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Design of Compact Solar-Powered Laundry System with Electricity Generation Capability

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Abstract— ***Traditional washing machines are energy-intensive appliances that rely entirely on grid electricity for operation. This study introduces a portable, solar-powered washing machine designed to enhance efficiency while minimizing environmental impact. Unlike conventional models, the proposed system utilizes renewable energy for washing and incorporates an energy-recovery mechanism during the drying phase, converting mechanical motion into storable electricity. As a result, the device significantly reduces both power and water consumption compared to standard washers. Its off-grid capability, lower operational costs, and sustainable design make it an eco-friendly alternative for domestic and remote applications. This innovation demonstrates how integrating renewable energy and energy regeneration can improve laundry technology while conserving resources.***

Index Terms— ***Solar Energy, Washing Machine, PV Cell, Alternator, Dc Motor***

I. INTRODUCTION

This innovative solution tackles worldwide issues including sustainable energy availability, environmental preservation, and community development. The system decreases dependence on non-renewable energy sources by utilizing solar power technology. Its compact and self-sufficient design makes it particularly suitable for remote locations, emergency situations, and temporary settlements where conventional power infrastructure is lacking. The design significantly lowers operational expenses while its energy recovery capability can supply power to auxiliary electronic devices.

The implementation of this concept requires the creation of optimized electrical parts that are both widely accessible and energy-conserving. A practical application of this system is demonstrated through a laundry appliance [1] that operates entirely on solar energy [2]. Photovoltaic panels directly transform sunlight into electrical energy [3], which is then accumulated in environmentally responsible lead-acid battery units with full recyclability [4]. The appliance incorporates dual compartments for effective washing and rinsing operations. User interaction is simplified through push-button controls for program selection, operation initiation/termination, and motor regulation managed by an embedded microcontroller. This mobile cleaning device consumes minimal power, operates without ecological harm, and is specifically engineered for regions lacking stable electrical supply.

The compact and mobile washing machine design operates using solar panel-generated electricity, ensuring uninterrupted power supply for efficient laundry performance [5]. This innovative system employs a permanent magnet DC (PMDC) motor rather than a PMAC motor, primarily because of its superior torque consistency and operational smoothness [6]. Motor speed regulation is achieved through an energy-efficient microcontroller that delivers optimal performance with minimal power consumption [7].

A key innovative feature of this project involves electricity generation through a mechanical system combining gears and an alternator, powered initially by solar energy. The system operates through an integrated energy cycle: solar-charged batteries provide power to the DC motor, whose mechanical output drives the alternator to produce additional electrical energy. This supplementary power can either be utilized immediately or stored for future requirements [8].

II. METHODOLOGY

This study follows a systematic three-phase approach to investigate, evaluate, and enhance washing machine functionality, ultimately transforming it into a versatile appliance. The research framework, illustrated in Fig.3 progresses through distinct developmental stages. The initial phase involved comprehensive investigation of existing challenges in portable washing systems.

Researchers completed this foundational stage through extensive literature review, examining scholarly articles, technical publications, online resources, and consultations with industry specialists.

Phase two concentrates on establishing experimental parameters and determining appropriate sample specifications. This stage incorporates various practical tests and empirical evaluations to gather crucial performance data.

The final development stage implements the electricity generation system using an alternator mechanism. This innovative component represents the culmination of the research process, adding new functionality to the appliance design.

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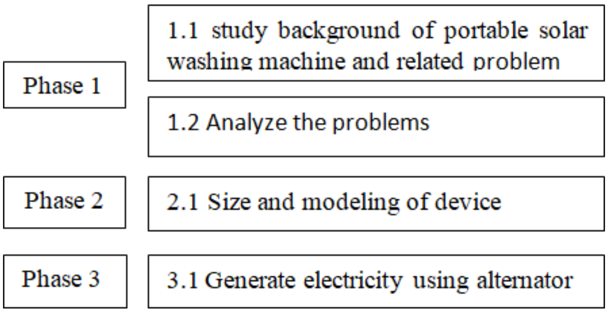

Fig.1.Flow Chart of Methodology

III. DESIGN CONFIGURATION

Fig.2. presents the conceptual layout of the solar- powered portable washing machine featuring integrated electricity generation capability. The system architecture incorporates four fundamental elements: photovoltaic panels for solar energy harvesting, energy storage batteries, a DC-powered drive motor, and an alternator unit for auxiliary power production. The complete mechanical design has been developed using AutoCAD software, with all dimensional parameters expressed in imperial units (inches) for manufacturing precision.

