IJMRT: Volume (7), Issue 5, 2025
International Journal of Multidisciplinary Research Transactions
(A Peer Reviewed Journal)
www.ijmrt.in

ISSN (Print):2663-2381
ISSN (Online):2663-4007

Groundnut Roasting Machine using Induction Heating

Hariharan M[1]*, Hariharan B[2], Rojar Gimson A[3], Joshuva Vasanthan K[4], Raj Kumar k[5]

[1,2,3,4]Student, Department of Electrical and Electronics Engineering, Saranathan College of Engineering, India.
[5]Associate Professor, Department of Electrical and Electronics Engineering, Saranathan College of Engineering, India.

*Corresponding Author

DoI: https://doi.org/10.5281/zenodo.15333928

Abstract

Traditional groundnut roasting methods that use firewood and gas contribute significantly to deforestation, carbon emissions, and health risks for street vendors. To address these issues, this project proposes a solar-powered induction heating groundnut roaster that is energy-efficient and environmentally friendly. The system incorporates a Zero Voltage Switching (ZVS) converter for improved efficiency and reduced switching losses [1][2][7]. An Arduino microcontroller automates temperature monitoring and control, enabling precise roasting and minimizing human intervention [3][11]. A motor-driven stirrer ensures uniform heat distribution, enhancing the overall roasting quality [5][6]. The system is powered by a solar photovoltaic panel with a battery backup to ensure uninterrupted operation even during low sunlight periods [4][12]. This innovative solution supports clean energy use, reduces operational costs, and improves the livelihood of street vendors by providing a safer and more reliable roasting method.

Keywords: Solar-Powered Roasting, Induction Heating, Zero Voltage Switching (ZVS), LC Tank Circuit, Temperature Control, Microcontroller-Based System, Real-Time Monitoring, Energy-Efficient.

1. Introduction

With increasing demand for sustainable energy in small-scale food processing, traditional firewood-based roasting methods pose environmental and health risks due to smoke emissions and inconsistent heating [5][6]. To overcome these issues, this project proposes a solar-powered Zero Voltage Switching (ZVS) induction heating system for groundnut roasting applications [1][3]. The system integrates a ZVS resonant converter to achieve high-efficiency, low-loss energy transfer, enabling precise temperature control while minimizing switching losses [2][7].

An Arduino microcontroller monitors and manages temperature levels, automating the induction coil's heating cycle. Upon reaching the required roasting temperature, the system activates a motorized stirrer to ensure even heat distribution and consistent roasting quality [5][14]. Powered by solar photovoltaic panels and supported by a battery bank, the unit ensures uninterrupted operation during low sunlight or nighttime conditions [4][8]. Real-time temperature data is also displayed on an LCD screen for monitoring and control.

By combining renewable energy utilization, intelligent heating control, and automation, this solution reduces dependence on fossil fuels, lowers operational costs, and improves roasting consistency. This innovative system supports sustainable street vending while addressing environmental concerns, enhancing food safety, and promoting green energy adoption in small-scale commercial applications [3][9].

2. Literature Review

Several studies have explored the use of solar-powered induction heating to replace traditional fuel-based roasting methods. Research emphasizes the benefits of ZVS converters in reducing switching losses and improving energy efficiency. Automated systems with microcontrollers enhance temperature control and reduce manual effort. Environmental factors influencing system performance are addressed through real-time monitoring and adaptive control. These advancements contribute to cleaner, cost-effective, and efficient roasting solutions for small-scale applications.

Table.1. Literature Review

S. No	Authors	Title	Year	Observation
1	Anusree & Sukesh	Solar Induction Heating with ZVS Converter	2020	Efficient energy conversion and minimal switching losses; however, the system faces high initial setup costs and complex design.
2	Dande & Markande	ZVS Converter for Solar-Powered Induction	2014	Improved system efficiency with low thermal losses, but the system is sensitive to load variations and requires precise control.
3	Meenakshi et al.	ZVS Induction Heating for Cooking	2019	Enhances system stability and energy-efficient operation, though it requires high-quality components and is weather-dependent.
4	Hajare et al.	ZVS-based Solar Heating for Industrial Use	2020	Offers reduced electromagnetic interference and better power control, but the complexity increases with scaling.
5	Channappa & Rajesh	ZVS Converter-Based Solar	2021	Provides better power factor and reduced harmonic distortion; however,

