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COMPACT HIGH-EFFICIENCY POWER INVERTER SYSTEM

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ABSTRACT
The project aims to develop a 200-watt power inverter which can convert 12V DC to 220V AC with high efficiency. This inverter system is designed to cater to small-scale applications where reliable power conversion is critical. The project integrates key components including a transformer, battery, DC-DC converter, battery indicator, a SMPS module and an inverter circuit. The transformer steps up the voltage from 12V DC to a higher AC voltage, while the DC-DC converter is used to charge the battery. The battery serves as the primary energy source, and the battery indicator provides real-time monitoring of the battery status. The inverter circuit then converts the low-voltage DC to 220V AC, ensuring efficient power output. The compact design of the system emphasizes space-saving while maintaining performance and efficiency, making it suitable for various applications requiring a reliable and efficient power conversion solution.

Keyword:
Power inverter, Transformer, Battery, DC-DC Converter, High Efficiency, SMPS Module.

I. Introduction
The compact high-efficiency power inverter system represents a significant advancement in power electronics, addressing the increasing need for portable and reliable power sources for various electronic devices. This inverter, with a power capacity of 200W, effectively converts 12V DC to 220V AC, making it suitable for applications requiring stable AC power. Powered by a Li-ion battery, the system ensures that it has sufficient energy storage for extended operation, providing an optimal balance between size and functionality. The design integrates advanced switching techniques, which help minimize power losses during the DC-to-AC conversion process, thereby increasing overall energy efficiency and reducing waste heat generation [1]. Furthermore, the inverter includes essential protective features such as over-voltage and over current protection, enhancing the safety and longevity of both the inverter and any connected devices [2]. One of the standout features of this inverter system is its compact form factor, which is achieved by employing high-density components and optimizing the layout to reduce size while maintaining performance. This makes the inverter especially useful in applications where space is a premium, such as in small-scale electronics, portable devices, or emergency power systems. The system's efficient design also incorporates superior thermal management solutions, which are essential for maintaining operational stability, especially under high-load conditions. These thermal management techniques ensure that the inverter continues to operate at its peak efficiency without overheating, even during prolonged usage [3]. Additionally, the inclusion of two USB charging ports alongside the AC output adds flexibility to the system, allowing users to charge electronic devices simultaneously while still powering larger equipment through the AC output, making it versatile for a variety of needs [4]. The inverter's power management system further elevates its efficiency by integrating a BMS that monitor and optimize battery usage, ensuring that the system

operates within safe limits and extends the lifespan of the battery. This capability allows the inverter to adjust its power output according to varying load conditions, ensuring a stable and reliable supply of power even when the load fluctuates. The battery management system also includes mechanisms to prevent deep discharges or overcharging, preserving the health of the Li-ion battery and ensuring long-term durability. These features contribute to the system's overall reliability and performance, making it suitable for use in a wide range of applications, from consumer electronics to more critical power backup situations [5]. In addition to its core functionality, the inverter's design emphasizes user convenience and ease of use. The combination of robust performance, protective features, and efficient power management makes the system ideal for individuals or small businesses needing a reliable power solution in remote or off-grid locations. Its small size does not sacrifice performance, making it an ideal candidate for portable power applications, and it is capable of supporting the needs of devices with varying power requirements. By providing both AC and USB outputs, the inverter addresses multiple user needs in a single, compact device. With careful attention to power conversion efficiency, thermal performance, and battery management, this inverter is positioned as a versatile, reliable, and user-friendly solution for portable energy demands [6][7].

II. Methodology

The development of the Compact High-Efficiency Power Inverter System followed a structured and iterative approach to address challenges in conventional inverter systems, such as inefficiency, bulky design, and limited functionality. The process began with a detailed analysis of existing inverters, identifying key limitations like high energy losses, lack of portability, and inadequate safety mechanisms. Based on this analysis, the project's objectives were defined, focusing on achieving high efficiency, compactness, and user-friendly features. The system was required to convert 12V DC to 220V AC with high efficiency while incorporating additional features like USB charging, voltage monitoring, and safety protections. A modular design approach was adopted to ensure flexibility and scalability, dividing the system into key subsystems: the power source (a 3S4P Li-ion battery pack with a 40A Battery Management System), the inverter circuit (using IRF3205 MOSFET's for efficient DC-AC conversion), the charging subsystem (featuring an XL4015 buck converter for constant voltage and current regulation), and auxiliary modules (including an LM2596DC-DC converter, cooling fan, and USB fast charging ports). Thermal management was a critical consideration, and a 12V mini cooling fan was incorporated to maintain operational stability under load conditions.

