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EED371- RESEARCH PROJECT REPORT

A Novel Algorithm based on Voltage and Current Perturbation to track global peak under partial shading conditions.

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Abstract:

The power- voltage curve of a partially shaded PV array contains multiple peaks and out of which one is global peak. It is important to track global maximum power point (GMPP) of a PV array under partial shading conditions more accurately and efficiently. In this research work, a novel GMPP technique for tracking the global peak of a PV array under partial shading conditions will be carried out. The GMPP tracking algorithms will be operated in a voltage or current perturbations based on the value of the control variable. In this technique, the generated reference voltage or reference current moves the operating point to the GMPP location. The proposed GMPP tracking algorithm will be compared with different existing GMPP tracking algorithms in terms of tracking efficiency and tracking time under partial shading conditions.

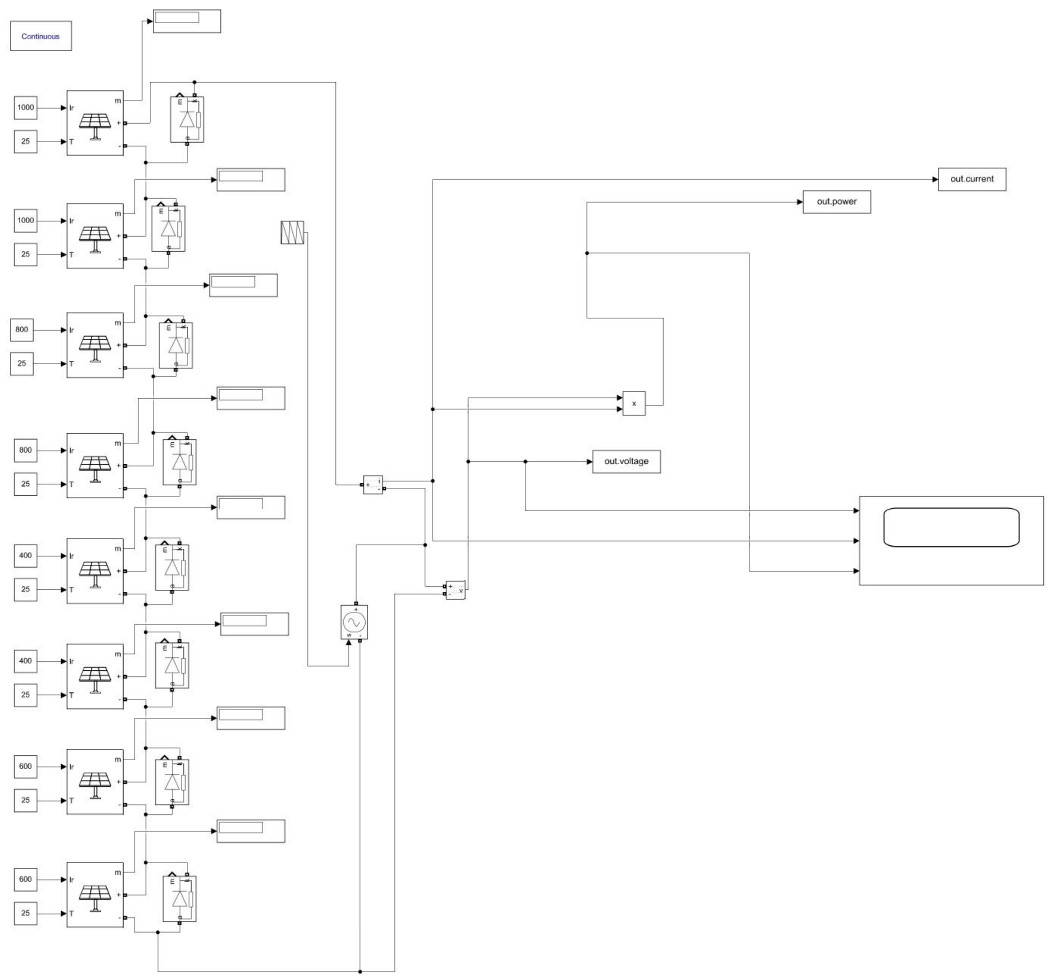
Introduction:

Over the past decade PV power generation has been on the forefront of renewable energy owing to its supremacy in installation, maintenance, operation, and modularity. It is used in several applications such as distributed power generation and standalone PV systems If a PV array receives uniform irradiance, only one maximum power peak will be observed in its $P - V$ characteristics In order to extract maximum energy output and achieve high economy, it is always desirable to operate PV panels at this maximum power point. However, it is not guaranteed that these PV arrays receive uniform irradiance all the time

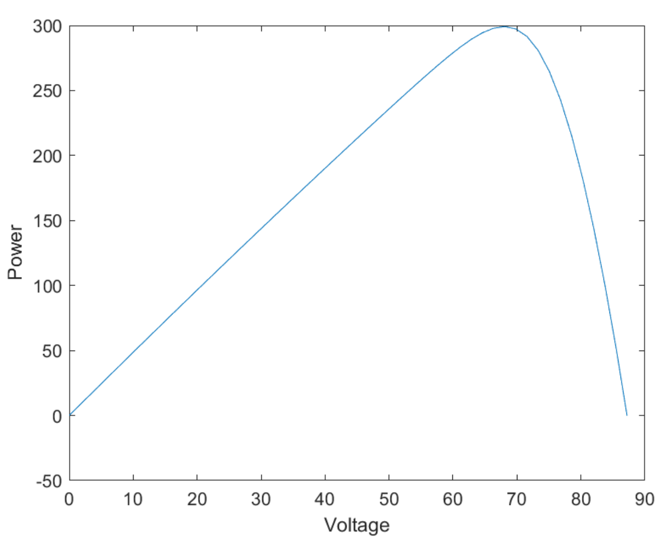
The Problem of Partial Shading:

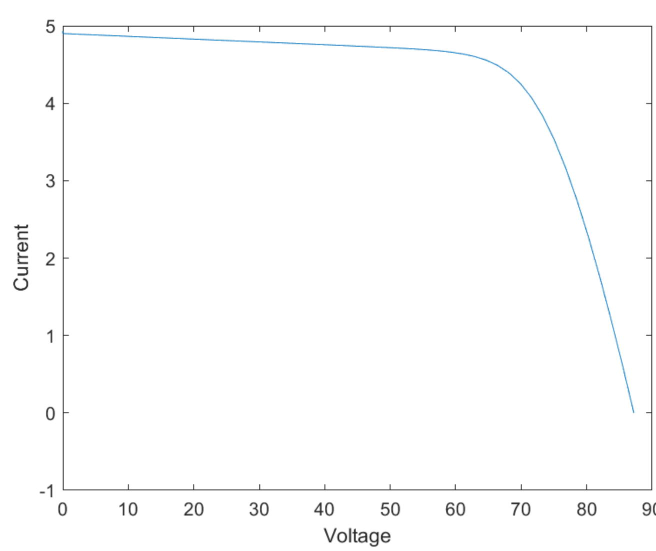
The power developed by a solar panel decreases if it does not get uniform radiation. Sometimes due to nearby buildings, passing clouds etc. PV modules might be partially shaded because of which the power output of the solar panel may decrease.It causes significant reduction in the system power output.Partial shading is a condition when modules connected in series it does not have same illumination compared to other modules , power generation in different modules different for same rating of the panel.But if same power does not flow to all modules lower generating modules will act as sink and absorb the power from modules which generate more power.Denser the partial shading more is the power loss.Because of absorption of power, cells would get heated up and cause hotspot problem which could result into cracking of glass shield. A hot spot is described as an over proportional heating of a single solar cell or a collection of cells compared to the surrounding cells.