		Induction Heating		it involves high complexity in design and control systems.
6	Yang et al.	ZVS Converter for High-Frequency Induction Heating	2018	Superior heat control and stable power delivery, but efficiency drops with extreme temperature conditions.
7	Zuo et al.	Solar-Powered Induction Heating with ZVS	2016	High efficiency and long-term cost savings with an environment-friendly design, though the system depends on solar availability and has limited scalability.
8	Zhang & Liu	Design of ZVS Converter for Solar Heating	2020	Low losses and improved thermal efficiency, but requires precise component selection for optimal performance.
9	Kumar & Pradhan	Solar-Powered ZVS Induction Heating System	2019	Lower maintenance costs and higher efficiency; however, it increases design complexity for solar integration.
10	Wang et al.	ZVS Converter for Induction Cooking	2021	Effective energy utilization and smooth heating process, but there is limited research on long-term reliability in solar applications.
11	Ramaraju et al.	ZVS Converter for Industrial Heating Applications	2019	Efficient power transfer and reliable operation under varied loads, though it requires careful calibration for specific heating applications.

12	Liang et al.	Solar-Powered Induction Heating with ZVS Converter	2020	High performance, reduced heat loss, and eco-friendly, but controlling power for diverse heating needs is complex.
13	Liu et al.	ZVS-based High-Efficiency Induction Heating	2021	Provides stable high-frequency operation and reduced energy waste, though it incurs high setup costs for solar-based systems.
14	Ahmed & Ali	Hybrid ZVS Converter for Solar Induction Heating	2022	Improved efficiency and performance with a hybrid system design, but the system is highly complex and requires advanced control systems.
15	Patel & Sharma	ZVS-Induction Heating for Solar Applications	2020	Enhances system efficiency and reduces switching loss during heating, though it is limited to smaller-scale applications due to cost constraints.

3. Proposed System

The proposed solar-powered induction heating system presents a sustainable and energy-efficient solution for groundnut roasting, particularly suitable for rural and off-grid regions. Traditional methods such as direct flame or resistive heating often result in uneven roasting, high energy consumption, and environmental concerns. This system utilizes solar panels combined with a Maximum Power Point Tracking (MPPT) controller to ensure consistent power delivery, even under varying sunlight conditions [1][2]. The power is supplied to a Zero Voltage Switching (ZVS) driver circuit that converts DC to high-frequency AC, which induces eddy currents in a metal container. This contactless heating ensures uniform roasting while minimizing power loss due to efficient switching at zero voltage [3][4].

An Arduino UNO microcontroller integrated with a MAX6675 thermocouple sensor provides real-time temperature monitoring and control. The heating system is automatically activated or deactivated based on the desired temperature range, improving safety and reducing the need for manual intervention [5][6]. A DC motor-driven stirrer is used to ensure even distribution of heat throughout the roasting process, preventing burning and enhancing product quality. Overall, this system combines clean energy, smart control, and practical design to offer a reliable, cost-effective alternative to conventional roasting methods, with potential for broader adoption in small-scale food processing industries [7][8].

