IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Enhanced P&O MPPT Algorithm With A Narrowed Search Range For Grid- Tied PV Systems

[1]G. Anil kumar, [2]P. Yaswanth, [3]P. Roswanth, [4]K. Pallavi, [5]M. Mahesh

1Assistant Professor and 2 3 4, 5 are scholars, Department of Electrical and Electronics Engineering, Bapatla Engineering College, Bapatla (522101), AP, India

Abstract: This paper presents a refined approach to maximizing the effectiveness of grid- connected photovoltaic (PV) systems through an enhanced Perturb and Observe (P&O) Maximum Power Point Tracking (MPPT) algorithm. While traditional P&O styles are valued for their simplicity, they frequently struggle with slow shadowing pets and significant power losses due to steady- state oscillations. Adaptive MPPT algorithms have surfaced as a result, stoutly conforming the anxiety step size grounded on propinquity to the maximum power point (MPP). still, they frequently come with increased computational complexity**.**

To strike a balance between speed, delicacy, and simplicity, the proposed Modified P&O(MPO) algorithm limits the MPP hunt zone to just 10 of the power- voltage (P- V) wind — where the MPP generally resides. It intelligently divides the wind into four regions using an estimated open- circuit voltage. In regions far from the MPP, it applies a large, fixed step size for quick shadowing, while by near regions, it adopts an adaptive strategy to minimize oscillations and power loss.

Simulation results using MATLAB/ SIMULINK under varying irradiance biographies including sinusoidal, ramp, and realistic one- day conditions — demonstrate the effectiveness of the proposed MPO algorithm. It achieves a fast confluence time of just 15 milliseconds and an emotional shadowing effectiveness of 99.8, outperforming both conventional and recent adaptive MPPT ways. This work highlights a practical and high-performance result for boosting the trustability and energy affair of ultramodern PV systems.

Index Terms **- Maximum Power Point Tracking Algorithm, Matlab Simulink, Open Circuit Voltage.**

I.INTRODUCTION

The world's energy requirements are soaring, but our old ways of generating power are running out of brume and harming the earth. That's why there's a big shift toward clean, renewable energy like solar power. Solar photovoltaic (PV) systems are a fantastic way to tap into the sun's energy — they're simple, easy to gauge, and don't need important keep. Plus, they produce electricity without any pollution, which is a palm for the terrain.

But then the catch solar panels aren't super effective, only converting about 9 to 17 of sun into usable power, and they're at the mercy of the rainfall. Cloudy days or changing temperatures can throw them off. The trick is to make sure the system is always working at its peak, hitting what's called the" maximum power point"(MPP) — the sweet spot where it generates the most electricity.

That's where our design comes in. We've taken a popular system called Perturb and Observe(P&O), which helps solar systems find that sweet spot, and made it indeed more. Our upgraded interpretation, called the Modified P&O(MPO) algorithm, is like giving the system a smarter GPS. It zooms in on just a bitsy 10 slice of the power- voltage wind to find the MPP super presto, without wasting time or energy. It's quick to reply when the sun's far from ideal and super precise when it's close to the perfect spot, keeping effects smooth and steady.

We tested this new approach using computer simulations in MATLAB/ SIMULINK, throwing all kinds of sun patterns at it — sudden changes, crimpy patterns, indeed a full day's worth of real- world conditions. The results? Our MPO algorithm nails it, locking onto the MPP in just 15 milliseconds and hitting an stupendous 99.8 effectiveness. It's a big step toward making solar power more reliable and effective, helping us make a cleaner, greener future.

II.SYSTEM DISCRIPTION

In this work, we developed a grid- connected solar photovoltaic (PV) system that's not just effective but also smart about how it captures and delivers power. At the heart of this system is a set of intelligent MPPT (Maximum Power Point Tracking) algorithms designed to help the PV panels operate at their stylish — indeed when sun and rainfall conditions are changing.
To explore and compare performance, we implemented three different P&O-based MPPT algorithm

2.1 Conventional P&O (CPO):

This is the classic interpretation — simple and extensively used. It perturbs the system's voltage slightly and observes whether the affair power increases.However, it keeps going in that direction, If it does.However, it reverses, If not. It's easy to apply but struggles with fast- changing conditions, and it can beget energy loss due to nonstop oscillation around the peak power point.

2.2 Adaptive P&O (APO):

This interpretation is smarter. It adjusts the size of its disquiet depending on how close it's to the maximum power point. However, it makes big jumps to get there briskly, If the system is far out. Once it's close, it takes lower way to reduce overshooting and minimize energy loss. It performs better in dynamic rainfall but requires further computational trouble.

2.3 Modified P&O (MPO) – Our Proposed Solution:

This is our own enhanced version of P&O, designed to bring together the best of both worlds: fast response and low complexity. Instead of searching the entire power-voltage curve, it focuses only on the most promising 10%—the area where the maximum power point is most likely to be. We divide the curve into four regions using the open-circuit voltage as a guide. In the outer regions, where we're far from the peak, the algorithm uses large, fixed steps for quick movement. In the central regions, it switches to an adaptive approach for fine-tuning.
The result? Faster convergence, lower energy loss, and higher efficiency—all without heavy computational load.

We tested these algorithms under various solar irradiance profiles—including step changes, sinusoidal variation, and full-day patterns—and observed how well each performed in a MATLAB/SIMULINK simulation of a complete grid-tied PV system. The proposed MPO algorithm consistently showed superior performance, reaching the maximum power point faster and more accurately than the others.

