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Simulation and Design of Boost Converter for $1KW_P$ PV System Using P&O and Incremental Conductance Algorithm

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Abstract:

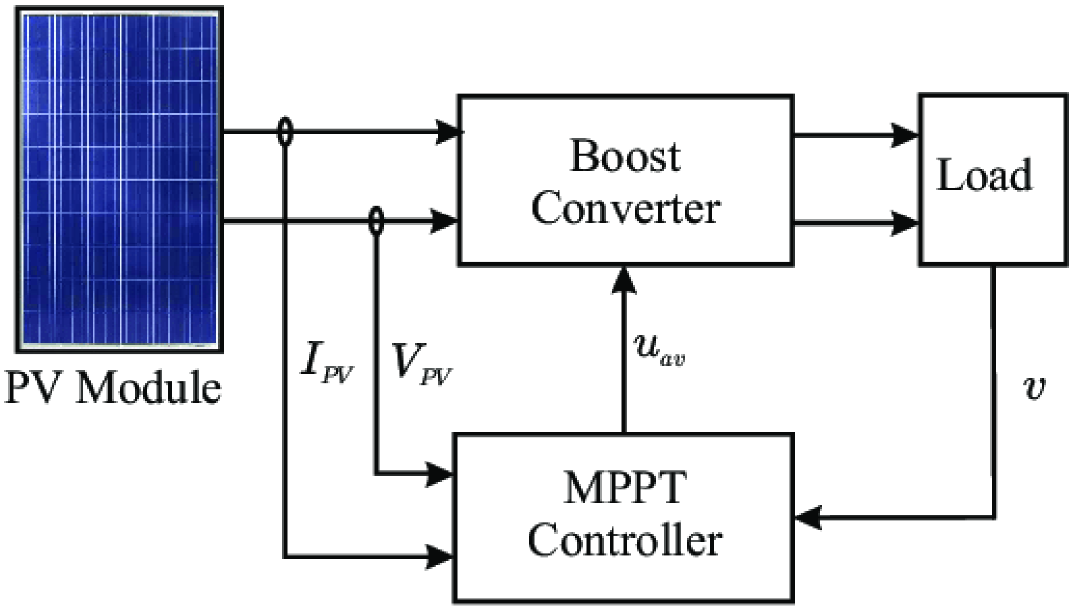
Solar photovoltaic energy has become a widely utilized form of renewable energy in distributed generation systems. Its popularity stems from the continuous advancements in solar technology and its integration into grid-connected systems, making it an attractive option for generating environmentally friendly electricity. In the context of solar energy, optimal power output is achieved by operating photovoltaic systems at their maximum power point, which is determined through the design calculation of a Boost converter. This notable undertaking confirms the simulation and design of a Boost converter for a 1KWp photovoltaic system using MATLAB/Simulink software, employing the P&O and incremental conductance algorithms.

I. INTRODUCTION

Currently, solar energy generation is widely regarded as one of the most feasible sources of renewable and environmentally friendly energy. It is preferred over other renewable energy sources due to its numerous benefits, such as being clean, renewable, and low maintenance. PV cells directly convert solar energy into electricity. PV panels and arrays produce direct current (DC) electricity, which needs to be converted to alternating current (AC) at a specific frequency to power electrical loads. Power converters are essential for connecting PV arrays to the grid. Solar energy can be transmitted to grid networks through grid-connected inverters. In such scenarios, maintaining a balance between the operational characteristics of the load and the photovoltaic cell is crucial.

An MPPT (Maximum Power Point Tracking) mechanism is employed to effectively capture and transmit the maximum power generated by a solar PV module to a load. This is achieved through the use of a dc-dc converter, which facilitates the transfer of the maximum power from the solar PV module to the load. The dc-dc converter acts as a connecting device between the load and the module. By adjusting the duty cycle, the load impedance as. perceived by the source is modified and matched to achieve maximum power transfer. Consequently, to optimize power extraction from a PV system, the implementation of an MPPT technique becomes necessary.

