International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 09 | Sep 2024 www.irjet.net p-ISSN: 2395-0072

Multiple Output Boost Resonant Inverter for Induction Heating

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Abstract -*Induction cooking devices have rapidly advanced in recent years, driven by their numerous benefits, including efficient, clean, and safe contactless energy transfer. This technology has already made a significant impact on the market, both in terms of adoption and economic effect. Central to these systems are inverters, which, when utilized effectively, can lower overall costs and improve system efficiency. The current focus in power electronic converters is on maximizing efficiency by reducing the number of components, leading to more compact, cost-effective designs with higher performance. However, power electronic switches introduce challenges such as electromagnetic interference (EMI), switching losses, and stress, which can increase costs, reduce efficiency, and necessitate additional maintenance. As a result, engineers are increasingly concentrating on developing converters with minimal components to address these issues.*

This paper introduces a multiple-output boosted resonant inverter aimed at improving the efficiency and performance of modern induction heating systems. The proposed design is capable of powering multiple induction loads while reducing current levels, thereby significantly enhancing converter efficiency. This approach enables a high-performance, cost-effective solution. A prototype has been constructed and tested to confirm the viability of the proposed converter, with simulations conducted using MATLAB/Simulink to support the findings.

***Key Words*: - Boost Inverter, Induction heating, sMultiple Output, Resonant Converter.**

1.INTRODUCTION

Induction heating technology has rapidly gained prominence due to its many advantages, such as high efficiency, cleanliness, and safety. These benefits have driven significant advancements in the field, leading to widespread adoption and notable economic impact. Unlike traditional heating methods that rely on direct contact or convection, induction heating works through electromagnetic induction to generate heat directly within the material. This method of contactless energy transfer offers unmatched precision and control, making it an ideal choice for a variety of applications, ranging from industrial processes to household appliances like induction cooktops[1].

At the heart of induction heating systems lies the inverter, a crucial component that converts electrical energy into the high-frequency alternating current (AC) necessary for efficient induction heating. The performance of the inverter is critical, as it directly affects the overall efficiency, cost, and reliability of the system. In recent years, there has been a growing focus in power electronics on maximizing efficiency by minimizing the number of components in these systems[2]. This approach not only leads to more compact designs but also enhances performance and reduces manufacturing costs. However, this pursuit of efficiency presents its own set of challenges.

Power electronic converters, particularly those involving high-frequency switching, introduce several undesirable factors that can adversely affect system performance. These factors include electromagnetic interference (EMI), switching losses, and thermal stress, all of which contribute to higher operational costs and lower efficiency. For example, EMI can disrupt the operation of nearby electronic devices, necessitating additional filtering and protective measures. Switching losses occur when power is dissipated during the transition between the on and off states of the electronic switches, which reduces the overall efficiency of the system. Thermal stress, caused by the rapid switching and high power levels, can lead to component degradation over time, increasing maintenance needs and the likelihood of system failure.

To address these challenges, modern engineers are increasingly focused on designing power electronic converters that use the fewest possible components while maintaining high efficiency and performance. The goal is to create systems that are not only cost-effective but also reliable and easy to maintain. This trend has led to the exploration of various inverter topologies and control strategies aimed at optimizing the performance of induction heating systems[3].

One promising development in this area is the multiple-output boosted resonant inverter, which has shown significant potential in improving the efficiency and performance of induction heating systems. This topology is designed to simultaneously supply multiple induction loads, thereby reducing the current levels required for each load and enhancing overall system efficiency. By distributing the power among multiple loads, the converter can operate at lower current levels, which helps reduce the losses associated with high-current operation. Additionally, the resonant nature of the inverter allows for soft switching—a technique that minimizes switching losses by ensuring that the voltage and current are at zero during the switching transitions. This not only improves efficiency but also reduces thermal stress on the components, leading to longer system lifespans and lower maintenance costs.

Designing and implementing such a system requires careful attention to various factors, including the selection of components, circuit layout, and the control strategy used to manage the inverter's operation. The choice of components is particularly important, as it directly influences the system's efficiency, cost, and reliability. High-quality components capable of withstanding high-frequency operation and thermal stress are essential to ensuring long-term performance. The circuit layout must also be optimized to minimize parasitic inductances and capacitances, which can contribute to losses and decrease the inverter's efficiency[4].