2.4 Solar Cell Modelling:

To make our solar power system feel like the real deal, we started by building a math model of a solar cell—the tiny piece that makes up every solar panel. We used something called the Single Diode Model because it's great at showing how a solar cell turns sunlight into electricity. Think of it as a simple recipe: there's a part that makes power from light, a diode that controls how electricity flows, and two resistors—one for energy that gets lost inside the cell and another for any leaks.
How much power a solar panel makes depends on a few things, and we captured it in this main equation:
$I_0 = N_p I_{ph} - N_p I_{sat}[\exp(q(V + R_s I_0)/AkTN_s) - 1] - N_p(V + R_s I_0/N_s R_s h)$
Don't worry about the fancy math It just says I_0 is the electricity the panel sends out, and V is the voltage. I_{ph} is the power made from sunlight, and I_{sat} is a small leak through the diode. N_p and N_s show how many cells are

connected side-by-side or in a row. The letters q, k, and T are science stuff for things like electron charge and temperature, and A is a number (usually 1 or 2) that tweaks how the diode works.
We also figured out the sunlight-powered current, I_{ph}, which depends on how bright the sun is and how hot the cell gets:
$I_{ph} = (G/1000) * (I_sc + K_i(T - T_i))$
Here, G is how strong the sunlight is, I_sc is the current when the cell is short-circuited in standard tests, K_i adjusts for temperature, T is the cell's actual heat, and T_i is a baseline temp (like 25°C).
Then, we modeled the diode's leaky current, I_{sat}, which changes with temperature:
$I_{sat} = (I_sc + K_i(T - T_i)) / [\exp((V_oc + K_v(T - T_i))/V_t) - 1]$
In this, V_oc is the voltage when the cell's circuit is open, K_v tweaks for temperature, and V_t (found with kT/q) is a voltage tied to heat.

These equations team up to make a model that acts like a real solar cell, responding to changes in sunlight and heat. It's like a digital version of a solar panel that behaves like one on a rooftop. This setup lets us test our MPPT algorithms in simulations that feel super close to the real world, so we know they'll work great out there.

2.5 Modeling of booster:

To make sure our solar system gives out the right voltage for the grid, we use a smart device called a boost converter. You can think of it like an energy booster—it takes the lower voltage from the solar panels and increases it to a higher level that's more useful. Inside, it has a few important parts: a fast electronic switch (called an IGBT), an inductor that stores energy like a spring, a diode that keeps the current flowing in the right direction, and a capacitor that smooths out any voltage bumps. The real trick is in how long the switch stays on during each cycle—that's what we call the duty cycle, and adjusting it is what controls the boost.

We modeled the converter's behavior using Kirchhoff's voltage and current laws, which help describe how energy moves through the system. The first equation shows how the inductor current changes over time:
dt/diL=Vpv−Vo/L+Vo*u/L

In this equation, iL is the current flowing through the inductor,
Vpv Is the voltage from the solar panel, Vo is the output voltage, L is the inductance value, and u is a binary value that's 1 when the switch is ON and 0 when it's OFF. This tells us how quickly the current ramps up or down depending on the switch's state and the voltage difference.

Next, we model how the output voltage across the capacitor changes:
dt/dVo= iL/C-iL/C*U
Here, Co is the output capacitor. This equation tracks how the output voltage increases or decreases depending on the inductor current and the switching activity.

Finally, there's a simple but important formula that shows the relationship between the input voltage from the PV array and the output voltage from the converter. It's based on the duty cycle
D, which represents the percentage of time the switch is ON:
Vo/Vpv =1/1−D
This means that by adjusting the duty cycle, we can boost the output voltage. As the duty cycle gets closer to 1, the output voltage increases—but we have to be careful not to push it too high. This control method is key to our MPPT (Maximum Power Point Tracking) algorithm, which continuously adjusts the duty cycle to draw the most energy possible from the solar panels.

In short, the boost converter is the bridge between the solar panel and the grid, helping us regulate and optimize power flow no matter how much sunlight is hitting the panels. This accurate mathematical modeling makes sure the system responds properly in all kinds of weather and sunlight conditions.

2.6 Inverter Designing:

In Our solar power system has a super important part called the Grid Side Inverter, or GSI. It's like a friendly helper that takes the electricity from our solar panels, which is DC (like a battery), and changes it to AC (like what your house uses). The grid, where we send our power, only likes AC, so this step is a big deal.

The GSI sits right before the grid and makes sure our electricity matches what the grid wants—same voltage, same rhythm, everything in sync.

Some fancy systems add extra controls, but ours keeps it simple. The GSI just focuses on turning DC into AC so the grid can use it. It uses a trick called Pulse Width Modulation (PWM) to make a nice, smooth AC signal that the grid loves. Think of the GSI as a cool bridge that lets all the clean energy from our solar panels flow happily into the grid for everyone to use.

2.7 Space Vector Modulation

Space Vector Modulation, or SVM, is a smart way to control the switches in a three-phase inverter, like the one in our solar power system's Grid Side Inverter. It's like a clever guide that tells the inverter how to change DC electricity (like from a battery) into AC electricity that the grid can use. Instead of just turning switches on and off without a plan, SVM uses a cool math trick to picture the AC output as a single spinning arrow in a flat space. This arrow moves around to copy the AC wave. By picking the right switch combinations, called "vector states," and timing them just right, SVM makes sure the inverter creates a smooth, clean AC signal that matches the grid's needs. It's really good at saving energy and keeping the output nice and quiet, with less unwanted noise. Think of SVM as a dance teacher, making sure every step is perfect so the power flows smoothly to the grid.

Here's the simple version of how it works: the inverter has six tiny switches, like little doors, that open and close to make the AC power. SVM decides which switches to use and for how long by following that spinning arrow. It chooses from eight switch patterns—six that move the arrow in different directions and two that act like a quick break. By mixing these patterns carefully, SVM builds a super smooth AC wave. What's great about SVM is that it's really accurate and uses the DC power better than other methods, like regular Pulse Width Modulation (PWM). It's like SVM is playing a game of drawing a perfect curve by connecting dots, making sure our solar energy gets to the grid without any trouble. That's why it's a top pick for inverters in solar systems, where saving energy and working well matter a lot.

