iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.68090

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Higher Efficiency Solar and Grid Connected Oven Using PI Controller

Dr. Reenu George[1], Prof Linu Jose[2], Afsiya Neznin Hashim VH[3], Ajilkurian[4], Joseph Nebu[5], Nashak AK[6]
Student, IEEE, Mar Athanasius College of Engineering (Autonomous), Kothamangalam, Ernakulam, Kerala, India, 686666

Abstract: This paper presents the development of a higher-efficiency solar and grid-connected oven that integrates solar energy and grid power for optimized cooking efficiency. Utilizing a Proportional-Integral (PI) controller[1], the system maintains precise temperature control by dynamically adjusting energy sources based on real-time availability. The research includes modeling photovoltaic (PV) modules and the integration of a boost converter, with simulations conducted using MATLAB. Results reveal significant improvements in temperature stability and reductions in energy consumption compared to traditional ovens. The system promotes decreased reliance on grid power while advancing sustainable energy practices. Challenges associated with initial setup costs and solar availability are also discussed. Ultimately, this innovative approach supports the transition toward renewable energy solutions in cooking applications.
Index Terms: Proportional-Integral controller, hybrid energy systems, solar energy, cooking efficiency.

I. INTRODUCTION

In recent years, the urgent need to combat climate change and reduce greenhouse gas emissions has driven a significant transformation in the global energy landscape. The heavy reliance on fossil fuels has resulted in environmental degradation, prompting a shift towards renewable energy sources. Among these, solar energy stands out due to its abundant availability and sustainability, positioning itself as a leading alternative in the quest for cleaner energy solutions. This project aims to explore the development of a higher-efficiency solar and grid-connected oven that leverages solar power integrated with conventional grid electricity. The integration of solar energy with grid power creates a unique [2]opportunity to design hybrid systems that enhance reliability and efficiency. One of the primary goals of this project is to develop an oven that can seamlessly transition between using solar energy and grid power, ensuring optimal performance regardless of external conditions. By maximizing the use of solar energy while maintaining operational stability, the system seeks to offer a practical solution for energy-efficient cooking applications. Central to this hybrid system is the Proportional-Integral (PI) controller, which plays a crucial role in balancing energy inputs from both solar and grid sources[3]. The controller continually adjusts the energy distribution based on real-time data, facilitating precise temperature regulation and Manuscript received December 1, 2012; revised Au- gust 26, 2015. Corresponding author: M. Shell (email: http://www.michaelshell.org/contact.html).Manuscript received December 1, 2012; revised August 26, 2015. Corresponding author: M. Shell (email: http://www.michaelshell.org/contact.html)Manuscript received Corresponding author: M. Shell (email: http://www.michaelshell.org/contact.html)Manuscript received December 1, 2012; revised August 26, 2015. Corresponding author: M. Shell (email: http://www.michaelshell.org/contact.html) revised August 26, 2015. Corresponding author: M. Shell (email: http://www.michaelshell.org/contact.html) efficient energy management. This capability is particularly vital in cooking applications, where consistent temperature maintenance is essential for performance and user satisfaction. Despite the advantages of integrating solar energy into cooking systems, challenges remain. Variability in solar energy availability, affected by weather conditions and time of year, necessitates robust control strategies to ensure reliable operation. This project addresses these challenges by developing a user-friendly system that allows for easy monitoring and adjustments, thereby promoting the adoption of renewable energy technologies. Ultimately, this initiative represents a step forward in enhancing energy efficiency and supporting the global shift towards sustainable energy solutions.

II. TOPOLOGY

A. Principle of Operation

The energy management system operates fundamentally through the DSPIC30F2010 microcontroller[4], which serves as the central control unit orchestrating various electronic components connected within the circuit. This microcontroller is capable of processing multiple input signals and generating appropriate output responses, allowing it to execute real- time control algorithms that adapt to changing operational conditions. It is instrumental in monitoring environmental parameters, such as current and voltage levels, and enables precise control over the system's performance. By integrating various sensors, the microcontroller can collect data necessary for optimizing energy flow, ensuring the system can respond swiftly to fluctuations in both energy generation and consumption, particularly in solar energy applications.

