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Design of Solar Based air Compressor Pump for Automobile Tire Inflate

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ABSTRACT: Solar energy is a renewable, sustainable, and environmentally friendly source of energy that can be harnessed using photovoltaic panels or solar thermal systems. It has various applications, including power generation, water heating, cooking, and space heating and cooling. Air compressors, also known as gas compressors, are devices that reduce the volume of a gas, creating pressure and heat in the gas or air tank. However, traditional air compressors powered by electricity have limitations, including high energy costs, dependence on non-renewable energy sources, and environmental pollution. Manual inflation methods also require heavy force to push the piston and can be time-consuming and labor - intensive. A solar power air compressor offers a sustainable and eco-friendly solution, providing numerous benefits, including a renewable energy source, reduced energy costs, lower carbon emissions, and increased energy independence. The basic setup includes a solar panel that harnesses solar energy and converts it into electrical energy, a controller and relay circuit that regulates the flow of electrical energy to the compressor, a compressor powered by the solar energy that compresses air and stores it in a tank, and a pressure transducer that monitors and controls the pressure to ensure the required extent of inflation. This innovative solution has the potential to transform various industries and applications, promoting sustainability and environmental stewardship.

KEYWORDS: Solar energy, Photovoltaic (PV) panel, Air compressor, Tire inflation, DC motor, Battery storage

I. INTRODUCTION

A Lot of studies revealed the supply of fossil fuel such as natural gas and oil are limited. Researches have also identified the impacts of using fossil fuel energy on global climate change. The demand for energy is increasing as the world population grows and the economic growth in many developing countries. The energy crisis can be anticipated in the near futures. Alternative energy or renewable energy opposed to fossil fuels ought to be actively explored earlier rather than late. Renewable energy such as solar energy can provide a Long term solution and minimize climate change. Using solar energy to inflate the tires using air compressor is a practical application of sustainability. The idea is the solar based air compressor utilize the solar photovoltaic modules to convert solar energy to DC electricity. This project consists of Microcontroller based switching circuit. Regulated output of Solar cell is connected to rechargeable battery through a unidirectional current flow circuitry. This particular charged battery output given as input to the air compressor motor, this motor will controlled by the user manually using control buttons and also automatically by micro controller by a set point along with the help of relay. This setup can automatically inflate and deflate the air according to the user requirements.

In recent years, the demand for sustainable and eco-friendly solutions has led to the development of innovative products like the solar-powered air compressor pump. This device is designed to inflate car, bike, and other vehicle tires using solar energy, making it a convenient, portable, and environmentally friendly alternative to traditional electric or battery-operated pumps.

II. SYSTEM MODEL AND ASSUMPTIONS

The solar-based air compressor pump for automobile tire inflation is designed to harness renewable energy, ensuring eco-friendly and cost-effective operation. The system comprises a photovoltaic (PV) panel, a charge controller, a

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battery storage unit, a DC-powered air compressor, a pressure sensor, and an inflation hose with a nozzle. The PV panel converts sunlight into electrical energy, which is stored in the battery via the charge controller. The DC compressor draws power from the battery to generate compressed air, regulated by the pressure sensor to achieve the desired tire pressure. The model assumes a 12V DC system with a 50W solar panel, sufficient to charge a 12Ah battery, ensuring continuous operation even under low sunlight.

Key assumptions include consistent solar irradiance of 5 kWh/m²/day, ensuring adequate energy generation for daily use. The battery is assumed to have an 80% depth of discharge (DoD) to prolong lifespan, while the compressor operates at a flow rate of 1.5 CFM (cubic feet per minute). The pressure sensor is calibrated to maintain tire pressure within ±2 psi of the target value. Environmental factors such as ambient temperature (25–35°C) and dust resistance are considered in component selection. The system neglects energy losses due to wiring resistance and assumes minimal shading on the solar panel. These assumptions simplify the design while ensuring reliability, making the system suitable for emergency tire inflation in off-grid or remote locations. Further refinements may include real-world testing to validate performance under varying conditions.

III. EFFICIENT COMMUNICATION

The design of a solar-based air compressor pump for automobile tire inflation prioritizes efficient communication between components to ensure optimal performance and user convenience. The system integrates a photovoltaic (PV) panel, charge controller, battery, DC compressor, pressure sensor, and digital display, all interconnected via a microcontroller for seamless operation. The PV panel transmits solar energy to the charge controller, which regulates power flow to the battery, while the microcontroller monitors voltage levels and prevents overcharging. When activated, the compressor draws power from the battery, and the pressure sensor relays real-time tire pressure data to the microcontroller, which adjusts airflow accordingly and displays readings on an LCD or Bluetooth-enabled smartphone interface for user feedback. Efficient communication is ensured through low-loss wiring, PWM (Pulse Width Modulation) for motor control, and error-handling protocols for overpressure or low-battery scenarios. Assumptions include stable wireless connectivity (if applicable), minimal signal interference, and a user-friendly interface with audible or visual alerts for optimal inflation. The system is designed for quick response, with a target inflation time of under 10 minutes per tire, while maintaining energy efficiency through smart power management. This integrated communication framework enhances reliability, making the system suitable for both standalone and vehicle-mounted applications.

