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Design and Development of a Solar-Powered Portable Dust Air Blower

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Abstract— *Dust accumulation on electrical, electronic, household, and photovoltaic equipment reduces operational performance and increases the need for regular cleaning. Conventional electric dust blowers are convenient but depend on grid electricity or mains-powered adapters, limiting their usefulness in outdoor and remote applications. This paper presents the design and development of a solar-powered portable dust air blower that combines photovoltaic energy harvesting, rechargeable battery storage, a DC blower motor, power electronics, and Arduino-based electronic control. A working prototype was assembled using a photovoltaic panel, PWM solar charge controller, rechargeable battery pack, DC-DC buck converter, motor driver, centrifugal DC blower, voltage-sensing circuit, Arduino Uno controller, display and a directed air nozzle. Studies reviewed for this work show that forced airflow can remove loosely deposited dust without water and can simultaneously provide a cooling effect in photovoltaic applications, and that solar-powered blower systems are technically feasible for continuous operation. Based on this literature and the assembled hardware, the proposed system is shown to be a practical, low-voltage, portable, and renewable solution for dry, non-contact dust cleaning of electrical, electronic, and photovoltaic surfaces.*

Keywords- *Solar energy, portable air blower, dust cleaning, photovoltaic system, rechargeable battery, DC blower, Arduino, PWM control*

INTRODUCTION

Dust is a common environmental contaminant that affects electrical equipment, electronic circuits, photovoltaic modules, household appliances, machinery, and other exposed surfaces. Accumulated dust can obstruct airflow, increase thermal resistance, reduce heat dissipation, and affect the performance and reliability of equipment. In photovoltaic systems, dust deposited on the module surface reduces the amount of solar radiation reaching the cells and can substantially decrease power generation. Recent reviews have therefore identified soiling as an important operational issue for photovoltaic systems [1]–[5].

Cleaning methods include manual cleaning, water-based cleaning, brushing, wiping, vibration, robotic cleaning, electrostatic techniques, coatings, and forced-air cleaning. Among these approaches, air blowing is attractive because it can remove loose particles without direct contact with the surface and without consuming water. Forced-air cleaning has been investigated particularly for photovoltaic modules in arid environments, where dust accumulation and water scarcity are important concerns [2], [6]–[9].

Solar energy provides an opportunity to operate a blower independently of conventional electricity. A photovoltaic panel can convert solar radiation into electrical energy, while a rechargeable battery can store energy for operation when sunlight is unavailable. Previous work on solar-powered air blowers has demonstrated that photovoltaic-

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powered blower systems can replace manually operated or conventional energy-dependent blower systems [10]. A solar-powered blower designed for furnace applications, for example, demonstrated substantially shorter melting times than a manually operated blower.

The objective of this paper is to design, assemble, and evaluate a solar-powered portable dust air blower. The work covers solar energy generation, battery storage, DC blower technology, motor control, power conversion, electronic monitoring, portability, and dust-cleaning applications, and reports on a physical prototype built from the proposed architecture.

LITERATURE REVIEW

Review Methodology

A literature review was conducted using publications available through major scientific databases and publisher platforms, including ScienceDirect, SpringerLink, IEEE Xplore, MDPI, and Wiley Online Library. The search focused primarily on literature published from 2016 to 2026, with greater emphasis on studies from 2021 to 2026. Search terms included solar-powered air blower, portable solar blower, dust air blower, photovoltaic dust cleaning, forced-air solar-panel cleaning, solar-powered DC motor, portable dust-cleaning system, and battery-powered blower. Studies were included when they investigated solar-powered blower systems, forced-air cleaning, photovoltaic dust removal, renewable-powered motor systems, or portable cleaning systems.

B. Effect of Dust on Equipment Performance

Dust contains particles originating from soil, sand, atmospheric pollution, industrial activities, and biological materials. Particle size, shape, humidity, wind velocity, and surface properties influence dust deposition [1], [3], [4]. On electronic equipment, dust accumulates on circuit boards and ventilation openings and can restrict cooling airflow, while on photovoltaic modules it reduces optical transmission and increases thermal and electrical losses. A recent review reported that dust buildup can cause efficiency reductions ranging from moderate losses under mild conditions to substantially higher losses in arid environments [3], and module orientation and tilt angle further influence the severity of the effect [4].

C. Review of Dust-Cleaning Technologies

Manual cleaning is simple but labour-intensive and inconvenient for rooftop or enclosed installations. Water-based cleaning is effective but consumes a scarce resource and is unsuitable for many electrical applications. Mechanical systems (brushes, wipers, rollers) provide effective cleaning but introduce moving parts and wear [2], [5]. Vibration-based cleaning can detach dust without water; an Arduino-based solar-panel cleaner combining an air blower with vibration reported approximately 30% higher daily energy output than the dust-accumulated condition [11]. Electrostatic and electrodynamic techniques avoid contact but add electronic complexity and humidity sensitivity [12]. Forced-air cleaning, using a fan, blower, or compressed-air system, is dry and non-contact; Li et al. investigated compressed airflow for simultaneous cleaning and cooling of photovoltaic modules and modelled dust adhesion, airflow release, and temperature variation [6].

D. Solar-Powered Air Blower Studies

Muhammad et al. developed a small solar-powered air blower for a charcoal-fired furnace using photovoltaic power and battery storage, reducing metal-melting time relative to manual operation [10]. Saravanan et al. investigated a solar-powered air blower for raisin drying, demonstrating solar-powered airflow for agricultural processing [13]. A 2025 study using an ejector blower and flexible brush reported a 26.23% average increase in power output after cleaning a 60 W photovoltaic panel [14], and a recent solar-powered IoT cleaning system combined a centrifugal blower, dust sensor, RTC, automated wiper, and cloud monitoring [15]. These studies confirm the feasibility of solar-powered blowers but focus mainly on industrial, agricultural, or large-scale PV-cleaning applications rather than a compact, general-purpose, portable device — the gap this work addresses.

Table 1- Summary Of Relevant Literature

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Study	Application	Major Finding
Kazem et al. [1]	PV dust & cleaning	Reviewed dust characteristics and cleaning methods
Najmi & Rachid [2]	PV cleaning	Compared cleaning technologies
Hasan et al. [3]	PV performance	Identified environmental factors affecting PV performance
Chanchangi et al. [4]	PV soiling	Reviewed effects of dust on PV performance
Li et al. [6]	Compressed airflow	Demonstrated combined cleaning and cooling
Habib et al. [7]	Automatic PV cleaning	Used Arduino, air blower and wiper
Gaurav et al. [11]	PV cleaning	Combined air blower and vibration
Muhammad et al. [10]	Solar-powered blower	Demonstrated solar-powered blower operation
Saravanan et al. [13]	Solar air blower	Applied solar airflow to raisin drying
Yusoff Zaki & Abdullah [15]	Smart PV cleaning	Combined blower, wiper, dust sensing, RTC, IoT

Table 2-Comparison of Dust -Cleaning Methods

METHODS

Method	Water	Portability	Energy	Contact	Main Limitation
Manual cleaning	Usually	Medium	Low	Yes	Labour intensive
Water cleaning	High	Low	Medium	Usually	Water consumption
Brush/wiper	Low	Medium	Medium	Yes	Mechanical wear
Vibration	None	Medium	Low-med	Limited	Less effective on adhered dust
Electrostatic	None	Low-med	Medium	No	High complexity
Compressed air	None	Low	High	No	Compressor requirement
DC blower	None	High	Low-med	No	Battery/runtime limitation
Solar-powered portable blower	None	High	Renewable	No	Solar availability & battery capacity

METHODOLOGY

A. Proposed System Architecture

The proposed device uses a photovoltaic panel to collect solar energy and a rechargeable battery to make that energy available on demand. The stored DC energy is routed through a buck converter and motor-driver stage before reaching the blower, while a voltage-sensing circuit and Arduino Uno controller form the low-power monitoring and control section. The basic energy flow is:

Solar Panel → Charge Controller → Battery → DC-DC Converter → Motor Driver → DC Blower → Nozzle

A parallel monitoring path (Battery → Voltage Sensor → Arduino → Display) and control path (Arduino → Motor Driver → Blower Speed Control) keep high-current power delivery separate from low-power sensing and control, as shown in Fig. 1.

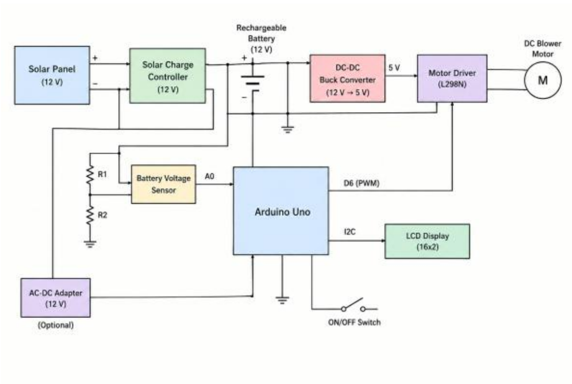

Fig.1.Circuit and control architecture of the proposed system (solar panel, charge controller, battery, buck converter, motor driver, blower, voltage sensor, Arduino Uno and LCD display

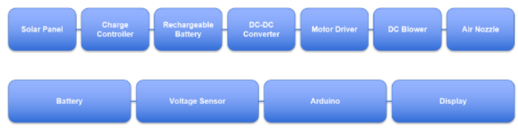

Fig. 2. Functional block diagram of the main power path and monitoring/control path.

B. Component Design

The solar panel (12 V rated) is the primary renewable source and is sized against blower power, battery voltage, charging losses and expected solar availability. The PWM solar charge

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controller regulates the charging interface between the panel and the 12 V rechargeable battery pack, which stores energy so the blower can run when sunlight is weak or unavailable. A DC-DC buck converter steps the 12 V rail down to a regulated 5 V supply for the Arduino, sensor and display electronics. An L298N motor-driver module switches and regulates power to the DC blower motor, with pulse-width modulation used to vary blower speed. A resistor-divider voltage sensor (R1/R2) scales the battery voltage into the Arduino's ADC input range (A0), and the Arduino Uno performs monitoring, PWM speed control (digital pin D6) and drives a 16×2 I2C LCD to display battery voltage and operating status. An ON/OFF switch provides manual control, and a fuse/protection stage limits fault current. Table I summarises the function of each component.

Table-3 Proposed components And Functions

Sr. No.	Component	Function
1	Solar panel (12 V)	Generates renewable electrical energy
2	Solar charge controller	Regulates battery charging
3	Rechargeable battery (12 V)	Stores energy
4	DC-DC buck converter (12→5 V)	Provides regulated low-voltage supply
5	Motor driver (L298N)	Controls blower motor power/speed
6	DC blower motor	Produces directed airflow
7	Battery voltage sensor	Measures battery voltage
8	Arduino Uno	Monitoring, PWM control, display driving
9	LCD display (16×2, I2C)	Displays operating information

C. Design Relationships

The blower is the largest electrical load, so the solar panel and battery are sized around blower voltage, current, operating duration and duty cycle. For a blower operating at voltage V and current I, the electrical power is:

$$P = V \times I \quad (1)$$

and the approximate battery energy required for an

operating time t is:

$$Eb = P \times t \quad (2)$$

Practical sizing additionally accounts for converter losses, motor-driver losses, battery efficiency, charging

Practical sizing additionally accounts for converter losses, motor-driver losses, battery efficiency, charging losses and allowable depth of discharge.

D. Assembly and Working Principle

Assembly began with the power-management section (solar panel → charge controller → battery) since it fixes the available voltage and current for the rest of the circuit. The regulated 5 V output was then routed to the Arduino and sensor electronics, while the 12 V blower supply was routed through the L298N driver stage. During operation: solar energy is collected during daylight and the charge controller manages battery charging; on power-on the Arduino reads the battery voltage through the sensor and checks whether it is within the permitted range; if acceptable, the motor driver enables the DC blower; the blower produces a high-speed air stream that the nozzle directs toward the dusty surface, with speed adjustable through PWM on pin D6; the LCD continuously displays battery voltage and blower status; and if the battery falls to the low-voltage protection threshold the Arduino stops the blower to protect the battery.

Fig. 3. Assembled prototype of the solar-powered portable dust air blower, showing the solar panel, charge controller, battery pack, Arduino control board and the blower/nozzle unit

RESULT

A. Prototype Realisation

The proposed architecture was assembled into a working hardware prototype (Fig. 3), comprising a photovoltaic panel, PWM charge controller, 12 V

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rechargeable battery pack, DC-DC buck converter, L298N motor driver, centrifugal DC blower with a conical nozzle, resistor-divider voltage sensor, and an Arduino Uno-based control board. On power-up, the Arduino successfully read the battery voltage, enabled the motor driver, and drove the blower, confirming correct operation of the power path and the monitoring/control path described in Section.

B. Literature-Based Performance Observations

The reviewed literature supports forced airflow as a useful waterless technique for removing loose dust, and confirms that solar-powered blower systems are technically feasible for practical operation. Table II summarises reported literature outcomes; these values were obtained by other authors under their own test conditions and are cited here only as a performance benchmark, not as measurements of this prototype.

Table-4. Literature-Based Performance Observations

Observation	Reported value / conclusion	Source
Air blower + vibration for PV cleaning	~30% higher daily energy output vs. dust-accumulated condition	[11]
Waterless PV cleaning (ejector blower + brush)	~26.23% average output increase after cleaning a 60 W panel	[14]
Solar-powered furnace blower	Demonstrated practical solar-powered air movement	[10]
Solar-powered raisin-dryer blower	Demonstrated solar-powered airflow for agricultural drying	[13]

C. Design Evaluation

From a system-design perspective, the assembled architecture meets the requirements identified in Section I: it is renewable-energy based, rechargeable, low-voltage, portable and capable of dry, non-contact cleaning. The battery improves usability because the blower can run after charging rather than only when sunlight is directly available, and separating the power path from the Arduino monitoring/control path (Fig. 1, Fig. 2) allowed each subsystem to be verified independently before full integration.

D. Recommended Experimental Measurements

The next evaluation stage should quantify:

- Solar-panel voltage and current during charging
- Battery voltage before, during and after blower operation
- Blower current and electrical power at different PWM duty cycles
- Airflow rate, outlet air velocity and static pressure
- Continuous operating time and solar charging time
- Dust-removal effectiveness on representative surfaces
- Temperature rise of the motor, driver, converter and battery

E. Limitations

A complete numerical dataset (airflow, static pressure, runtime, charging time and dust-removal efficiency) has not yet been measured on the assembled unit, so such figures are not reported for the proposed device. Overall operating time also remains linked to to battery capacity and blower power — a higher-power blower cleans faster but reduces runtime — a trade-off to be quantified experimentally.

CONCLUSION

This paper presented the design, literature grounding, and hardware realisation of a solar-powered portable dust air blower for dry, non-contact cleaning of electrical, electronic, household, outdoor and photovoltaic equipment. The reviewed literature confirms that dust accumulation degrades equipment and photovoltaic performance, that forced-air cleaning is an effective waterless alternative, and that solar-powered blower systems are technically feasible. Building on these findings, a working prototype combining a photovoltaic panel, charge controller, rechargeable battery, DC-DC converter, motor driver, DC blower, voltage sensor, Arduino Uno controller, LCD display and nozzle was assembled and verified to power on,

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monitor battery voltage and drive the blower as designed.

The system offers a renewable, waterless, portable and controllable cleaning solution, and provides a realistic base for further prototype development. Future experimental work should quantify blower power, airflow velocity, nozzle geometry, battery capacity, solar charging time, operating duration and dust-removal efficiency, and can extend the platform with automatic dust sensing and IoT monitoring.

Future Scope

- Integration of a dust sensor for automatic cleaning
- Automatic blower-speed adjustment using PWM and sensor feedback
- IoT-based monitoring of battery and blower status
- High-efficiency brushless DC blower
- Maximum power point tracking for improved solar utilisation
- Lightweight lithium-ion battery with dedicated BMS
- Interchangeable nozzles and CFD-based airflow optimisation
- Controlled dust-removal experiments on electronic and PV surfaces

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