To ensure the stability and reliability of the power supply, an LM317 [5]voltage regulator is employed, which maintains consistent voltage levels across the system regardless of variations in load. This component is vital for delivering clean power to the microcontroller and other sensitive devices, preventing fluctuations that could lead to malfunction or inefficiency. Complementing the voltage regulator, capacitors including 0.1µF and 22pF are strategically placed throughout the circuit to filter out high-frequency noise and provide decoupling, further enhancing the stability of the system. These capacitive elements help to smoothen the power supply, ensuring that peak demand from connected loads does not disrupt the overall operation.

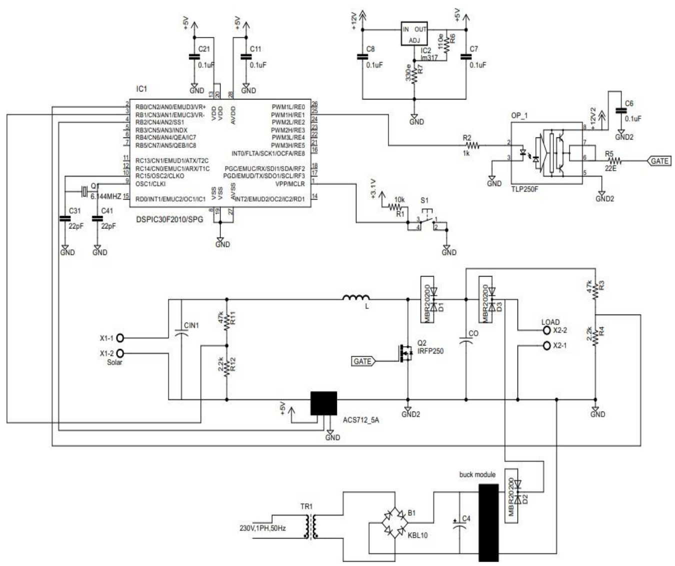


Fig. 1. DSPIC30F2010 Solar Control Circuit

The system incorporates MOSFETs, like the IRFP250, to manage high current switching effectively, enabling the control of larger loads without the thermal and efficiency issues associated with traditional mechanical switches. These MOSFETs are controlled by the microcontroller, which can turn them on or off based on the real-time conditions assessed from the current sensors, such as the ACS712. This not only prevents potential overloads by cutting off power when necessary but also allows for efficient operation by ensuring that loads receive only the power they require at any given moment. Additionally, protection diodes like the MBR20200 are included to safeguard the circuit against voltage spikes that can occur from inductive loads, ensuring longevity and reliability in the system's operation. This holistic approach intricately ties together the components to create a robust energy management solution suitable for renewable energy applications like solar power.

B. System Overview

The block diagram presented in Fig. 3 illustrates the opera- tional flow of the higher efficiency solar and grid-connected oven system. The system initiates with a solar panel that captures sunlight and converts it into direct current (DC) electricity through the photovoltaic effect. This first step is crucial as it harnesses renewable energy, serving as the primary energy source for the oven[6]. The DC output from the solar panel may not be sufficient for the system's operational needs, so it proceeds to a DC-DC boost converter. This converter steps up the low voltage output of the solar panel to a higher voltage level, optimizing it for efficient energy distribution within the system.

Following the boost conversion[7], the enhanced DC power is directed towards the heating element of the oven, which utilizes this energy for cooking purposes. To ensure seamless operation, the system also integrates a grid power module. This component serves as a backup energy source, providing addi- tional reliability and stability[8]. When solar energy generation is insufficient—due to weather variability or nighttime—this module automatically engages to supply power to the oven, ensuring continuous performance without interruption. The hy- brid approach of utilizing both solar and grid energy enhances the system's overall efficiency and operational resilience.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

A Proportional-Integral (PI) controller plays a pivotal role in the system's design. It continually monitors the temperature of the oven[9], adjusting the energy input dynamically from either the solar or grid source based on real-time needs. This level of control allows for precise temperature regulation[10], which is essential in cooking applications where consistency is key. Furthermore, the PI controller optimizes energy man- agement strategies, maximizing the utilization of solar energy while minimizing reliance on grid power.