Intensity of solar irradiance directly controls amount of output current and temperature of solar cell affects output voltage.We have done simulation based study for partial shading conditions and all simulation models of PV cell and panel are modelled with the use of Simscape in Simulink environment. We have done MATLAB simulation of PV modules under Partial Shading Conditions and Uniform Shading conditions. We connected 8 cells in series in accordance with the array used in the research. For Uniform shading conditions we have taken all panel’s Irradiance to be the same.Under STC(Standard Test Conditions) Temperature of the cells are taken as 25°C and Solar Irradiance as 1000 watts per metre square.

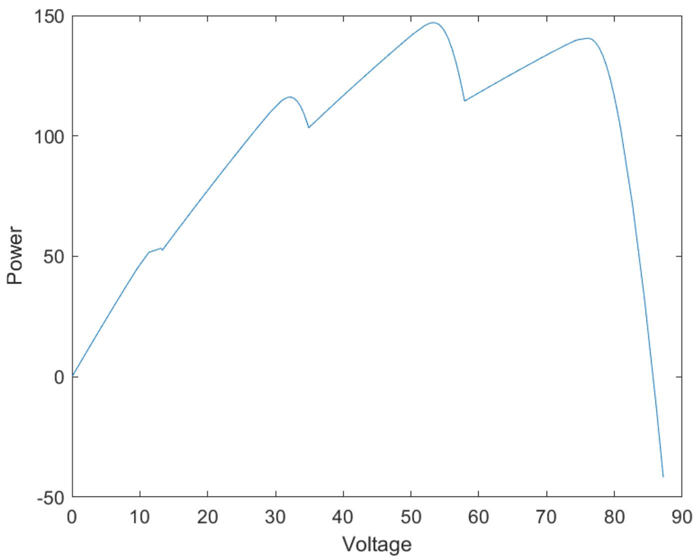


Uniform Shading : (all modules have same Irradiance)

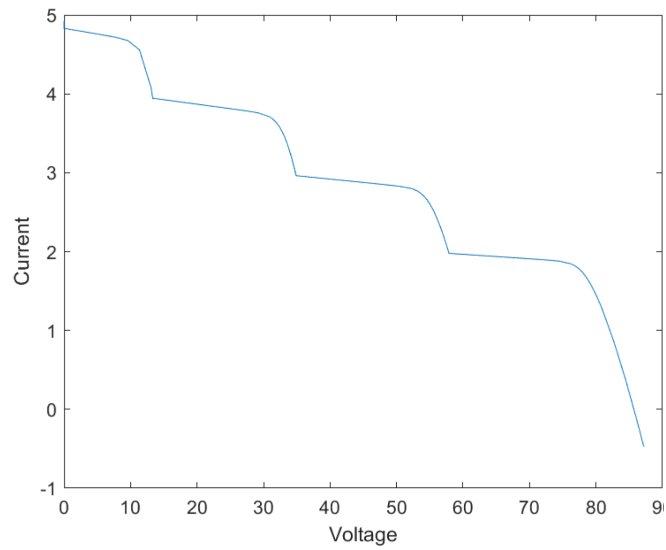




Partial Shading [1000, 1000, 800, 800, 400, 400, 600, 600]W/m²



P-V characteristic of of solar array with Non uniform irradiance



I-V characteristic of solar array with Non uniform irradiance

An effort is made to explain the behaviour of the solar PV array in different shading patterns.For Uniform and partial shading conditions the Voltage-Current (V-I) and the Power-Voltage(P-V) characteristics are shown.The different characteristics parameters of each of the module are shown in Table-1

TABLE I
SPECIFICATIONS OF PV MODULE AT STC

Parameter	Notation	Value
Open Circuit Voltage	V_{ocm}	10.9 V
Short Circuit Current	I_{scm}	4.9 A
Voltage at MPP	V_{mpm}	8.5 V
Current at MPP	I_{mpm}	4.4 A
Maximum Power	P_{mpm}	37.5 W
Number of cells in module	N_s	18

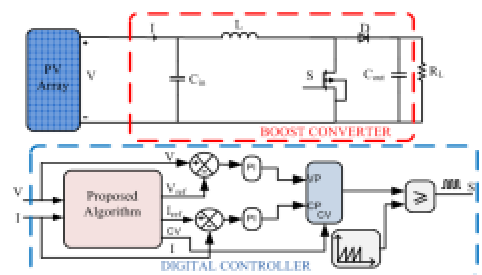


Fig. 1. Proposed MPPT empolyed PV system.