II. Block Diagram:

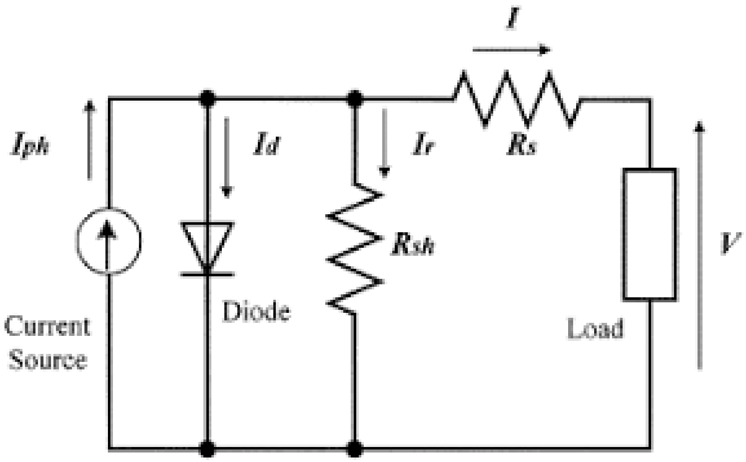


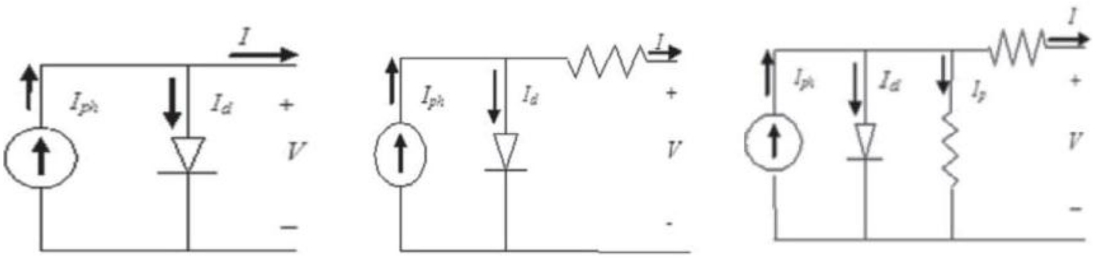
Block Diagram

The provided image illustrates a fundamental block diagram consisting of a solar panel, a DC-DC power converter, an MPPT controller, and a load. Initially, voltage and current measurements from the photovoltaic cells are captured using voltage and current sensors. These readings are then fed into the MPPT controller, where they are utilized by the MPPT algorithm to track the solar panel's maximum power point. The output of the MPPT block is then transmitted to the DC-DC converter, which can adjust either the voltage or the duty cycle. The role of the DC-DC converter is to ensure a constant operating voltage is maintained at the maximum power point. This can be achieved by modifying the duty cycle of the constant converter.

III. Equivalent model of single diode solar cell:

The general model of an equivalent circuit consists of various components, including a photocurrent, a diode, a parallel resistor representing leakage current, and a series resistor indicating the internal resistance **of** the circuit. A photovoltaic cell can be described as a p-n junction embedded within a small semiconductor wafer or sheet. It harnesses the photovoltaic effect, which promptly converts electromagnetic radiation from solar energy into electricity. When exposed to sunlight, the semiconductor absorbs photons with energies exceeding the band-gap energy, generating electron-hole pairs in proportion to the incident intensity. The internal electric potential of the p-n junction separate these charge carriers, resulting in a photocurrent that is directly proportional to the intensity of solar radiation. It is important to note that this description pertains to a photovoltaic (PV) system.