In addition, various sensors and control circuitry are integrated into the system to ensure effective operation and usability[11]. These components facilitate monitoring of the system's performance, allowing users to easily engage with the technology and make necessary adjustments. The system's design embodies a commitment to enhancing energy efficiency in cooking applications while promoting the adoption of renewable energy solutions[12], setting a foundation for further innovation in hybrid energy systems.

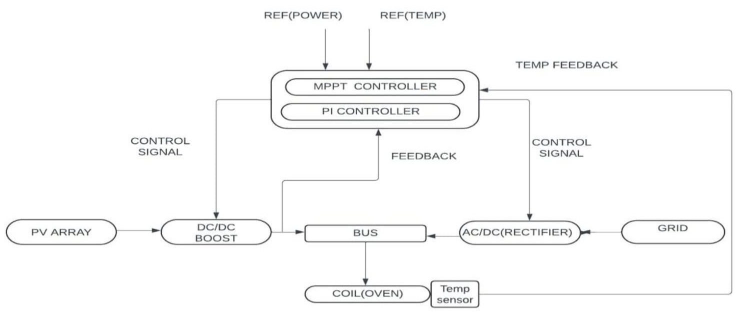


Fig. 2. System Overview of the Solar and Grid-Connected Oven

C. *Design of PV Module*

The basic unit of a solar module is solar cells or photovoltaic cells[11]. A solar cell converts energy in the photons of sunlight into electricity by means of the photoelectric phe- nomenon found in certain types of semiconductor materials such as silicon and selenium. A single solar cell can only

TABLE I

SOLAR PANEL MODELLING PARAMETERS

Rated power	200W
Voltage at max power	26.4V
Current at max power	7.58A
Open circuit Voltage	39.9V
Short circuit current	8.21A
Total no of cells in series	54
Total no of cells in parallel	1

produce a small amount of power[13]. To increase the output power of a system, solar cells are generally connected in series or parallel to form PV modules. The modelling of photovoltaic panel is carried out mathematically using the equation

$$I_{ph} = [I_{SCr} + K_i(T - 298)] * \lambda/1000 \quad (1)$$

$$I_{rs} = \frac{I_{SCr}}{exp(\frac{qV_{oc}}{N_s KAT}) - 1} \quad (2)$$

$$I_o = I_{rs}\left(\frac{T}{T_r}\right)^3 exp\left[\frac{qE_{go}}{Bk}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right] \quad (3)$$

$$I_{PV} = N_p I_{ph} - N_p I_o \left[exp\left(\frac{q(V_{PV} + I_{PV} R_s)}{N_s AKT}\right) - 1\right] \quad (4)$$

where

V_{PV} is the output voltage of a PV module (V)

I_{PV} is the output current of a PV module (A) T_r is the reference temperature

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

T is the module operating temperature in Kelvin
I_{ph} is the light-generated current in a PV module (A)
I_o is the PV module saturation current (A)
k is Boltzmann constant
q is the electron charge
R_s is the series resistance of a PV module
I_{SCr} is the PV module short-circuit current at 25 degrees Celsius and 1000 $\frac{W}{m^2}$
K_i is the short-circuit current temperature coefficient at I_{SCr} E_{go} is the band gap for silicon = 1.1 eV
N_s is the number of cells connected in series
N_p is the number of cells connected in parallel

D. *Design of Boost Converter*

A boost converter is a DC-DC converter that steps up the input voltage to a higher output voltage efficiently.
Input Voltage (Vin): 15-20 V
Output Voltage (Vout): 24 V
Output Current (Iout): 1.5A
Switching Frequency (fsw): 20 kHz
article amsmath

The duty cycle D is calculated as:

$$D = 1 - \frac{V_{in(min)}}{V_{out}} = 1 - \frac{17}{24} = 0.292$$

The inductance L is given by:

$$L = \frac{V_{in}(V_{out} - V_{in})}{\Delta I_L \cdot f_s \cdot V_{out}} = \frac{17 \times (24 - 17)}{0.1 \times 25000 \times 24} = 1\,\text{mH}$$

