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

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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 review examines the design and development of a solar-powered portable dust air blower that combines photovoltaic energy harvesting,rechargeable battery storage,adcblower motor, power electronics, and electronic control. Recent literature on photovoltaic soiling,forced-air cleaning,solar-powered blowers, automated cleaning systems, and renewable-powered motor applications was reviewed to identify suitable design approaches and research gaps. Studies demonstrate that forced airflow can remove loosely deposited dust without water and can simultaneously provide a cooling effect in photovoltaic applications.Solar-powered blower research has also demonstrated the feasibility of using photovoltaic generation and battery storage for continuous blower operation. However, most existing studies focus on industrial furnaces, food drying, or solar-panel cleaning rather than a compact general-purpose portable dust blower for electrical and electronic equipment. Based on the reviewed literature, a portable system can be developed using a solar panel, charge controller, rechargeable battery, dc blower, motor driver, dc-dc converter, voltage sensing circuit, switch, display, and protective enclosure. Arduino-based control can provide speed regulation,battery monitoring,and future automation. The review identifies low-voltage operation, portability, energy efficiency, battery autonomy, airflow performance, thermal management, and protection of sensitive electronic components as important design considerations. The proposed concept offers a practical approach for reducing dependence on conventional electricit while supporting sustainable and portable cleaning applications.

Keywords—

Solar energy, portable air blower, dust cleaning, photovoltaic system, rechargeable battery, dc blower, Arduino

1, 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 isunavailable. Previous work on solar-powered air blowers has demonstrated that photovoltaic-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 review is to investigate the design considerations and technological approaches required for developing a solar-powered portable dust air blower. The review focuses on solar energy generation, battery storage, dc blower technology, motor control, power conversion, electronic monitoring, portability, and dust-cleaning applications.

A. Review Methodology

A literature review was conducted using publications available through major scientific databases and publisher platforms, including Science Direct ,SpringerLink,Pub Med where relevant, IEEE Xplore, MDPI, Wiley Online Library, Oxford Academic, and other scholarly sources. The search focused primarily on English-language literature published from 2016 to 2026, with greater emphasis on recent studies from 2021 to 2026.

The principal search terms included:

- “solar powered air blower”
- “portable solar blower”
- “dust air blower”
- “solar powered cleaning”
- “photovoltaic dust cleaning”
- “airblower photovoltaic cleaning”
- “forced air solar panel cleaning”
- “solar powered dc motor”
- “portable dust cleaning system”
- “battery powered blower”
- “solar energy powered blower”

Studies were included when they investigated solar-powered blower systems, forced-air cleaning, photovoltaic dust removal, renewable-powered motor systems, portable cleaning systems, or associated power-management technologies. Articles that were unrelated to air movement,dust removal,solar energy, or portable cleaning applications were excluded.

I. EFFECT OF DUST ON EQUIPMENT PERFORMANCE

Dust contains particles originating from soil, sand, atmospheric pollution, industrial activities, biological materials,and other environmental sources. Particle size, shape, composition, humidity, wind velocity,surface properties,and installation conditions influence dust deposition [1], [3], [4].

For electronic equipment, dust can accumulate on circuit boards and ventilation openings.

The resulting layer may restrict cooling airflow and contribute to temperature rise. In photovoltaic systems, dust reduces optical transmission and increases the thermal and electrical losses associated with the module. Reviews,have reported considerable performance losses depending on the environment, dust characteristics, exposure period, and cleaning interval [1], [3], [4].

The impact is particularly significant in dry and dusty regions. A recent review reported that dust buildup can cause efficiency reductions ranging from moderate losses under mild conditions to substantially higher losses inarid environments[3].Another review found that dust accumulation, environmental conditions, module orientation, and tilt angle collectively influence photovoltaic performance [4].

Therefore, a practical dust-removal system should provide adequate airflow while minimizing energy consumption, surface damage, and operating complexity.

II. REVIEW OF DUST-CLEANING TECHNOLOGIES

Several dust-cleaning methods have been reported in the literature.

A. Manual Cleaning

Manual cleaning is simple and requires relatively low initial investment.However,itislabour-intensive and may require water, cleaning materials, ladders, or access to difficult locations. Frequent manual cleaning is also inconvenient for electronic equipment and rooftop photovoltaic installations.

B. Water-Based Cleaning

Water can effectively remove dust and adhered contaminants.However,water consumptionis a significant disadvantage in water-scarce regions. Water can also cause problems when cleaning electrical and electronic equipment.