Hardware Components

a. Li-ion Battery Pack (3S4P Configuration)

- Configuration: 3 cells in series and 4 in parallel, providing a total voltage of 12.6V (4.2V per cell max) and a capacity of 8Ah.
- Energy Density: Offers high energy density with minimal weight, ideal for portable inverter systems.
- Lifecycle: Typically lasts 300-500 charge cycles, depending on charge/discharge rates and temperature management.

b. Battery Management System (BMS)

- Primary Role: Protects the battery by monitoring and balancing cell voltages, ensuring each cell charges and discharges evenly.
- Safety Features: Includes temperature monitoring and cuts off power during unsafe conditions like short circuits or overheating.
- Current Handling: The 40A rating ensures the system can handle peak loads without damaging the battery.

c. XL4015 Buck Converter

- Operating Modes: Regulates power with constant current (CC) for safe charging and constant voltage (CV) for maintaining optimal battery charge levels.

- Input Voltage Range: Accepts up to 36V input, stepping it down to 12.6V with high efficiency (>90%).
- Heat Dissipation: Built-in heat sink ensures consistent performance during extended charging.

d. IRF1404 MOSFETs

- Specifications: High current-handling capacity (202A max) and low on-resistance (3.7mΩ) reduce power loss during DC-AC conversion.
- Switching Speed: Capable of fast switching for high-frequency PWM, minimizing switching losses.
- Thermal Management: Requires heat sinks to maintain efficiency under high loads.

e. Charging SMPS Module (24V 6A)

- Voltage and Current Control: Provides a stable 24V DC output for efficient battery charging, ensuring minimal ripple and noise.
- Efficiency: High conversion efficiency (~85-90%) reduces power loss during charging.
- Safety Features: Includes overload, over-voltage, and thermal protection for secure operation.

f. LM2596 DC-DC Converter

- Voltage Regulation: Steps down 24V or 12.6V to power low-voltage components like relays and microcontrollers.
- Efficiency: Operates at >90% efficiency, reducing heat generation and power loss.
- Compact Size: Easy to integrate into small spaces in the system.

g. Mini Cooling Fan

- Heat Dissipation: Prevents overheating of MOSFETs, converters, and other components during high-load conditions.
- Smart Control: Can be linked to a temperature sensor to activate only when needed, reducing energy consumption.

h. USB Fast Charging Modules

- Dual Functionality: Provide additional utility by offering 12V 2A outputs for charging external devices like smartphones or power banks.
- Safety: Built-in over-current and short-circuit protection ensures safe charging of connected devices.

i. Voltage Indication Display

- Real-Time Monitoring: Displays the battery's charge level, allowing users to gauge the remaining runtime and plan recharging.
- Compact and Efficient: Low power consumption ensures it doesn't significantly impact the battery runtime.

III. Block Diagram

The block diagram of the Compact High-Efficiency Control Inverter Framework gives a visual representation of the system's useful engineering and component intuitive. At the centre of the framework is the Li-ion Battery Pack, designed in a 3S4P course of action, which serves as the essential vitality source. This battery pack supplies a steady 12V DC input to the inverter circuit. The Battery Administration Framework (BMS) is coordinates with the battery to screen and ensure against cheating, over-discharging, and short-circuiting, guaranteeing solid operation and longevity. The XL4015 Buck Converter interfaces to an outside control source and controls the charging voltage and current conveyed to the battery pack. This converter works in both steady voltage (CV) and steady current (CC) modes, keeping up ideal charging conditions. The LM2596 DC-DC Converter infers its input from the buck converter to control the system's transfer, guaranteeing consistent exchanging between charging and releasing modes.

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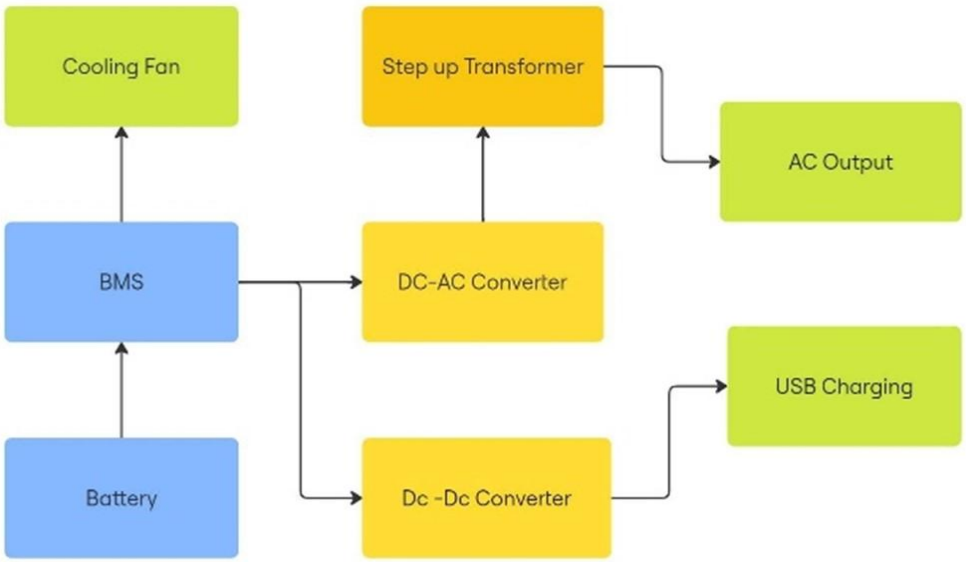

Fig.3.1: Block Diagram.