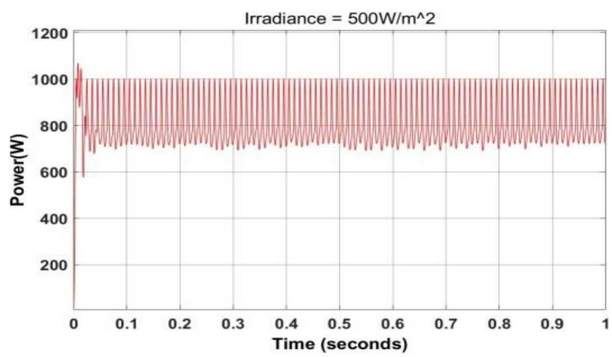
The minimum output capacitance $C_{out(min)}$ is:

$$C_{out(min)} = \frac{I_{out} \cdot D}{f_s \cdot \Delta V_{out}} = \frac{1 \times 0.292}{25000 \times 0.1} = 117\,\mu F$$

III. SIMULATION AND ANALYSIS

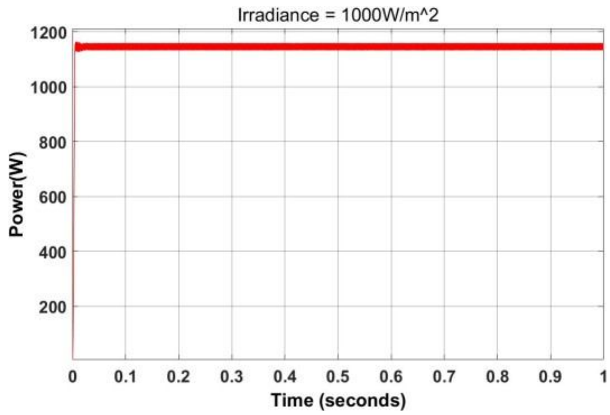
The simulation and analysis of the higher efficiency solar and grid-connected oven reveal that integrating solar energy with grid power significantly enhances system performance and energy management. Utilizing a Proportional-Integral (PI) controller[14], the system effectively balances energy inputs, optimizing temperature regulation and improving overall efficiency. Results indicate that the dual-source integration not only stabilizes energy output under varying conditions but also promotes sustainable energy use, making it a viable solution for energy-efficient cooking.

The simulation results at different irradiance values (500 W/m² and 1000 W/m²) show distinct power output behaviors for the photovoltaic (PV) module. At 500 W/m², the power output initially peaks with fluctuations before stabilizing around 1000 W[15], likely due to the Maximum Power Point Tracking (MPPT) adjustments. In contrast, at 1000 W/m², the power output quickly stabilizes at approximately 1200 W with minimal oscillation, indicating more consistent performance at higher irradiance levels.



International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

The simulation analysis of the dual source integration system reveals significant advancements in optimizing energy output and stability by effectively combining solar power with grid electricity. The implementation of a Proportional- Integral (PI) controller allows for dynamic balancing of energy inputs, ensuring that the system can adapt to real-time energy demands and availability. This integration not only maximizes the utilization of renewable resources but also



mitigates the challenges associated with intermittent solar energy generation, enhancing the overall resilience of the energy system. Furthermore, the results indicate that the dual-source approach can maintain stable operation even during low sunlight conditions, thanks to seamless grid support. This capability is particularly beneficial for remote or off-grid areas, where reliance on renewable energy is crucial for reducing fuel consumption and promoting sustainability. Overall, the findings underscore the potential of dual source integration in contributing to a more reliable, efficient, and environmentally friendly energy future, aligning with global sustainability goals and supporting the transition towards greener energy infrastructure.