C. Mechanical Cleaning

Mechanical systems use brushes, wipers, rollers, or robotic mechanisms. They can provide effective cleaning but introduce moving parts, mechanical wear, additional weight, and maintenance requirements. Recent reviews classify mechanical systems among the important active cleaning approaches for photovoltaic installations [2], [5].

D. Vibration-Based Cleaning

Vibration can detach dust from surfaces without requiring water. Some systems combine vibration with air blowing to improve dust removal.A reported Arduino-based solar-pane cleaner used an air blower together with vibration and obtained approximately 30% higher daily energy output compared with the dust-accumulated condition [11].

E. Electrostatic and Electrodynamic Cleaning

Electrodynamic screens and electrostatic techniques remove particles using electrical forces.

These methods can reduce direct mechanical contact, but their electronic complexity, high-voltage requirements, humidity sensitivity, and cost can limit practical use. Experimental studies have also investigated airflow-assisted electro dynamic cleaning to remove strongly adhered particles [12].

F. Forced-Air Cleaning

Forced-air cleaning uses a fan, blower, or compressed-air system to produce an airflow capable of dislodging loose particles. It has the important advantage of being a dry and non-contact cleaning technique.

Li et al. investigated compressed airflow for simultaneous cleaning and cooling of photovoltaic modules. Their study developed models for dust adhesion, airflow release, and temperature variation and experimentally evaluated he influence of airflow parameters on cleaning and power generation [6].

The literature therefore supports air blowing as an important technique for applications where water use and physical contact should be minimized.

III. SOLAR-POWERED AIR BLOWER SYSTEMS

The use of solar energy too perate air-moving equipment has been demonstrated in several applications.

Muhammad et al. developed a small solar-powered air blower for a charcoal-fired furnace.Their system used photovoltaic power and battery storage to operate a blower. Compared with manual operation, the solar-powered blower reduced the time required to melt metals, demonstrating the practical feasibility of solar-powered air movement [10].

Saravananetal.investigated a solar-powered air blower for raisin drying. The work demonstrated the use of solar energy too perateanair-movingsystem for agricultural processing [13].

These studies demonstrate that solar-powered blower systems can be used in different applications. However,there viewed applications generally focus on industrial, agricultural, or thermal processes. There is comparatively less emphasis on compact, portable, low-voltage solar-powered dust blowers designed specifically for general cleaning of electrical and electronic equipment.

This gap provides the motivation for developing the proposed portable system.

PROPOSEDSOLAR-POWEREDPORTABLE DUST AIR BLOWER

The proposed system isintended to providea compact source of high-speed air for removing loose dust from electrical, electronic, household, and outdoor equipment.

The basic energy flow is:

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

An Arduino controller can monitor the battery voltage and control the blower speed.

A. Solar Panel

The solar panel is the primary renewable energy source. It converts sunlight into dc electrical power. The panel rating should be selected according to the blower power requirement, battery voltage, charging losses, and expected solar availability.

B. Solar Charge Controller

The charge controller regulates the energy transferred from the solar panel to the rechargeable battery. It prevents inappropriate charging conditions and provides a controlled interface between the photovoltaic source and battery.

C. Rechargeable Battery

The battery stores energy generated during sunlight and allows the blower to operate when solar irradiation is insufficient. Battery capacity should be selected based on blower power and desired operating duration.

The approximate energy requirement is:

$$E=P\times t$$

where (E) is energy, (P) is blower power, and (t) is operating time.

D. DC Blower Motor

The dc blower is the main actuator. A centrifugal blower is particularly suitable when relatively high air flow and static pressure are required in a compact package. Centrifugal blowers use an impeller to accelerate air and direct through an outlet [10].

E. Motor Driver

A motor-driver circuit controls the power supplied to the blower motor.Pulse-width modulation can be used to regulate motor speed.

F. DC-DC Buck Converter

The dc-dc converter provides the required regulated voltage to electronic components when the battery voltage ishigher than the controller or display operating voltage.

G. Battery Voltage Sensor

A voltage-sensing circuit continuously monitors battery voltage. The controller can use this information to indicate battery status and prevent excessive discharge.

H. Arduino Controller

An Arduino microcontroller can provide intelligent control of the system. It may be programmed to:

1. Monitor battery voltage.
2. Control blower speed.
3. Display operating status.
4. Detect low-battery conditions.
5. Provide automatic shutdown.
6. Support future sensor integration.

I.Display

An LED or LCD display canindicate battery voltage, operating mode, and blower status.

J.Portable Enclosure and Nozzle

A lightweight enclosure protects the electronics and battery. A properly designed nozzle concentrates airflow and improves dust-removal performance.

