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Pv Off Grid System with Improved Charge Controller Using Closed Loop Control

*Midun S[1], Vibhishan A[2], Avinash R[3].

[1, 2, 3] *UG, Electrical and Electronics Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India.*

Email id: *midun.20ee@kct.ac.in[1], vibhishan.20ee@kct.ac.in[2], avinash.20ee@kct.ac.in[3].*

***Corresponding Author Orcid ID:** 0009-0006-5685-1471*

Abstract

A photovoltaic (PV) off grid system is a cutting-edge energy system that harnesses solar power to provide reliable electricity to localized areas. This abstract focuses on enhancing the performance of PV standalone off grid systems through the implementation of an advanced charge controller employing closed-loop control strategies. These autonomous energy systems, powered by solar panels, offer a decentralized solution to electricity generation and distribution. Traditional charge controllers may not efficiently adapt to varying solar irradiance levels, leading to suboptimal energy harvesting. The closed-loop control system proposed in this work addresses the need for dynamically adjusting the charging algorithm in response to real-time environmental conditions, ensuring maximum energy captured from the PV system. The open circuit voltage algorithm plays a pivotal role in increasing the overall efficiency of the PV micro grid. By responding intelligently to changes in solar irradiance and load requirements, the system minimizes energy losses and maximizes the utilization of available renewable resources, thereby addressing the need for efficient energy management. The results obtained from MATLAB simulation are compared with other methods in terms of maximum power efficiency. The results suggest that the open circuit voltage algorithm is efficient.

Keywords: *MATLAB, Boost Converter, PV off-Grid, Maximum Power Point Tracking, Open Circuit Voltage.*

1. Introduction

The development of new techniques to maximise the efficiency of photovoltaic power utilisation is fueled by the increasing demand for photovoltaic energy, which calls for an improved scheme based on fractional open circuit voltage to extract maximum power from photovoltaic systems under constant conditions [1]. For the solar system to maximise system efficiency, it must run at Maximum Power Point (MPP). The MPP is the location on the P-V curve where, at a specific temperature and irradiance level, photovoltaic power reaches its maximum. However, tracking the MPP is challenging due to the non-linear features of the PV module. The documentation displays a range of illumination conditions. While considerably easier to execute, the classic MPPT methods—such as the perturb and observe, fractional voltage, and current methods—have poor efficiency, are unable to track MPP under shifting irradiance circumstances, as demonstrated in Figure 6, oscillate or fluctuate around MPP, among other issues. In comparison to standard methodologies, the suggested method tracks MPP efficiently even with variable irradiance, and its power oscillations are significantly reduced [2]. By contrasting the tracking performance under shifting amplitude irradiance with the traditional perturb and observe and incremental conductance, the efficacy of the proposed technique is assessed. Figure 1 displays the I-V and P-V curves with varying radiation levels. The final simulation result of boost current and PV power is shown in Figure 10 and 11.

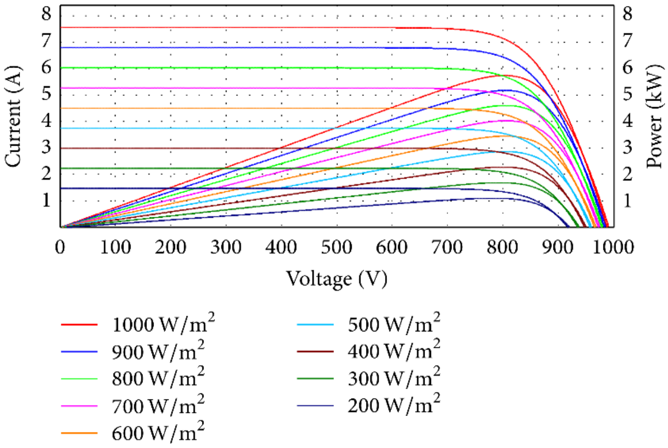


Figure 1 I-V and P-V Curve with Different Irradiation

2. Methodology

2.1 Charge Controller Algorithm

The PV array voltage that corresponds to the maximum power shows a linear dependency with respect to [3] array open circuit voltage for varying irradiation and temperature levels. This is utilized by the fractional open circuit voltage based MPPT. Out of all the MPPT techniques mentioned in the literature, this one is the most straightforward. With the help of the voltage and current added to the grid, we can calculate the instantaneous power drawn from the panel. OCV is proportional to temperature variation, which is determined by the open circuit voltage algorithm flowchart displayed in Figure 2.