IV. CONCLUSION

This paper presents the development of a higher efficiency solar and grid-connected oven that utilizes a Proportional- Integral (PI) controller, marking a significant advancement in the integration of renewable energy with traditional power systems. The simulation results included in this study demon- strate that this hybrid system effectively optimizes energy man- agement, ensuring consistent performance through seamless transitions between solar and grid power. By enhancing energy efficiency and reducing reliance on non-renewable sources, this innovative approach not only contributes to sustainable energy solutions but also paves the way for further research and development in hybrid energy systems, ultimately support- ing the global shift towards renewable energy adoption. The design process detailed in this paper encompasses the modeling of the photovoltaic (PV) module and the boost converter, which are critical components for maximizing en- ergy capture and conversion efficiency. The extensive literature review highlights existing advancements in solar energy appli- cations, providing a solid foundation for the proposed system. Furthermore, the MATLAB simulations validate the system's performance under varying environmental conditions, show- casing its adaptability and reliability in real-world scenarios. In addition to its technical contributions, this research emphasizes the importance of integrating renewable energy sources into everyday applications, such as cooking, to promote sustainability in domestic and industrial settings. The findings suggest that the hybrid system not only enhances energy efficiency but also offers cost savings to users by reducing dependence on conventional energy sources. As the world increasingly shifts towards sustainable energy solutions, this work serves as a vital step in demonstrating the feasibility and benefits of hybrid energy systems, encouraging further exploration and innovation in this field.

REFERENCES

[1] H. Fathabadi, "Novel high efficiency dc/dc boost converter for using in photovoltaic systems," Solar Energy, vol. 125, pp. 22–31, 2016.

[2] M. L. Azad, S. Das, P. K. Sadhu, B. Satpati, A. Gupta, and P. Arvind, "P&o algorithm based mppt technique for solar pv system under differ- ent weather conditions," in 2017 International Conference on Circuit, Power and Computing Technologies (ICCPCT), pp. 1–5, IEEE, 2017.

[3] S. Bennett, "Development of the pid controller," IEEE Control Systems Magazine, vol. 13, no. 6, pp. 58–62, 1993.

[4] R. P. Borase, D. Maghade, S. Sondkar, and S. Pawar, "A review of pid control, tuning methods and applications," International Journal of Dynamics and Control, vol. 9, pp. 818–827, 2021.

[5] K. Dubey and M. Shah, "Design and simulation of solar pv system," in 2016 international conference on automatic control and dynamic optimization techniques (ICACDOT), pp. 568–573, IEEE, 2016.

[6] UR, Prasanna and Umanand, "Hybrid solar cooking,"

[7] M. Gaboriault and A. Notman, “A high efficiency, noninverting, buck- boost dc-dc converter,” in Nineteenth Annual IEEE Applied Power Elec- tronics Conference and Exposition, 2004. APEC’04., vol. 3, pp. 1411– 1415, IEEE, 2004.

[8] A. Verma and A. K. Kori, “Higher efficiency solar and thermal hybrid power plant based on pi controller,” in 2020 Fourth International Con- ference on Computing Methodologies and Communication (ICCMC),

[9] pp. 699–703, IEEE, 2020.

[10] T. Ma, H. Yang, and L. Lu, “Solar photovoltaic system modeling and performance prediction,” Renewable and Sustainable Energy Reviews, vol. 36, pp. 304–315, 2014.

[11] A. Siebert, A. Troedson, and S. Ebner, “Ac to dc power conversion now and in the future,” IEEE transactions on industry applications, vol. 38, no. 4, pp. 934–940, 2002.

