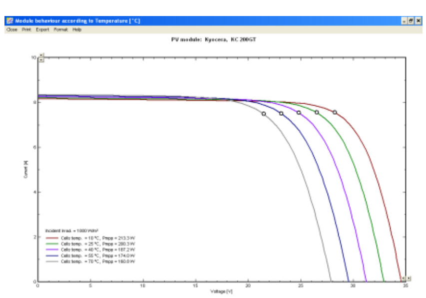

Fig. 2. Effects of Temperature on V-I Curve

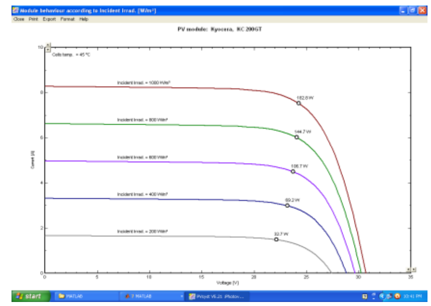

Fig. 3. Effects of Insolation on V-I Curve

B. Power-voltage (P-V) curve

Curves are plotted between the power on the X axis and voltage on the Y axis. By these curves we can find out the maximum power at maximum voltage.

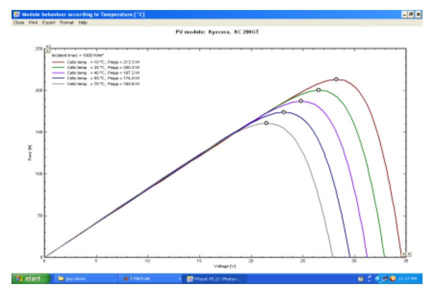

Fig. 4. Effects of Temperature on P-V Curve

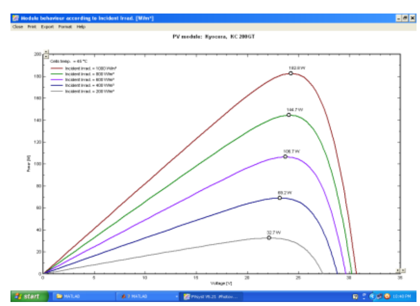

Fig. 5. Effects of Insolation on P-V Curve

At the short circuit current point, the power output is zero, since the voltage is zero. At the open circuit voltage point, the power output is also zero, but this time it is because the current is zero.

In the hardware circuit a suitable maximum power position tracking system is chosen. The tracking system can be single axis tracking for simplicity.

V. MATHEMATICAL MODELING

Table 1. Parameters of the KC200GT Solar Array

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I_{mp}	7.61 A
V_{mp}	26.3 V
$P_{max,e}$	200.143 W
I_{sc}	8.21 A
V_{oc}	32.9 V
K_V	-0.123 V/K
K_I	0.0032 A/K
N_s	54
$I_{o,n}$	9.825*e^{-8} A
I_{pv}	8.214 A
A	1.3
R_p	415.405 ohm
R_s	0.221 ohm

$$I_{ph} = I_L - I_d$$
(1)

Where I_{ph}= photon generated current
I_L=Load current
I_d=diode current

$$I_d = I_o\left[e^{\left(\frac{Vq}{k/T}\right)} - 1\right]$$
(2)

Where I_o=reverse saturation current of the diode
V= forward voltage V
q =charge C
k =Boltzman constant
T= temperature K

$$I_{ph} = GI_{sc}$$
(3)

Where Isc is the_short-circuit current of the module at 1000 W/m2
G=present insolation/1000

$$AmpHoursVoltage = Power * Hours * Days \quad (4)$$

Where Power (Watts) – The expected load to be run
Hours – The amount of hours to be run per day
Days – The amount of days to last with no re-charging
Voltage – The system's voltage 24V DC

The basic equation from the theory of semiconductors that mathematically describes the I–V characteristic of the ideal PV cell is

$$I = I_{pv,cell} - I_{o,cell}\left[e^{\left(\frac{Vq}{akT}\right)} - 1\right]$$
(5)

$$I_d = I_{o,cell}\left[e^{\left(\frac{Vq}{akT}\right)} - 1\right]$$
(6)