$$V_{OC} = - k_1 * T + k$$

The PV system's maximum voltage that may be extracted is equal to [4]. The PV voltage is displayed in Figure 8.

$$V_{MPP} = K2 * V_{OC}$$

K2 is a constant that is smaller than unity. Its optimal value ranges from 0.73 to 0.8. The PV panel's SCC is dependent on the amount of irradiation. The table 1 describes this relationship.

$$I_{SC} = k3 * E$$

The PV characteristic can be used to calculate the constant k3. Figure 7 displays PV current. Nonetheless, under different lighting conditions, the ideal operating current for maximum output power is related to the short circuit current. [5]

$$I_{MPP} = k_4 * I_{SC}$$

The proportional constant, k4, ranges from 0.8 to 0.9 in this case. The SCC measurement is required by this control technique.

Table 1 Evaluating $K2 = V_{MPP}/ V_{OC}$

Irradiance	Open Circuit Voltage, V_{OC}	Power, P	$K_2 = V_{MPP}/V_{OC}$
@ 400 W/m²	33.94	4.47	0.78
@ 600 W/m²	34.93	5.64	0.78
@ 800 W/m²	35.16	26.48	0.77
@ 1000 W/m²	36.30	37.69	0.76

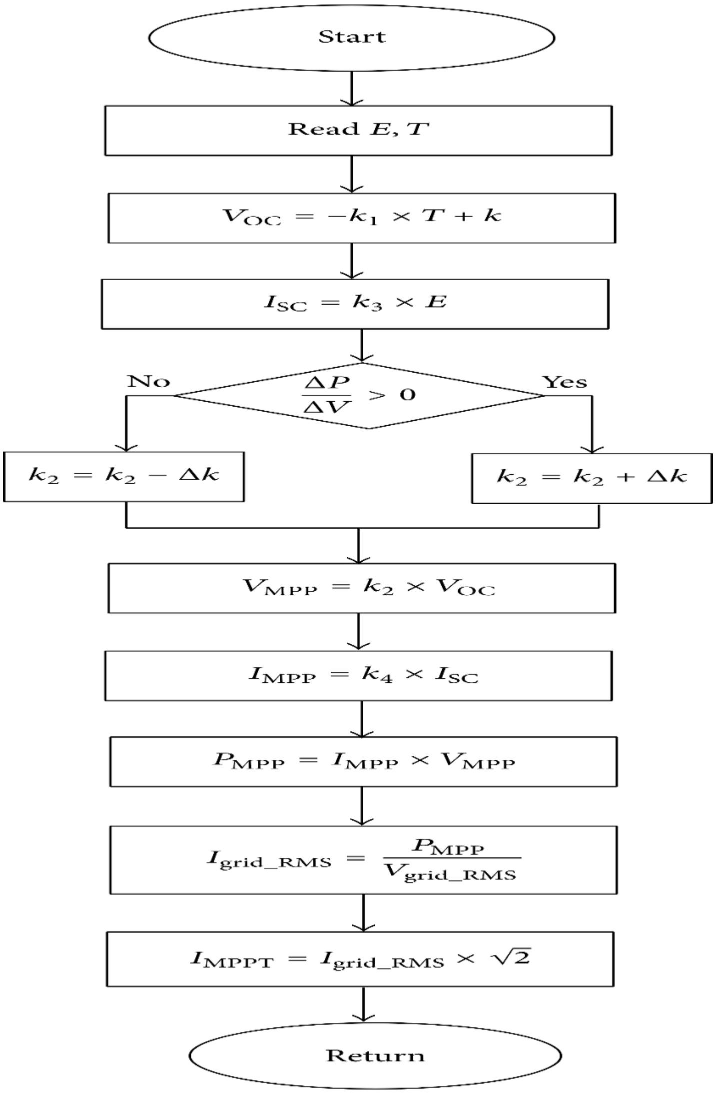


Figure 2 Flowchart of Open Circuit Voltage Algorithm

3. Results and Discussion

3.1 Simulation

The PV Standalone Off-Grid System is simulated using the MATLAB Software and we've used the [6] Open Circuit Voltage Algorithm by Developing Corresponding MATLAB Code. Simulation of Circuit of Off-Grid System are shown in Figure 3.