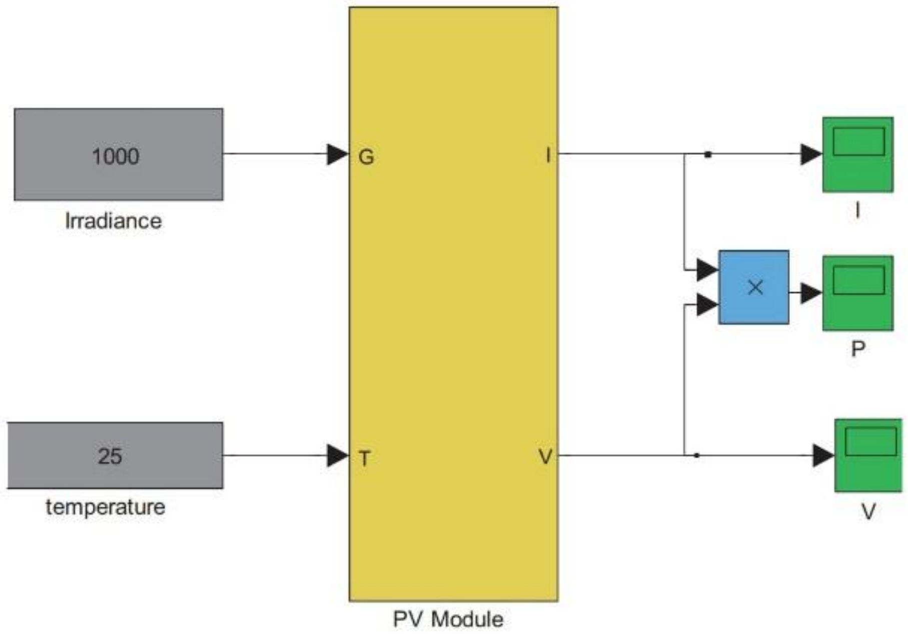




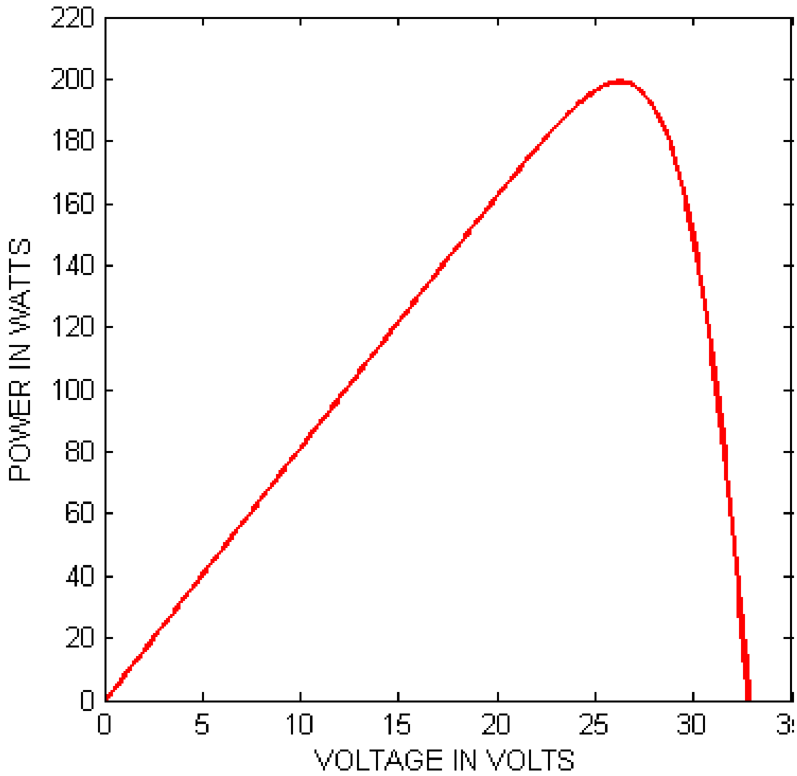
a) Ideal single diode model b) Practical model with Rs c) Practical model with Rs and Rp

The internal losses of the current are not taken into account in the calculation. A diode is connected in the opposite direction to the current generated by the light source. The equation used for calculation is I = Iph - Id, where Iph indicates the photocurrent and Id is the diode current. The diode current is proportional to the saturating current and can be determined using the formula Identifier = Io [exp(V / (A * Ns * VT)) - 1]. The voltage supplied to the diodes is denoted by V, and VT is calculated as VT = K * Tc / q, where Io denotes the reversed saturating or leaking current of the diode (in amperes), and K represents the Boltzmann constant (1.381 * 10^-23). The equation Io [exp(V + I * Rs / a) - 1] = Id relates to the current leak of the parallel resistor, denoted as Ip. Ultimately, the equation Iph - Id - Ip = Iph - Id - Ip holds true.

