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Design and Implementation of a Solar-Powered Smart Stone Flour Mill

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ABSTRACT –

Access to affordable flour-milling solutions remains a significant challenge in many rural regions, where unreliable electricity supply and high costs restrict the use of conventional electric mills. To address this issue, a solar-powered smart stone flour mill has been developed that integrates renewable energy with automated grinding control. The proposed system uses a photovoltaic module as its primary energy source, supported by a charge controller and rechargeable battery to ensure stable and continuous operation. A robust copper-winding DC motor drives the stone-grinding mechanism, allowing grains to be processed into fine flour while retaining their natural nutrients and texture. The ESP32 microcontroller serves as the core control unit, regulating motor operation, acquiring sensor data, and executing safety logic. Multiple parameters including battery condition, grain weight, motor temperature, grinding time, and rotational speed—are continuously monitored and displayed to the user through a TFT graphical interface. Users can select different grinding settings, such as automatic or fine, to achieve the desired flour consistency. The system's safety features—such as over-temperature shutdown and low-battery protection—promote reliable and secure operation. Experimental trials confirm that the prototype can perform efficient grinding solely from solar power, providing stable flour output even during periods without sunlight, thanks to stored battery energy. The combination of stone-based flour production with modern embedded control and renewable power creates an effective, low-cost, and eco-friendly alternative to traditional milling systems. This solution is especially well-suited for households, small-scale food processors, and communities in off-grid or power-scarce locations.

Keywords – Keywords: Solar Energy, Photovoltaic System, Renewable Energy, Flour Mill, DC Motor.

I. Introduction

Flour milling is an important household activity, especially in rural and semi-urban areas where grains like wheat, rice, and jowar are consumed daily. However, electric mills rely on continuous power supply, which is often unavailable in many regions. Manual stone grinding, though known for its superior flour quality, requires heavy physical effort and is not suitable for everyday use. This creates a need for a convenient, efficient, and power-independent flour milling system.

The proposed *solar-powered smart stone flour mill* addresses this issue by using solar energy to operate a DC motor that drives the grinder. An *ESP32 microcontroller* manages operations, displays key parameters such as battery level and motor speed, and ensures safety with features like overload and temperature protection. The system offers both *automatic and fine grinding modes*, providing an eco-friendly, cost-effective, and user-friendly solution for households in off-grid and power-deficient areas.

II. Litrature Review

Traditional flour milling using stone grinders produces high-quality, nutrient-rich flour but requires a lot of physical effort and time. While electric mills improved speed and convenience, they cause heat build up that reduces nutritional value and rely heavily on electricity, limiting their use in rural areas with frequent power cuts. Stone grinding remains valuable for its ability to preserve natural fibers and nutrients, making it ideal for modern adaptation through renewable energy and automation.

The proposed *solar-powered smart stone flour mill* combines traditional grinding quality with modern technology. It uses solar energy to power a DC motor, while an *ESP32 microcontroller* manages system control and a *TFT display* provides real-time monitoring of parameters such as motor speed, temperature, and battery level. This integration of solar energy and embedded automation offers a compact, efficient, and eco-friendly solution, perfectly suited for rural and off-grid households seeking sustainable and convenient flour milling.

III. System Description

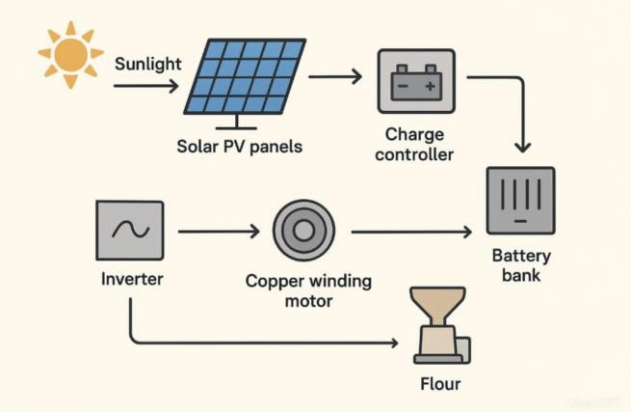
The *solar-powered smart flour mill system* combines renewable energy, automation, and traditional stone grinding for efficient and user-friendly operation. It consists of four main modules: *solar power*, *grinding*, *control and processing*, and *user interface*.

The *solar power module* converts sunlight into electricity using PV panels and stores it in a battery through a charge controller for continuous operation. The *grinding module* uses a DC motor-driven stone grinder that maintains the natural nutrients of grains. The *ESP32 control module* regulates motor speed, monitors parameters like voltage, temperature, RPM, and weight, and ensures safety through overload and heat protection. The *TFT display interface* shows real-time data such as battery level, grinding mode, speed, and temperature, allowing easy monitoring and smooth operation.