2.8 Grid specifications

The grid in our solar power system is like the giant web that sends electricity to houses and shops. It has a couple of important details to keep things running nicely. The document says the grid uses 380 volts, which is how strong the electricity is. It also works at 50 hertz, which is like the beat or speed of the electricity flow—pretty common in lots of places! These details matter because our Grid Side Inverter has to match this voltage and beat to push the solar power into the grid without any trouble. It's like making sure your phone plugs into the right charger so it works perfectly—this grid setup makes sure our solar energy flows smoothly for everyone to use!

III. P&O MPPT ALGORITHMS

3.1 Conventional P&O MPPT Algorithm

The Conventional Perturb & Observe (CPO) algorithm is extensively espoused due to its simplicity, as depicted in Fig. 3. The strategy of the CPO algorithm can be epitomized as follows

- Continuously observe power variations (1 P).
- undo the reference voltage until the maximum power point (MPP) is tracked.

During the shadowing process, the direction of voltage anxiety is determined by the sign of 1.However, the voltage anxiety continues in the same direction, If 1 P is positive.

Again, if 1 P is negative, it indicates that the MPP is far down, and the voltag anxiety should be reduced to track the MPP.

The oscillation situations around the MPP and the settling time response are determined by the breadth of the voltage or duty cycle step size used in the CPO algorithm. thus, the CPO algorithm utilizes a fixed step size, which can be moreover small or large. When a small step size is employed, it results in lower steady- state oscillation situations but slower confluence time and increased power loss. On the other hand, using a large step size reduces the confluence time but leads to advanced oscillation situations. Accordingly, several experimenters have explored variations to the CPO algorithm to address the limitations of response time and steady- state oscillation situations.

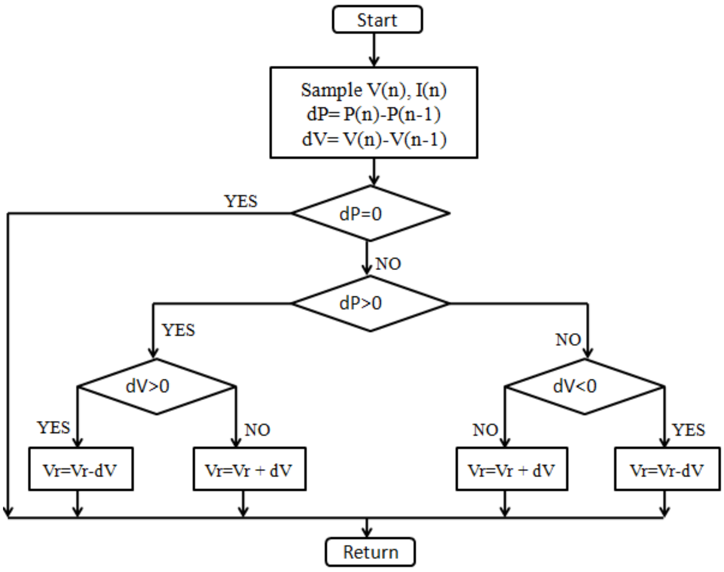

Figure:3.1: Conventional P&O MPPT Algorithm Flow Chart

3.2 Adaptive P&O MPPT Algorithm

To overcome the limitations of conventional P&O algorithms, colorful adaptive P&O algorithms have been developed, exercising either duty cycle or voltage anxiety approaches. These adaptive algorithms aim to address issues related to dynamic shadowing response and steady- state oscillations. They intelligently acclimate the anxiety step size during the shadowing process grounded on the propinquity to the MPP. In order to maximize tracking speed, a large anxiety step size is used when the operating point is far from the MPP. As the operating point gets near to the MPP, the anxiety step size is stoutly reduced to a lower value. Adaptive P&O algorithms employ varying anxiety step sizes according to the operating point, allowing for fast shadowing with minimum steady- state oscillations. The adaption of the anxiety step size is achieved through a relationship between the variations in power (P) and voltage (V)

$\Delta Vn\ 1 = M * \Delta P/ \Delta Vn$

Where

M is an delicacy constant. Another system can be used which substantially grounded on the logarithmic function,

$\Delta Vn\ 1 = M \cdot \ln (\Delta Pn/ \Delta Vn)$

Adaptive P&O algorithms give fast dynamic response and good steady- state stability. still, they bear fresh computations when operating far from the MPP. To reduce these computations, a fixed step- size can be used in the far region from the MPP, performing in a lower hunt area for the MPP wind where adaptive step- size is applied.

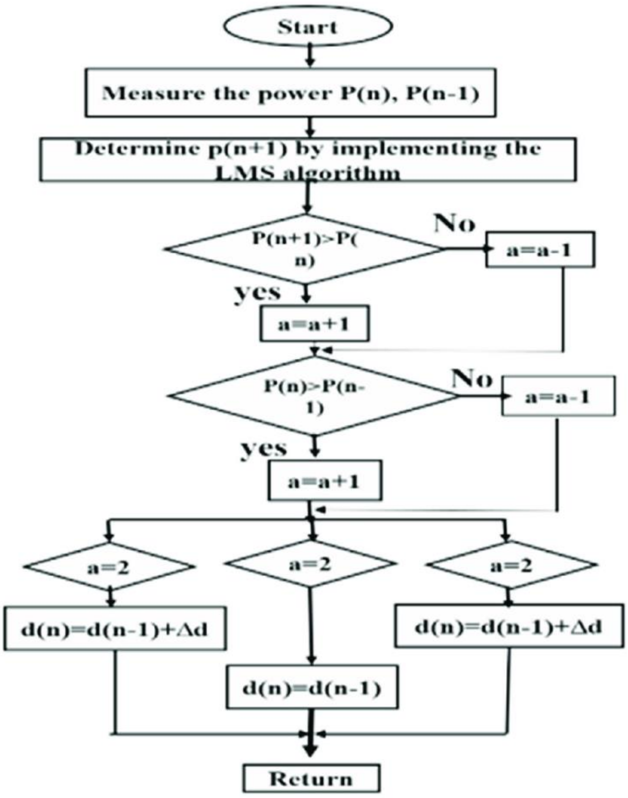

Figure-3.2: Adaptive P&O MPPT Algorithm Flow Chart

3.3 Modified P&O MPPT Algorithm

The Modified MPPT (MPPT) algorithm is designed to combine the fast response of fixed- step P&O with the delicacy of adaptive styles, while reducing complexity. rather of searching across the entire power- voltage wind, this approach focuses the hunt within a narrow 10 zone where the maximum power point (MPP) is most likely to be. This targeted strategy reduces gratuitous calculations and pets up the shadowing process.