3.1. Block Diagram

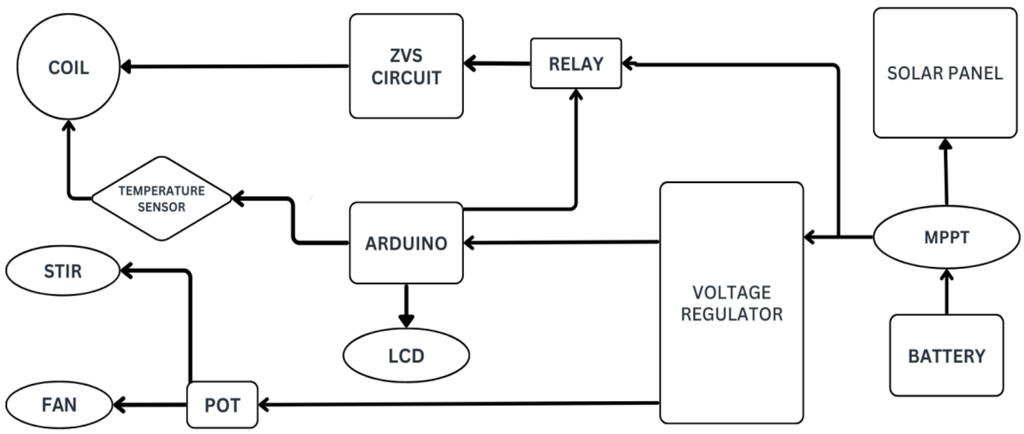

Figure.1. Block Diagram

Zero Voltage Switching (ZVS) is a soft-switching technique used in power electronic converters to reduce switching losses and electromagnetic interference (EMI), particularly in high-frequency applications. Unlike hard-switching, where power devices switch with both voltage and current present, ZVS ensures that the switch turns on or off when the voltage across it is near zero, minimizing losses and thermal stress. This is achieved using a resonant LC circuit that naturally creates zero-voltage points, allowing the MOSFET to switch with minimal energy loss. In an induction heating system for groundnut roasting, the coil acts as the heating element, generating a magnetic field that induces eddy currents in a metal container, resulting in uniform, contactless heating. A relay, controlled by an Arduino or gate driver, connects or disconnects power to the heating circuit, ensuring safety and automation. A voltage regulator supplies a constant DC voltage to control electronics, while a battery ensures continuous operation during power outages. A solar panel powers the system, and an MPPT charge controller optimizes energy usage by regulating power to the ZVS converter and managing battery charging. The Arduino microcontroller coordinates system operations, receiving input from a temperature sensor and controlling devices like the relay, fan, and stirrer. The LCD provides real-time user feedback, the potentiometer allows adjustment of roasting parameters, the fan cools electronic components, and the stirrer ensures even roasting by continuously mixing the groundnuts. Together, these components enable an efficient, automated, and eco-friendly roasting system.

3.2. ZVS Converter Circuit

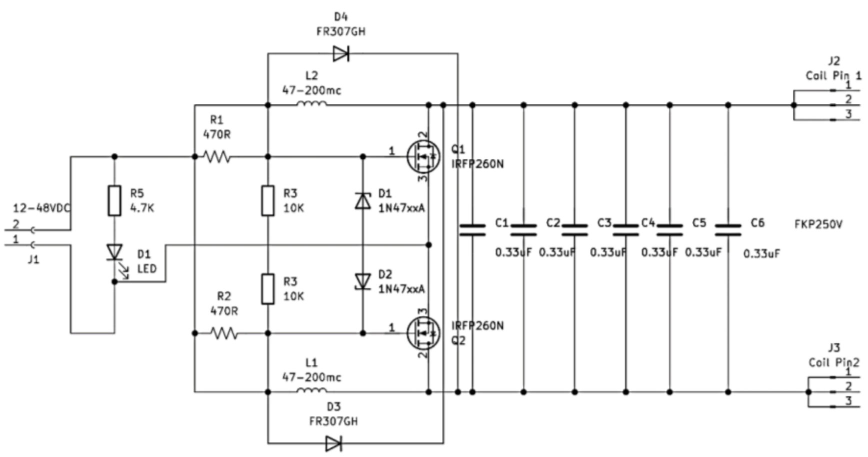

Figure.2. ZVS Converter Circuit

Table.2. Circuit Components Details

S.No	Component	Description
1	IRFP260N MOSFET	A high-speed N-channel power MOSFET used as the main switching device in the ZVS circuit. It enables self-resonant operation, switching at near-zero voltage to reduce losses. It supports up to 50A, 200V, and has low low RDS(on) (drain-to-source on-resistance),ideal for high-power induction heating.
2	200 µH Ferrite-Core Inductors (2x)	Placed in series with each MOSFET drain, these inductors control resonant frequency and shape circuit behavior. They limit di/dt to enable soft switching and form part of the LC tank. Ferrite cores provide compact, high-inductance performance.
3	FR307 Ultra-Fast Diodes	Positioned across each inductor, they provide a reverse current path during switching transitions, protecting MOSFETs from voltage spikes and aiding energy recirculation. Their fast response suits high-frequency operation.
4	1N4742A Zener Diodes (12V)	Connected to each MOSFET gate, they clamp gate voltage to 12V, preventing over-voltage damage and ensuring safe, regulated operation of the gate drive circuitry.
5	0.33 µF High-Voltage Film Capacitors (6x)	Connected in parallel to form the capacitive part of the LC tank. This configuration enhances capacitance, reduces ESR and ESL, improves thermal/electrical performance, and increases reliability over a single large capacitor.
6	Gate Resistors (470Ω) & Pull-down Resistors (10kΩ)	470Ω resistors limit inrush current to the gate, reducing ringing. 10kΩ resistors from gate to source ensure gate discharge on turn-off, preventing floating gates and false triggering.
7	Work Coil (6 mm Hollow Copper Tube)	Forms a spiral/pancake coil to generate an alternating magnetic field for induction heating. The hollow tube allows coolant flow for thermal management during extended operation.