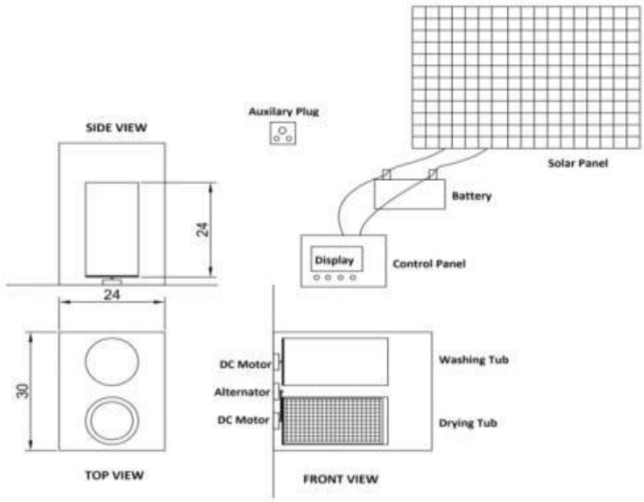

Fig.2.Disigning model of Compact Solar-Powered Laundry System with Electricity Generation Capability

IV. PHOTOVOLTAIC CELL CHARACTERISTICS

A. Modeling of solar cell

Photovoltaic cell equivalent circuit consists of series resister and shunt resister. The series resister is denoted by Rs and shunt resister is denoted by Rsh.

The Photovoltaic cell equivalent circuit diagram is shown in below fig.3.

The value of series resistance is low where value of shunt resistance is very high. Modules are formed by connecting series parallel photovoltaic cell and multiple modules form photovoltaic arrays [9].

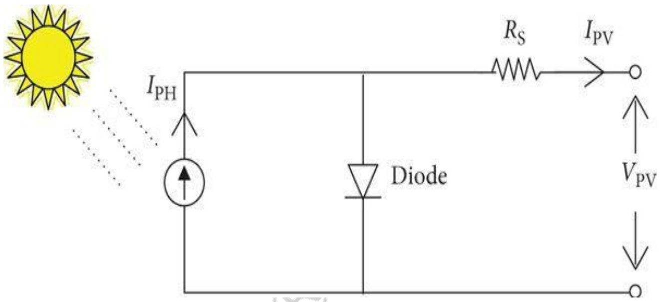

Fig.3. Photovoltaic Cell Equivalent Circuit Diagram

$$I=I_l-I_{rsat}[\exp(q(v+I_{rs})/\alpha K_t)-1]-V+I_{rs}/r_{sh}$$

Where,
I = current flowing through photovoltaic cell;
I_l =current generated by photovoltaic cell when solar gets illuminated
I_{rsat} = reverse saturation current;
I_{rs} = current flowing through series resister
q= constant of coulomb (1.602×10 -19 Celsius);
K= constant of Boltzmann's (1.380649×10 -23 Joules per Kelvin);
t= temperature of cell in degree Celsius;
α= ideality factor of P-N junction diode;
r_s,r_{sh}= series and shunt resister of photovoltaic cell

B. Current and Voltage curve

Current and voltage curve are graphical representation of photovoltaic cell and give outline of relation between current and voltage produced by photovoltaic cell at different temperature and irradiance. The product of output voltage and current produce output power. The graph is obtained every voltage level and every radiation level when multiplication of output voltage and current is done.At the same time voltage move from short circuit to open circuit shown in below fig.3.

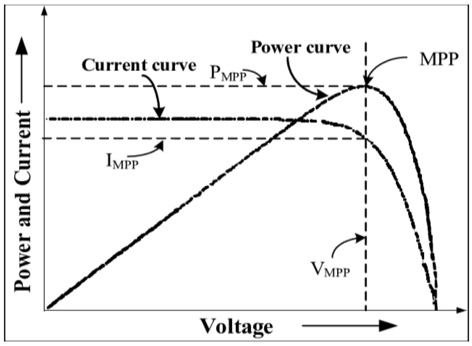

Fig.4. Current and Voltage Curve of Solar Panel

The voltage across the cell is maximum and current of the cell is minimum when load is not connected. When photovoltaic cell is short circuited the voltage across cell is minimum and current reaches its maximum value due to positive and negative leads connected together.

The maximum power point is the point at which photovoltaic cell generates maximum electric power is shown in fig.4. The corresponding value of open circuit voltage is

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nearly 0.8-0.9 volt and short circuit current is nearly 0.85-0.95. The actual value of current and voltage vary with temperature.

V. SIMULATION

A. Simulation Layout and Results

The figure illustrates a PWM-controlled DC motor system, where a PWM reference voltage is input to a Controlled PWM Voltage block to generate a PWM signal. This signal is fed into an H-Bridge, which modulates the power supplied to the DC motor, allowing control of its speed and direction. The motor's output is monitored using a current sensor and a speed measurement block, which respectively output the motor's current consumption and rotational speed (RPM). The system also includes a grounding reference and a function block representing zero input to simulate specific conditions.