To make this work, the power- voltage (P- V) wind is divided into four regions grounded on the estimated open- circuit voltage (Voc)
Regions 1 & 4(far from MPP) Use a large fixed step size to snappil get near to the MPP.
Regions 2 & 3(near to MPP) Use an adaptive step strategy to fine- tune the voltage and reduce oscillations.
To estimate where the MPP lies, the algorithm uses a simple commensurable relationship

$VMPP = \; Koc * Voc$
Where
$VMPP$ is the voltage at the maximum power point

Voc is the open- circuit voltage of the panel
Koc is a constant (generally around 0.76)
This equation helps constrict the hunt to the most likely region around the MPP.

Adaptive Step Size (within focused region)
When the system is operating in the inner regions (close to MPP), the step size is calculated stoutly, analogous to the adaptive system

$S = M * \Delta Pn / \Delta Vn$
Where
S is the adaptive step size
$\Delta Pn$is the change in power
ΔVn is the change in voltage
$M$is a tuning constant

The full shadowing sense in this Modified MPPT is

1. Estimate Voc
2. Divide the P- V wind into 4 regions grounded on predefined voltage thresholds $V1$, $V2$, and $VMPP$
3. Use large step size in the external zones
   If $0 < Vpv < V1$ or $V2 < Vpv < Voc$, then perturb the duty cycle with a fixed large step ΔDL
4. Use adaptive step when in the focused MPP zone:
   If $V1 < Vpv < VMPP$ or $VMPP < Vpv < V2$ VMPP, then use the adaptive equation above