TABLE II
SPECIFICATIONS OF BOOST CONVERTER

Parameter	Notation	Value
Inductance	L	1.5 mH
Input Capacitance	C_{in}	300 μF
Output Capacitance	C_{out}	300 μF
Load Resistor	R_L	150 Ω
Switching Frequency	f	25 KHz

Research Gap:

When there is partial shading, conventional MPPT techniques cause power loss because they are unable to track global MPP though they are simple to use and computationally effective.Under these circumstances, it is essential to monitor the global peak in order to boost the PV system's efficiency. The global peak is tracked using a number of global MPPT (GMPPT) algorithms such as Modified MPPT methods , array reconfiguration methods, deployment of different converter topologies. The last two techniques demand complicated control, need for additional hardware and have larger switching loss. Many researchers adopt modified GMPPT techniques because they are easy to use, flexible control and are economical.

Most modified GMPPT techniques work in two steps. The GMPPT algorithm moves the operating point close to the global peak in the first stage and conventional methods are employed to find GMPP in the second stage.In reference papers,artificial neural network (ANN) and fuzzy controller-based intelligent MPPT approaches are employed in the first stage, and P&O or INC is operated to track the global peak in the second stage. However, fuzzy-based GMPPT algorithm need a rule base that needs to be formulated, whereas ANN-based algorithm required extensive training of neurons. The literature has demonstrated the effectiveness of standard evolutionary algorithms in addressing non-linear issues, but numerous modified variants are being proposed to improve the effectiveness of the GMPP tracking process.

Another popular class of GMPPT algorithms that is based on observations of P-V and I-V characteristics under partial shading conditions are scanning-based methods.In order to detect the step change in the current, a scanning-based methodology is provided,where the currents are sampled at integer multiples of the open-circuit voltage of a single module (Vocm). To distinguish the global maximum from all the local maxima, the HC algorithm is used at each step to converge the operating point to the local peak.
In the current control based algorithm, PV current is sampled at multiples of 0.9 of operational current, either in forward or backward direction. When termination criteria are found the tracking process is terminated. It has been found that if the shading pattern changes quickly over time, this method will become misguided and is likely to become entangled in one of the LMPPs, due to the fact that critical parameters are not incidentally updated for insolation change.

In order to overcome the above mentioned limitations a novel GMPPT method for partially shaded PV arrays is proposed based on Voltage and Current Perturbations.

Consolidated working of the Algorithm:

This MPPT algorithm will work in two stages. At first, the operating point will move close to the global peak using voltage and current perturbations and in the second stage, P&O algorithm will be used to track the GMPP accurately.

1. **Initialization**

The operating voltage and current are sensed and the power is calculated. P_{max}, V_{mp} are updated. Compute V_{min} and I_{min}. Shift the operating point to V_{min} by setting CV = 1. If P > P_{max}, update, P_{max}, V_{mp} and I_{min}.Set CV = 0 and check for the termination criteria in Step 2.