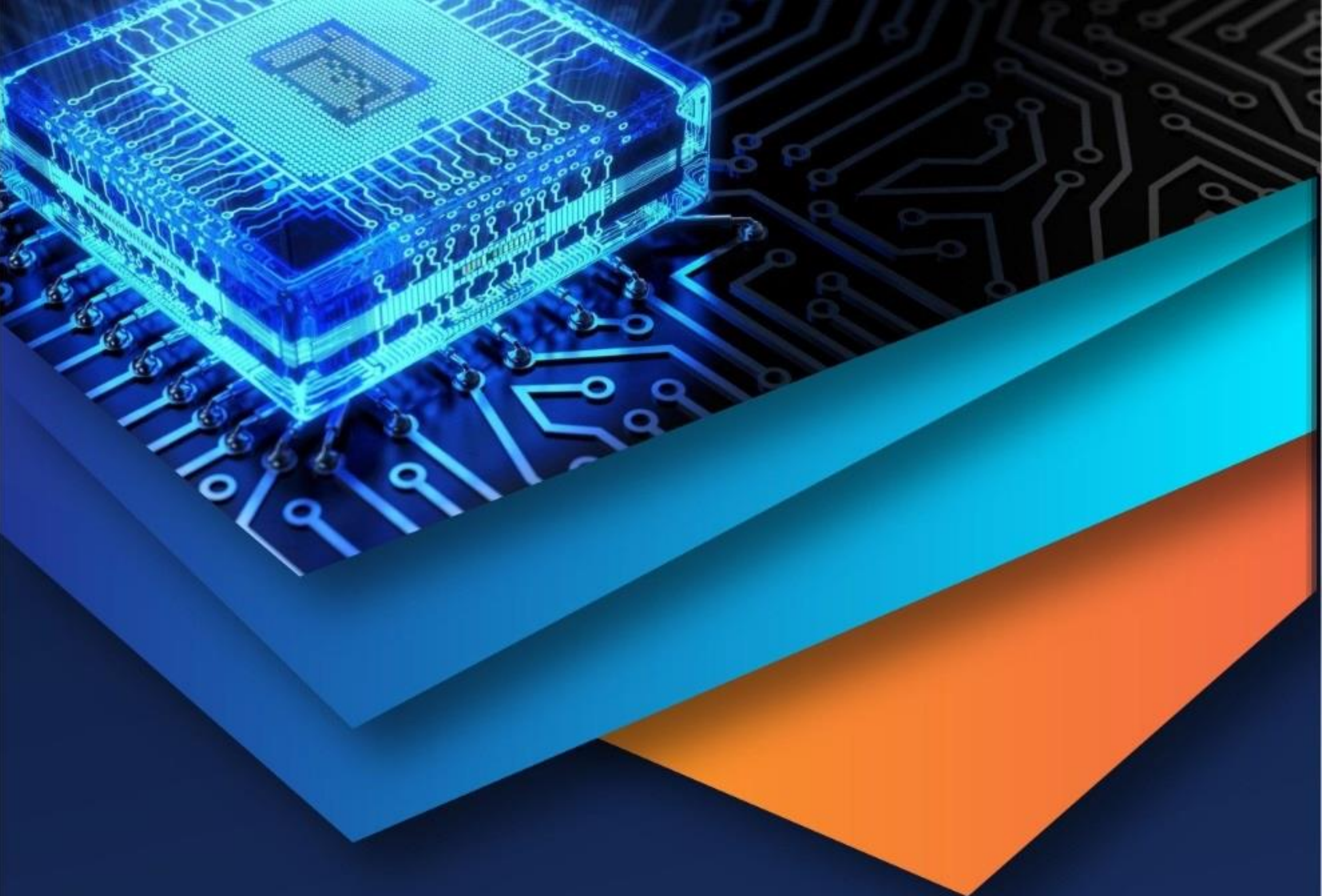
[12] P. Mohanty, G. Bhuvaneswari, R. Balasubramanian, and N. K. Dhaliwal, “Matlab based modeling to study the performance of different mppt techniques used for solar pv system under various operating conditions,” Renewable and Sustainable Energy Reviews, vol. 38, pp. 581–593, 2014.

[13] M. L. Swarupa, E. V. Kumar, and K. Sreelatha, “Modeling and simula- tion of solar pv modules based inverter in matlab-simulink for domestic cooking,” Materials Today: Proceedings, vol. 38, pp. 3414–3423, 2021.

[14] M. A. Moussa, A. Derrouazin, M. Latroch, and M. Aillerie, “A hybrid renewable energy production system using a smart controller based on fuzzy logic,” Electrical Engineering & Electromechanics, no. 3, pp. 46– 50, 2022.

[15] A. O. Victor and E. Ejiogu, “Hybrid solar thermal/electricity automated oven,” Adv. Sci. Technol. Eng. Syst. J, vol. 5, p. 188, 2020.

[16] G. Zubi, F. Spertino, M. Carvalho, R. S. Adhikari, and T. Khatib, “Development and assessment of a solar home system to cover cooking and lighting needs in developing regions as a better alternative for existing practices,” Solar Energy, vol. 155, pp. 7–17, 2017.



10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY