

Control of Utility Grid Connected Solar Photovoltaic Array

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Abstract: The consumption of electricity generation by photovoltaic system has increase in daily purpose. The generation of photovoltaic system plant focus on the maximum profit of collect solar energy. In this paper we are control the renewable energy based solar photovoltaic system using MATLAB. The grid connected MATLAB model is studied under solar radiation and changing weather condition. In this we generate excess amount of electricity and send to the utility grid. Here we used MPPT technique which is implemented in DC-DC step up converter to permit P-V module to give power at maximum power point. The output of this converter is given to the 3-level inverter and it synchronized the utility grid.

Keywords: Solar Energy; Solar Photo-voltaic Array System; Maximum Power Point Technique; Voltage Source Converter; DC-DC Boost Converter; Grid.

I. Introduction

Tracking is the maximum power point of a photo-voltaic array is usually an essential part of the PV system. Due to the growing demand on electricity the limited stock and rising prices of conventional sources (such as coal and petroleum etc) photovoltaic (PV) energy becomes a alternative it is omnipresent freely available environment friendly, less operational and maintenance cost. Thus the demand of PV generation system has to be increased for standalone and grid connected modes of PV system Therefore an efficient maximum power point tracking technique is expected to track the MPP at all environmental condition and then force the PV system to operate at the MPP point. MPPT is an essential component of a PV system. Solar photovoltaic system are one of the fastest growing renewable energy generation system. The energy generated from PV system is depend on environmental factors such as solar irradiation, cloud coverage, wavelength, reflection and ambient temperature. These factors can negatively affect the PV cell conversion efficiency. PV energy system has some advantage such as pollution free, abundant availability, less maintenance. In solar photovoltaic system the optimum efficiency (which is 7-16%) second inverter efficiency (90-97%) and the efficiency of MPPT algorithm (over 98%). In photovoltaic system integrated to grid, the grid inverter is three inverter in this paper it is an important component which invert dc power which is obtain from P-V system array alternating power to synchronized voltage and frequency of connected utility grid. In this paper the major component are photovoltaic plant, consist of P-V array, MPPT unit, three level inverter, step-up converter and utility grid.

The function of PV array is to convert the solar irradiation which is comes from solar energy into dc power. The MPPT algorithm is also connected to the PV array which allow PV array P-V array to produce maximum power. The unidirectional power is obtained and then changed into ac power with the help of three level inverter and then this ac power is filter through LC filter and fed to utility grid .A boost converter is also to provide link between MPPT and inverter for boost purpose. In order to match inverter output current with the grid voltage and reduce the total harmonic distortion. The voltage source converter is used in this paper.

II. Review on MPPT Techniques

The following techniques are used in MPPT techniques applied on various PV applications such as solar vehicles, space satellite.

A) FRACTIONAL OPEN CIRCUIT VOLTAGE TECHNIQUE

In this technique, V_{mpp} can be calculated from the below relationship as follows.

$$V_{mpp} = K_{oc} \cdot V_{oc}$$

It is found that the value of K_{oc} varies between 0.78 and 0.92. K_{oc} can be calculated by analyzing the PV system ay wide range of solar radiation and temperature. In this method, the PV system is open circuited at load end for a fraction of second and V_{oc} is measured, then V_{mpp} is calculated. Repeating this process V_{oc} is sampled repeatedly in every few seconds and value of V_{mpp} is updated.

B) LOOK-UP TABLE TECHNIQUE

In this technique, MPP of a PV system is calculated before hand for each probable environmental condition and stored in the memory device of MPPT control system. During the operation, the corresponding MPP for a particular condition is selected from that memory and implemented.

C) FEEDBACK VOLTAGE OR CURRENT TECHNIQUE

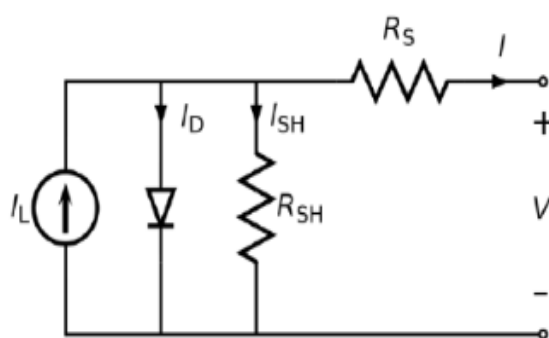
This technique is used in the system which has no battery. Without a battery, a simple controller is needed to fix the bus voltage at a constant level. In this method, the feedback of panel voltage is taken and compared with a pre-calculated reference voltage the duty ratio of dc/dc converter is continuously adjusted so that it operates close to that of MPP.

