A Casestudy On Direct MPPT Algorithm For PV Sources

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Abstract - **PV Module Maximum Power Point Tracker (MPPT) is a photovoltaic system that uses the photovoltaic array as a source of electrical power supply. Every photovoltaic (PV) array has an optimum operating point, called the maximum power point, which varies depending on cell temperature, the insulation level and array voltage. The function of MPPT is needed to operate the PV array at its maximum power point. In the recent decades, photovoltaic power generation has become more important due its many benefits such as needs a few maintenance and environmental advantages and fuel free. However, there are two major barriers for the use of PV systems, low energy conversion efficiency and high initial cost. To improve the energy efficiency, it is important to work PV system always at its maximum power point. important role in photovoltaic (PV) power systems because they maximize the power output from a PV system for a given set of conditions, and therefore maximize the array efficiency. Thus, an MPPT can minimize the overall system cost. MPPTs find and maintain operation at the maximum power point, using an MPPT algorithm. Many such algorithms have been proposed. The mostly used MPPT are P&O and Incremental Conductance Method and Constant voltage and current, Pilot cell etc. This paper proposes a comparison on P&O method, incremental conductance method and direct voltage measurem*ent***

Index Terms- Maximum power point tracking (MPPT) algorithm, photovoltaic (PV) system, incremental conductance

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1 Introduction

The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions. Solar energy has offered promising results in the quest of finding the solution to the problem. The harnessing of solar energy using PV modules comes with its own problems that arise from the change in insulation conditions. These changes in insulation conditions severely affect the efficiency and output power of the PV modules. Solar energy has the advantages of maximum reserve, inexhaustibleness, and is free from geographical restrictions, thus making PV technology a popular research topic. In this world 80 % of the green houses gases are released due to the usage of fossil fuel based. The world primary energy demand will have increased almost 60% between 2002 and 2030. Among available renewable energy sources, Photovoltaic panel due to pollution free, little maintenance and it is noise free. PV array are used in many applications such as water pumping, battery charging, hybrid vehicles, and grid connected PV systems. Power delivered from a PV panel depends on present environment conditions (irradiation and temperature), therefore PV needs the operating point to be tracked continuously in order to optimize the maximum available power (MPP) from using a Maximum Power Point Tracker (MPPT) algorithms. Actually MPPT is a process oftracking the maximum power point under different solar irradiation and temperature through regulating the voltage of the solar array. The open-circuit voltage and short-circuit current of the solar array depends on solar irradiation and temperature. Hence, its only through MPPT that we can extract as much energy as possible form a solar panel as a source under different conditions that exist. Many techniques have been proposed to reach the MPP and track it over time. MPPT techniques can be divided in two categories: indirect and direct. The first one makes use of an offline analysis of the PV system, while the second one carries out online measurements of the voltage and current to determine the position of the MPP. Other indirect methods employ a fuzzy logic controller. This solution takes the advantage that the implementation is robust and easy, since no exact mathematical models are required. If solar panel is directly connected to the battery load or Resistive load, the characteristics of voltage and current curve resultant of PV panel is determine by the actual load on it. That is, load impedance forcefully moves the operating point of PV panel to locate the junction I-V and load line curve. Hence, this operating point generally is away from maximum power point taken out. Because of PV power change due to environmental changes, hence there is no such guarantee to deliver maximum power. By use of MPPT controller leads

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to resolve the mismatching impedance between connected load and PV panel. By observing the various algorithms, it found that each has some limitations on extracting power from Photovoltaic cells. In this paper, we proposed a Novel algorithm for MPPT, it is able to both track the MPP of the PV source at every time changes in environment and improves speed, accuracy, and efficiency of PV array. In this paper, a solution to implement the principle presented in without the need of computing derivatives is proposed: the technique is simple, robust to noise, and is oriented to get a fully working MPP tracker. The method is suitable to control a specifically designed circuit, which can substitute the dc/dc converter used as interface in the PV inverters. In fact, the proposed circuit is able to both track theMPP of the PV source and charge the dc link of the inverter. Less number of sensors needed in the controller circuitry since the MPPT controller is only utilizing the source voltage information. By utilizing a variable step-size algorithm, it improves the speed, accuracy, and efficiency of the PV system for better MPP.