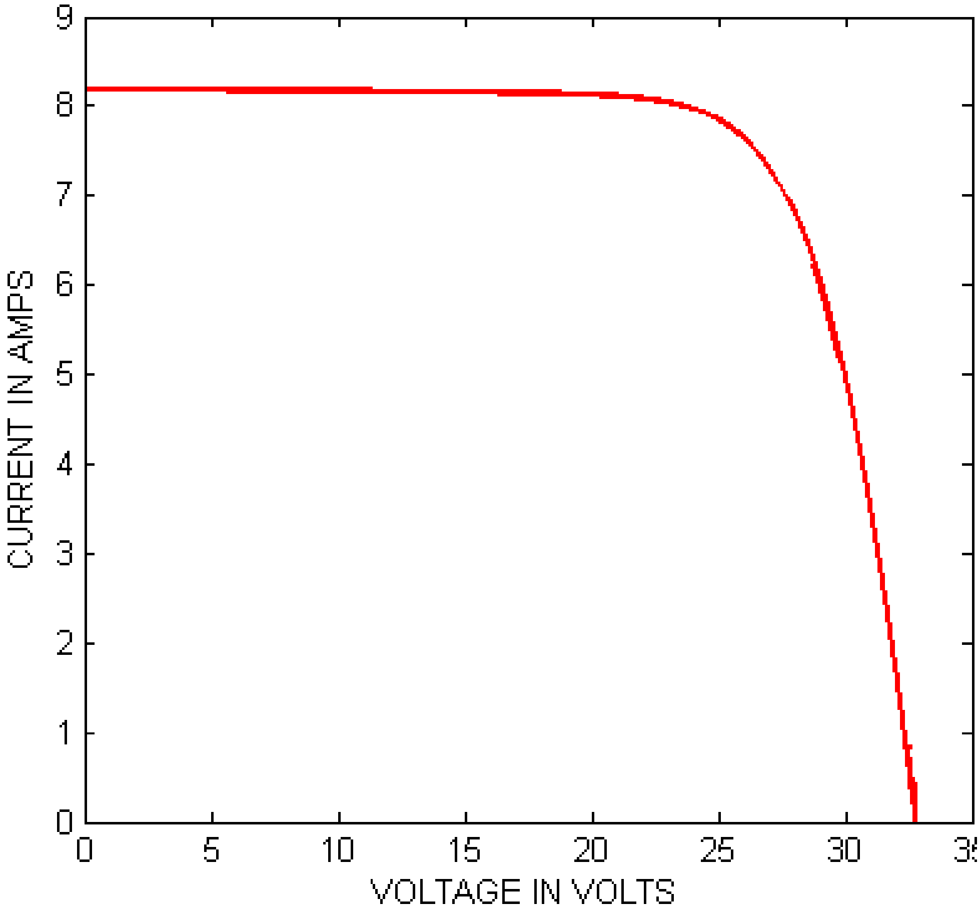
IV. Grouped system of PV model



V. PV Characteristics of PV cell

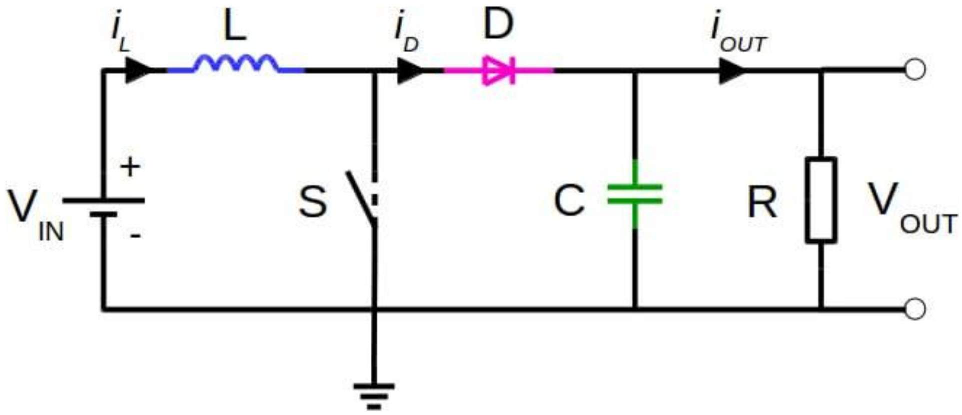


VI. Characteristics of PV cell



VII. BOOST CONVERTER

A DC-DC converter is an electrical circuit that transforms direct current from one voltage level to another, based on specific requirements. This type of power converter can operate across a wide range of power levels, from very low to extremely high, similar to those used in large-scale high voltage power transmission networks. DC-DC converter circuits employ switches and passive components to achieve high-frequency power conversion while minimizing switching noise and effectively regulating the output voltage. The configuration of energy storage devices depends on the desired step-up or step-down operation and the specific application. Typically, DC-to-DC converters are designed to transfer power in one direction, from a dedicated input to a dedicated output. However, by implementing active rectification, it is possible to make any switching regulator topology bidirectional, enabling power transmission in both directions. Bidirectional converters are particularly valuable in applications such as regenerative braking in automobiles, where power can be both consumed from and supplied to the wheels during operation.



Calculation of Boost Converter Parameters