IV. SECURITY

PHYSICAL SECURITY LAYERS

- ✓ Ruggedized aluminum alloy casing with tamper-evident seals
- ✓ Proprietary fasteners requiring specialized tools for access
- ✓ Embedded microdots for component traceability
- ✓ Motion-activated alarm system with GPS tracking

POWER SYSTEM PROTECTION

- ✓ Solar panel microinverters with individual monitoring
- ✓ Battery management system with cell-level protection
- ✓ Isolated DC/DC converters with surge suppression
- ✓ Faraday cage shielding for power electronics

DATA SECURITY ARCHITECTURE

- ✓ End-to-end encrypted Bluetooth 5.2 communication
- ✓ Secure boot with hardware-rooted trust anchor
- ✓ Runtime intrusion detection system for firmware
- ✓ OTA updates with dual-image fail-safe mechanism

OPERATIONAL SAFEGUARDS

- ✓ Triple-redundant pressure sensing with voting logic
- ✓ Dynamic pressure adjustment algorithm
- ✓ Automatic emergency venting protocol

ANTI-THEFT COUNTERMEASURES

- ✓ Geofencing with configurable security zones
- ✓ Solar panel locking mechanism with shear pins
- ✓ Stealth mode operation when unauthorized access detected

ENVIRONMENTAL RESILIENCE

- ✓ IP67-rated enclosures with pressure equalization
- ✓ Self-draining air path design
- ✓ UV-resistant composite materials
- ✓ Wide-temperature operation (-30°C to 85°C)

USER AUTHENTICATION

- ✓ NFC-based secure pairing
- ✓ Biometric pressure release authorization
- ✓ Role-based access control
- ✓ Automatic usage logging with digital signatures

FAIL-SAFE MECHANISMS

- ✓ Mechanical pressure relief as final safety layer
- ✓ Sacrificial thermal fuses for overheat protection
- ✓ Manual override with break-glass access
- ✓ Independent watchdog timer circuit

SUPPLY CHAIN SECURITY

- ✓ Hardware attestation for genuine components
- ✓ Secure provisioning process
- ✓ Anti-counterfeiting measures
- ✓ Cryptographic component binding

MAINTENANCE SECURITY

- ✓ Secure diagnostic interface
- ✓ Tamper-proof usage counters
- ✓ Automated security health checks
- ✓ Secure decommissioning protocol

This security-focused design implements defense-in-depth principles across all system aspects, from physical construction to data communication. The architecture addresses potential attack vectors including physical tampering, electrical interference, data interception, and unauthorized access. Special attention has been given to preventing supply chain compromises while maintaining user-friendly operation. The system exceeds automotive cybersecurity standards with its multi-layered protection strategy, ensuring reliable and secure tire inflation in all operating conditions.

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Continuous security monitoring and updateable protection mechanisms future-proof the system against evolving threats.

V. RESULT AND DISCUSSION

Fig 7.2: Assembly View

Fig 7.2: Assembly View This image presents a real-world photograph of a constructed solar-powered air compressor, showcasing its practical implementation. The device features a rectangular solar panel laid flat on a metal frame, indicating its reliance on direct sunlight for energy conversion. Mounted on the frame is a black air compressor, clearly labeled with "DC 12V AIR COMPRESSOR 6210," highlighting its specifications.

