LAB # 07

Implementation of Maximum Power Point Tracking (MPPT) Algorithm Using MATLAB and Simulink

Objectives:
- To understand the working of Charge Controller
- To understand the algorithm of MPPT
- To learn how to track maximum power using MATLAB function
- To analyze different parameters of boost converter connected with PV array and with different value of irradiance
- To understand how to calculate the efficiency of MPPT algorithm

Components Required:
- PV Array
- Inductor
- Capacitors
- Constants
- MATLAB Function
- PWM Generator
- Repeating Sequence
- Goto, From Block
- IGBT (insulated Gate bipolar transistor)
- Diode
- Current Measurements, Voltage Measurements
- Scope
- Display

Related Theory:
The maximum power point (MPP) describes the point on a current voltage (I-V) curve at which the solar PV device generates the largest output i.e. where the product of current intensity (I) and voltage (V) is maximum.

The MPP may change due to external factors such as temperature, light conditions and workmanship of the device.

In order to ensure maximum power output (P_{max}) of a solar PV device in view of these external factors, maximum power output trackers (MPPT) may be operated to regulate the resistance of the device.
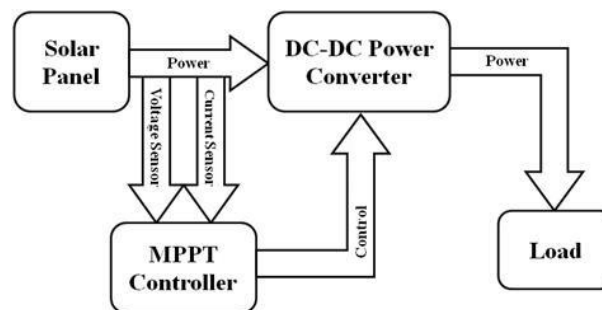
MPPT Charge Controller:

The MPPT charge controller ensures that the loads receive maximum current to be used (by quickly charging the battery). Maximum power point could be understood as an ideal voltage at which the maximum power is delivered to the loads, with minimum losses. Charge controllers manage interactions and energy flows between a PV array, battery, and electrical load. This is also commonly referred to as peak power voltage.
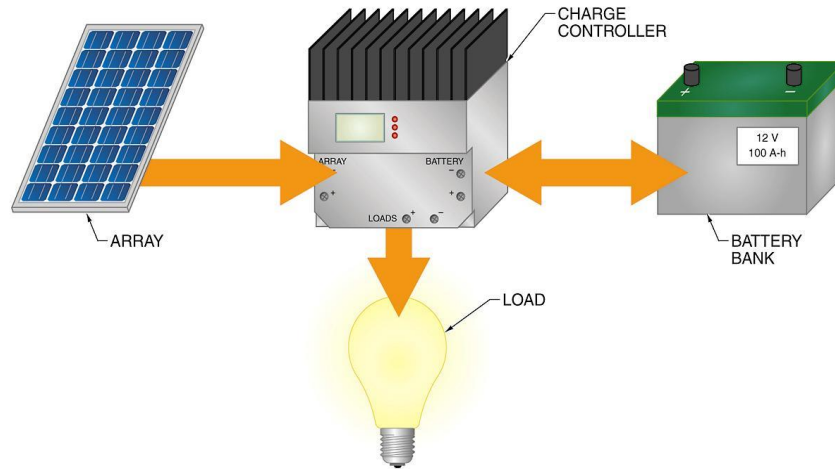

MPPT charge controllers working:

Anyone familiar with the charging and discharging characteristics of the battery is familiar to the fact that the voltage of the battery varies with its charge content.

As current flows from a high potential to low potential, the steeper the gradient or voltage difference, the greater is the flow of current.