The simulation of the circuit is given below,

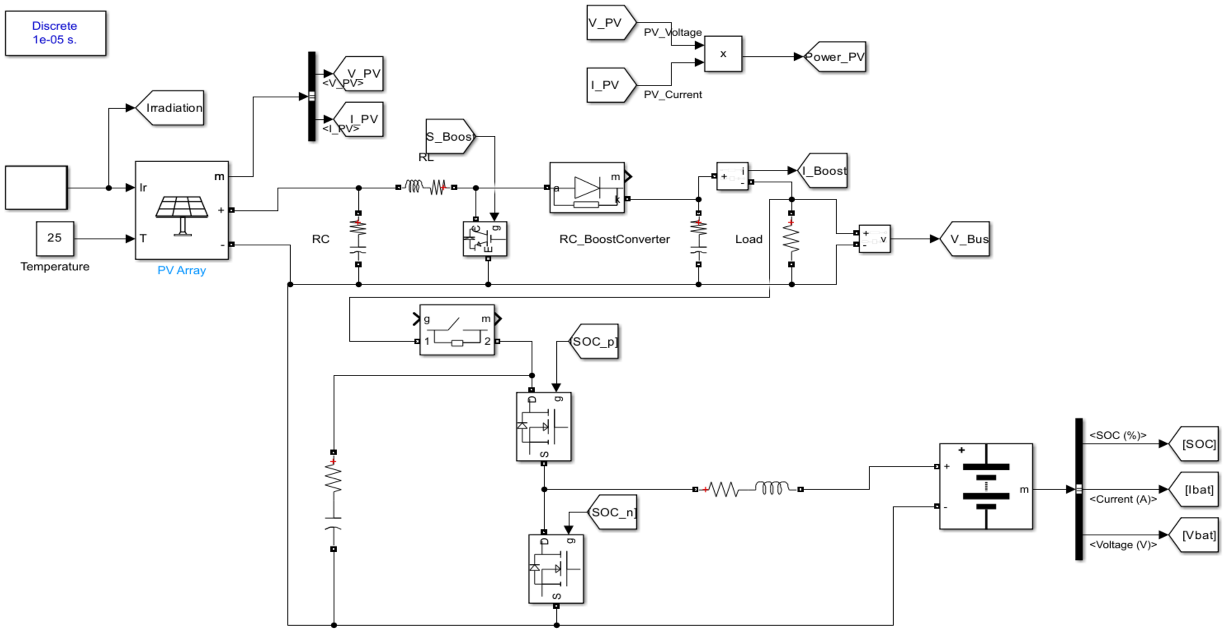


Figure 3 **Simulation of Circuit of Off-Grid System**

The MATLAB Code for the algorithm is applied using the following Function block, [7] Bus voltage are shown in Figure 9.