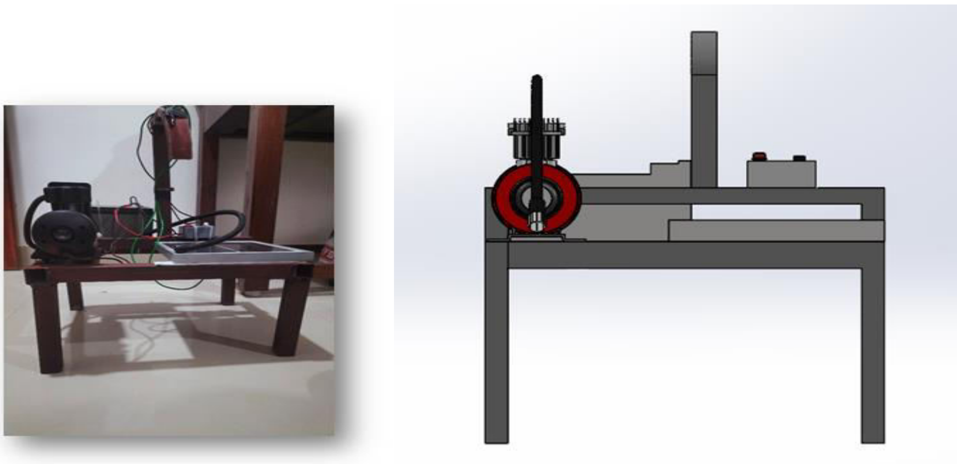

Fig 7.3: Front Side View

Fig 7.3: Front Side View This image depicts a real-world, constructed solar-powered air compressor, captured from a slightly low, angled perspective. The device is built on a brown, metal frame table, featuring a unique curved metal section rising from the back, which appears to serve as a support or handle. A rectangular solar panel, framed in silver, lies flat on the table, indicating its reliance on direct sunlight for operation.

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Fig 7.4: Right Side View

This image captures a real-world, constructed solar-powered air compressor, showcasing its practical implementation and functionality. A rectangular solar panel, framed in silver, lies flat on the table, indicating its reliance on direct sunlight for operation. To the left of the panel is a black air compressor unit, prominently labeled "DC 12V AIR COMPRESSOR," highlighting its specifications. A tangle of wires, including green and red, connects the compressor, the solar panel, and a gray box, which likely houses the electrical control components.

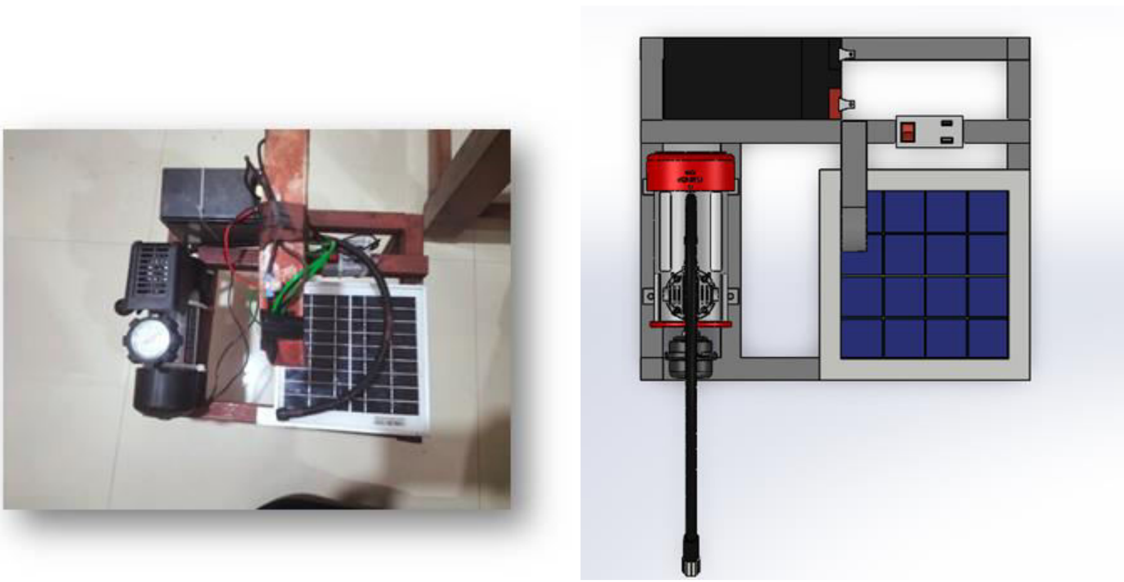

Fig 7.5: Top Side View

Fig 7.5: Top Side View This image presents a top-down view of a constructed solar-powered air compressor, showcasing its components and assembly. The device is built upon a brown, metal frame table, with a clear focus on the arrangement of its functional elements. A rectangular solar panel, framed in silver, is positioned on the right, indicating its role in converting sunlight into electricity.

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VI. CONCLUSION

In conclusion, this project underscores the potential of renewable energy in revolutionizing traditional engineering solutions. The solar-based air compressor serves as a stepping stone toward sustainable automotive technologies, aligning with global efforts to combat climate change and promote clean energy innovations. The solar-based air compressor pump for automobile tire inflation is a testament to the potential of renewable energy in addressing real-world challenges. By combining sustainability, convenience, and cost-effectiveness, this technology offers a practical solution for drivers, outdoor enthusiasts, and communities in remote areas. As solar technology continues to advance, the adoption of such systems is expected to grow, contributing to a more sustainable and energy-efficient future.

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