Beyond hardware design, the control strategy is vital to the inverter's performance. Advanced control techniques, such as pulse-width modulation (PWM) and phase-shifted control, can be employed to regulate the inverter's output and ensure optimal operation. These control strategies must be finely tuned to balance trade-offs between efficiency, power output, and system stability. For instance, increasing the switching frequency can reduce the size of passive components and improve the system's dynamic response, but it can also lead to higher switching losses and increased EMI. Therefore, the control strategy must be designed to achieve the best possible performance within the system's constraints[5].

The proposed multiple-output boosted resonant inverter has been validated through prototype testing, with results confirming its viability as a high-performance and cost-effective solution for modern induction heating systems. The prototype demonstrated that the inverter could effectively power multiple loads with enhanced efficiency and reduced current levels, supporting the theoretical advantages of the proposed topology. Additionally, simulations conducted using MATLAB/Simulink provided further insights into the inverter's operation and performance under various conditions, helping to refine the design and optimize the control strategy. This ensured that the final implementation met the desired performance standards.

In summary, the development of efficient and cost-effective power electronic converters is essential for advancing induction heating technology. The multiple-output boosted resonant inverter represents a significant leap forward in this regard, offering a solution that enhances the performance and efficiency of induction heating systems while reducing overall system costs and complexity. As the demand for induction heating continues to rise, the adoption of innovative inverter topologies like this one will be crucial in meeting the needs of both industrial and consumer applications. Future research and development should focus on further improving the efficiency and reliability of these systems by exploring new materials and technologies that can extend the capabilities of induction heating. By continuing to innovate in this field, the full potential of induction heating technology can be realized, leading to more sustainable and efficient heating solutions across various industries.

2. ARCHITECTURE OF THE SYSTEM

This architecture shown in the Fig-1, combines various components that work together to convert, regulate, and distribute power efficiently to multiple inductive loads. The input AC voltage is first processed by the boost resonant converter, which increases and regulates the voltage, while the pulse generation circuit ensures precise control over the converter's operations. The output power is then delivered to the main and auxiliary inductive loads, which utilize the energy for their respective heating functions. This integrated system design is highly effective in meeting the demands of modern induction heating applications, offering a reliable and efficient solution for both industrial and consumer use.

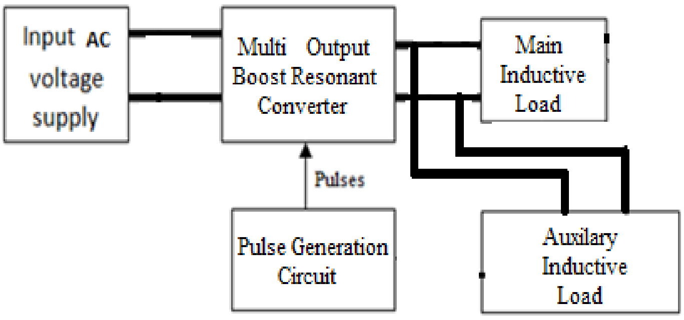

Fig-1: Architecture of the system

2.1 Input AC Voltage Supply

The Input AC Voltage Supply serves as the initial source of electrical power for the system. It typically originates from a standard mains supply, delivering alternating current (AC) that the system will convert and regulate to power the inductive loads. The importance of this supply cannot be overstated, as it provides the foundational energy needed for the entire operation. The AC voltage is subjected to conversion processes that tailor it to the specific requirements of the inductive loads, ensuring that the system operates effectively and efficiently.

2.2 Multi-Output Boost Resonant Converter

At the core of the system is the Multi-Output Boost Resonant Converter. This component is responsible for converting the input AC voltage into a higher, more suitable voltage that can power the system's inductive loads. The term "boost" refers to the converter's ability to step up the input voltage to meet the demands of the loads. This process is crucial because the inductive loads often require a voltage that is higher than what is supplied directly from the mains. The "resonant" aspect of the converter refers to the use of inductance and capacitance to create a resonant circuit, which allows for energy to be transferred efficiently at high frequencies. This resonant operation not only enhances energy efficiency but also reduces switching losses and stress on the system's components. The multi-output capability indicates that the converter can simultaneously provide power to multiple loads, such as a primary inductive load and an auxiliary one, without sacrificing performance.

2.3 Pulse Generation Circuit

The Pulse Generation Circuit is an essential part of the control mechanism for the converter. This circuit generates precise pulses that control the switching devices within the converter, such as MOSFETs or IGBTs. These pulses determine the timing and frequency of the switching actions, which are critical for maintaining the resonant conditions within the converter. Proper pulse generation is necessary to ensure that the converter operates at optimal efficiency, minimizes energy losses, and provides the correct power levels to the inductive loads. Without this precise control, the system could suffer from inefficiencies, increased wear on components, and even potential failure.