2. MPPT CONTROL ALGORITHM

Large number of MPPT methods and different DC-DC converter topologies have been proposed for extracting the power from solar energy are presented and find the maximum operating power point (MPP). These various methods are available in terms of cost, speed, required sensors, implementation, complexity, popularity, and some other conditions. These methods are categorized in order to conventional techniques and artificial intelligencetechniques. The MPPT algorithm operates based on the truth that the derivative of the instantaneous power is equal to zero at the maximum power point. However, most widely used MPPT algorithms are

1. Perturb and Observe (P&O)
2. Incremental Conductance

A satisfactory MPPT costs comparison can be carried out by knowing the technique adopted in the control device, the number of sensors, and the use of additional power component, considering the other costs equal for all the devices. To make all the cost comparable between them, the computation cost comparison is formulated taking into account the present spread of MPPT methods. The number of sensors required to implement the MPPT technique also affects the final costs. Most of the time, it is easier and more reliable to measure voltage than current and the current sensors are usually more expensive and bulky. The irradiance or temperature sensors are very expensive and uneconomic.

2.1. Perturb and Observe Method

This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle. In this algorithm a slight perturbation is introduce to the system.This perturbation causes the power of the solar module various. If the power increases due to the perturbation then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses that is if the PV array operating voltage changes and power increases, the control system moves the PV array operating point in that direction; otherwise the operating point is moved in the opposite direction. The drawback of P&O is that it cannot determine when it has actually reached the MPP. Instead, it oscillates around the MPP, changing the sigh of the perturbation after each P measurement. This method requires high sampling rates and fast calculations of the power slope.