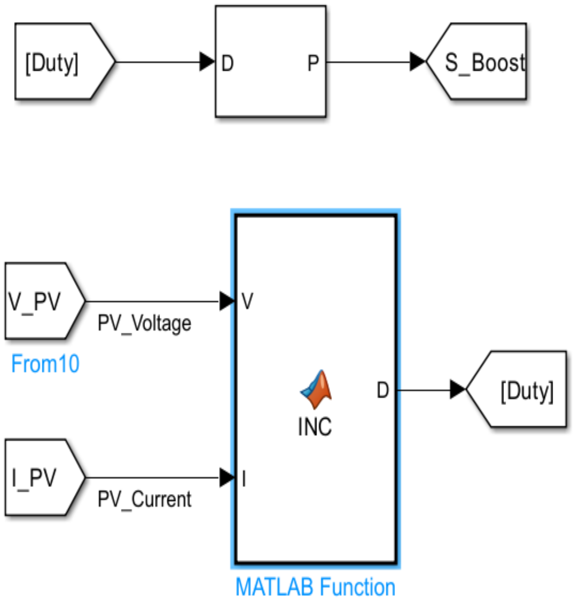


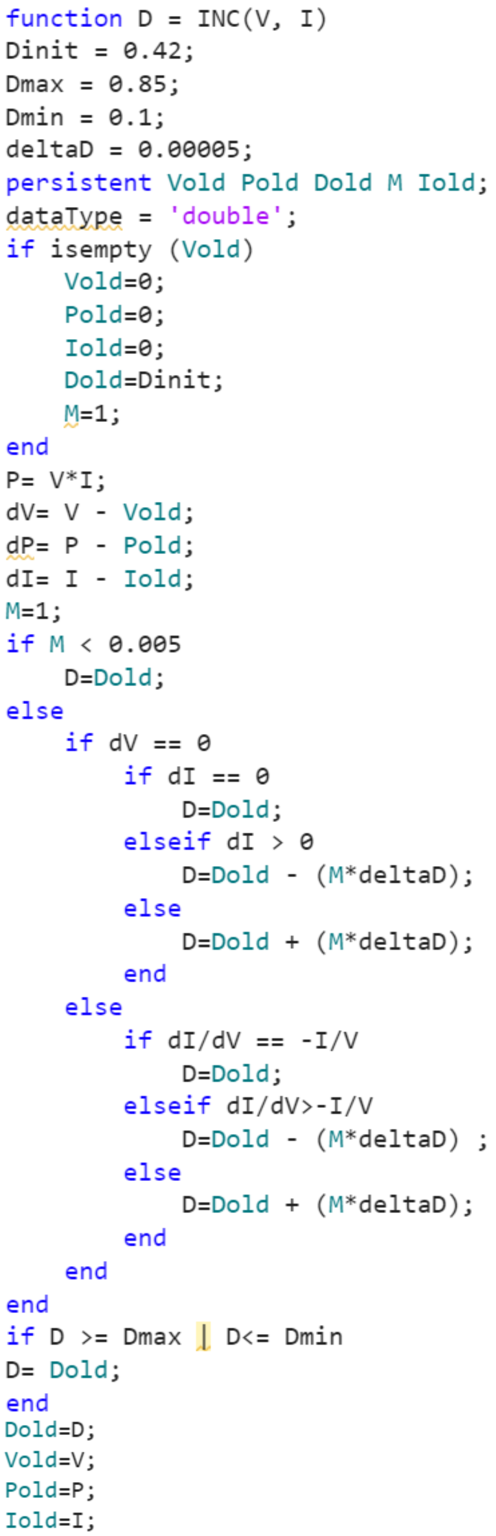
Figure 4 **Function Block for Closed Loop Control**

Table 2 **Simulation Parameters at 1000 W/m^2 for 5 parallel strings**

Maximum power current, I_m	7.35*5 = 36.75 A
Maximum power voltage, V_m	29 V
Open circuit voltage, V_{oc}	36.3 V
Maximum power, P	213.15*5 = 1067.5 W
Battery Voltage, V_{bat}	48 V
Inductance, L	5 mH
Capacitance, C	3300 x 10^{-6} F
Boost Current	9.6 A
Bus Voltage	96 V
DC ref. Voltage	220 V

The MATLAB code for the Open Circuit Voltage Algorithm is given below the table 2 Simulation

Parameters at 1000 W/m2 for 5 parallel strings. Function Block for Closed Loop Control are in Figure 4.



```
function D = INC(V, I)
Dinit = 0.42;
Dmax = 0.85;
Dmin = 0.1;
deltaD = 0.00005;
persistent Vold Pold Dold M Iold;
dataType = 'double';
if isempty (Vold)
    Vold=0;
    Pold=0;
    Iold=0;
    Dold=Dinit;
    M=1;
end
P= V*I;
dV= V - Vold;
dP= P - Pold;
dI= I - Iold;
M=1;
if M < 0.005
    D=Dold;
else
    if dV == 0
        if dI == 0
            D=Dold;
        elseif dI > 0
            D=Dold - (M*deltaD);
        else
            D=Dold + (M*deltaD);
        end
    else
        if dI/dV == -I/V
            D=Dold;
        elseif dI/dV>-I/V
            D=Dold - (M*deltaD) ;
        else
            D=Dold + (M*deltaD);
        end
    end
end
if D >= Dmax | D<= Dmin
D= Dold;
end
Dold=D;
Vold=V;
Pold=P;
Iold=I;
```