Where I_d is the Shockley diode equation
$I_{0,cell}$ is the reverse saturation current of the diode
q is the electron charge (1.60217646 × 10^{-19} C)
k is the Boltzmann const (1.3806503 × 10^{-23} J/K)
T(in Kelvin) is the temperature of the p–n junction
a is the diode ideality constant
$I_{pv,cell}$ is the current generated by the incident light (it is directly proportional to the Sun irradiation)

The basic equation of the elementary PV cell does not represent the I–V characteristic of a practical PV array. Practical arrays are composed of several connected PV cells and the observation of the characteristics at the terminals of the PV array requires the inclusion of additional parameters to the basic equation.

$$I = I_{pv} - I_o\left[e^{\left(\frac{V+R_sI}{aV_t}\right)} - 1\right] - \frac{(V + R_sI)}{R_p}$$
(7)

$$V_t = \frac{N_s kT}{q}$$
(8)

Where V_t is the thermal voltage of the array with N_s cells connected in series.

Cells connected in parallel increase the current and cells connected in series provide greater output voltages. If the array is composed of N_p parallel connections of cells the PV and saturation currents may be expressed as

$$I_{pv} = I_{pv,cell} * N_p$$
(9)

$$I_o = I_{o,cell} * N_p$$
(10)

The light-generated current of the PV cell depends linearly on the solar irradiation and is also influenced by the temperature.

$$I_{pv} = \frac{\left(I_{pv,n} + K_I \Delta T\right) G}{G_n}$$

(11)

$$\Delta T = T - T_n$$

(12)

Where $I_{pv,n}$ (in amperes) is the light-generated current at the nominal condition.

T and T_n being actual and nominal temperatures.

G is the irradiation on the device surface.

G_n is the nominal irradiation.

$$I_o = I_{o,n} \left(\frac{T_n}{T}\right)^3 e^{\left[\frac{qEg}{ak}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right]}$$

(13)

Where $I_{0,n}$ is the nominal saturation current

E_g is the bandgap energy of the semiconductor (Eg =1.12 eV for the polycrystalline Si at 25 °C)

$$I_{o,n} = \frac{I_{sc,n}}{e^{\left(\frac{V_{oc,n}}{aV_{t,n}}\right)} - 1}$$

(14)

Where $V_{t,n}$ being the thermal voltage of N_s series-connected cells at the nominal temperature T_n.

$$I_o = \frac{I_{sc,n} + K_I \Delta T}{e^{\left(\frac{V_{oc,n} + KV\Delta T}{aV_t}\right)} - 1}$$

(15)

This is the modified equation which aims to match the open-circuit voltages of the model with the experimental data for a very large range of temperatures. The saturation current I_0 is strongly dependent on the temperature and this equation simplifies the model and cancels the model error at the vicinities of the open-circuit voltages, and consequently, at other regions of the I–V curve.

$$P_{max,m} = P_{max,e} = V_{mp} I_{mp}$$

(16)

At the (V_{mp}, I_{mp}) point of the I–V curve, i.e., the maximum power calculated by the I–V model of ($P_{max,m}$) is equal to the maximum experimental power from the datasheet ($P_{max,e}$) at the MPP. The relation between R_s and R_p, may be found by making $P_{max,m}$ = $P_{max,e}$ and solving the resulting equation for R_s, as shown.

$$P_{max,m} = V_{mp} \left\{ I_{pv} - I_o \left[e^{\left(\frac{q\left(V_{mp} + R_s I_{mp}\right)}{kaTN_s}\right)} - 1 \right] - \frac{\left(V_{mp} + R_s I_{mp}\right)}{R_p} \right\} = P_{max,e} \quad (17)$$

$$R_p = \frac{V_{mp}\left(V_{mp} + I_{mp} R_s\right)}{\left\{ V_{mp} I_{mp} - V_{mp} I_o e^{\left(\frac{q\left(V_{mp} + I_{mp} R_s\right)}{N_s kaT}\right)} + V_{mp} I_o - P_{max,e} \right\}} \quad (18)$$

Which means that for any value of Rs there will be a value of R_p that makes the mathematical I–V curve cross the experimental (V_{mp}, I_{mp}) point.

$$I = f\left(V, I\right) \text{ and } V = f\left(I, V\right)$$

(19)

The I–V points are easily obtained by numerically solving

$$g\left(V, I\right) = I - f\left(V, I\right) = 0$$

(20)

$$I_{pv,n} = I_{sc,n} \frac{R_p + R_s}{R_p}$$

(21)