I. COMPONENTSREQUIRED

TABLE I

PROPOSED COMPONENTS FOR THE PORTABLE SYSTEM

Sr. No.	Component	Function
1	Solar panel	Generates electrical energy
2	Solar charge controller	Controls battery charging
3	Rechargeable battery	Stores energy
4	DC blower motor	Produces airf low

5	Motor driver module	Controls blower motor
6	DC-DC buck converter	Provides regulated voltage
7	Battery voltage sensor	Measures battery voltage
8	Arduino controller	Performs monitoring and control
9	AC-to-DC adapter	Optional backup charging source
10	ON/OFF switch	Manual power control
11	LED/LCD display	Displays operating information
12	Portable enclosure	Protects and houses components
13	Air blower nozzle	Directs air flow
14	Wires/connectors	Electrical interconnection
15	Fuse/protection circuit	Provideselectrical protection

IV. DESIGN CONSIDERATIONS

A. Power Requirement

The blower is expected to be the largest electrical load. Therefore, the solar panel and battery should be sized primarily according to the blower's voltage, current, operating duration, and duty cycle. For a blower operating at voltage (V) and current (I):

$$P=VI$$

The battery energy required for operating time (t) is approximately:

$$E_b=Pt$$

Practical design should additionally consider converter losses, motor-driver losses, battery efficiency, and allowable depth of discharge.

B. Air flowand Pressure

A useful dust blower should not be evaluated only by motor power.Air flowrate,outlet velocity,and static pressure are also important.

A narrow nozzle can increase the local air velocity, whereas a larger outlet can provide greater volumetric airflow. Therefore, nozzle dimensions should be selected according to the intended cleaning application.

C. Portability

The proposed system should have:

- Compact dimensions.
- Low overall weight.
- Ergonomic handle.
- Protected electrical connections.
- Rechargeable battery.
- Detachable or replaceable nozzle.
- Safelow-voltage operation.

D.Battery Backup

Battery storage is important because solar irradiation is not constant. The battery allows the blower to operate during cloudy conditions and indoors after charging.

E.Thermal Management

The blower motor,motor driver,battery,and dc-dc converter can produce heat. Adequate ventilation and thermal protection should there fore be provided.

F.Electronic Equipment Safety

High-pressure air can potentially damage delicate components or dislodge small parts. Therefore, the proposed blower should preferably provide adjustable airflow instead of only maximum-speed operation.

VII. COMPARISON OF CLEANING APPROACHES

TABLE II

Method	Water	Portability	Energy Requirement	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–medium	Limited	Less effective for strongly adhered dust
Electrostatic	None	Low–medium	Medium	No	High complexity
Compressed air	None	Low	High	No	Compressor requirement
DC blower	None	High	Low–medium	No	Battery/run Time limitation
Solar-powered portable blower	None	High	Renewable	No	Solar availability and battery capacity

IX. REVIEW OF REPORTED STUDIES

TABLE III

SUMMRY OF RELEVANT LITERATURE

Study	Application	Majorfinding
Kazem et al. [1]	PV dust and cleaning	Reviewed dust characteristics and cleaning methods
Najmi and Rachid [2]	PV cleaning	Compared different cleaning technologies
Hasanetal.[3]	PV performance	Identified environmental factors affecting PVperformance
Chanchangietal.[4]	PV soiling	Reviewed effects of duston PV performance
Lietal. [6]	Compressed airflow	Demonstrated combined cleaning and cooling
Habibetal. [7]	Automatic PV cleaning	Used Arduino,airblower,and wiper
Gauravetal. [11]	PVcleaning	Combined air blower and vibration
Electrostatic cleaning study[12]	PV cleaning	Investigated airflow-assisted electrodynamic dust removal
Muhammadetal.[10]	Solar-poweredblower	Demonstrated solar-powered blower operation
Saravanan et al.[13]	Solar air blower	Applied solar-powered airflow to raisin drying
Waterless cleaning study [14]	PVcleaning	Used ejector blower and brush

Recent work further demonstrates that waterless systems can combine air blowers with mechanical cleaning. A 2025 study using an ejector blower and flexible brush reported a 26.23% average increase in power output after cleaning a 60 W PV panel [14].

Similarly, a recent solar-powered IoT cleaning system combined a centrifugal air blower, solar panel, dust sensor, RTC, automated wiper, and Blynk monitoring,demonstrating the direction toward self-sustaining and intelligent cleaning systems [15].

VIII. ADVANTAGESOFTHEPROPOSEDSYSTEM

The proposed solar-powered portable dust air blower offers several advantages.

8. Renewable Energy Operation

Solar energy reduces dependence on grid electricity.

9. Portable Operation

The rechargeable battery and compact enclosure allow the device to be used at different locations.