2. **Termination Criteria**

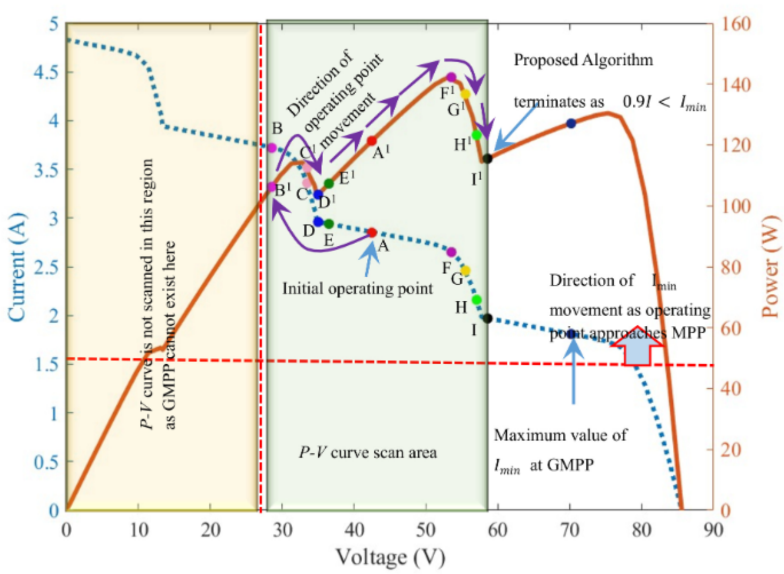
Check for the condition I_{ref} = 0.9*I. If it is satisfied, stop global peak tracking and operate P&O in the next stage to retain the global peak, else check the value of CV . If it is zero,go to step 3, else go to step 4.

3. **Current Perturbation**

Assign P_{old} as the present power (P) and compute I_{ref}.Shift the operating point to I_{ref}.Check for P > P_{max}. If this condition is satisfied, update P_{max},V_{mp} and I_{min}. Set CV = 1 and go to Step 2.

4. **Voltage Perturbation**

Assign P_{old} as the present power (P) and compute V_{ref} using (3). Shift the operating point to V_{ref}.Check for P > P_{max}. If this condition satisfies, update P_{max}, V_{mp} and I_{min}. To check if the operating point is in current source or voltage source region, check if P > P_{old}. If P > P_{old}, it implies that the operating point is in the current source region. Hence assign CV = 0 and go to Step 2. If P < P_{old}, the operating point is in the voltage source region and there is no change in the value of CV . Before the next perturbation in VP mode, go to Step 2.



Proposed Parameters:

1. I_{ref} = 0.9*I
2. V = V + ΔV
3. V_{min} = P_{max} / I_{mp} @ STC
4. I_{min} = P_{max} / 0.9 * V_{oc} array
5. 0.9*I < I_{min} (Termination criteria)

6. $V_{ref} < 0.9V_{ocm}$
7. $P > P_{old}$ says operating point is in current source region (CV=0)
8. $P < P_{old}$ says operating point is in voltage source region (CV=1)

These are the parameters that the algorithm uses to characterise a PV array for optimal performance. Few of the parameters need to be adjusted for optimal performance in the field.

Flowchart of proposed algorithm:

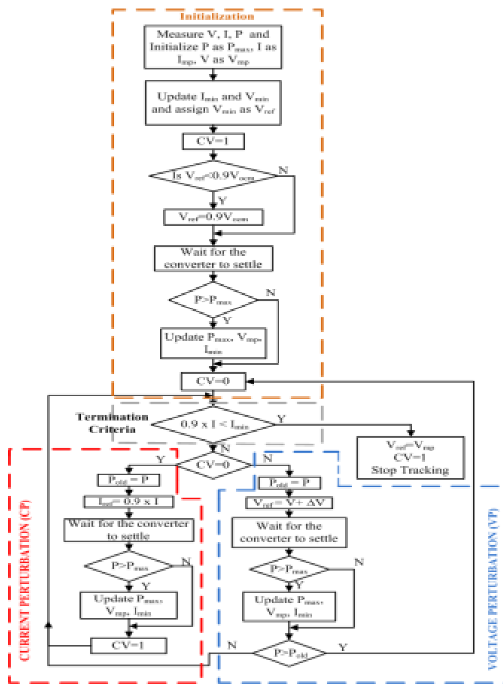
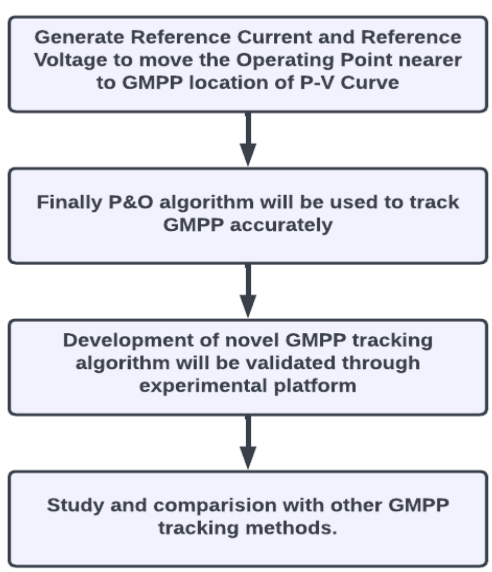