P	= 1000;
Vin	= 122.8;
fs	= 10e3;
V out	= 250;
Iou tmax	= P/V out;
Del IL	= 0.01 * Iout max *(Vout/Vin);
Del Vout	= 0.01 * Vout;
L	= (Vin *(Vout -Vin))/(delIL*fs * Vout)
C	= (I outmax *(1- (Vin/Vout)))/(fs* delVout)
R	= V out/ I outmax
d	= (V out-Vin)/V out

OUTPUTS:

L	=0.0767
C	=8.1408e-05
R	=62.5000
D	=0.5088

VIII. MAXIMUM POWER POINT TRACKING

Conventional solar panels typically convert only 30-40% of the incident solar energy into electrical energy. To enhance the performance of solar panels, the highest power point tracking (MPPT) technology is employed. According this theorem, the power output of a circuit is maximized when the Thevenin impedance (source impedance) is same as the load impedance. Therefore, finding the maximum power point involves achieving impedance matching. By connecting a boost converter to the supply side of a solar panel, the output voltage can be enhanced, enabling its utilization for applications such as motor loads.

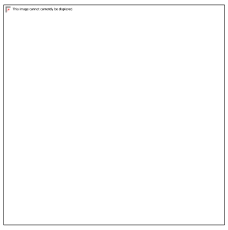
Efficient power point tracking techniques are implemented by adjusting the duty cycle of the boost converter. These techniques aim to optimize the extraction of power from the solar panel and include the following:

1. Perturbation Algorithm and
2. Incremental Conductance method

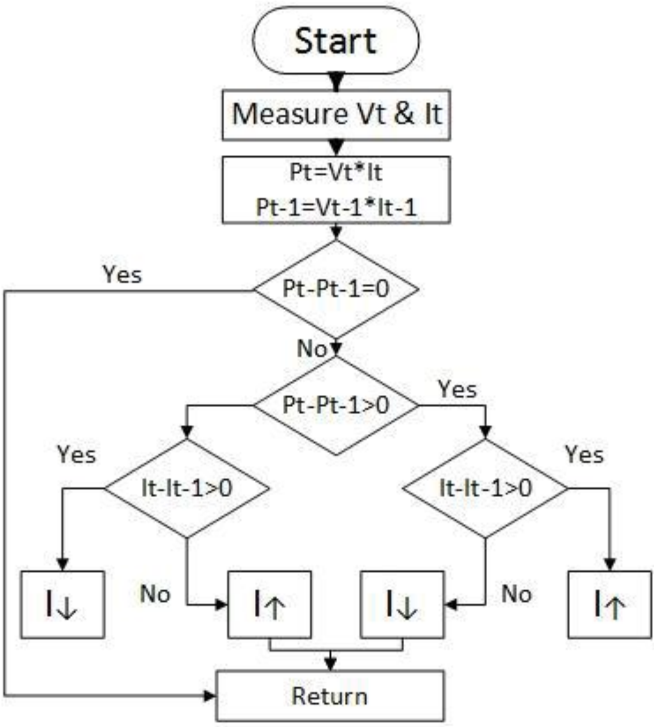
Perturb and Observe Algorithm:

The primary method used to estimate the maximum voltage from the solar panel to the DC connection capacitor is called perturb and observe (P&O). This approach, while relatively simple in terms of time complexity, has a drawback. It does not halt when it reaches the maximum power point (MPP) and continues to oscillate in both directions. When this happens, it indicates that the technique has come very close to the MPP. To address this, we have two options: either define an acceptable error limit or introduce a wait function, which increases the time complexity of the process.

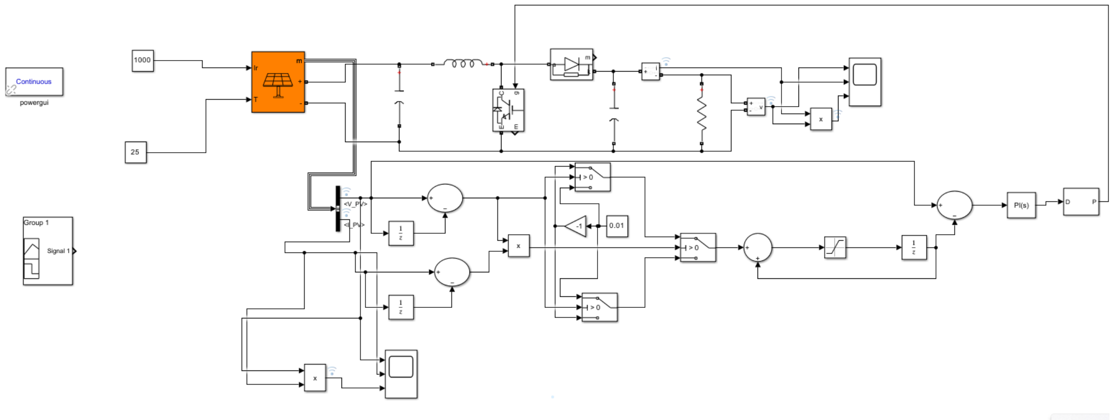
Perturb & Observe algorithm on p-v curve



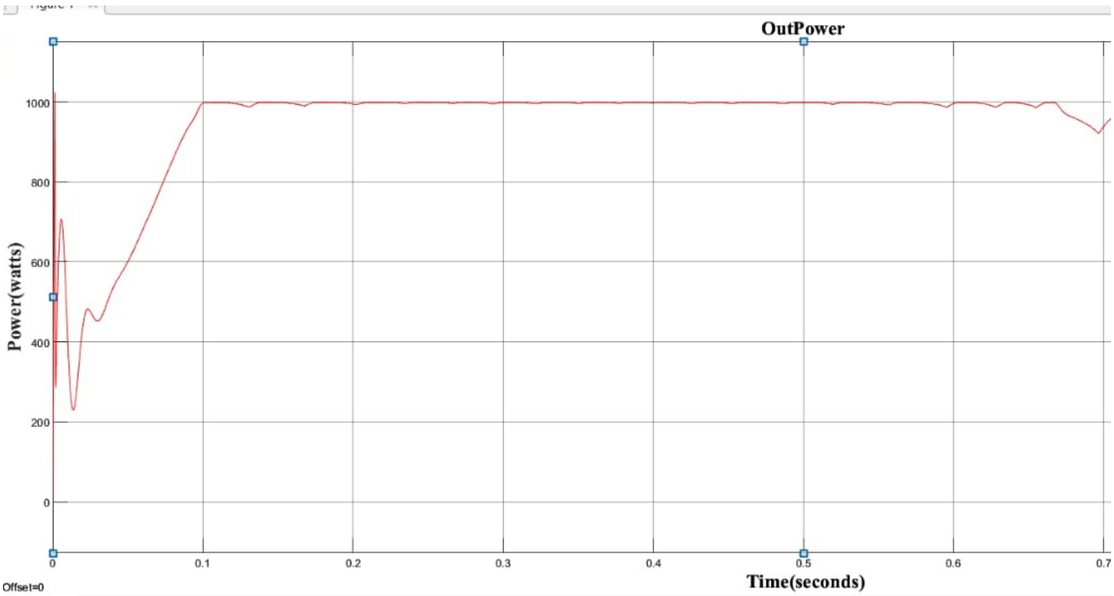
Flowchart of P&O:



Simulation



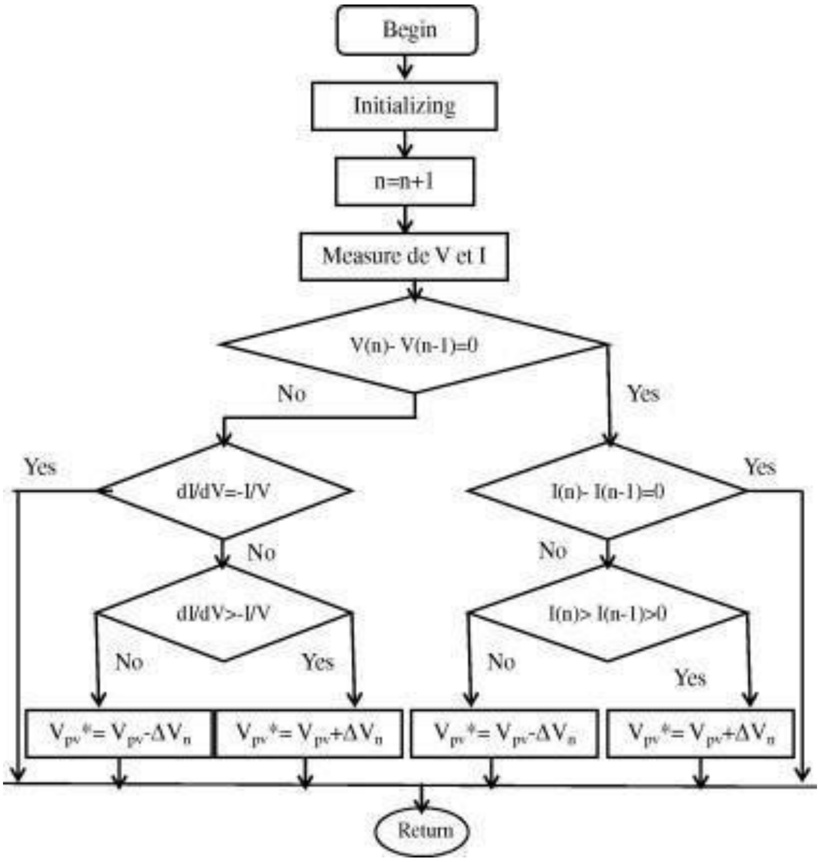
P&O Result:



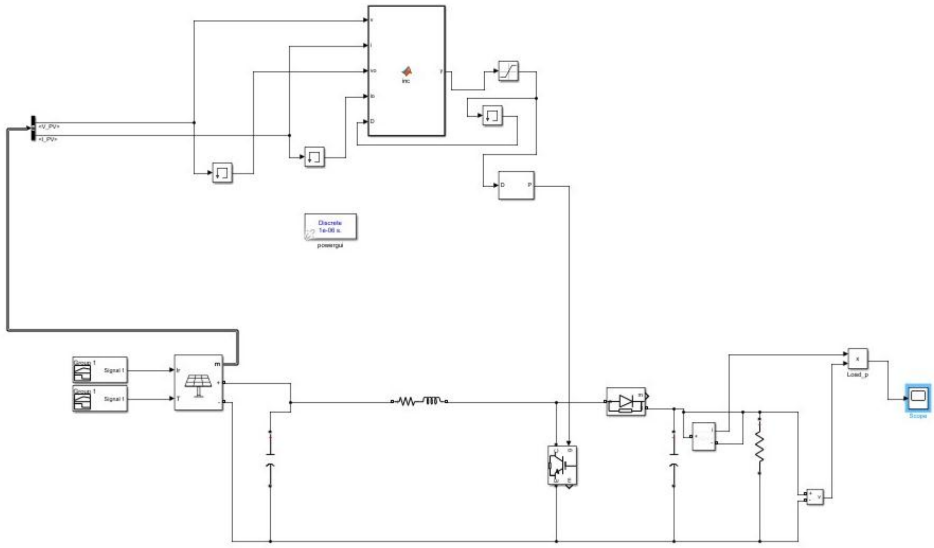
Incremental Conductance:

The Incd method involves using voltage and current sensors to estimate the output voltage and current of a photovoltaic array. At the maximum power point (MPP), the slope of the PV curve is zero. The graph on the left illustrates the instantaneous conductance of a solar panel. The MPP is reached when the instantaneous conductance matches the solar conductance. By simultaneously detecting both voltage and current, the issue caused by changes in irradiance is mitigated. However, the implementation of this approach becomes increasingly challenging and costly. As we progress down the list of algorithms, the complexity of the algorithm and the associated implementation costs decrease, making some options more suitable for highly intricate systems.

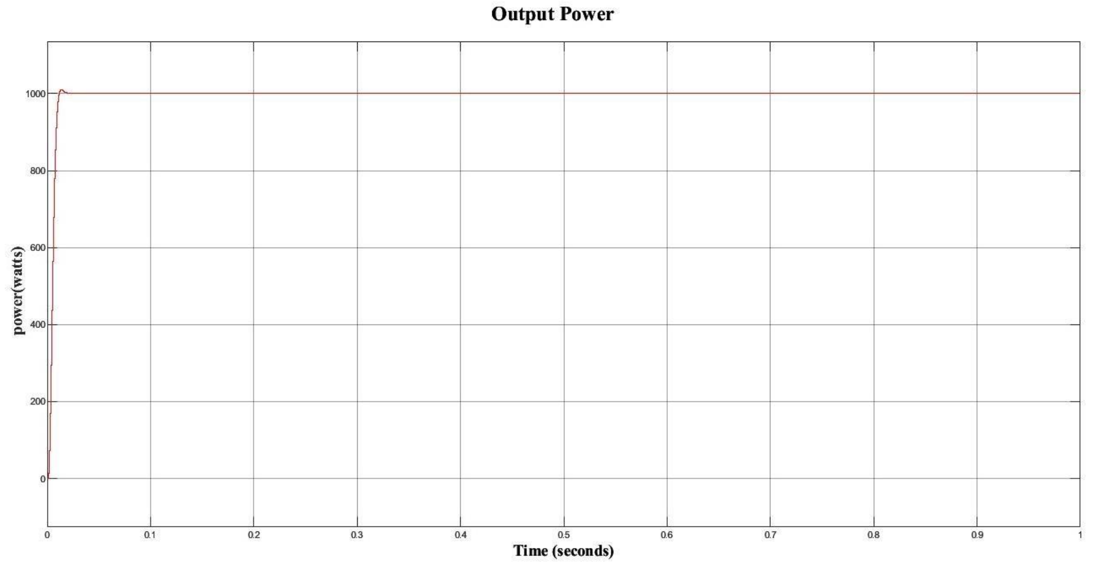
Flowchart



Incremental conductance Simulink model:



Result



CONCLUSION

This study examines and validates the simulation of the MPPT algorithm, including P&O and incremental conductance. The 1KW PV system is intended for the boost converter. Under variable irradiance situations, the classical MPPT method P&O frequently does not produce the best results. Therefore, as evidenced by the results above, that limitation is overcome by the incremental conductance algorithm. We have made an effort to comprehend the dynamics and steady state performance of PV systems using MPPT algorithms.

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