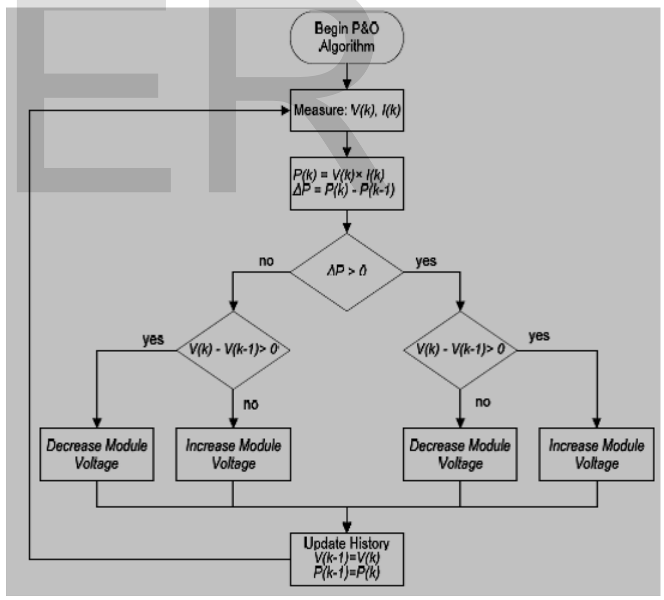

Figure1. P&O Algorithm

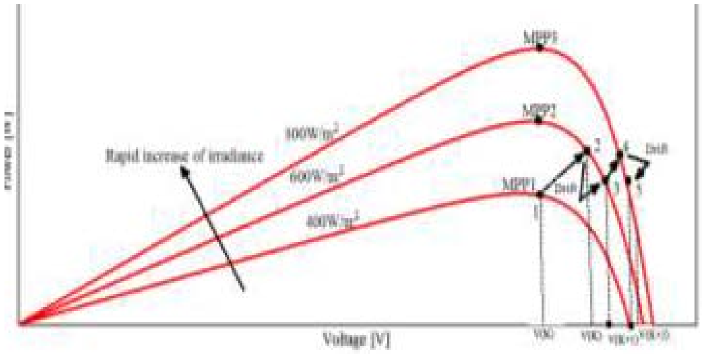

Figure2. Power and voltage under varying irradiance

2.2. Incremental Conductance Method

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method The incremental conductance algorithm is based on the fact that the slope of the curve power vs voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right In both P&O and In Cond schemes, how fast the MPP is reached depends on the size of the increment of the reference voltage the drawbacks of these techniques are mainly two. The first and main one is that they can easily lose track of the MPP if the irradiation changes rapidly The MPP can be calculated by using the relation between dI/dV and –I/V. If dP/dV is negative then MPPT is lies on the right side of recent position and if the MPP is positive the MPPT is on left side Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in ΔI is noted, indicating a change in atmospheric conditions and the MPP. The algorithm decrements or increments *Vref* to track the new MPP. The increment size determines how fast the MPP is tracked. Fast tracking can be achieved with bigger increments but the system might not operate exactly at the MPP and oscillate about it. IC methods can be used for finding the MPP, improve the PV efficiency, reduce power loss and system cost Implementation IC on a microcontroller produced more stable performance when it compared to P&O. The disadvantage of this algorithm is the increased complexity.

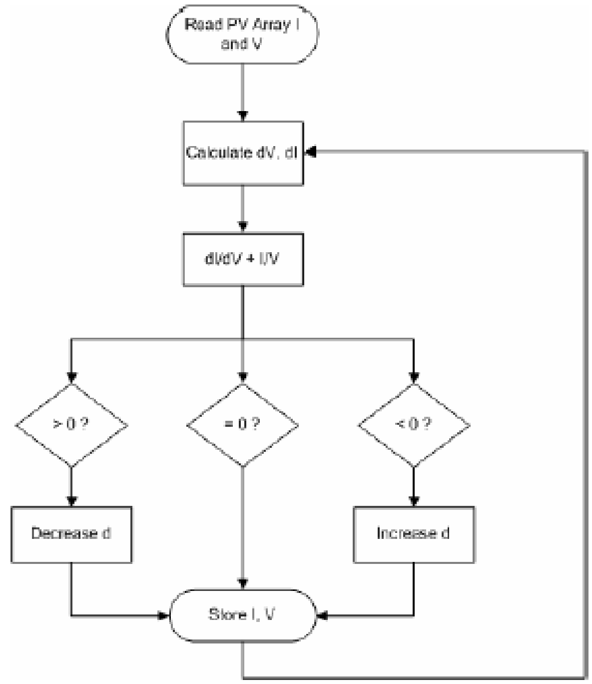

Figure3. Incremental conductance algorithm

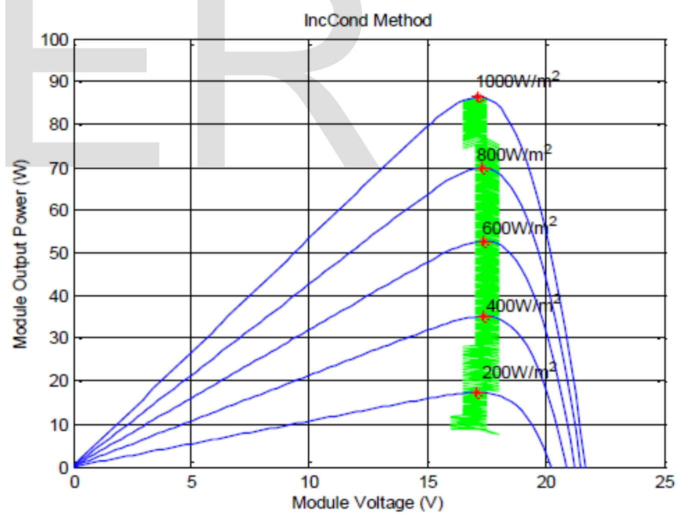

Figure4. Power and voltage under varying irradiance

$$\frac{dP}{dV} = 0 \qquad \text{at MPP}$$

$$\frac{dP}{dV} > 0 \qquad \text{left of MPP}$$
$$\frac{dP}{dV} < 0 \qquad \text{right of MPP}$$

Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V}$$

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} \qquad at\ MPP$$
$$\frac{\Delta I}{\Delta V} > -\frac{I}{V} \qquad left\ of\ MPP$$
$$\frac{\Delta I}{\Delta V} < -\frac{I}{V} \qquad right\ of\ MPP$$