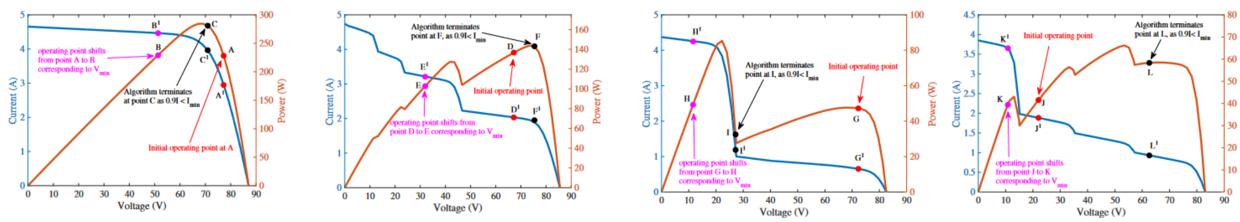
Fig. 5. Flowchart of the Proposed System.

Methodology: The following is a simplified flowchart that the paper utilised to formulate their algorithm and then effectively compare it to other GMPPT algorithms.



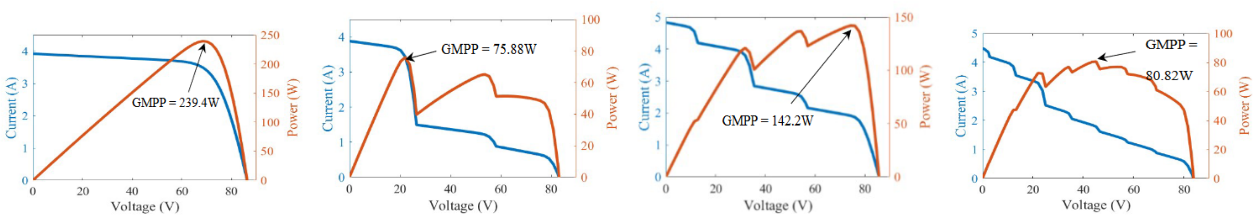
Results:

The proposed algorithm is verified using simulations in MATLAB and is validated using experimental results. Eight different shading patterns namely, Pattern 2, Pattern 3, Pattern 4, Pattern 5, Pattern 6, Pattern 7, Pattern 8 and Pattern 9 are used to verify the proposed technique. The gains of the PI controller are iteratively tuned looking into the dynamic response of the system. A custom made matlab program was made to mimic the algorithm to simulate its performance. This gives a holistic view of the array performance even under what might come forth as rare edge cases. These edge cases are very important as they can expose potentially instabilities in the algorithm.



(a) (b) (c) (d)

Fig. 6. $P-V$ and $I-V$ characteristics of (a) Pattern 2 (b) Pattern 3 (c) Pattern 4 (d) Pattern 5.



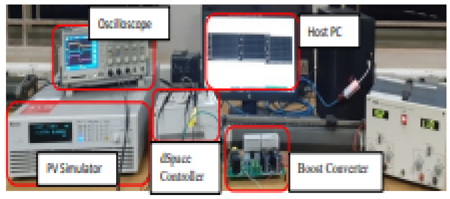
(a) (b) (c) (d)

Fig. 7. $P-V$ and $I-V$ characteristics of (a) Pattern 6 (b) Pattern 7 (c) Pattern 8 (d) Pattern 9.