2.4 PWM Generator

The PWM Generator takes the output from the PID controller and converts it into a Pulse Width Modulated signal. PWM is a technique used to control the amount of power delivered to an electrical load, in this case, the BLDC motor. The duty cycle of the PWM signal (the ratio of the on-time to the total period of the signal) directly correlates with the motor speed. A higher duty cycle means more power is delivered to the motor, increasing its speed, while a lower duty cycle decreases the power and slows the motor.

2.5 Inductive Load

The Main Inductive Load represents the primary application of the system's output power. In the context of induction heating, this load could be the main heating element, such as a coil used for cooking or an industrial heating process. The performance of this load depends heavily on the stability and quality of the power it receives from the converter. If the converter operates as intended, the main inductive load will function efficiently, providing consistent and reliable heating performance. This component is the primary beneficiary of the converter's output, and its efficiency is directly linked to the overall success of the system.

3. SIMULATION ANALYSIS

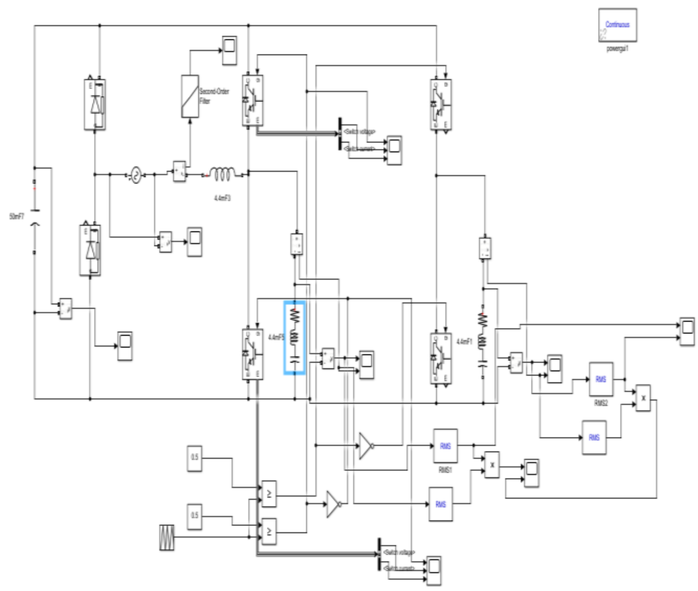

Fig-2: Simulation circuit

The simulation diagram in Fig 2, shows the MATLAB simulation circuit

3.3 System Operation

The dual-output inverter system enhances the efficiency and performance of multi-burner induction cooking by converting input AC power into high-frequency AC suitable for driving induction heating elements. It features a dual-output inverter with two half-bridge structures, allowing independent power distribution to two separate induction coils. This configuration efficiently splits power between the outputs, ensuring effective operation of both heating zones. Transistor switches, such as MOSFETs or IGBTs, control the power conversion, while snubber capacitors minimize switching losses by absorbing energy during transitions. Series resonant tanks, comprising inductors and capacitors, are connected to each half-bridge, enabling soft-switching conditions (zero voltage or zero current switching) that reduce losses and component stress. The resonant frequency of each tank is tuned to match the system's operating frequency, ensuring efficient energy transfer.

The system achieves up to 95% efficiency by managing switching losses and maintaining resonance. A key advantage is the minimal use of components; by integrating two outputs into a single inverter, the system eliminates the need for separate inverters for each burner, leading to a compact, lightweight, and cost-effective design. The high-frequency AC output generates magnetic fields

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that induce currents in cooking vessels, producing heat. Overall, the system offers an efficient, versatile, and affordable solution for multi-burner induction cooking, optimizing performance through reduced losses and component usage.

4. RESULTS AND ANALYSIS

The waveform shown in the Fig 3 is the input supply voltage waveform of the inverter .