The heart of the inverter framework is the DC-AC Change Circuit, which employments high-efficiency IRF1404 MOSFETs. These components handle the transformation of 12V DC into a 220V AC yield, utilizing an altered sine wave plan. This yield is made accessible through an AC Outlet, empowering the framework to control little family machines or other gadgets. Extra USB Quick Charging Modules are coordinates to supply 5V yields, supporting the charging of convenient electronic gadgets such as smartphones.

For real-time framework checking, the plan incorporates a Voltage Sign Show, which appears the battery's charge status. A Scaled down Cooling Fan is joined into the framework to oversee warm dissemination viably, guaranteeing steady operation indeed beneath high-load conditions. All components are encased inside a tough acrylic case, which is planned for compactness and incorporates straightforward areas for perceivability and maintenance.

Parameters and specifications of the inverter

- Rated Voltage: 12v
- Rated Current: 16.6A
- Max Current: 20.8A
- Output Power: 200w
- Max Output Power: 250w
- Li-ion Battery Voltage: 11.1
- Li-ion Battery Capacity: 8Ah
- Li-ion Battery Max Current Draw: 24A
- Protection Features: Shrot circuit, Over voltage, Over Current, Temperature.
- Charging Voltage: 12.6v
- Charging Current: 2A
- Max load discharge time: 30min

IV. Results and Discussion

The project successfully integrates a 12V DC to 230V AC inverter, 3S4P Li-ion battery pack, and various supporting modules to create an efficient and reliable power management system. The 200W inverter provides stable power, while IRF1404 MOSFETs ensure efficient operation. The 8Ah battery pack with a 40A BMS offers safe charging and discharging with over-voltage, over-current, and short-circuit protection. A 30A relay controls the charging and load functions, while the XL4015 buck converter with CC and CV modes ensures safe battery charging at 12.6V. The cooling fan maintains optimal temperature, and the USB fast charging modules offer convenient external device charging. A

voltmeter display provides real-time battery voltage monitoring, and the 24V 6A SMPS module efficiently charges the battery. All components are housed in a 3mm black and transparent acrylic casing, providing durability and visibility while ensuring a compact and user-friendly design.

Fig.4.1: Inverter front and top view

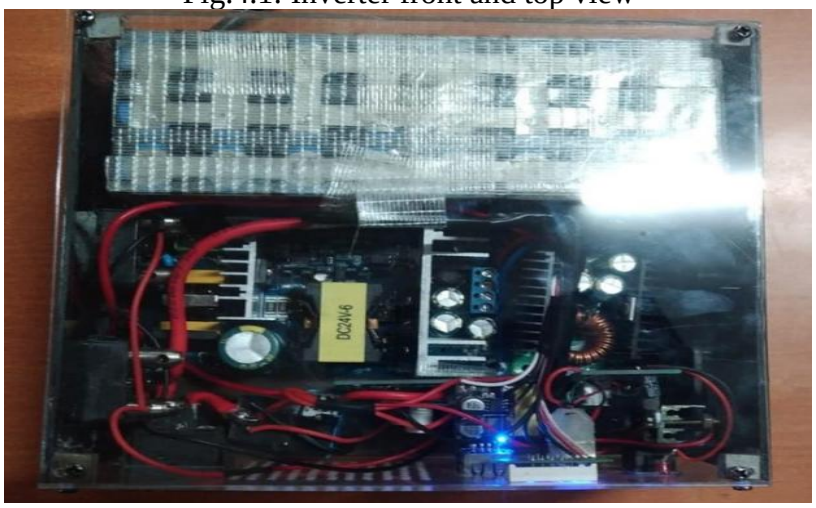

Fig.4.2: Inverter top view

Fig.4.3: Inverter in working condition.

V. Conclusion

The Compact High-Efficiency Power Inverter System successfully demonstrates the integration of efficient power conversion, compact design, and user-friendly features. By utilizing advanced components such as the IRF3205 MOSFETs, a robust 3S4P Li-ion battery with a Battery Management System, and an XL4015 buck converter, the system achieves reliable 12V DC to 220V AC conversion with minimal energy loss. The inclusion of USB charging ports, voltage display, and a cooling fan enhances usability and operational stability. This inverter system provides a versatile and portable solution, making it ideal for small-scale applications requiring efficient and dependable power management.

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