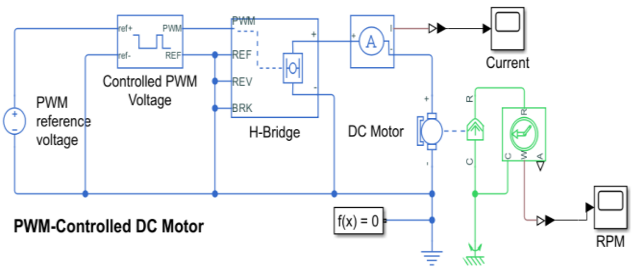

Fig.5. Simulation Model of PMW Controlled DC Motor with No Load

In this PWM-controlled DC motor setup, the starting and full-load currents are kept under control using a smart feedback system. When the motor starts, the PWM voltage is increased gradually—like easing into acceleration—so there's no sudden surge of current. As the motor runs, a current sensor keeps an eye on how much current is flowing. If it gets too high, the system automatically adjusts the PWM signal to keep it in check. The H-Bridge also plays an important role by handling direction changes and braking, helping manage the current when the motor is under heavy load or slowing down. This setup keeps the motor running smoothly and safely, protecting it from damage.

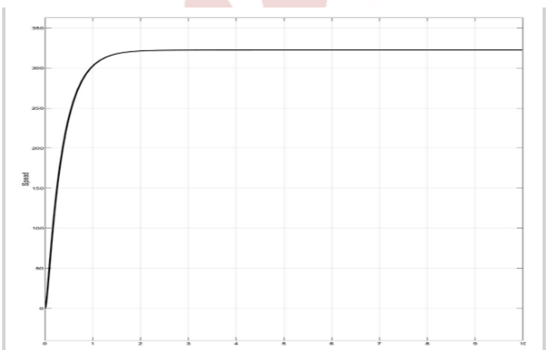

Fig.6. Speed Curves of PMW Controlled DC Motor with No Load

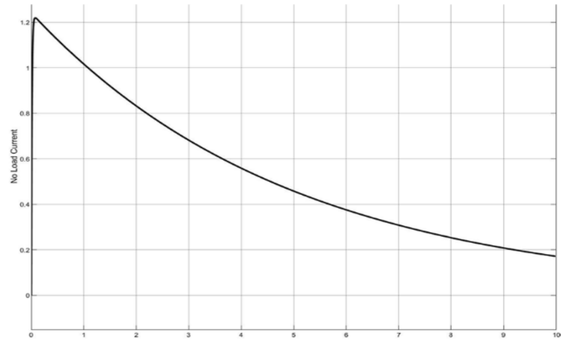

Fig.7.Current Curves of PMW Controlled DC Motor with No Load

The first graph shows the rotational speed (RPM) response of the DC motor over time, where the motor rapidly accelerates and reaches a steady-state speed of approximately 320 RPM within about 2 seconds, indicating a fast and stable startup behavior.

The second graph illustrates the armature current response, which initially spikes due to inrush current when the motor starts, then quickly decays to near zero as the motor reaches its steady-state speed, reflecting the typical current behavior of a DC motor during acceleration. Together, these graphs demonstrate efficient motor performance with quick acceleration and minimal steady-state current

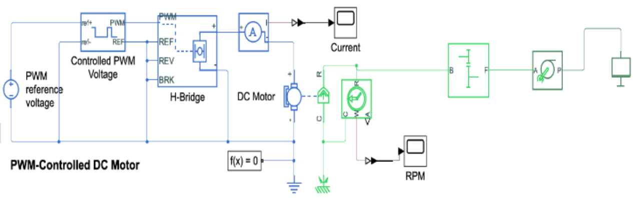

Fig.8. Simulation Model of PMW Controlled DC Motor with Load

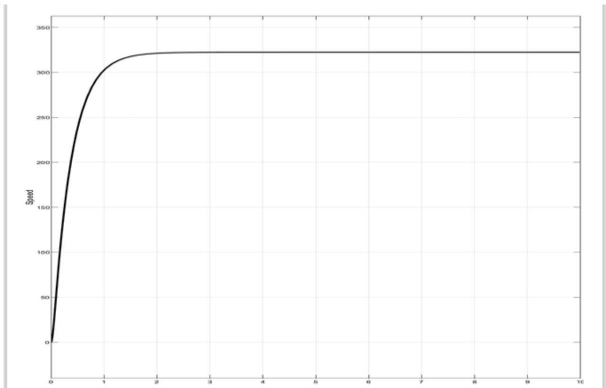

Fig.9. Speed Curves of PMW Controlled Dc Motor with Load

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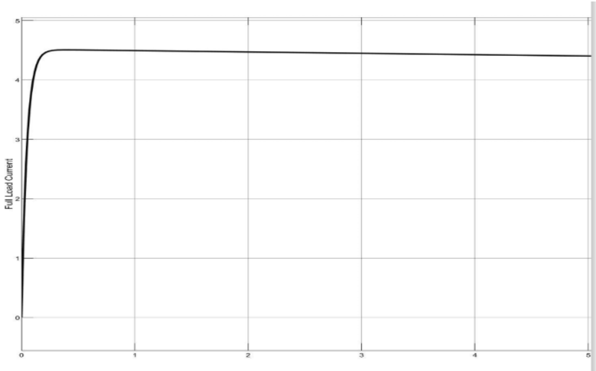