3. PROPOSED METHOD

MPPT techniques can be divided in two categories: indirect and direct. The first one makes use of an offline analysis of the PV system, while the second one carries out online measurements of the voltage and current to determine the position of the MPP. The fractional open-circuit voltage (Voc) and fractional short-circuit current (Isc) methods exploit the quite linear relationship between the Voc or Isc and the value of, respectively, the voltage or current at the MPP condition. In some works, to have better results, the previous techniques are used together. Most of the these methods require to measure both voltage and current to identify the MPP, since the power needs to be calculated. The voltage can be easily measured, for instance, through a resistive divider, while the current measurement is more complicated. To overcome the problems related to current measurement, some authors have proposed solutions that estimate the MPP position making use of a voltage sensor only and complementing it with other information available from the system. In this paper, an approach was proposed that is successful in actually measuring the position of the MPP requiring only the PV generator voltage measurement: the idea is to connect the PV source to a suitable capacitive load and to measure the voltage across it as the source is charging and a solution to implement the principle pr sented in without the need of computing derivatives is proposed: the technique is simple, robust to noise, and is oriented to get a fully working MPP tracker. The method is suitable to control a specifically designed circuit, which can substitute the dc/dc converter used as interface in the PV inverters. In fact, the proposed circuit is able to both track theMPP of the PV source and charge the dc link of the inverter. The interface perfomance and a comparison with other method has been carried out.

3.1 Detection Method Of MPP

The basic idea of the proposed method is presented referring to Fig.5, where the evolution over time of some quantities related to a capacitor being charged by the PV source is shown. In this case, the instantaneous power, *p(t)*, can be calculated as

$$p(t) = C.v(t).\frac{dv(t)}{dt} = \frac{C}{2}.\frac{dv(t)}{dt}$$

where *v(t)* is the capacitor voltage, *C* is its capacitance, and *v2(t)* the square of the voltage value. The position of the MPP was identified by considering the derivative of *p(t).* The MPP is lcated where the derivative of the instantaneous power *p(t)* is equal to zero. As is possible to observe from (5), this point corresponds to the inflection point of the square of the voltage, *v2(t)*, which is where the slope of *v2(t)* has the maximum value.

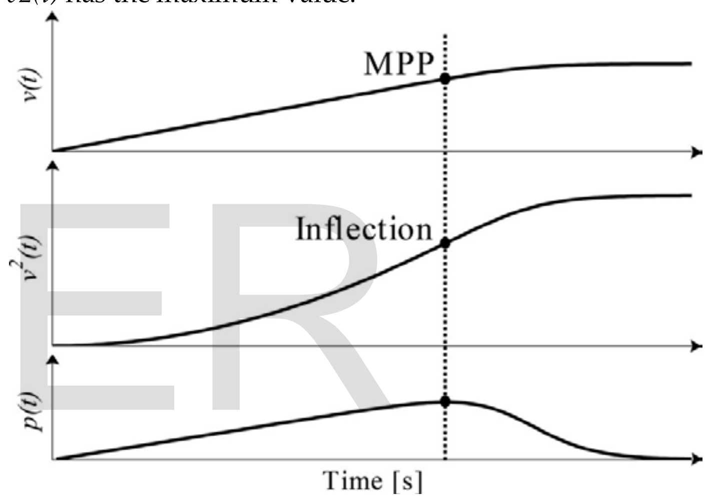

Figure5.Voltage across the capacitor,its squared value and instantaneous power verses time.

To find out when the slope of *v2(t)* stops increasing, the control logic (programmed in a microcontroller) subdivides the charge of the capacitor into a number of time intervals *Ti* . During each *Ti* , a given number *n* of voltage samples are acquired by a microcontroller, which computes the slope of *v2(t)*. The slope of *v2(t)* is the angular coefficient *m* obtained by a linear regression on the points. When the MPP has passed and a discharge has occurred, the angular coefficient *m* and the voltage *V* reached at the end of the first charging interval are compared to the two values stored in memory, referred to the estimated MPP. If mi is the last iteration and mi−1 is the previous iteration stored in the memory. If *mi* > *mi*−1 , the MPP has not been reached, Otherwise, if *mi* < *mi*−1 , the MPP has just been passed. Thus the algorithm iterates a double discharge, a retuning and two sampling intervals until a new steady condition is reached. As soon as the transient finishes, the search for the MPP restarts.