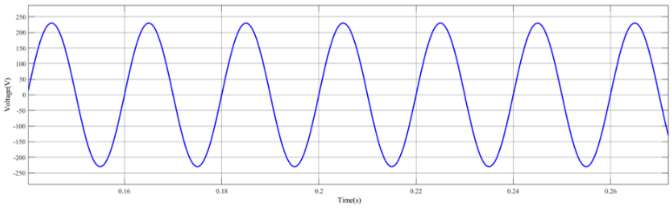

Fig-3: Input supply voltage waveform of the inverter

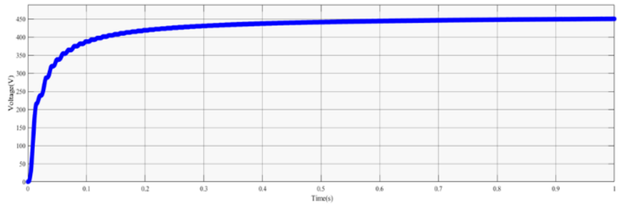

Fig-4: DC link voltage waveform of proposed inverter

Fig 4 shows the DC link voltage waveform of the proposed inverter

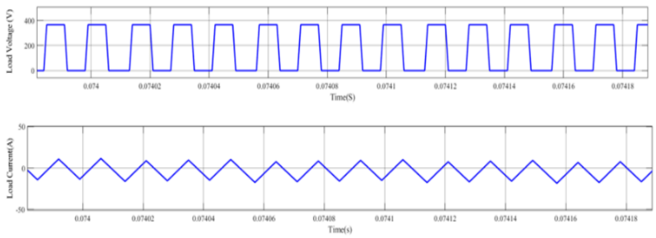

Fig-5: Load voltage and current waveforms of proposed inverter

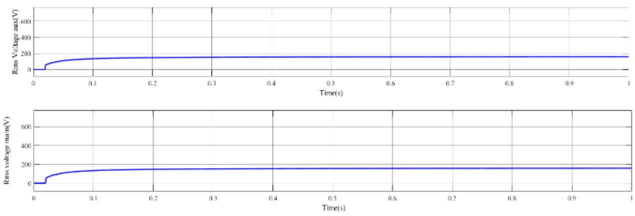

Fig-6: RMS Voltage of Load1 and Load2 for duty ratio of 0.5.

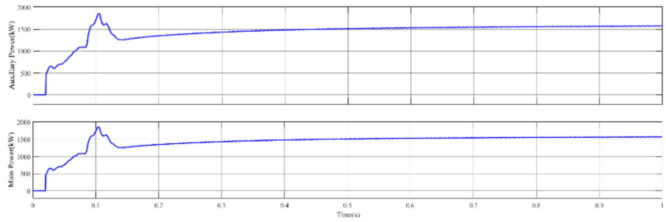

Fig-7: Power consumed by Load1 and Load2

Fig -5, shows the load voltage and current waveforms of the proposed inverter system, whereas Fig-6 shows the RMS voltage of Load 1 and Load 2 for the duty ratio of 0.5 .Fig-7, shows the power that is consumed by load1 and load 2.

4. HARDWARE SETUP

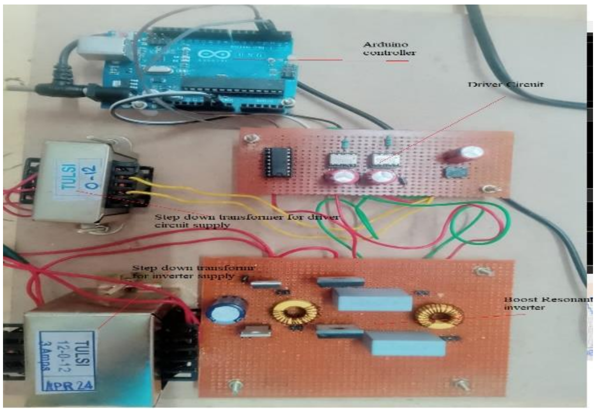

Fig-8: Hardware prototype of proposed inverter

Fig-8, shows the hardware prototype of the system.The components used are Arduino controller,driver circuit,step down transformer and boost resonant inverter

5. CONCLUSION

This study focuses on developing a dual-output inverter system for induction cooking, eliminating the need for multiple inverters in multi-burner applications. The proposed converter topology incorporates two half-bridge structures and snubber capacitors to reduce switching losses, achieving up to 95% efficiency. Series resonant tanks are employed for safe commutation, further minimizing losses. The design optimizes efficiency by maintaining low total losses, and the use of fewer components results in a lighter, smaller, and more cost-effective converter. Compared to conventional single-output systems, this approach enhances overall performance while reducing the system's size and cost.

5. REFERENCES

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BIOGRAPHIES

Dr. M.N Dinesh is currently the Professor of EEE, RV College of Engineering, Bengaluru. His area of interests are Insulators for HV applications, controlsystems and power electronics

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