10. Waterless Cleaning

Air cleaning does not require water, making the system suitable for electrical and electronic equipment.

11. Battery Backup

Stored solar energy permits operation when sunlight is unavailable.

12. Low-Voltage Operation

The use of dc power improves electrical safety compared with direct mains-powered operation.

13. Intelligent Control

Arduino-based control can support battery monitoring, speed control, display, and automatic protection.

14. Low Maintenance
The proposed design contains relatively few mechanical components

15. Future Expandability
The system can later incorporate dust sensors, temperature sensors, wireless monitoring, automatic

XI. LIMITATIONS AND RESEARCH GAPS

Although solar-powered air-blower technology has been demonstrated, several research gaps remain.First, many published solar-powered blower systems have been designed for specialized applications such as furnaces and agricultural drying rather than portable general-purpose cleaning [10], [13].

Second, photovoltaic dust-cleaning research commonly focuses on large solar installations. A portable blower intended for electronics requires different design priorities, including low weight, controlled airflow,battery autonomy, user safety, and compact packaging.

Third, blower performance should be evaluated using standardized measurements such as airflow rate, air velocity, static pressure, electrical power consumption,operating time,and dust-removal effectiveness.

Fourth, the relationship between blower power consumption and cleaning benefit requires further optimization. A high-power blower may remove dust effectively but reduce battery operating time.

Finally, future systems should investigate intelligent control in which airflow is automatically adjusted according to dust concentration,battery state, and cleaning requirements

XII.PROPOSEDSYSTEMARCHITECTURE

The proposed architecture can be represented as:

Solar Panel

↓

Solar Charge Controller

↓

Rechargeable Battery

↓

DC-D CConverter

↓

Motor Driver

↓

DC Blower

↓

Air Nozzle→Dust Removal

In parallel:

Battery→Voltage Sensor→Arduino→Display and

Arduino → Motor Driver → Blower Speed Control This arrangement separates the high-power blower path from the low-power monitoring and control path

XIII.FUTURESCOPE

Future research can improve the proposed system through the following developments:

1. Integration of a dust sensor for automatic cleaning.
2. Automatic blower-speed adjustment using PWM.
3. IoT-based monitoring of battery and blower status.

4. Use of ahigh-efficiency brushless dc blower.
5. Maximum power point tracking for improved solar utilization.
6. Light weight lithium-ion battery integration.
7. Interchangeable nozzles for different cleaning applications.
8. Airflow optimization using computational fluid dynamics.
9. Development of a smart low-battery protection system.
10. Experimental comparison of different blower geometries.
11. Evaluation of dust-removal efficiency for electronic equipment.
12. Integration of solar charging with USB or other auxiliary outputs.
13. Development of a foldable solar panel for improved portability.
14. Development of an automatic cleaning mode using dust concentration feedback

CONCLUSION

This review examined the design and development of a solar-powered portable dust air blower by integrating research on solar energy,blower technology, forced-air cleaning, photovoltaic dust removal, battery storage, and electronic control. The literature indicates that dust accumulation can significantly affect equipment and photovoltaic performance and that forced-air cleaning provides an attractive waterless alternative for removing loose particles.

Previous studies have established the feasibility of solar-powered blowers in industrial and agricultural applications, while recent research has demonstrated the effectiveness of air blowers in automated photovoltaic cleaning systems[10],[13]–

[15].

However, a clear opportunity remains for a compact, low-voltage, rechargeable, and portable blower specifically designed for dust cleaning of electrical and electronic equipment. The proposed architecture combines a solar panel,charge controller, rechargeable battery, dc blower, motor driver, dc-dc converter,voltage sensor,Arduino controller,display, and nozzle. Such a system can provide renewable, waterless, portable, and controllable dust cleaning.

Future experimental work should focus on optimizing blower power, airflow velocity, nozzle geometry,battery capacity, solar charging time,operating duration, and dust-removal efficiency. The integration of automatic sensing and IoT monitoring can further transform the proposed device into an intelligent and sustainable cleaning system.

CONFLICTOFINTEREST

The authors declare that there is no conflict to finterest associated with this review article.

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AUTHORCONTRIBUTIONS

Dr. Prosanjeet Sarkar: Academic guidance, supervision, technical review, critical revision, and approval of the manuscript.

DivyaKale: Conceptionanddesign,literaturesearch, acquisition of data, analysis and interpretation of literature,draftingofthemanuscript,criticalrevision, and final approval.

Pratiksha Sute: Literature analysis, critical revision, and final approval.

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DECLARATIONOFUSEOFAIINSCIENTIFIC WRITING

Nothing to declare.

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