D) ESTIMATED-PERTURB-PERTURB TECHNIQUE

The EPP technique is an extended perturbation and observation method. This technique has one estimate mode between two perturb modes. The perturb process conducts the search over the highly nonlinear PV characteristic and the estimate process compensates for the perturb process for irradiances-changing condition. The technique is complex but its tracking speed is faster and more accurate than that of perturb and observe method.

3) MODEL OF P-V CELL

A simple ideal equivalent circuit model for cell obtain by the parallel combination of an ideal current source and real diode is shown in below



Fundamental circuit representation of solar cell

Where:

- I: Current of solar cell (A)
- Isc: Short circuit current (with assuming no series/ shunt resistance)
- ID : Saturation current of diode (A) q : Electron charge (1.6*10-19C) k : Boltzmann constant (1.38064*10-23J/Kelvin)
- T : Temperature in Kelvin (K)
- V : Output voltage of solar cell (V)
- Rs : Series resistance of solar cell(Ω)
- Rsh : Shunt resistance of solar cell (Ω)

In this paper, the parameter specification of PV module used is given in Table (I)

TABLE I. SPECIFICATIONS OF SUNPOWER SPR-305-WHT OF PV CELL

Parameters	Values
Voltage at peak power point (Vp)	54.70(V)
Current at peak power point (Ip)	5.580 (A)
Open circuit voltage (Vocv)	64.20(V)
Short-circuit current (Iscc)	5.960 (A)
Coefficient of Temp (Vocc)	0.177(V/deg.c)
Coefficient of Temp (Iscc)	0.003516(A/deg.C)
Coefficient of Temp (Vp)	-0.186 (V/deg.C)
Coefficient of Temp (Ip)	- 0.00212(A/deg.c)
Modules connected in series	5 (Nser)
Strings in parallel	50 (Npar)

4) BOOST/STEP-UP CONVERTER (DC TO DC)

Drawback of step-down/buck dc-dc converter is that when converter switch is on it transfer power from input to output but when converter switch is off zero output value across p-v module is obtain which gives the point of operation stay near the open circuit voltage which provide losses. Boost converter gives a dc output voltage which is more than the applied dc input voltage, filter which consisting of inductor and capacitor, is utilized to decrease ripple in dc output voltage and dc output current respectively and is connected at output terminal of the converter. The operating principle step-up/boost converter consists two different states of operation. x When switch is on that is switch is close, result an increase in current. x When switch is off that is open, result in reducing in inductor current.

5) CONTROLLER

It is consisting of two controller which is power controller and current controller. Power controller senses the grid voltage and current and provides the corresponding grid active and reactive power as per requirement of the circuit. Power controller also sense three level inverter output voltages and current and provide the active and reactive power respectively. The main purpose of current controller is to provide triggering pulse according to reference values.

6) PV CHARACTERISTIC

PV1 is a subsystem when double click on it subsystem mask will open. In this we can change the value of short circuit current, open circuit voltage current at Pmax voltage at Pmax. To view circuit inside in this block right click on the block select mask and look under mask. Now circuit inside the block will be displayed .In the first PV module (1) block actual P-V,I-V characteristic system is constructed. This output Vpv and Ppv is given at output.

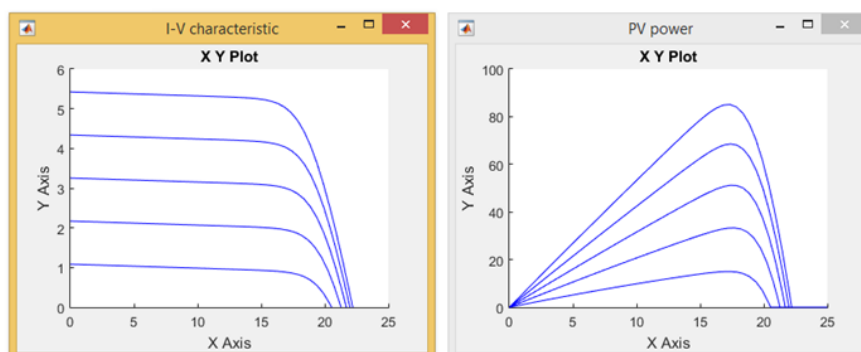


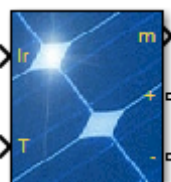
figure: PV characteristic

7) PV Array

Implement PV array modules

Library

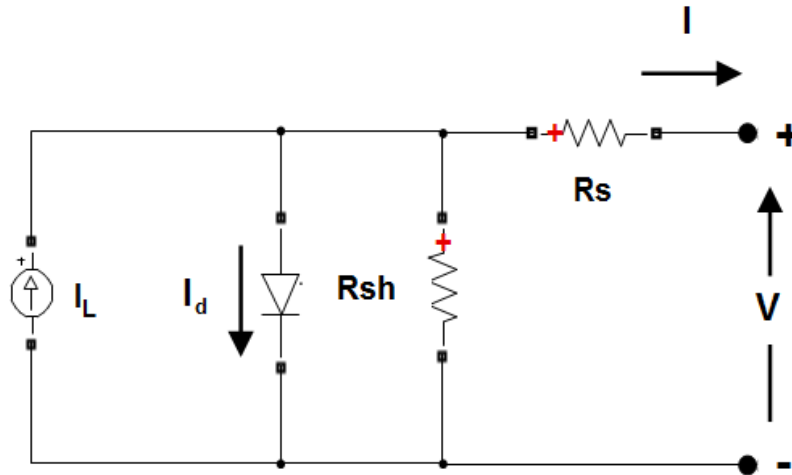
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Description