3.3. Circuit Operation

The Zero Voltage Switching (ZVS) induction heating circuit is a self-oscillating resonant converter that converts a DC input into high-frequency alternating current to drive an induction heating work coil. The system centers around a resonant LC tank, composed of a copper tube-based work coil (L3) and high-voltage capacitors (C1–C6). Two N-channel MOSFETs (S1 and S2) in a half-bridge arrangement initiate oscillation upon the application of DC voltage. The imbalances in gate threshold voltages or parasitic tolerances cause S1 to conduct first, which allows current to flow through the LC tank, starting resonance. This resonant energy exchange between the magnetic field of the coil and the electric field of the capacitors drives the system's oscillation.

The ZVS mechanism is crucial in minimizing switching losses, electromagnetic interference (EMI), and thermal stress. As the LC tank’s energy builds, the current direction reverses periodically, causing voltage swings at the MOSFETs' drains. The drain voltage of S1 drops near zero as current direction changes, enabling the self-driven switching of the MOSFETs. The gate-drive network of resistors (R1, R2), inductors (L1, L2), and steering diodes (D1, D2) passively controls the MOSFET gates by responding to the drain voltage, ensuring each MOSFET switches ON when its drain voltage is minimal, achieving zero-voltage switching without external controllers or PWM drivers.

Several passive components enhance the performance of the ZVS circuit. Gate resistors (R3 and R4) limit inrush current and suppress EMI, while fast-recovery diodes (D1 and D2) steer gate currents for reliable switching. Zener diodes (D3 and D4) protect the MOSFET gates from overvoltage, and series inductors (L1 and L2) introduce necessary timing and filtering. The use of multiple capacitors (C1–C6) improves thermal performance and resonance quality. The copper tube work coil minimizes skin effect losses at high frequencies, enhancing efficiency. This design operates without active cooling by using short duty cycles to reduce thermal accumulation, making it ideal for compact, efficient induction heating applications.

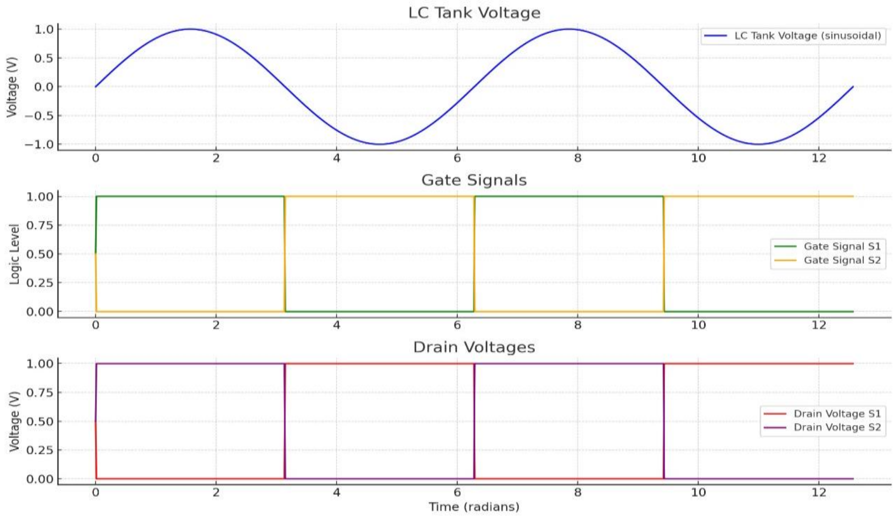

Figure.3. Voltage Waveform

The above voltage waveform shows the output voltage of (LC)- inductor and capacitor tank or resonant tank voltage, gate signal of S1 and S2 switches, drain voltage across S1 and S2 switches. For positive half cycle the S1 switches is triggered. And for the negative half cycle the switch S2 triggered. The voltage across the LC tank is sinusoidal, but the drain voltages of S1 and S2 are square-like.