This potential gradient could be made steeper by two ways:

• By increasing the output voltage of the Solar Panel
• By decreasing the voltage of the battery (discharging the battery)
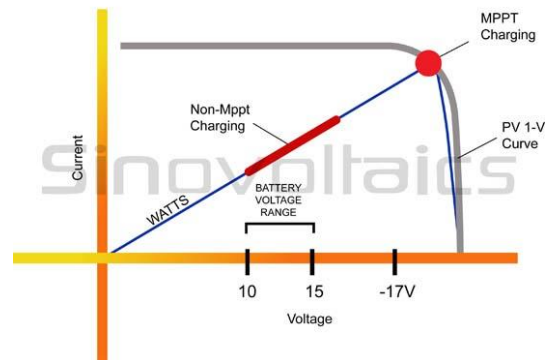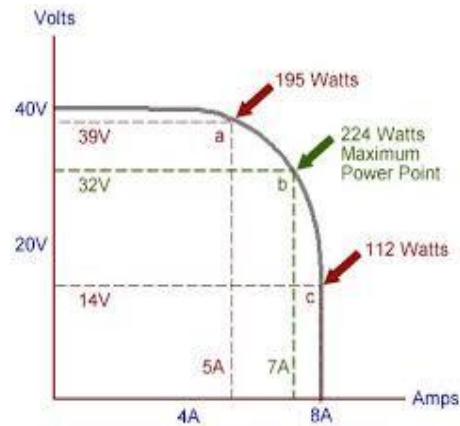
i) Using increased panel voltage to deliver maximum power:

Batteries could only be charged, if the output voltage of the solar panel is greater than that of the batteries, to facilitate a flow of current from the panel to the battery.

The output voltage of the panel depends on different factors, including the weather (irradiance). On a sunny day, the output voltage may be higher than the rated output voltage, while during a cloudy day the output voltage is probably less.

Normal controllers do not have the capacity to utilize this higher output voltage to deliver more power. However, MPPT charge controllers have the ability to adjust the voltage in order to get a boost of current during times of peak demand.

MPPT delivers higher than rated charge to the battery as they can adjust the voltage to current ratio.

ii) Using battery voltage for delivering maximum power:

Current and Voltage are inversely proportional to each other. With other words, if the current increases, the voltage drops and vice versa.

By lowering the current, by introducing some resistance in the path of the current, the MPPT charge controller can boost up the voltage.

This voltage to current ratio adjustment is called Maximum power point tracking. MPPT typically increases the current to the battery by approximately 25% to 30%.

It is important to keep in mind is that an 80% discharged battery will charge faster than a 50% discharged battery.

The reason for this is that, when the battery starts to discharge, its voltage also reduces. The larger the gap between the solar panel output voltage and the battery voltage, the more current will flow into the battery, and the faster the battery will be charged.

MPPT charge controllers use both principles mentioned above to deliver the maximum amount of power. This type of solar charge controllers come pre-programmed with adjustable set-points which can be edited and adjusted according to your needs. If you need to choose between a standard and a MPPT charge controller, usually paying a bit more for a proper MPPT controller is

the way to go. Most charge controllers include displays or LEDs to indicate battery voltage, state of charge, and/or presenting operating mode.

MPPT Perturbation and observation (P&O) Algorithm:

MPPT algorithms are used to control the duty cycle or the operating voltage of a photovoltaic system to ensure maximum power at all times.

There are different methods of MPPT but most common is the Perturb and Observe (P&O): This is the most widely used algorithm in the industry. It involves perturbation of the operating voltage or the duty cycle based on a comparison of the generated power. This ensures maximum power point. This algorithm perturbs the operating voltage to ensure maximum power. While there are several advanced and more optimized variants of this algorithm, a basic P&O MPPT algorithm is shown below.
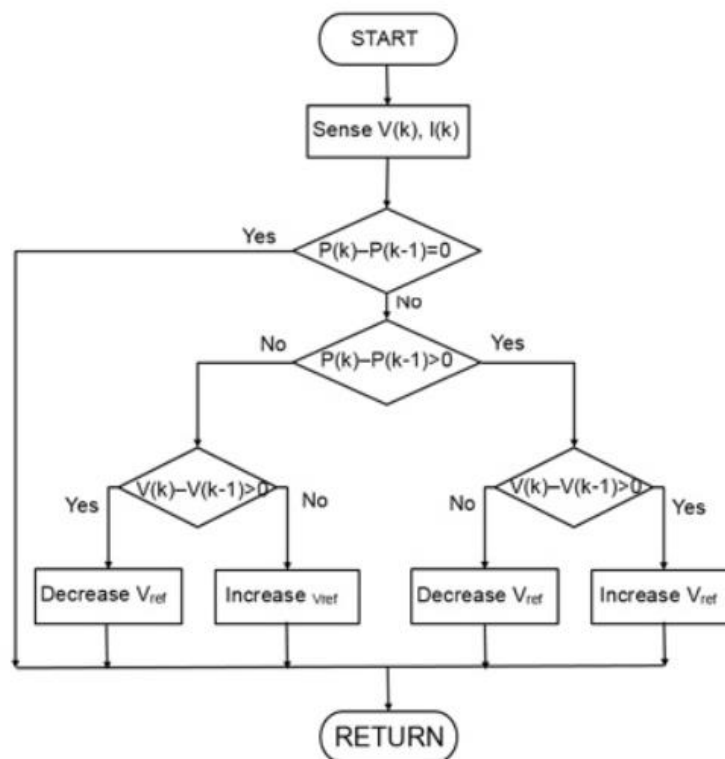
MPPT algorithms are typically used in the controller designs for PV systems. The algorithms account for factors such as variable irradiance (sunlight) and temperature to ensure that the PV system generates maximum power at all times.

