

Design And Fabrication of Multi- Sources Renewable Power Generation System

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Abstract— The Hybrid Power Generation System Using Solar, Wind and Piezoelectric Energy Sources is designed to provide a reliable and sustainable electrical power supply by combining three renewable energy harvesting techniques. The system uses a 12 V, 60 W solar panel as the primary energy source, supported by a 12 V, 10 W wind generator and a 12 V, 10 W piezoelectric generator integrated with a footstep power generation mechanism. The electrical energy obtained from these sources is regulated through a hybrid charging arrangement and DC boost converter before being stored in a 12 V, 5 Ah rechargeable battery. A microcontroller continuously monitors source voltage, battery condition, and load requirements using voltage sensors. An LCD display provides real-time information regarding system operation and energy status. The stored energy can supply 12 V DC loads directly, while a DC-to-AC inverter converts the battery output into 220 V AC for suitable AC loads. The proposed system improves renewable energy utilization, reduces dependence on conventional electricity, and demonstrates an integrated approach for decentralized and sustainable power generation.

Keywords—Solar Energy, Wind Energy, Piezoelectric Energy, Hybrid Power Generation, Energy Storage.

I. INTRODUCTION

The increasing demand for electrical energy, depletion of conventional fossil-fuel resources, and growing environmental concerns have created a strong need for clean, renewable, and sustainable power generation technologies. Conventional electricity generation based on coal, petroleum, and natural gas contributes significantly to greenhouse-gas emissions and environmental pollution. Renewable energy sources such as solar and wind energy provide cleaner alternatives; however, their power output is strongly dependent on environmental conditions. Solar panels generate electricity primarily during daylight hours, whereas wind generators require suitable wind speed for effective operation. Therefore, combining multiple renewable sources can improve the reliability and availability of electrical power [1].

A hybrid renewable energy system integrates two or more energy sources to overcome the limitations of individual generation technologies. In the proposed system, solar energy,

wind energy, and piezoelectric energy are combined to develop a compact and versatile power generation platform. The solar photovoltaic panel acts as the major energy source because solar energy is widely available and can be directly converted into electrical energy. A 12 V, 60 W solar panel is considered for the proposed prototype. During periods of adequate wind availability, a 12 V, 10 W wind generator supplements the solar output and contributes additional electrical energy to the common energy storage system [2].

The third energy source is based on piezoelectric energy harvesting, which converts mechanical stress or deformation into electrical energy. In the proposed system, piezoelectric generators are incorporated into a footstep mechanism. When a person steps on the platform, mechanical force is applied to the piezoelectric elements, producing electrical energy. Although the energy generated from an individual footstep is relatively small, repeated footsteps in locations such as railway stations, bus terminals, shopping areas, educational institutions, and public walkways can provide useful supplementary energy. A 12 V, 10 W piezoelectric generation arrangement is considered for the prototype concept [3][4].

Since the three sources produce variable electrical outputs, appropriate power-conditioning and energy management arrangements are required. The generated electrical energy is directed through a hybrid charging arrangement and DC boost converter to obtain a suitable regulated voltage for battery storage. A 12 V, 5 Ah rechargeable battery is used to store the generated energy and provide power when renewable generation is insufficient. Energy storage is particularly important because solar, wind, and footstep generation are intermittent and cannot always match the instantaneous load demand [5].

A microcontroller-based monitoring system is incorporated to improve system control and observation. Voltage sensors are used to measure the voltage generated by the renewable sources and the battery condition. The controller processes the measured values and provides information regarding the operating status of the system. An LCD display presents important parameters such as source voltage, battery voltage, charging condition, and load status, allowing the user to monitor the prototype in real time [6][7].

The stored battery energy can be utilized in two ways. 12 V DC loads, such as LEDs, DC fans, and USB charging circuits, can be supplied directly from the battery through appropriate regulation. For conventional electrical appliances requiring AC supply, a 12 V DC-to-220 V AC inverter module converts the stored DC energy into AC power. Thus, the proposed system can demonstrate both DC and AC power utilization from a common renewable energy storage unit [8].