Figure 5 Algorithm code for the charge controller

3.2 Simulation Results

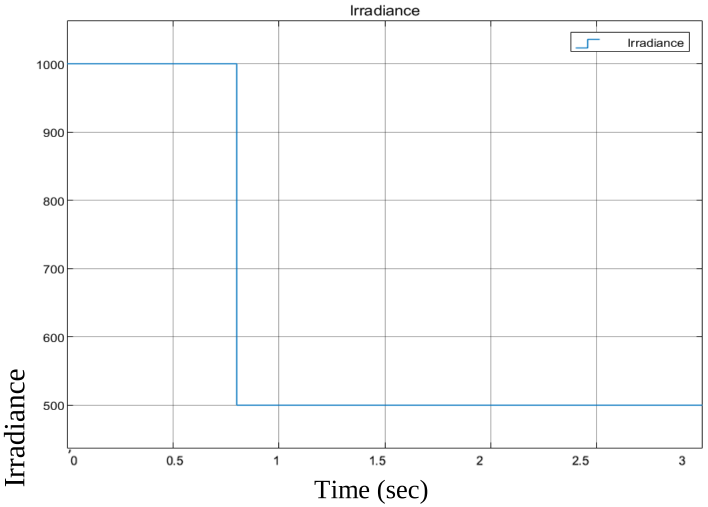


Figure 6 Irradiance

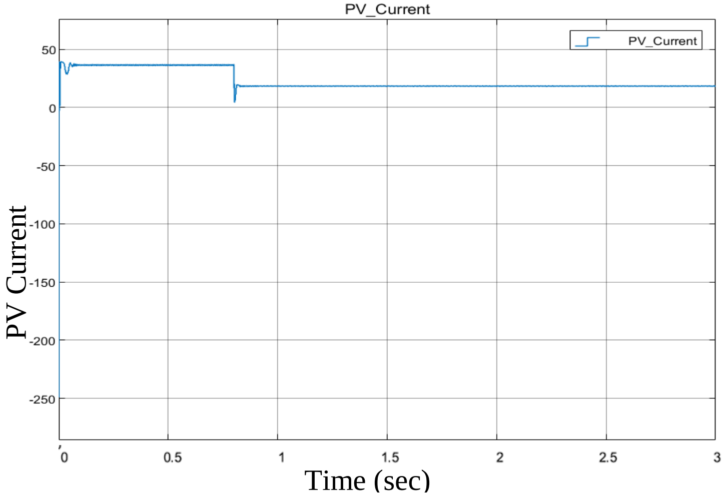


Figure 7 PV Current

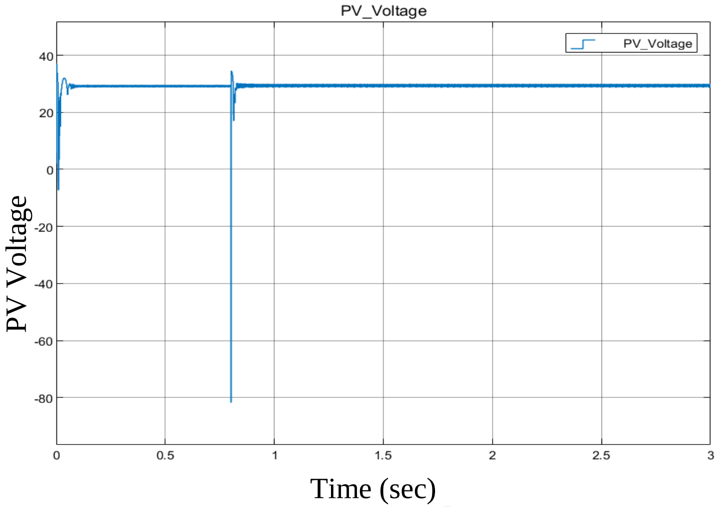


Figure 8 PV Voltage

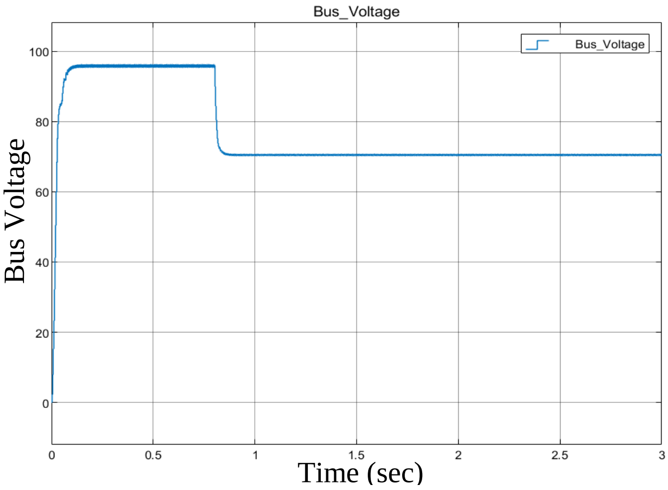


Figure 9 Bus Voltage

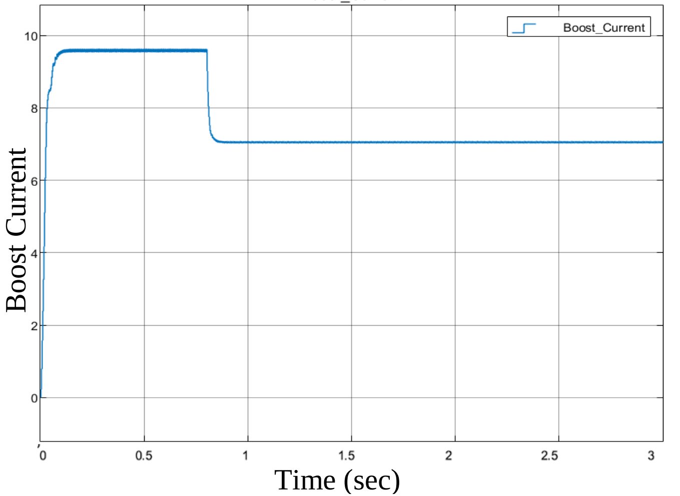


Figure 10 Boost Current

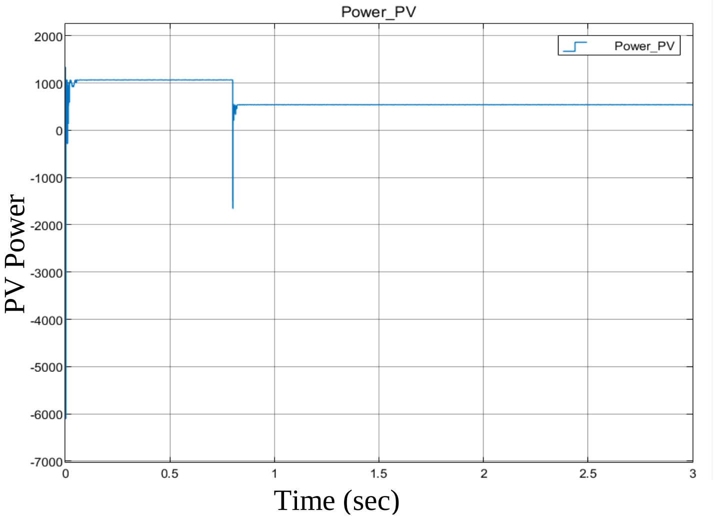


Figure 11 PV Power

Conclusion

In conclusion, the implementation of an advanced charge controller with closed-loop control strategies in PV micro grids represents a pivotal step towards overcoming existing challenges and unlocking the full potential of solar power. By dynamically adjusting the charging algorithm in response to real-time environmental conditions, this paperwork ensures maximum energy capture, addressing inefficiencies associated with traditional charge controllers. The adaptive charging algorithm plays a central role in enhancing the overall efficiency of PV micro grids, minimizing energy losses, and optimizing the utilization of renewable resources. This work not only addresses current limitations in standalone micro grid systems but also contributes significantly to the broader objectives of building a resilient and environmentally friendly energy infrastructure. Embracing such advancements is crucial for paving the way towards a more sustainable and self-reliant future in energy generation and distribution.

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