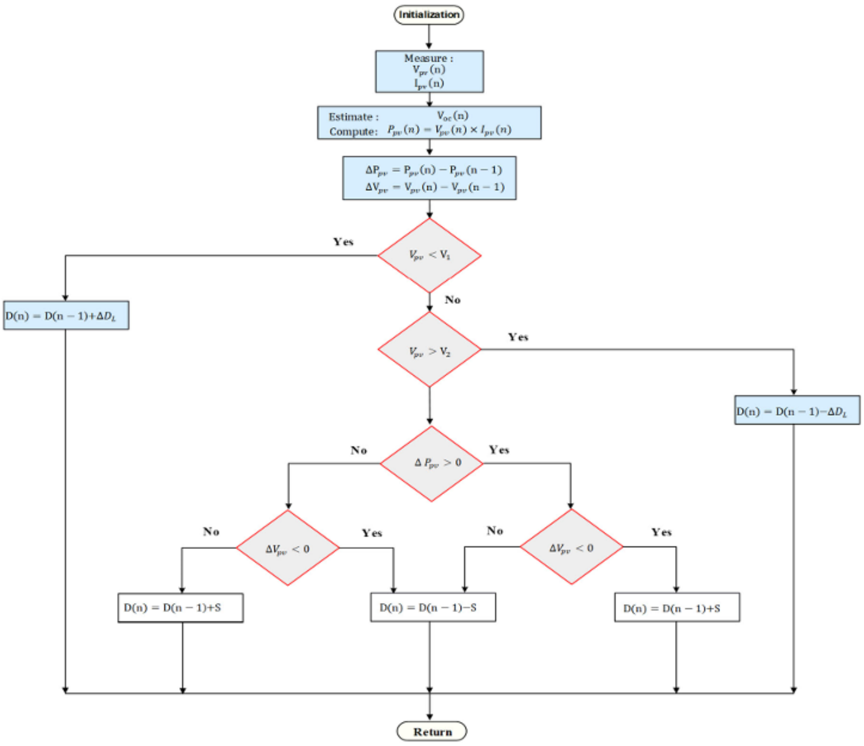

Figure :3.3 Flow chart of MPO Algorithm Strategy

IV.SIMULATION AND RESULTS

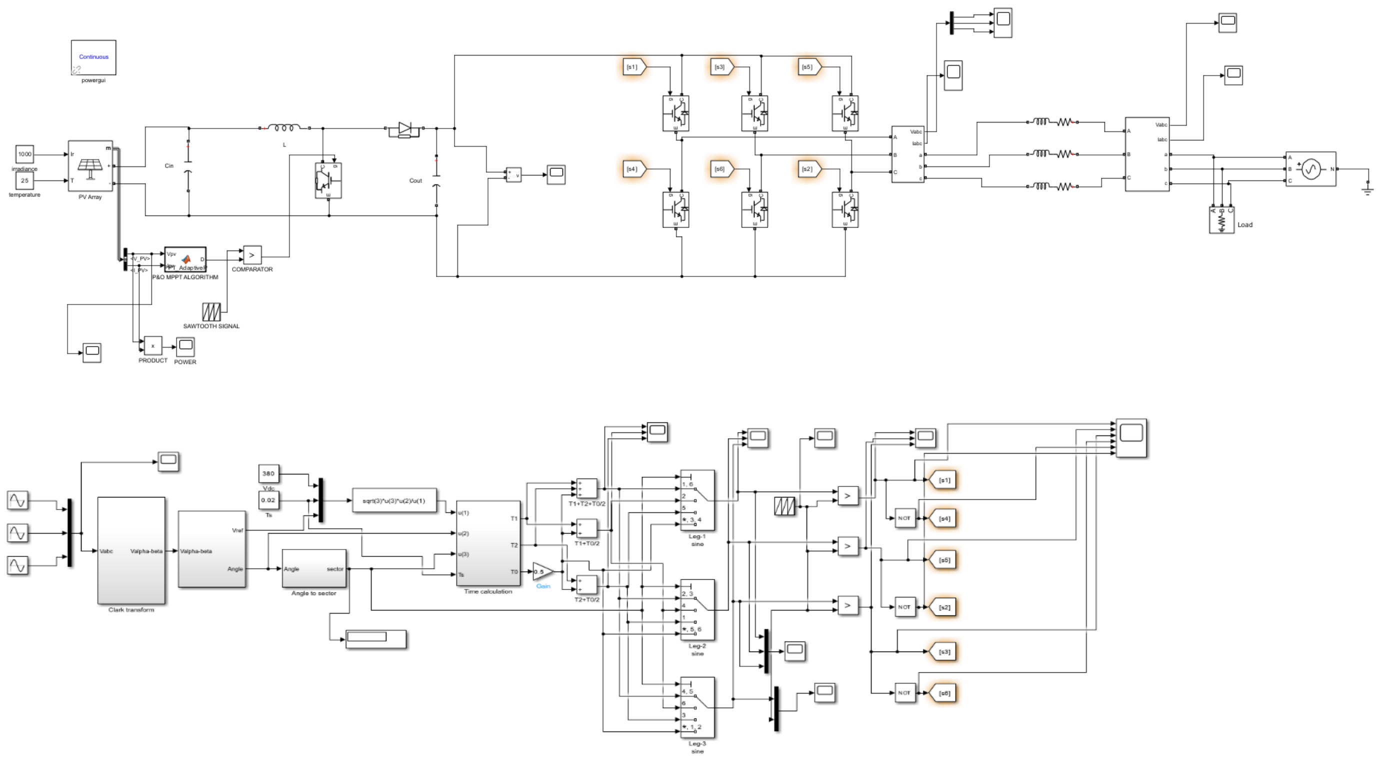

Fig.4.1 MATLAB Simulation Diagram

4.1 Booster output:

The output from the solar array is taken as the input to the booster circuit. This booster circuit will step up or step down the voltage levels. A perfect clean dc output is obtained.

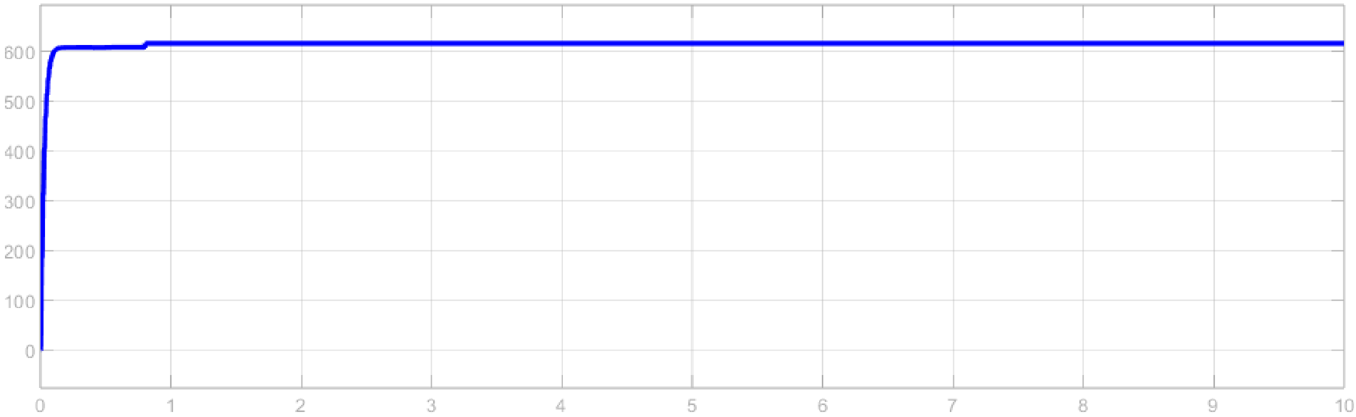

Fig.4.2. Booster output

4.2 Space Vector Modulation Output:

Svm generates the gate pulses for the 6 igbts used to design the inverter.