3.4. LC Calculation

To achieve resonance in an induction heating LC tank circuit, the resonant frequency is determined by the values of the inductor (L) and the capacitor (C) using the standard resonance formula. In our design of ZVS, We know the value of the inductor(L) and capacitor(C).hence we need to find the resonance frequency.

Standard Resonance Formula

$$f = \frac{1}{2\pi\sqrt{LC}}$$

4. Methodology

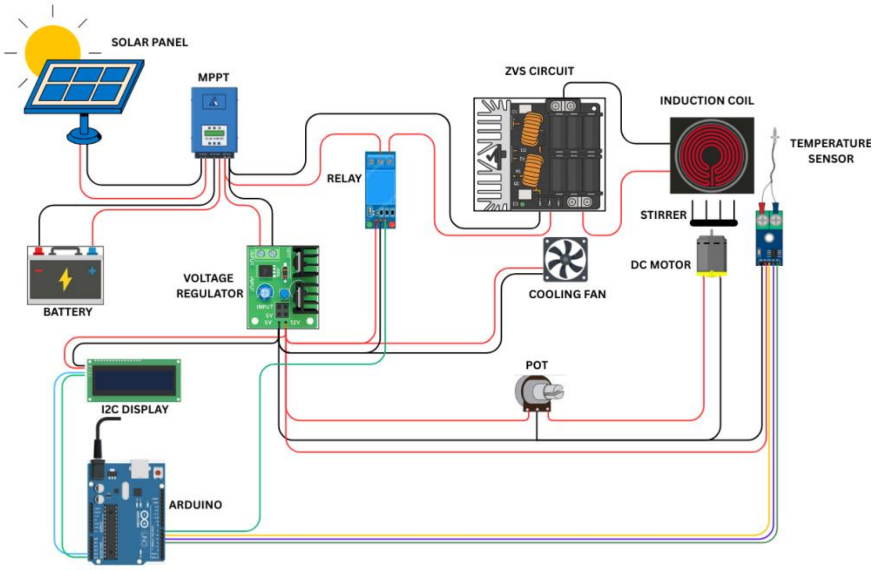

Figure.4. Connection Diagram

This project integrates four key subsystems: power supply, induction heating, control and monitoring, and a stirring mechanism. Power is sourced from a 48V solar photovoltaic panel rated at approximately 1100W, capable of delivering up to 22.9A. To maximize energy extraction under varying sunlight conditions, a Maximum Power Point Tracking (MPPT) controller is used. It dynamically adjusts the panel's operating point to harvest maximum power. The energy generated not only drives the system during daylight hours but is also used to charge a 48V, 75Ah battery. This battery ensures uninterrupted operation by supplying stored energy during low-light or nighttime conditions. A voltage regulator steps down the 48V supply to required levels (5V or 12V) for powering low-voltage electronics like sensors, microcontrollers, and cooling fans.

The induction heating subsystem is powered through a Zero Voltage Switching (ZVS) converter, which utilizes a half-bridge MOSFET setup. This converter produces a high-frequency AC signal that energizes a flat spiral copper pancake coil. The alternating magnetic field generated by the coil induces eddy currents in a nearby metal container, generating heat internally due to the skin effect. This enables contactless and uniform heating. A relay governs the switching of the ZVS circuit, acting as a safety mechanism to disconnect power when required.

Control and monitoring are handled by an Arduino Uno microcontroller. The Arduino receives real-time data from a connected temperature sensor and displays the readings on an I2C LCD module. When the temperature surpasses a pre-set threshold of 160°C, the Arduino triggers a relay to disconnect the ZVS circuit, thereby preventing overheating. Additionally, the system includes a DC motor-based stirring mechanism to ensure uniform heating of the groundnuts. The speed of this motor can be manually controlled via a potentiometer, allowing adjustments based on the heating requirements. The motor is powered through a separate voltage regulator to maintain stable performance. These integrated subsystems collectively deliver an efficient, automated, and solar-powered induction heating solution with built-in safety and energy optimization features.