TABLE III
INSOLATION LEVEL FOR EIGHT SHADING PATTERNS

Patterns	Insolation Level in W/m^2							
	M1	M2	M3	M4	M5	M6	M7	M8
Pattern 2	950	950	950	950	950	950	950	950
Pattern 3	1000	950	800	675	675	450	450	450
Pattern 4	900	900	900	200	200	200	175	175
Pattern 5	800	800	400	400	300	300	200	200
Pattern 6	800	800	800	800	800	800	800	800
Pattern 7	800	800	400	300	300	300	175	175
Pattern 8	1000	1000	850	850	575	575	435	435
Pattern 9	950	850	720	510	415	325	250	175

To validate above performed simulations, experiments were carried out in the laboratory set up shown below. Chroma PV simulator is used as a PV array with eight PV modules connected in series. The same shading pattern shown in Table III is implemented using a PV simulator. The output of the PV simulator is connected to a 0.4 kW boost converter. The output of the converter is connected to a resistive load and dSPACE Microlab box 1202 is used as an MPPT controller.



Hardware set up of the PV system.

TABLE V
TRACKING PERFORMANCE OF GMPPT METHODS IN EXPERIMENT

Patterns	Tracking Speed(s)			Energy Efficiency (%)		
	Proposed	[30]	[31]	Proposed	[30]	[31]
Pattern 2	0.37	1.50	0.86	92.60	70.72	82.80
Pattern 3	0.68	1.30	1.16	86.40	74.00	76.80
Pattern 4	1.19	3.70	3.12	88.10	63.00	68.80
Pattern 5	1.39	4.10	2.66	86.10	59.00	73.20
Pattern 6	0.57	2.10	1.50	85.91	48.12	62.94
Pattern 7	1.24	4.10	2.69	81.63	40.11	60.15
Pattern 8	0.74	1.18	1.10	89.03	82.51	84.29
Pattern 9	1.13	3.50	2.50	90.91	71.88	80.00

TABLE VI
COMPARISON OF PROPOSED ALGORITHM BASED ON DIFFERENT PARAMETERS

Qualities	Proposed	[30]	[31]	[27]
Tracking Speed	High	Medium	High	Low
Energy Efficiency	High	Low	Medium	Low
Convergence to GMPP after tracking is terminated	High	Medium	Medium	Low
Number of perturbation steps to reach GMPP	Very Less	Less	Less	More
Fixed period scanning in the second stage	No	Yes	No	No
Steady State Oscillations	Medium	Medium	Medium	Low

Conclusive findings of Research paper:

- Able to track Global peak among multiple local peaks - Approximates location of Global peak and then use conventional PO
- Very quick tracking speed - Skips a lot of overlapping scan regions in P-V curve
- Low cost since the existing controller is bootstrapped for this application - Control loop has additional parts to approximate GMPP. Also no neural processors, to faff about
- Significantly less oscillations around MPP - Quicker convergence Because of 2 phase process
- Better efficiency - Unnecessary scanning of MPP avoided after lock on GMPP. Also less loss
- Less complex - Based only on simple to implement linear algorithms. No Neural network or fuzzy logic
- Still has excellent performance even under uniform irradiance - No performance loss in response and efficiency in primary mode of operation

- Copes with irregular positions of global peak that other algorithms struggle with - Sudden shifts in location of peaks leads to longer convergence time in other algorithms
- Starter parameters are very easy to calculate or easy to extrapolate for very good approximations - very quick startup - Only open circuit voltage and few other constants required, most of which are given in the datasheet of panel
- Both voltage and current perturbation capability for quick response and efficiency - Helps with sudden shifts in MPP location and very low irradiance
- Low number of parameters to optimise to get good performance - Need to adjust only power change threshold, endpoint voltage and current

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