Fig.10.Current and Speed Curves of PMW

The graph illustrates the power output response of a PWM-controlled DC motor system over time. It shows a rapid rise in electrical current output during the initial startup phase i.e 4.7 amp, reaching a steady-state value shortly after around 1 second. The smooth transition and stable plateau indicate that the motor achieves and maintains a constant operating power efficiently, with minimal oscillations or fluctuations, reflecting a well-tuned and stable system performance.

VI. CONNECTION DIAGRAM

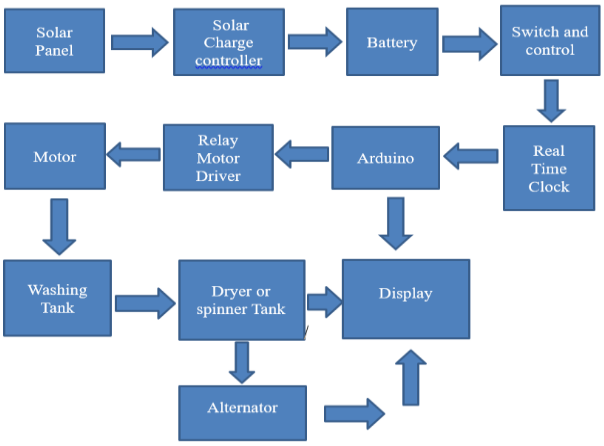

Fig.11.Block dia. of Design of Compact Solar-Powered Laundry System with Electricity Generation Capability

The figure illustrates a solar-powered smart washing machine system. A solar panel charges a battery through a solar charge controller, and the stored energy is managed by a switch and control unit. This unit is linked to a real-time clock, which coordinates timing with an Arduino microcontroller. The Arduino, receiving timing input, controls a motor via a relay motor driver. The motor drives a washing tank and then a dryer or spinner tank. An alternator is connected to the spinner tank, possibly for energy recovery. The system status and process information are shown on a display connected to the Arduino, enabling real-time monitoring and control.

VII. HARDWARE SETUP

Fig.8. demonstrates the hardware design of the proposed portable solar-powered washing machine, which includes an integrated power generation system. The setup features two compartments: one for washing and another for drying. The washing tub operates at 320 RPM, while the drying tub rotates at 280 RPM, with both motor speeds regulated by the microcontroller. Additionally, the system incorporates a solar panel to recharge the battery. When fully charged, the battery delivers 13 volts and 4.5 amperes, generating 60 watts of power.

Fig.12.Hardware Setup of Compact Solar-Powered Laundry System with Electricity Generation Capability

Fig.13.Hardware Setup of Compact Solar-Powered Laundry System with Electricity Generation Capability

VIII. CALCULATIONS

- Charging Time = Battery capacity/charging current (solar)
  Where,
  - Battery capacity =7 Ah, 3.33A=2.10 hours
  - Running time =battery capacity/motor power,
    Where,
    - Battery capacity = 12V*7 Ah=84Ah
    - Motor power = I/P power =12 V*3.45A=41.42 W.
    - Run Time=84 Wh/41.42W =2.02 hours before discharged
    - Regenerative power produces at 50 to 60 watts.

IX. CONCLUSION

This portable solar-powered washing machine is a smart and eco-friendly way to do laundry, especially in places where electricity is limited or unavailable. By using solar energy, it cuts down on the need for traditional power, helping both the environment and your wallet. One standout feature is its built-in alternator, which can generate extra electricity to charge small devices—perfect for rural areas or emergencies. With its compact size, two working modes, and energy-efficient design, it shows how renewable energy can be used in everyday life to make things easier and more sustainable.

Looking ahead, there are some great ideas to make this machine even better. It could be upgraded with automatic water level and soap sensors to make washing simpler and more hands-free. Adding smart features like phone app control through IoT would let users track and manage the machine remotely. MPPT technology could help get the most out of solar power, and switching to brushless DC motors would make it more durable and efficient.

Making the machine lighter and easier to fold would boost portability, and offering larger versions could help entire communities or support people during disasters.

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