The PV Array block implements an array of photovoltaic (PV) modules. The array is built of strings of modules connected in parallel, each string consisting of modules connected in series. This block allows you to model preset PV modules from the National Renewable Energy Laboratory (NREL) System Advisor Model (Jan. 2014) as well as PV modules that you define.

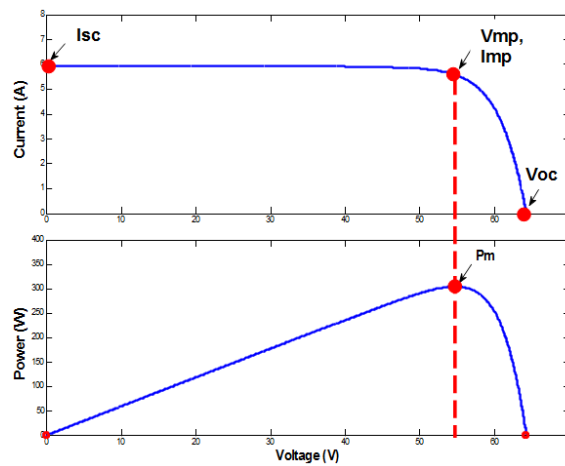
The PV Array block is a five parameter model using a current source I_L (light-generated current), diode (I_0 and nI parameters), series resistance R_s , and shunt resistance R_{sh} to represent the irradiance- and temperature-dependent I-V characteristics of the modules.



The diode I-V characteristics for a single module are defined by the equations

$$I_d = I_0 \left[\exp\left(\frac{V_d}{V_T}\right) - 1 \right]$$

$$V_T = \frac{kT}{q} \times nI \times N_{cell}$$



where:

I_d = diode current (A)

V_d = diode voltage (V)

I_0 = diode saturation current (A)

nI = diode ideality factor, a number close to 1.0

k = Boltzman constant = 1.3806×10^{-23} J.K⁻¹

q = electron charge = 1.6022×10^{-19} C

T = cell temperature (K)

N_{cell} = number of cells connected in series in a module

8) Parameters

- [Parameters Tab](#)
- [Advanced Tab](#)

Parameters Tab

Parallel strings

Number of strings of series-connected modules that are connected in parallel. The default value is 40.

Series-connected modules per string

Number of PV modules connected in series in each string. The default value is 10.

Module

Select User-defined or a preset PV module from the NREL System Advisory Model database. Over 10,000 modules are listed from main manufacturers, sorted in alphabetical order. The NREL database includes manufacturer datasheets measured under standard test conditions (STC) (irradiance=1000 W/m², temperature=25 degrees C).

When you select a module, this data from the NREL database updates when you apply your changes: Ncell, Voc, Isc, Vmp, Imp maximum power, as well as temperature coefficients of Voc and Isc. The function computes the five corresponding model parameters (IL, I0, nI, Rsh, Rs) using an optimization function and displays them on the right side of the dialog box.

When you select User-defined, you can enter your own specifications for the module data (Ncell, Voc, Isc, Vmp, Imp, and temperature coefficients of Voc and Isc). When you apply the changes, the function computes the five model parameters.

The default value is 1Soltech 1STH-215-P.

Maximum Power (W)

Power obtained at maximum power point (Vmp, Imp). Pmax is computed as $P_{max} = V_{mp} \times I_{mp}$. The default value is 213.15 W.

Cells per module (Ncell)

Number of cells per module. The default value is 60.

Open circuit voltage Voc (V)

Voltage obtained when array terminals are left open. The default value is 36.3 V.

Short-circuit current Isc (A)

Current obtained when array terminals are short circuited. The default value is 7.84 A.

Voltage at maximum power point Vmp (V)

Voltage at maximum power point. The default value is 29 V.

Current at maximum power point Imp (A)

Current at maximum power point. The default value is 7.35 A.

Temperature coefficient of Voc (%/deg.C)

Defines variation of Voc as a function of temperature. The open-circuit voltage at temperature T is obtained as $V_{ocT} = Voc (1 + beta_Voc(T-25))$,

where Voc is the open-circuit voltage at 25 degrees C, VocT is the open-circuit voltage at temperature T (in degrees C), beta_Voc is the temperature coefficient (in %/degrees C), and T is the temperature in degrees C.