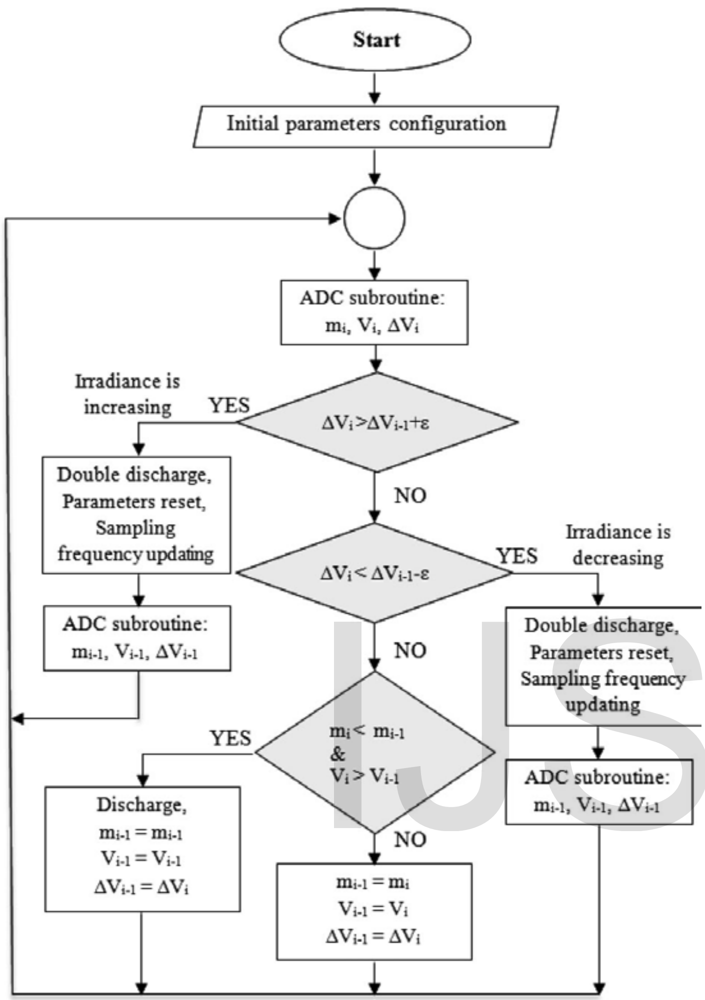

Figure6. Flow chart of the algorithm.

Fig. 6, shows the flowchart of the algorithm to find out when the slope of *v2(t)* stops increasing. The algorithm as described so far can correctly detect and track the MPP in presence of a varying irradiance. So that *v2(t)* can be considered linear with good approximation.

3.2 . Schematics Of Inverter Interface

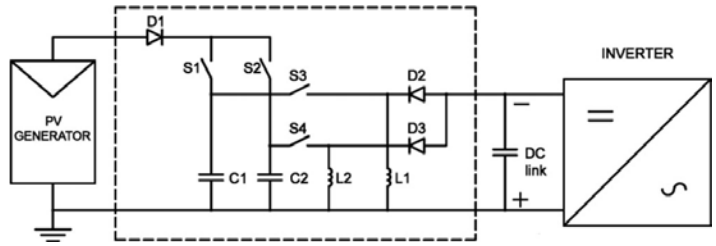

Figure7. Circuit of Inverter

The circuit of inverter interface of proposed method is called double capacitor interface (DCI). The DCI is composed of two identical subcircuits: one made of S1–*C*1–S3–*L*1, the other one made of S2–*C*2–S4–*L*2 as shown in fig7. The purpose of having two subcircuits is that when the first has reached the MPP, the second is connected to the PV source while the first transfers energy to the dc link. Initially, only S1 is closed and *C*1 is connected to the PV source: the capacitor is charged and every *Ti* the microcontroller monitors the voltage across it. The switch remains closed until the MPP condition is reached. As soon as the MPP on *C*1 is detected, S1 is opened and S3 and S2 are closed. S2 is kept closed until theMPP on *C*2 has been reached; at that point, S2 is opened, S4 and S1 are closed and the cycle starts again.