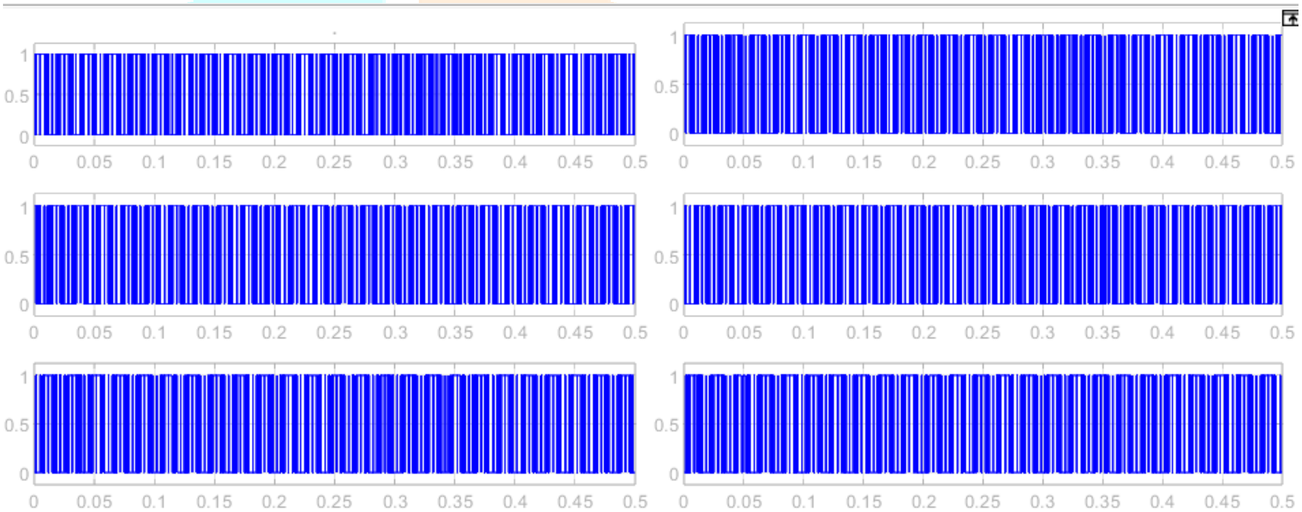

Fig.4.3. Gate Pulses for Inverter

4.3 Inverter Output:

The output of the high-frequency inverter was monitored using a scope block and that confirmed the generation of alternating high-frequency pulses. The displayed waveform exhibits symmetric switching behavior which is required for optimum inductive coupling, where proper gating signals have minimal distortion and impressive resonance matching with the transmitting coil.

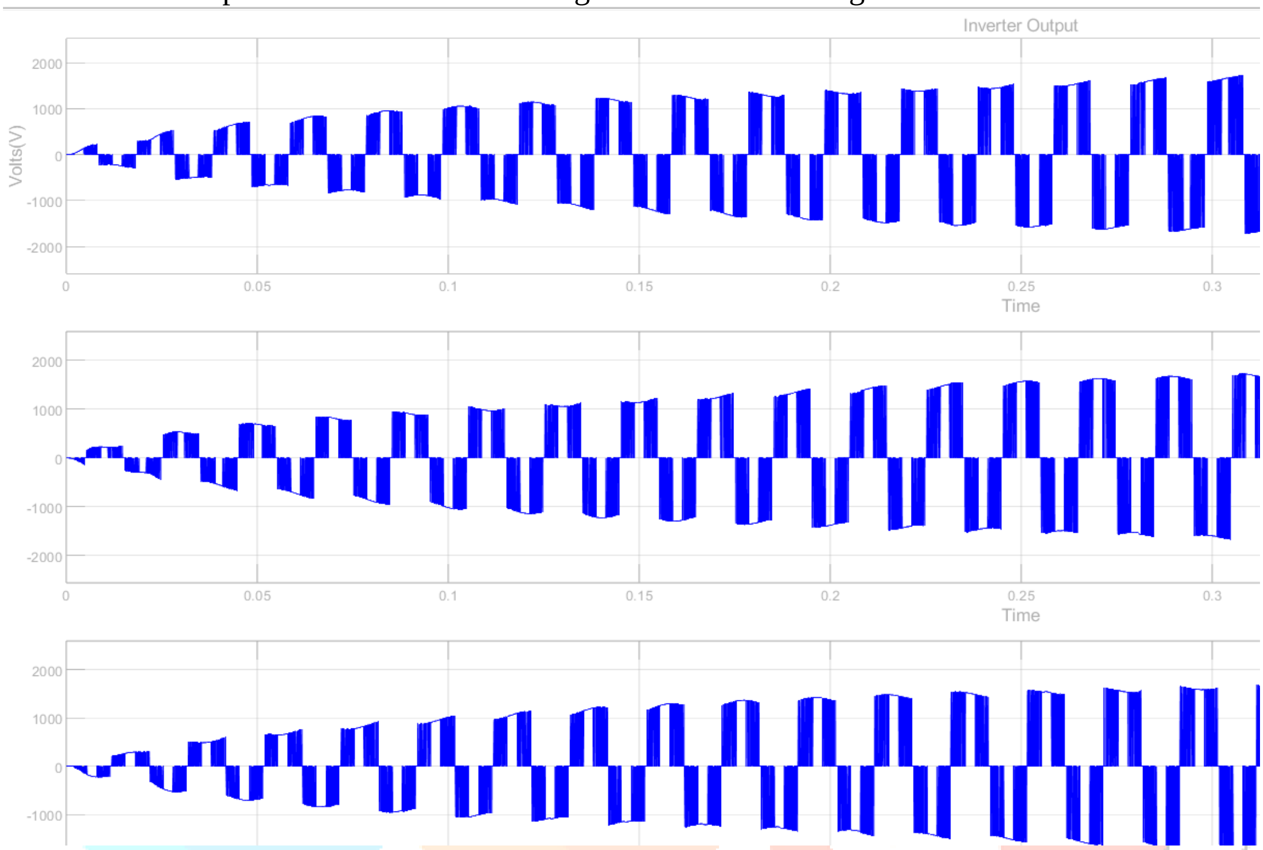

Fig.4.4 Inverter output

4.4 Conventional Mppt algorithm Output:

In the early stages of our work, we also used the Conventional MPPT technique Specifically the basic Perturb and Observe (P&O) method. This is one of the simplest and most commonly used MPPT algorithms. It works on a straightforward idea: the system slightly perturbs the voltage and observes how the power output changes. If the power increases, it keeps moving in the same direction. If the power decreases, it reverses the direction of the perturbation. It's like playing a guessing game with the sun nudging the voltage back and forth until it lands near the sweet spot where the power is highest.While this method is easy to implement and doesn't require much processing power, it has some clear drawbacks. Since the step size is fixed, it often causes the system to oscillate around the maximum power point instead of settling exactly on it. It also tends to respond slowly to rapid changes in sunlight, which can lead to missed energy capture during cloudy or dynamic weather conditions. In our simulations, the Conventional MPPT did manage to track the MPP and maintain power output, but it showed more fluctuations and slower response compared to the Adaptive and Modified MPPT techniques. It's a good starting point for MPPT design, but not the most efficient when high performance and quick response are needed.