This algorithm can be implemented in Simulink using MATLAB function block, a standard block from Simulink library that lets you implement the algorithm using MATLAB language. When you simulate the model, this MATLAB code is converted into C code and is compiled along with other blocks in the model. Notice that it is very simple to implement this algorithm using conditional statements within MATLAB, as you can see below.

```matlab
function duty = MPPT_algorithm(vpv,ipv,delta)
% Initialize algorithm parameters and define maximum & minimum
% values of duty cycle
duty_init=0.1;
duty_min=0;
duty_max=0.85;
% Define internal values for the voltage and power as persistent
% variables
persistent Vold Pold duty_old;

% Initialize the internal values for the voltage and power on the
% first pass
if isempty(Vold)
    Vold = 0;
    Pold = 0;
    duty_old = duty_init;
end
% Calculate measured array power
P = vpv*ipv;
dV= vpv - Vold;
dP= P - Pold;
% Increase or decrease duty cycle based on conditions
if dP ~= 0 && vpv>30
    if dP < 0
        if dV < 0
            duty = duty_old - delta;
        else
            duty = duty_old + delta;
        end
    else
        if dV < 0
            duty = duty_old + delta;
        else
            duty= duty_old - delta;
        end
    end
else
    duty=duty_old;
end
```

```
% Check duty cycle values
if duty >= duty_max
    duty=duty_max;
elseif duty < duty_min
    duty=duty_min;
end
% Update internal values
duty_old=duty;
Vold=vpv;
Pold=P;
```

P&O is one the simplest MPPT methods with excellent performance and can be easily implemented in low cost systems. The principle lies in disturbing the voltage or the current of the PV module and observing its effect on the resulting power. The algorithm compares the power of the previous step with that for the next step so that it can increase or decrease the voltage or current. This method changes the reference value, which can be a constant current or voltage. The operating point is then periodically moved towards the MPP by either increasing or decreasing the array voltage or current. The current is then modified at a constant rate, which represents a parameter that must be adjusted to obtain tradeoffs between fast dynamic response and reduced steady-state ripple. It is worth to mention that the performance can be improved by changing the step for the converter's duty cycle, so that tracking can be adjusted to better achieve MPP. When such step is variable, the method is called modified P&O.
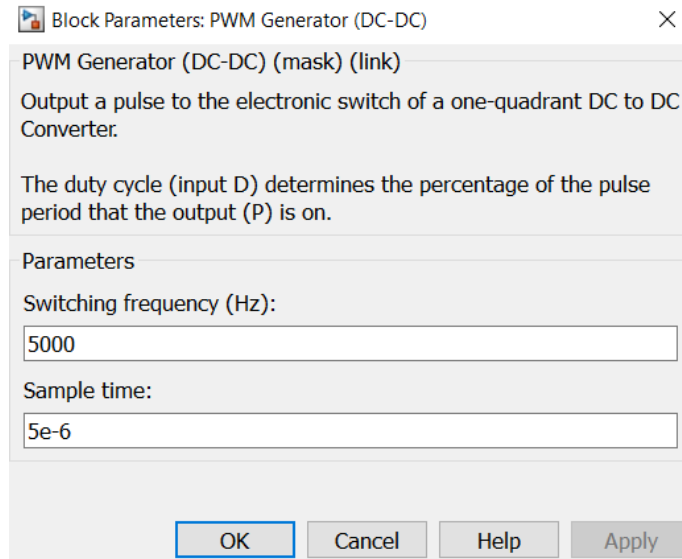
Simulation of Boost Converter with MPPT:

In order to maximize the use of solar energy, we generally focus on the PV power generation system, which includes modeling of PV systems and maximum power point tracking (MPPT) methods for PV arrays. Using the software MATLAB/Simulink, a model of solar energy power generation system with MPPT control based on fixed step perturbation and observation method is obtained. Using the Embedded MATLAB Function module, the core function of MPPT is achieved. The MPPT control is realized by means of MATLAB/Simulink simulation.
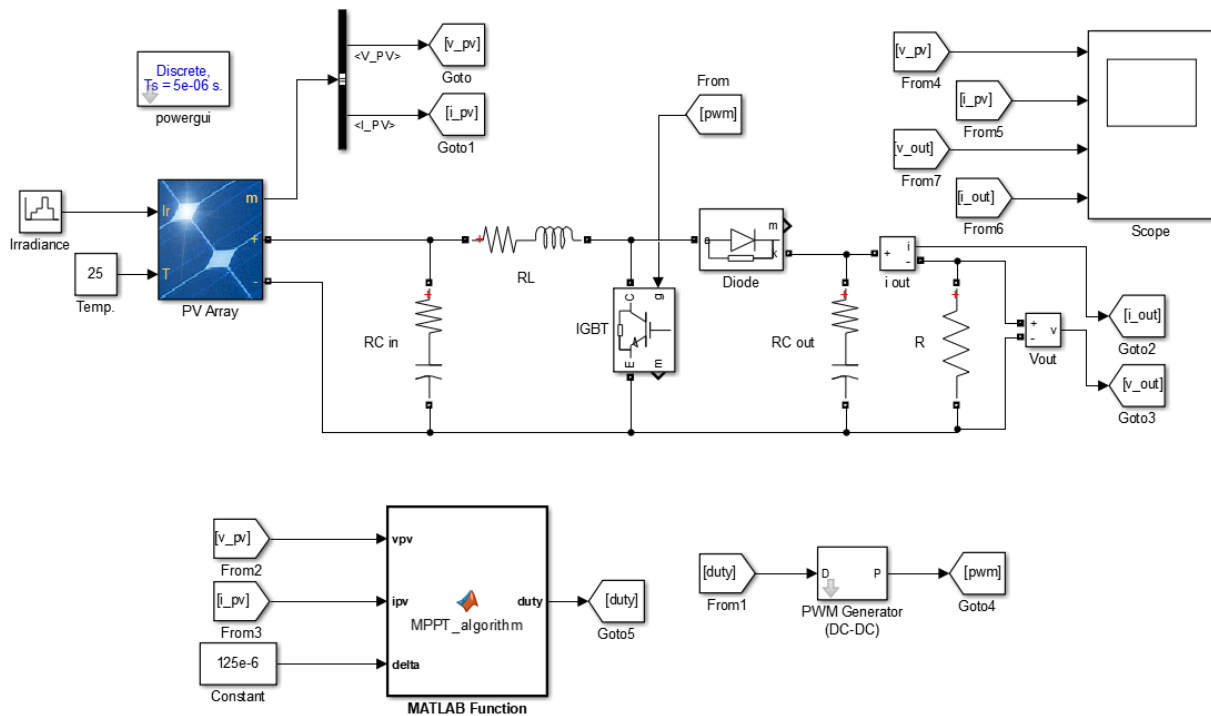
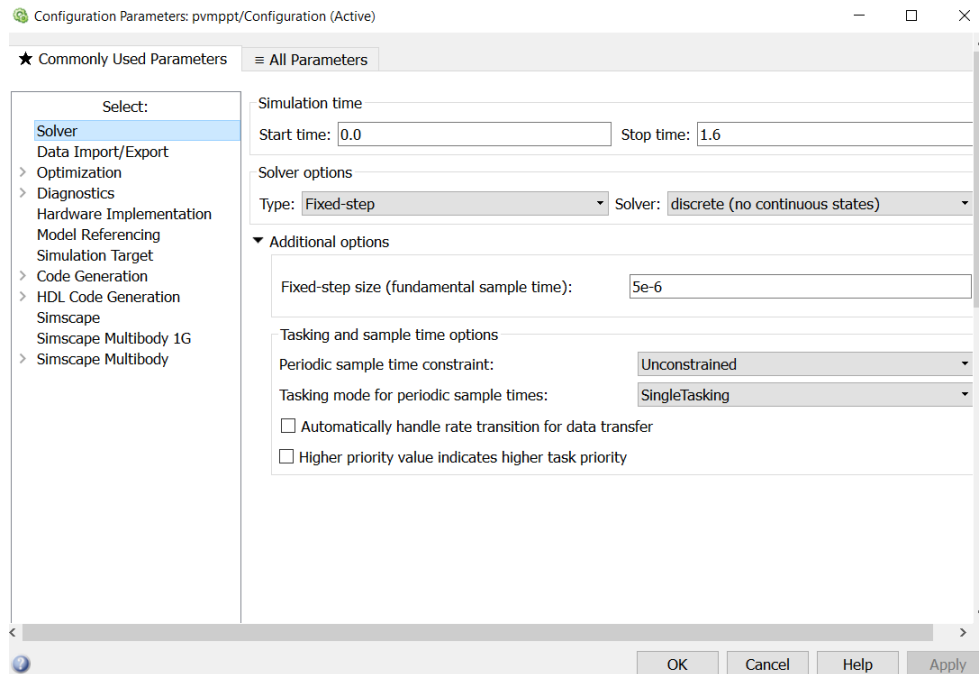**Irradiance Parameters Using Repeating Sequence Block:**
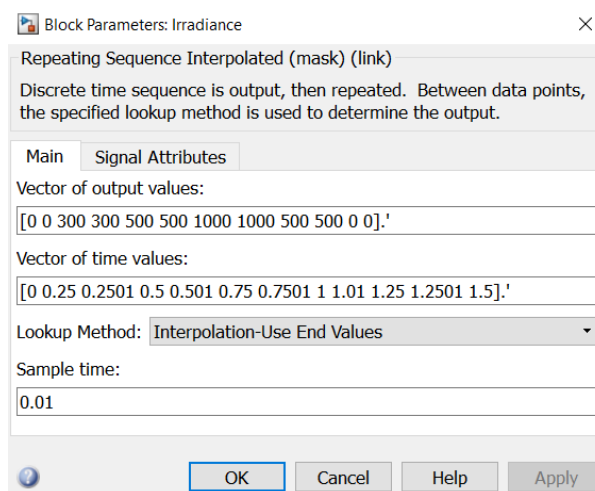
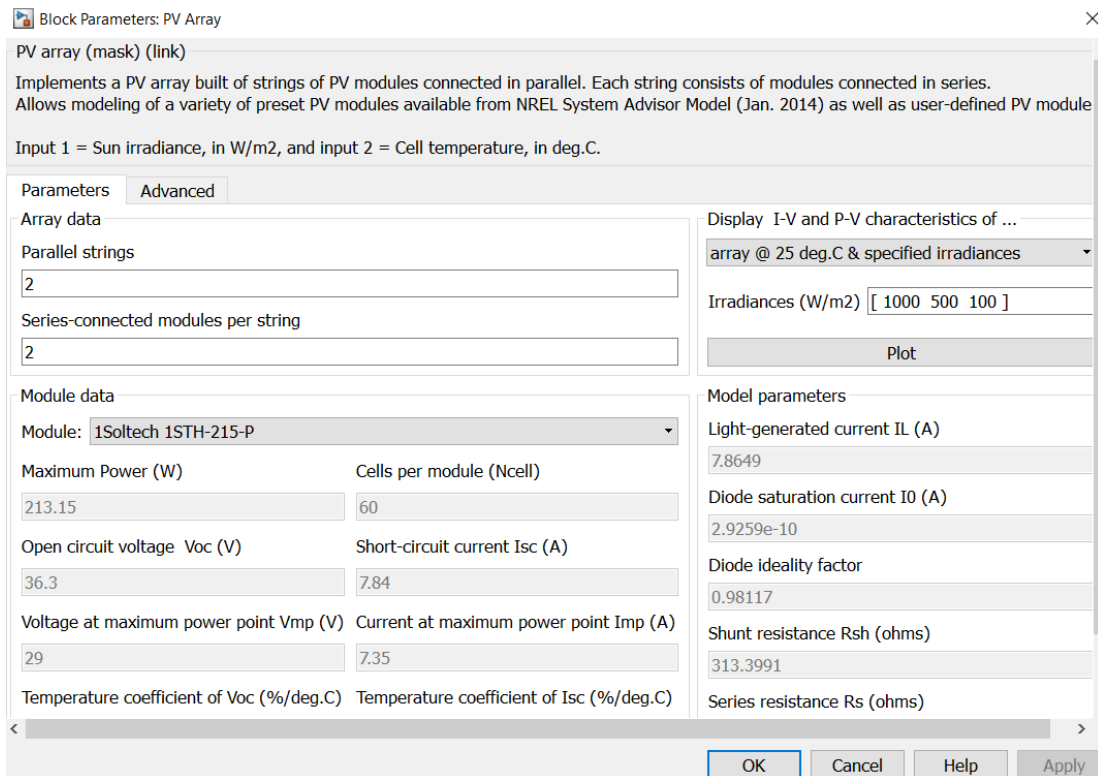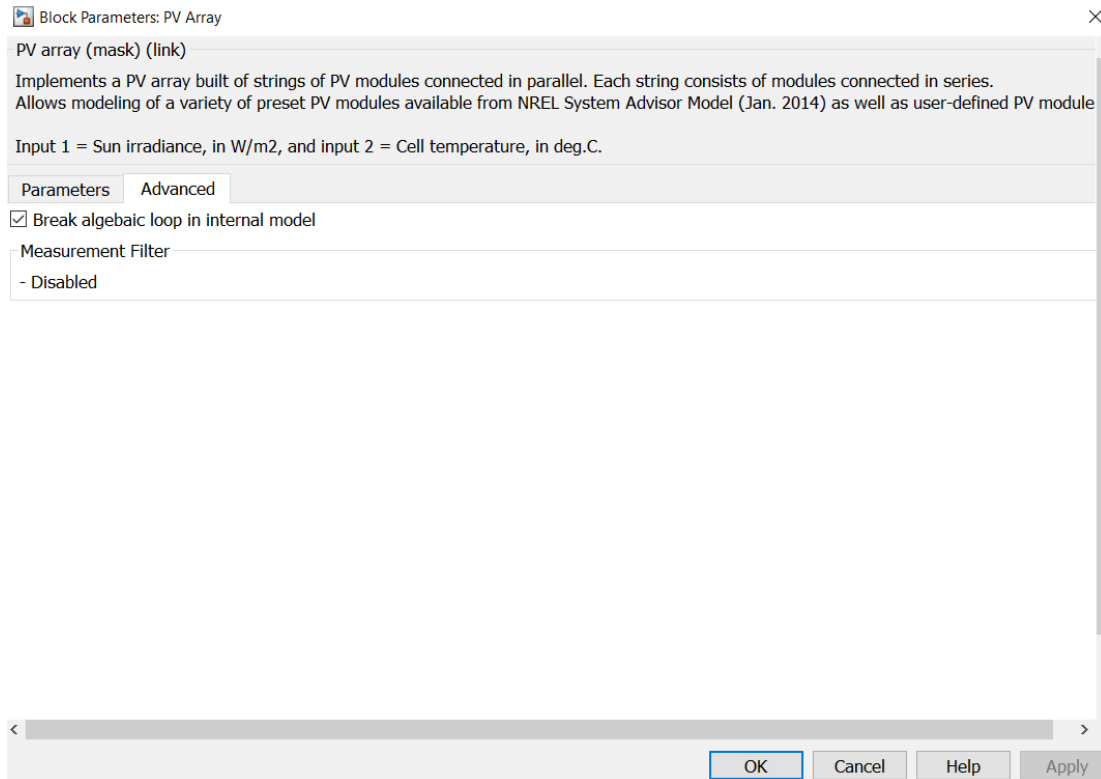## PWM Generator Parameters:

Simulation Diagram of MPPT with PV Array:

Simulink Model Configuration Parameters:

PV Array Parameters:

Boost Converter Parameters:

R-C in & out: 1e-4 Ω, 100e-6 µF

R-L: 0.1 Ω, 2e-3 µH

R: 20 Ω

Output Waveforms of Input Voltage, Current and Power:

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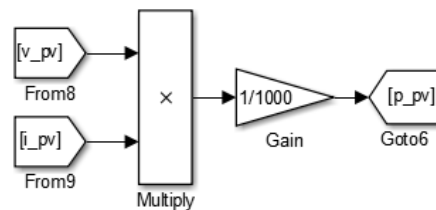
Efficiency Calculations:

The MPPT essential problem is to deal with the efficiency of power transfer of solar cell that depends upon sunlight amount, which drops on the solar panels. In addition to the characteristics of electrical load, changes in amount of sunlight, leads to change in the load characteristics, that give high power transfer efficiency. A load characteristic is referred as maximum power point and the process of discovering such point be considered MPPT.

In order to estimate the power efficiency (η), the maximum power (ideal power) known under the given circumstances, which the solar array may produce. We know from the PV Array Plot that the maximum power is around 852W at 1000W/m^2.

So, we can also write it as ideal power is 0.852KW per 1000W/m^2.
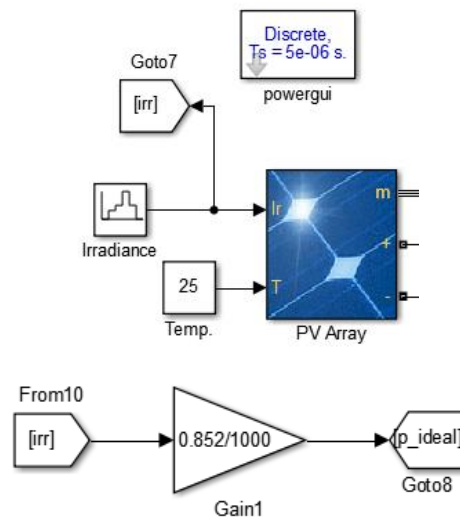
The actual output power of PV Array is calculated as following:

To convert the actual output power into KW, we divide the power by 1000, as shown the above gain block.

MPPT P&O algorithm efficiency can be calculated using the following formula:

$$\eta = 1 - \frac{|P_{ideal} - P_{pv}|}{P_{ideal}}$$

The mean block is added in efficiency to calculate the mean efficiency of MPPT P&O algorithm. The parameter of mean block and efficiency calculations block is shown below:
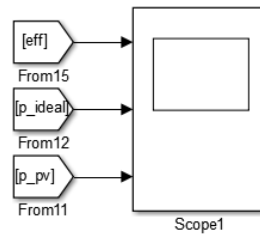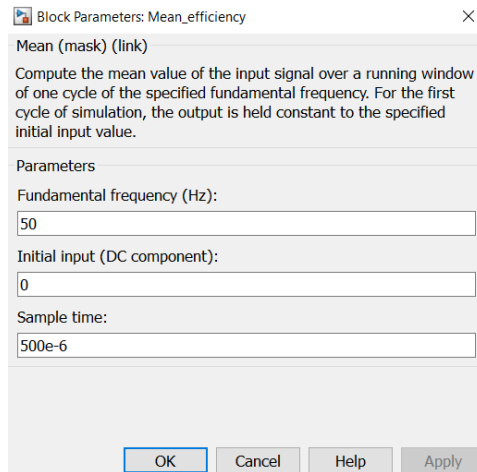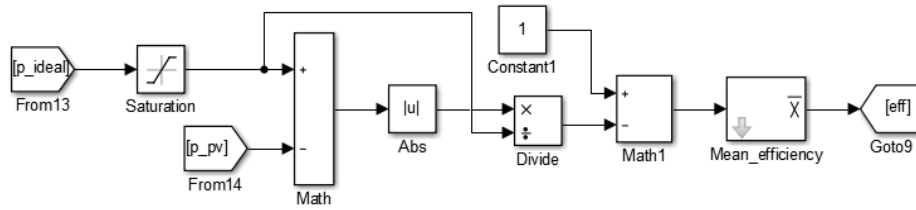
The output waveforms will compare how P&O algorithm reacts to different changes in solar array irradiance. Any changes in the irradiation immediately lead a change of the available power, inducing a displacement of the operating point from the maximum power point, which has for significance a degradation of the efficiency of the considered PV system.

Final MPPT Simulation Block Diagram:

Output Waveform of MPPT Efficiency, Ideal and Actual Output Power:

Conclusion and Comments:

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