The default value is -0.36099 %/deg.C.

Temperature coefficient of Isc (%/deg.C)

Defines variation of Isc as a function of temperature. The short-circuit current at temperature T is obtained as

$$I_{scT} = I_{sc} (1 + alpha_Isc(T-25)),$$

where Isc is the short-circuit current at 25 degrees C, IscT is the short-circuit current at temperature T (in degrees C), alpha_Isc is the temperature coefficient (in %/degrees C) and T is the temperature in degrees C.

The default value is 0.102 %/deg.C.

Display I-V and P-V characteristics of..

To display the I-V and P-V characteristics of one module or of the whole array, for variable irradiance or for variable temperatures, select an option:

one module @ 25 deg. C & specified irradiances

array @ 25 deg. C & specified irradiances

array @ 1000 W/m2 & specified temperatures

The selected characteristics display when you click **Plot**.
The default value is array @ 1000 W/m² & specified temperatures.

Irradiances (W/m²)

This parameter is available only if Display I-V and P-V characteristics of is set to one module @ 25 deg.C & specified irradiances or array @ 25 deg. C & specified irradiances. Enter a vector of irradiances in W/m². The default value is [1000 500 100].

T_{cell} (deg. C)

This parameter is available only if **Display I-V and P-V characteristics of** is set to array @ 1000 W/m² & specified temperatures. Enter a vector of temperatures in degrees C. The default value is [45 25] deg. C.

Light-generated current I_L (A)

Current for one module under STC, flowing out of the controllable current source that models the light-generated current. An optimization function determines this parameter to fit the module data. The default value is 7.8649 A.

Diode saturation current I_0 (A)

Saturation current of the diode modeling the PV array for one module under STC. An optimization function determines this parameter to fit the module data. The default value is 2.9259e-10 A.

Diode ideality factor

Ideality factor of the diode modeling the PV array. An optimization function determines this parameter to fit the module data. The default value is 0.98117.

Shunt resistance R_{sh} (ohms)

Shunt resistance of the model for one module under STC. An optimization function determines this parameter to fit the module data. The default value is 313.3991 Ω .

Series resistance R_s (ohms)

Series resistance of the model for one module under STC. An optimization function determines this parameter to fit the module data. The default value is 0.39383 Ω .

Advanced Tab

Break algebraic loop in internal model

By default this parameter is not selected. You then get an algebraic loop in the internal diode model, both in a continuous model or in a discrete model. If you use the block in a discrete system using large sample times, this algebraic loop is required to get an iterative, accurate solution for the highly nonlinear diode characteristics. For example, the PV array connected to an average model of power electronic converter runs with a sample time as large as 50e-6 sec, and Simulink[®] can solve the algebraic loop.

When the PV array block is connected to a detailed power electronic converter where real switches are simulated, you need to specify a small sample time to get accurate resolution in PWM pulse generation (for example, 1e-6 sec with a 5 kHz PWM inverter). In this case, to speed up simulation, select this parameter to break the algebraic loop.

When the model is discrete, break the algebraic loop by using a one-simulation-step time delay. This approach can cause numerical oscillations if the sample time is too large.

When the model is continuous, break the algebraic loop by using a first-order filter. The **Time constant (s)** parameter then becomes visible.

When the model uses an algebraic loop (i.e., the parameter is not selected), current and voltage measurement filters are used inside the continuous and the discrete model to help solve the algebraic loop. The **Measurement Filter Time constant (s)** parameter then becomes visible.

Time constant (s)

The filter time constant is visible in a continuous model only when **Break algebraic loop in internal model** is selected. The default value is 1e-6 sec.

Measurement Filter Time constant (s)

The measurement filter time constant is visible in both discrete and continuous model when **Break algebraic loop in internal model** is not selected. The default value is 5e-5 sec.

Inputs and Outputs

Ir

Connect to this input a Simulink signal representing varying sun irradiance in W/m².

T

Connect to this input a Simulink signal representing varying cell temperature in degrees C.

m

Simulink output vector containing five signals. You can select these signals using the Bus Selector block in the Simulink library.

Signal	Signal Name	Definition
1	V_PV	PV array voltage (V)
2	I_PV	PV array current (A)
3	I_diode	diode current (A)
4	Irradiance (W/m ²)	Irradiance (W/m ²)
5	Temperature (deg C)	Temperature (degrees C)

III. Conclusion

The PV module characteristic of a P-V system is shown in the above section. The P-V, I-V characteristic is shown above. The model explains solar P-V cell is the effect of physical environmental condition based on solar radiation and cell temperature. The voltage source controller is used to synchronize P-V cell plant, step-up converter and inverter with utility grid. The model is used a tool to forecast the nature of grid connected P-V plant under solar radiation and temperature change.

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