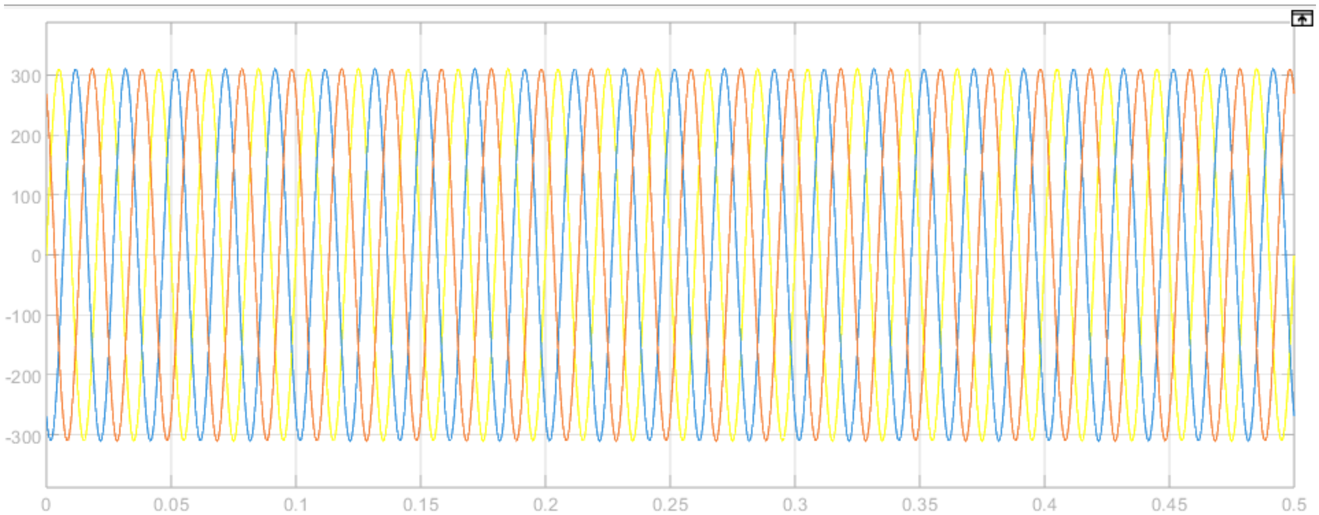

Fig.4.5. voltage wave form when conventional mppt is used

4.5 Adaptive Mppt Algorithm output:

In our system, we also explored the Adaptive MPPT (Maximum Power Point Tracking) technique, which builds upon the basic P&O method but with more intelligence and flexibility. Instead of sticking to a fixed step size for every voltage adjustment, the adaptive approach makes the system more responsive by dynamically changing the step size based on how close or far the system is from the maximum power point (MPP). When the power output is far from its peak, the algorithm takes larger steps to reach the target quickly. As it gets closer to the MPP, it automatically reduces the step size, allowing the system to fine-tune its position with more precision and minimize unnecessary oscillations. This smart adjustment helps the PV system handle fast-changing conditions—like passing clouds or fluctuating sunlight—much more effectively than traditional methods. With the Adaptive MPPT in place, the power converter can better follow the optimal operating point in real-time. The outcome is a smoother tracking process, improved efficiency, and a more stable output. In our simulations, this approach helped maintain good power delivery while keeping the system from overreacting to minor changes, showing how adaptive control brings both speed and stability to MPPT tracking.

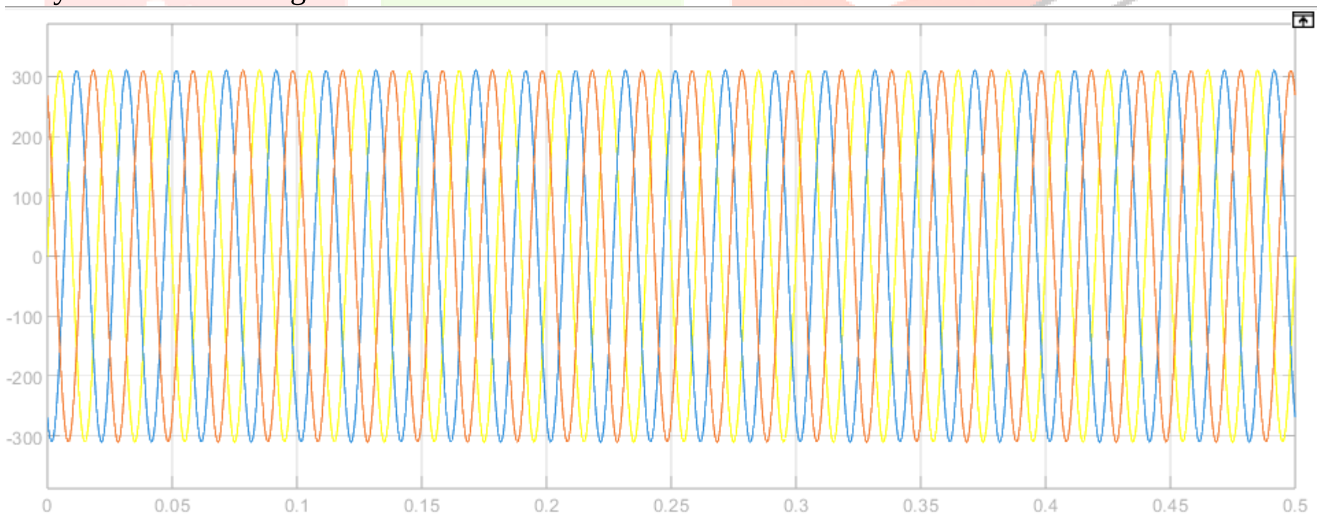

Fig.4.6. voltage waveform for adaptive mppt algorithm

4.6 Modified Mppt algorithm:

In our system, we implemented a Modified MPPT (Maximum Power Point Tracking) technique—an enhanced version of the traditional P&O method. Unlike the conventional approach that continuously hunts for the maximum power point across the entire power-voltage curve, our Modified MPPT smartly narrows the search to just 10% of the curve where the MPP is most likely to be. It uses a large fixed step when the system is far from the peak and switches to a smaller adaptive step as it gets closer, allowing for faster tracking and fewer power losses. This balance between speed and precision helps the PV system react more smoothly to changes in sunlight without unnecessary oscillations.