3.3 . Simulation Results

Fig. 8, shows the simulation results of voltage and time under varying irradiance. Fig 8(a) shows simulation results under decreasing irradiance and Fig 8(b) shows simulation results under increasing irradiance. The voltage across the PV array after a rapid change of irradiance is shown. The mean value of the TF for a series of simulations ranging from 50 to 1000 W/m2 was found to be about 99.4%.Since an irradiance variation has occurred, the MPP research cannot be accurate and the algorithm parameters have to be retuned. For this reason, a double discharge on the capacitor is triggered. This simulation can be useful to evaluate the behavior of the proposed method with different values of irradiance, as normally happens during a day. The algorithm has proved to be able to properly adjust the sampling frequency in accordance to the power delivered by the source.

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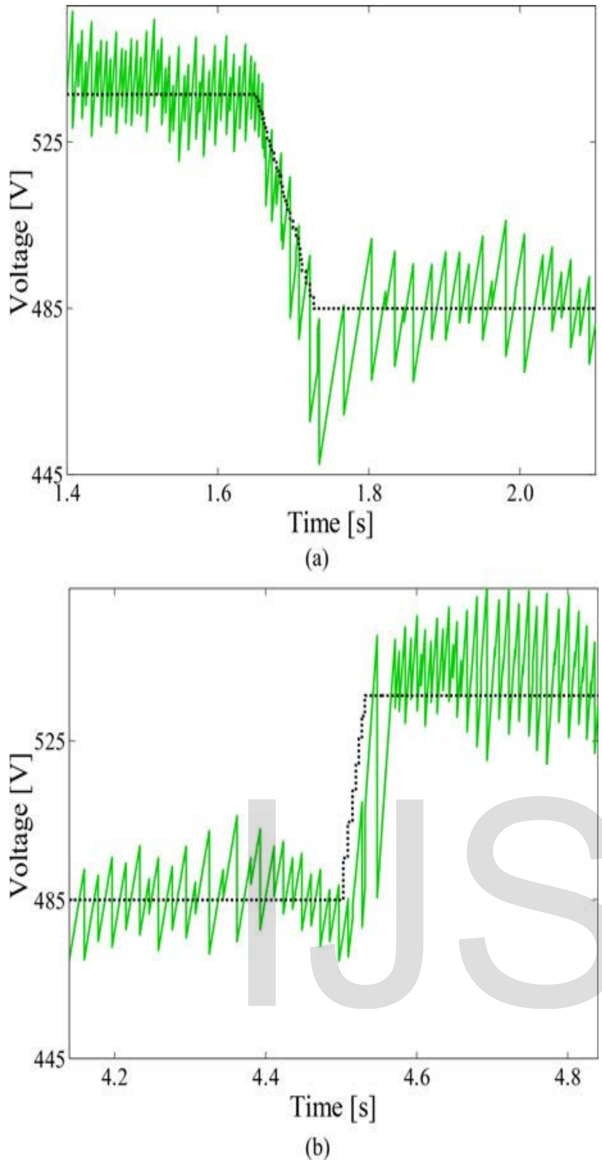

Figure8. Voltage and time under decreasing and increasing irradiance

4. CONCLUSION

A direct MPPT algorithm for PV applications has been presented: it exploits only the voltage measurements across a capacitor to actively follow the MPP; this allows to eliminate the current transducer. It works in a satisfactory way under varying irradiance. The proposed algorithm satisfies extracting maximum power with high efficiency due to rapid change of weather, minimizing the oscillations around MPP, giving quick and high response, and finally increasing stability of PV system.The tracking efficiency was evaluated to be 99.4%, while the DCI efficiency was estimated to be 97.8%. This paper provided a clear, accurate, and practical powerful tool for MPP field applications.

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