5.Result and Discussion

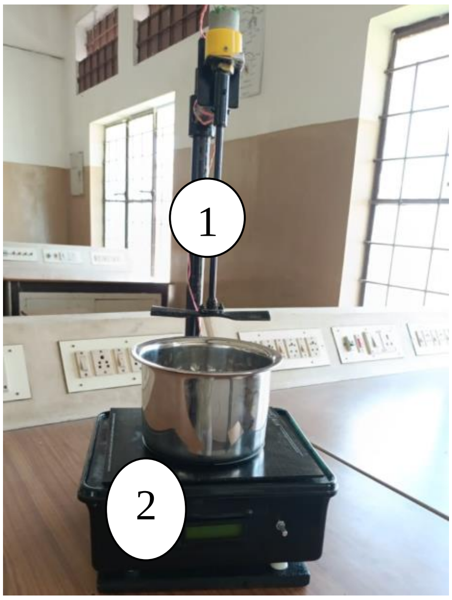

Figure.5. Prototype

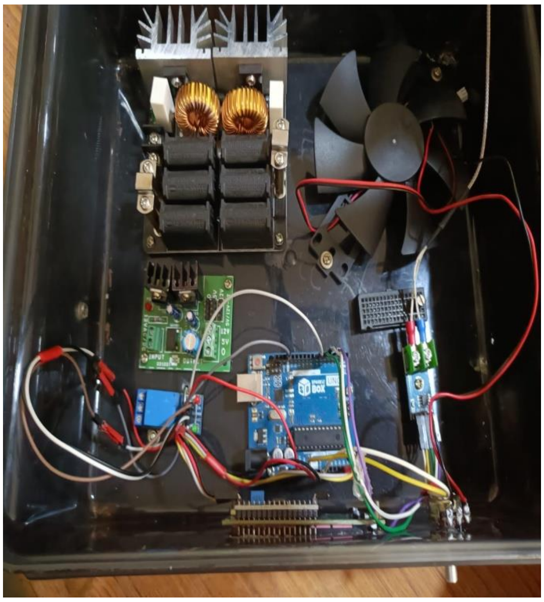

Figure.6. Hardware Setup

The experimental setup illustrated in the figure comprises two primary components. The element marked as (1) represents the mechanical stirrer assembly, which includes a vertically mounted DC motor coupled to a horizontal stirrer blade. This configuration enables controlled agitation of the contents within the vessel during the heating process, aiding in uniform heat distribution and enhanced process efficiency.

The component labeled (2) is the induction heating unit, a comprehensive system integrating several critical modules. This includes the Zero Voltage Switching (ZVS) circuit, which enables efficient high-frequency induction heating; a copper coil functioning as the work coil; a microcontroller-based control unit for real-time operation and feedback management; a temperature sensor for continuous thermal monitoring; a voltage regulator for stable power supply; and a cooling fan to dissipate heat generated during prolonged operation. Additionally, a metallic pot is placed above the induction coil to serve as the heating vessel. This integrated arrangement facilitates automated and controlled thermal processing, as detailed in the following sections.

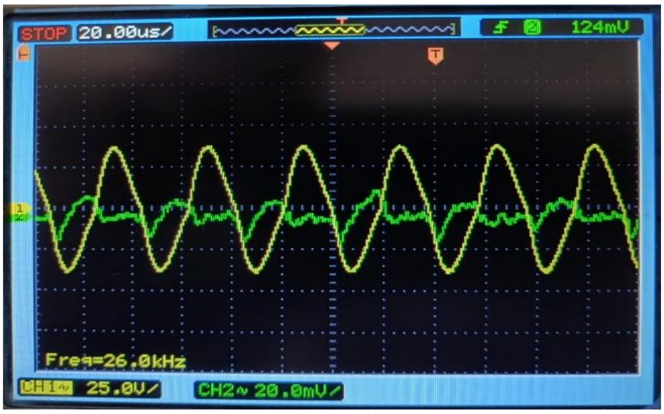

Figure.7. DSO Output Wave from ZVS Circuit

The DSO-captured waveform at 26 kHz shows smooth, in-phase sinusoidal voltage (yellow) and current (green) across the induction coil. This resonance confirms Zero Voltage Switching, minimizing switching losses and maximizing efficiency. Real-time DSO verification proves reliable ZVS operation for induction heating.