3 heading must end with a colon. The body of the level-3 section immediately follows the level-3 heading in the same paragraph. Headings must be in 10pt bold font. For example, this paragraph begins with a level-3 heading.

IV. System Architecture

A. Block diagram :



B. Working :

1. Solar Energy Conversion

The system starts when sunlight falls on the solar PV panels. These panels convert solar radiation into DC electrical energy. This renewable energy acts as the main input source for powering the flour mill system.

2. Power Regulation & Storage

The DC power generated is sent to the charge controller, which regulates voltage and current to ensure safe charging. It prevents battery over-charging and deep discharge. The regulated power is stored in the battery bank, allowing the system to run even during low sunlight.

3. DC/AC Power Supply to Motor

Stored battery energy is then supplied to run the flour mill. If the motor is DC, power is delivered directly; if the motor is AC, the inverter converts DC to AC. This ensures stable power is supplied to the copper-winding motor for proper operation.

4. Stone Grinding Operation

The copper-winding motor drives the stone grinding mechanism. When activated, rotating stones crush grains fed from the hopper. This low-speed grinding preserves nutrients and produces finer flour. The ground material is then collected at the outlet.

5. Flour Collection

The crushed flour passes through the stone grinding unit and is filtered to remove unwanted coarse particles. The final fine flour is collected in a cloth bag or container, ready for use.

V. Technical Approach

The technical approach adopted in this project integrates renewable-energy conversion, embedded motor control, traditional stone-based grinding, and real-time monitoring. The system architecture is divided into five operational stages: solar energy utilization, power management, electromechanical grinding, sensing and data acquisition, and user–system interaction.

A. Solar Energy Utilization & Power Management

A photovoltaic (PV) module converts incident solar radiation into DC electrical power. The generated power is routed to a solar charge controller, which performs voltage/current conditioning to ensure optimal charging of the lead-acid battery. The controller prevents battery damage through over-charge and deep-discharge protection. The charged battery serves as a stable DC power source for the motor and ESP32 controller, allowing operation during non-sunlight hours or fluctuating irradiance.

B.Electromechanical Grinding Operation

The grinding subsystem is driven by a copper-winding DC motor powered through the stored DC supply. The motor rotates a pair of stone grinding discs, producing mechanical abrasion required to convert grains into flour. Grain input through the hopper is forced between the stones where controlled compression breaks it down. The ground material passes through a sieve to maintain particle uniformity and is collected in a container or cloth outlet. The mechanical configuration minimizes heat build-up, thus preserving the nutritional integrity of the flour.

C.Sensing and Data Acquisition

To enable automated control, the system integrates multiple sensors that provide continuous feedback to the *ESP32 microcontroller*. A *voltage sensor* monitors the battery status, while a *temperature sensor* tracks the thermal condition of the motor and stone assembly. The *RPM sensor* measures the motor speed, and the *load or weight sensor* determines the quantity of grain and flour. The real-time data collected from these sensors allow the microcontroller to make intelligent decisions, dynamically adjusting motor performance and system operation under varying load conditions to ensure efficiency, safety, and consistent flour quality.

D.Embedded Control Logic (ESP32)

The ESP32 microcontroller executes the primary control algorithms. It generates PWM signals to modulate motor speed through a motor driver and adjust torque output. Based on real-time sensor feedback, ESP32 ensures that the grinding process remains within optimal operational constraints. It selects grinding modes (Automatic / Fine), manages power utilization, and implements protective actions such as shutdown during overload, high temperature, or low voltage. This increases system reliability and operational safety.

E.User Interface and Data Visualization

The *TFT graphical display* serves as an intuitive interface for real-time visualization of key operational parameters such as battery percentage, grinding mode, motor speed (RPM), temperature, grain or flour weight, and estimated remaining time. It enhances user interaction by clearly presenting system status, performance metrics, and alert messages. This user-friendly interface simplifies operation, allows easy monitoring of the milling process, and minimizes the need for manual intervention, making the system more efficient and convenient to use.

VI. Conclusion

The Developed Solar-Powered Smart Stone Flour Mill Provides An Efficient And Sustainable Method For Grain Processing. Utilizing Solar Energy Stored In A Battery, The System Functions Independently Of Conventional Power Supply, Making It Suitable For Remote And Rural Regions. The Copper-Winding Motor Delivers The Necessary Torque To Operate The Stone Grinder, Ensuring High-Quality Flour With Preserved Nutrients. The Esp32 Microcontroller Intelligently Controls Motor Operation And Continuously Monitors Key Parameters Such As Temperature, Rpm, And Battery Level To Ensure Safe Performance. Additionally, The Tft Display Presents Real-Time System Information, Improving User Interaction And Ease Of Operation. Thus, The Proposed Design Offers An Eco-Friendly, Cost-Effective, And Reliable Solution For Household Flour Production.

Acknowledgment

The heading of the Acknowledgment section must not be numbered. The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” **Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page**.

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