This Equation uses the resistances R_s and R_p to determine I_{pv}=I_{sc}. The values of R_s and R_p are initially unknown but as the solution of the algorithm is refined along successive iterations the values of R_s and R_p tend to the best solution and $I_{pv,n}$ becomes valid and effectively determines the light-generated current I_{pv} taking in account the influence of the series and parallel resistances of the array. Initial guesses for R_s and R_p are necessary before the iterative process starts. The initial value of

R_s may be zero. The initial value of R_p may be given by

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$$R_{p,\min} = \frac{V_{mp}}{I_{sc,n} - I_{mp}} - \frac{V_{oc,n} - V_{mp}}{I_{mp}}$$

(22)

$$I_m = I_{pv} - I_o\left[e^{\left(\frac{V+R_s I}{aV_t}\right)} - 1\right]$$

(23)

Determines the minimum value of R_p, which is the slope of the line segment between short-circuit and maximum-power remarkable points. Although R_p is still unknown, it surely is greater than $R_{p,\min}$ and this is a good initial guess.

VI. SIMULATION

A. Complete Simulation

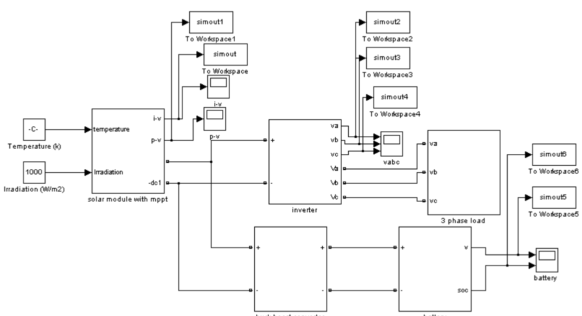

Fig. 6. Complete Simulation

The constant values of temperature and irradiance are given as input to the solar module. And the generated dc output voltage is given to the inverter. The inverted output is given to the three phase load. The generated dc voltage is also given to the dc-dc chopper and it is fed to the battery.

B. Solar PV module with MPPT circuit

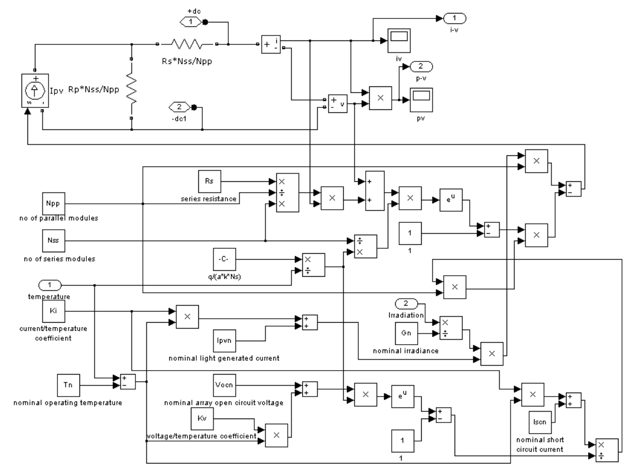

Fig. 7. Solar PV Module with MPPT Circuit

The solar equivalent circuit is used instead of the solar cells. The power output of the solar equivalent circuit is controlled by the MPPT circuit. I_m is the control signal to the equivalent circuit. The photovoltaic current is found by suitably varying the values of series and parallel resistances. The difference of photovoltaic current and the output current gives the model current.

C. Inverter circuit

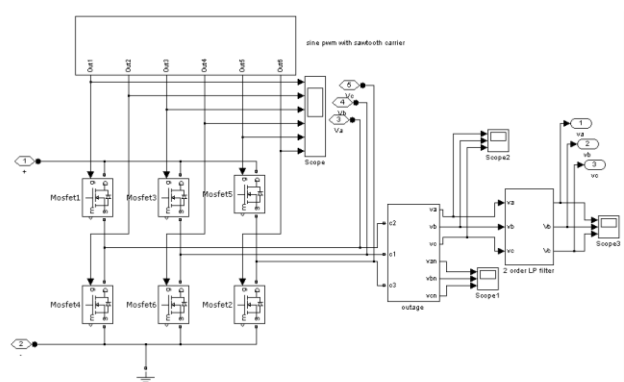

Fig. 8. Inverter Circuit

This is a three phase inverter. Power MOSFET's are used as switches. The obtained ac output is tapped out through the centre taps of the switches. This ac voltage is given to the second order low pass filter where the harmonics are removed and the output is given to grid as well as load.

Here the sine wave is used to control the gating signal. The sawtooth signal is used as the carrier signal. The PWM technique is adopted to generate the gating signal. The filter circuit has a capacitor branch along with other filters. It contains fifth and seventh order harmonic tuned filters. There is also a high pass damped filter for better harmonic reduction.

D. DC-DC converter

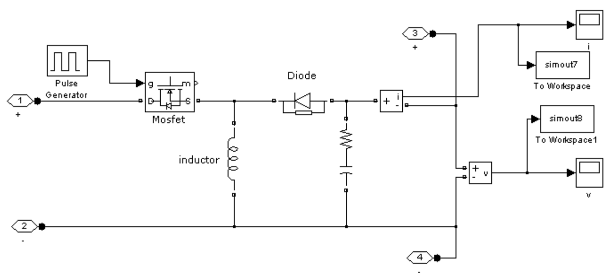

Fig. 9. DC-DC Converter

Here the buck-boost chopper is used as the dc-dc converter. And power MOSFET is used for switching. The control of the switch is through a pulse generator.

E. Battery

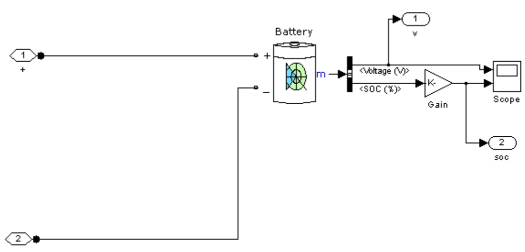

Fig. 10. Battery

The chopped dc output is given to the battery. From the battery the state of charge and voltage are monitored.

VII. RESULTS

A. V-I characteristics

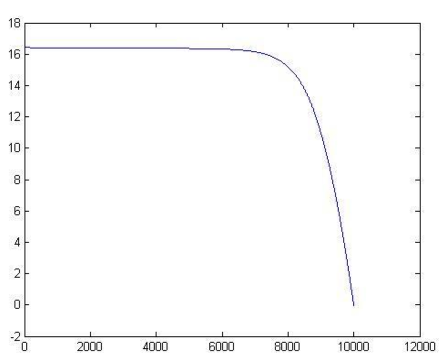

Fig. 11. V-I Characteristics

The graph gives the V-I characteristics of the solar PV array. The x-axis takes the value of current and y-axis takes the value of voltage.

B. P-V characteristics

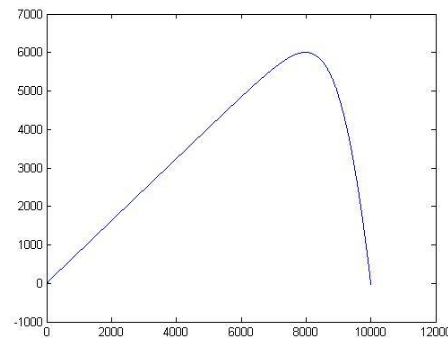

Fig. 12. P-V Characteristics

The graph gives the P-V characteristics of the solar PV array. The x-axis takes the value of voltage and y-axis takes the value of power.

C. Battery voltage

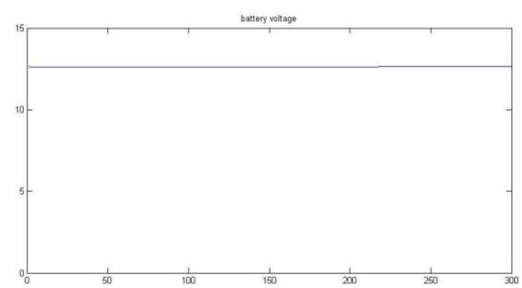

Fig. 13. Battery Voltage

The graph shows the characteristics of battery output voltage. The x-axis takes the value of time and y-axis takes the value of voltage. A constant voltage is obtained as output.

D. Battery state of charge

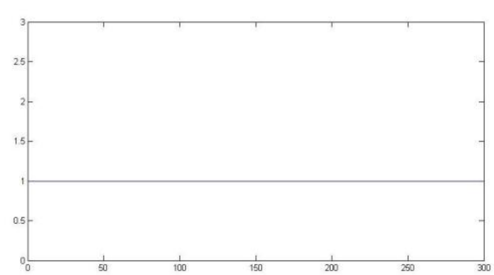

Fig. 14. Battery State Of Charge

The graph shows the characteristics of state of charge of the battery. The x-axis takes the value of time and y-axis takes the value of SOC. The curve is straight line.

E. Three phase ac voltage

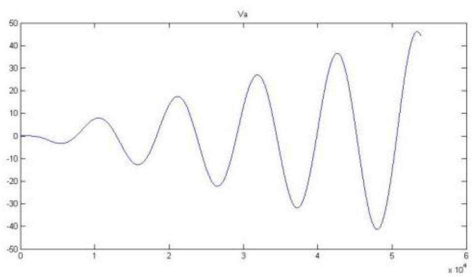

Fig. 15. V_a Voltage Curve

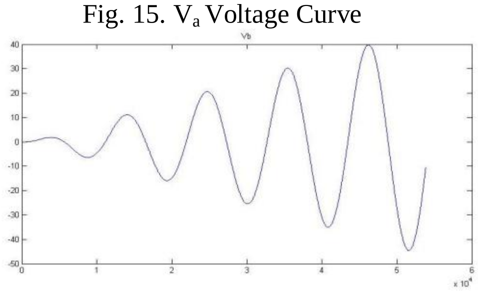

Fig. 16. V_b Voltage Curve

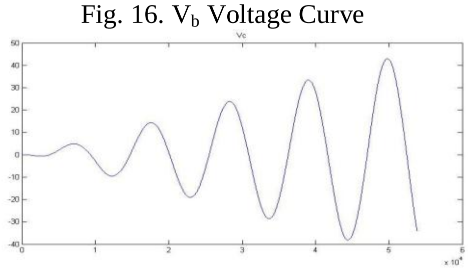

Fig. 17. V_c Voltage Curve

The graphs shows the characteristics of three phase ac voltage output. The x-axis takes the value of time and y-axis takes the value of V_a, V_b, V_c respectively.

VIII. CONCLUSION

Herewith the solar power optimization has been developed with the MATLAB SIMULINK software. In this project solar power is generated from the solar PV array. This project will provide maximum power from the solar panel to all the devices connected to it. The obtained dc power is controlled and stored in battery. The dc power is converted into ac power by the inverter and given to the load. A maximum power point tracker circuit optimizes the power from the solar array. This simulation circuit can be implemented in hardware along with tracker circuit to obtain optimized power.

REFERENCES

[1] Feel-Soon Kang, Sung-Jun Park, Su Eog Cho, Cheul -U Kim, and Toshifumi Ise, "Multilevel PWM Inverters Suitable for the Use of Stand-Alone Photovoltaic Power Systems", *IEEE Trans. Energy Convers.*, vol. 20, no. 4, pp. 906–915,Dec. 2005.

[2] Nobuyoshi Mutoh, Takayoshi Inoue, "A Control Method to Charge Series-Connected Ultraelectric Double-Layer Capacitors Suitable for Photovoltaic Generation Systems Combining MPPT Control Method", *IEEE Trans. Ind. Electron.*, vol.54, no. 1, pp. 374–383, Feb. 2007.

[3] Patricio Flores, Juan Dixon, Micah Ortúzar, Rodrigo Carmi, Pablo Barriuso, and Luis Morán, "Static Var Compensator and Active Power Filter With Power Injection Capability, Using 27-Level Inverters and Photovoltaic Cells", *IEEE Trans. Ind. Electron.*, vol.56, no. 1, pp. 130–138, Jan. 2009.

[4] Sergio Busquets-Monge, Joan Rocabert, Pedro Rodriguez, Salvador Alepuz and Josep Bordonau, "Multilevel Diode-Clamped Converter for Photovoltaic Generators with Independent Voltage Control of Each Solar Array", *IEEE Trans. Ind. Electron.*, vol.55, no.7, pp.2713–2723, Jul. 2008.

[5] Tsai-Fu Wu, Hung-Shou Nien, Chih-Lung Shen, and Tsung-Ming Chen, "A Single-Phase Inverter System for PV Power Injection and Active Power Filtering With Nonlinear Inductor Consideration", *IEEE Trans. Ind. Appli.*, vol.41, no.4, pp. 1075–1083, Jul/Aug. 2005.