6. Conclusion

The Solar-Powered Groundnut Roasting Machine with Induction Heating offers an energy-efficient, sustainable solution to automate the roasting process. Utilizing solar energy, it minimizes reliance on grid power, making it ideal for small-scale farmers and remote industries. Induction heating provides precise, uniform roasting, enhancing groundnut flavor and texture. A temperature sensor with an LCD enables real-time monitoring for controlled heating, preventing over- or under-roasting. A 12V DC motor with a gear system stirs the groundnuts at a consistent low speed, ensuring even heat distribution and avoiding burning. This automation improves efficiency and reduces labor costs. Operating on renewable energy, the system is both eco-friendly and economical. Future upgrades may include automated temperature regulation, multi-seed roasting modes, and IoT-based remote monitoring for enhanced control. Enhancing solar panel and battery efficiency would increase runtime, and commercial scaling could boost productivity. These improvements would help evolve the system into a fully autonomous, sustainable, and energy-efficient food processing solution for both small and large-scale applications.

REFERENCES

[1]. K. V. Anusree and A. Sukesh, "Solar Induction Cooker," 2020 International Conference on Power Electronics and Renewable Energy Applications (PEREA), Kannur, India, 2020, pp. 1-6. doi: 10.1109/PEREA51218.2020.9339725.

[2]. H. D. Dande and S. D. Markande, "Solar based Induction Heating system," 2014 Annual IEEE India Conference (INDICON), Pune, India, 2014, pp. 1-5. doi: 10.1109/INDICON.2014.7030382.

[3]. S. R. Meenakshi, S. Lokesh, and S. Sundaramahalingam, "Solar Powered Induction Cooking System," 2019 2nd International Conference on Power and Embedded Drive Control (ICPEDC), Chennai, India, 2019, pp. 325-332. doi: 10.1109/ICPEDC47771.2019.9036681.

[4]. S. L. Hajare et al., "A Review on Solar Based Induction Heater," International Journal of Innovative Research in Technology, vol. 6, issue 12, 2020, pp. 570-572.

[5]. Y. A. Unguwanrimi et al., "Development and Performance Evaluation of a Manually Operated Groundnut Roaster," Arid Zone Journal of Engineering, Technology and Environment, vol. 16, no. 4, 2020, pp. 725-732.

[6]. H. U. Kabri et al., "Modification and Performance Evaluation of a Manually Operated Drum Groundnut Roaster," Savannah Journal of Agriculture, vol. 1, no. 2, 2006, pp. 88–93.

[7]. M. R. Patel and A. K. Pandey, "Design and Implementation of ZVS Resonant Converter for Solar Induction Heating," International Journal of Power Electronics and Drive Systems, vol. 9, no. 2, 2018, pp. 456-463.

[8]. P. K. Singh and S. K. Jain, "Solar Powered ZVS Induction Heating System for Rural Applications," Renewable Energy Focus, vol. 25, 2018, pp. 45-52.

[9]. L. Chen et al., "Development of a Solar-Powered ZVS Induction Heating System for Cooking Applications," Energy Conversion and Management, vol. 150, 2017, pp. 62-70.

[10]. J. Wang and Y. Li, "Design of a High-Efficiency ZVS Induction Heating System Powered by Solar Energy," IEEE Transactions on Industrial Electronics, vol. 65, no. 8, 2018, pp. 6400-6408.

[11]. S. Gupta and M. K. Das, "Implementation of ZVS Resonant Converter for Solar-Based Induction Heating," International Journal of Renewable Energy Research, vol. 9, no. 3, 2019, pp. 1234-1242.

[12]. T. Nakamura et al., "A Study on Solar-Powered Induction Heating Using ZVS Technique," Journal of Renewable and Sustainable Energy, vol. 11, no. 4, 2019, 045101.

[13]. R. Kumar and V. Singh, "Optimization of ZVS Induction Heating System for Solar Applications," Energy Procedia, vol. 158, 2019, pp. 1230-1235.

[14]. A. Lateef et al., "Development of Manually-Operated Groundnut Roasting Machine," ABUAD Journal of Engineering Research and Development, vol. 6, no. 1, 2023, pp. 88-93.

[15]. Sharma and R. K. Tripathi, "Performance Analysis of ZVS Inverter for Solar-Based Induction Heating Applications," Journal of Electrical Engineering & Technology, vol. 14, no. 3, 2019, pp. 1123-1130.