The result of using this Modified MPPT was very promising. After processing the power through the boost converter and inverter, we successfully achieved a clean, stable 3-phase sine wave output—just what's needed for seamless grid integration. The waveform quality indicates that the system is not only tracking the MPP effectively but also converting and delivering the power efficiently. This confirms that our MPPT strategy is doing its job well and that the overall system is performing reliably under dynamic conditions.

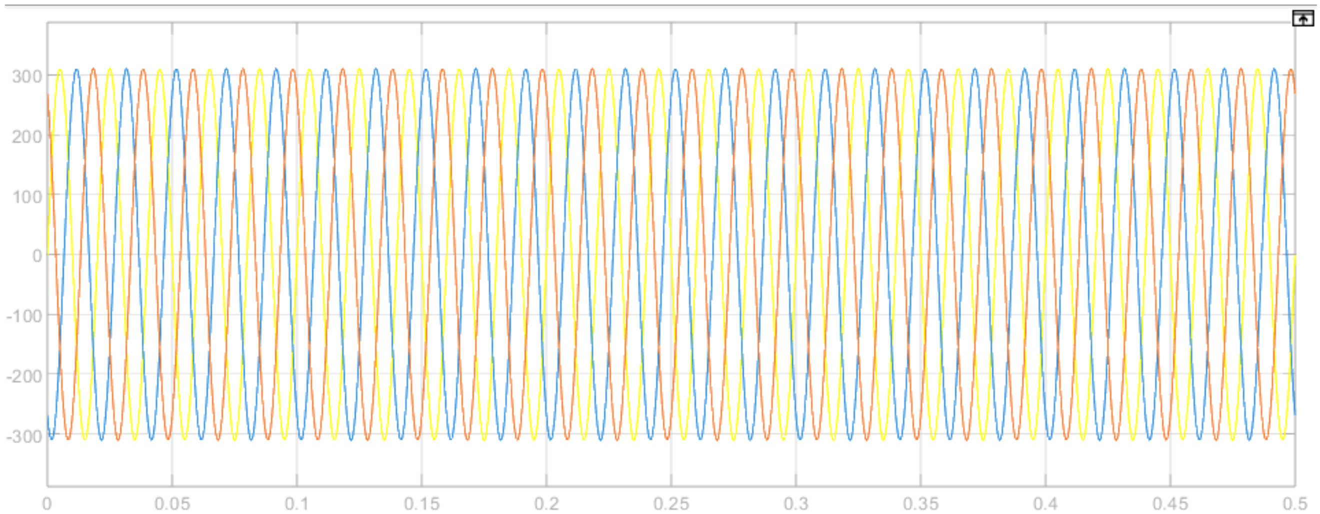

Fig.4.7 Voltage wave form when modified mppt used

APPENDIX

VI. CONCLUSION

The solar power project described in the document is all about making solar panels work better by getting the most energy possible out of them and sending it to the grid smoothly. The big win here is a new way to track the best power point, called the Modified Algorithm, which beats older methods by being faster and steadier. The project tested this new approach using computer simulations with different sunlight patterns, like sunny days, wavy light changes, and a full 10-hour day with clouds and showers. The results? The Modified Algorithm is super quick, locking onto the best power point in just 15 milliseconds, and it's really efficient, hitting 99.8% efficiency with hardly any wobble in the power output. This means more solar energy gets used and less gets wasted, making the whole system more reliable for feeding clean power to homes and businesses.

The design compared three ways to track the maximum power point (MPPT). First, there's the Conventional Perturb and Observe (CPO) system, which is simple and popular. It works by tweaking the voltage a little and checking if the power gets better or worse, also keeps going in the right direction. But it has issues if it uses big tweaks (Large-Step CPO), it's fast but wobbles a lot around the stylish point, hitting only 98.8 effectiveness with a 20- volt ripple. However, it's steadier with just a 3- volt ripple and 99, If it uses bitsy tweaks (Small- Step CPO).3 effectiveness, but it's super slow, taking 120 milliseconds to settle. Second, the Adaptive Perturb and Observe system is smarter. It changes the tweak size grounded on how close it's to the stylish point — big tweaks when far down, small bones

when close. This makes it briskly and steadier than the CPO, but it needs redundant computations, which can decelerate effects down a bit. Eventually, the Modified Algorithm (called MPO in the document) is the star of the show. It splits the power- voltage wind into four zones grounded on the open- circuit voltage. Far from the stylish point, it uses big, fixed tweaks to drone in fast. near to the stylish point, it switches to adaptive tweaks to stay super steady. This quintet gives it the stylish of both worlds a zippy 15- millisecond settling time, a bitsy 2- volt ripple, and a top- notch 99.8 effectiveness. It's like chancing the perfect balance between speed and smoothness, making it a great fit for solar systems that need to keep up with changing sun while delivering steady power to the grid.

References

[1] A. K. Abdelsalam, A. M. Massoud, S. Ahmed, and P. N. Enjeti, ''High-performance adaptive perturb and observe MPPT technique for photovoltaic-based microgrids,''

[2] H. Fathabadi, ''Novel fast dynamic MPPT (maximum power point tracking) technique with the capability of very high accurate power tracking,'' *Energy*, vol. 94, pp. 466–475, Jan. 2016.

[3] A. Belkaid, I. Colak, and O. Isik, ''Photovoltaic maximum power point tracking under fast varying of solar radiation,'' *Appl. Energy*, vol. 179, pp. 523–530, Oct. 2016.

[4] H. Tao, M. Ghahremani, F. W. Ahmed, W. Jing, M. S. Nazir, and K. Ohshima, ''A novel MPPT controller in PV systems with hybrid whale optimization-PS algorithm based ANFIS under different conditions,'' *Control Eng. Pract.*, vol. 112, Jul. 2021, Art. no.104809.