The overall objective of this project is to develop a practical and educational prototype demonstrating how different renewable energy sources can work together to improve energy availability. By integrating solar, wind, and piezoelectric footstep generation with battery storage, monitoring, and power conversion, the proposed system provides an environmentally friendly approach to decentralized electricity generation. The concept can be further developed for smart buildings, public infrastructure, rural applications, and low-power standalone systems where multiple small renewable energy sources can collectively contribute to useful electrical power.

II. PROBLEM IDENTIFICATION

- **Intermittent Generation:** Solar and wind power depend on sunlight and wind availability.
- **Conventional Energy Dependence:** Excessive use of grid and fossil fuels causes pollution and resource depletion.
- **Wasted Footstep Energy:** Human movement energy is normally wasted and can be harvested using piezoelectric sensors.
- **Limited Integration:** Solar, wind, and piezoelectric sources are rarely combined in small-scale systems.
- **Variable Output:** Different sources produce fluctuating voltage, requiring proper power conditioning.
- **Monitoring Requirement:** Voltage, battery status, charging, and load need continuous monitoring.
- **AC/DC Requirement:** The system should provide 12 V DC and 220 V AC outputs.

A. Existing System

Existing systems mainly use solar, wind, or solar-wind combinations with batteries, charge controllers, and inverters. Piezoelectric footstep energy and intelligent monitoring are generally limited.

B. Drawbacks

- Dependence on weather conditions.
- Intermittent power generation.
- Footstep energy is usually unused.
- Variable voltage output.
- Limited monitoring and control.
- High cost and complexity in some systems.
- Limited flexibility between AC and DC loads.

III. LITERATURE REVIEWS A)

Literature Survey:

Bhimaraju and Mahesh 2024, reviewed recent developments in photovoltaic–wind hybrid renewable energy systems, focusing on system configurations, energy storage, optimal sizing, demand response, and technical, economic, and environmental performance. The study highlighted that individual solar and wind systems suffer from weather-dependent intermittency, while hybridization improves reliability by combining complementary generation profiles. Different standalone and grid-connected architectures were examined along with battery-storage technologies and optimization approaches. The authors also discussed the increasing role of electric vehicles as controllable loads and storage resources. The review provides useful design considerations for developing reliable hybrid renewable systems and demonstrates the importance of proper source sizing, storage selection, and energy-management strategies.

Kechida et al. 2024, investigated smart control and energy management for a standalone renewable hybrid system incorporating photovoltaic generation, wind energy, battery storage, and power-electronic converters. Their work emphasized intelligent coordination among generation sources, storage, and electrical loads to improve system efficiency and utilization. The proposed management approach addresses the intermittent nature of renewable generation by controlling energy flows according to operating conditions. The study demonstrates that appropriate control strategies can improve the utilization of renewable resources while maintaining reliable power availability. This research is particularly relevant to the proposed project because it supports the integration of multiple renewable sources with battery storage and a microcontroller-based monitoring and energy-management system.

Akvile Giedraityte et al. 2025, review examined optimization approaches used for Hybrid Renewable Energy Systems (HRES), considering combinations of solar, wind, biomass, geothermal, hydropower, and other renewable resources. The study discussed the importance of optimal component sizing, energy storage, system reliability, economic performance, and environmental sustainability. It identified optimization as an essential requirement because renewable generation varies with environmental conditions and load demand. Various mathematical and computational approaches were assessed for improving system design and operational performance. The review also highlighted future challenges related to uncertainty, storage integration, control complexity, and increasing renewable penetration. These findings support the development of a compact hybrid prototype with multiple energy sources and coordinated battery-based energy management.

Samala et al. 2025, presented a comprehensive review of hybrid renewable energy systems, particularly focusing on solar and wind integration and their relationship with power-quality improvement. The study emphasized that renewable sources provide sustainable electricity but introduce fluctuations because their generation depends on environmental conditions. The authors investigated system integration, power-electronic interfaces, energy management

techniques, and power-quality challenges. Their work also examined the role of unified power-quality conditioning technologies in improving voltage and current quality when renewable sources are integrated into electrical networks. The study demonstrates that combining renewable generation with suitable power-conditioning equipment can improve system stability and energy utilization. These findings are relevant to the proposed system because DC conversion and inverter stages are required to supply practical AC and DC loads.

Savio et al. 2025, developed a solar–wind hybrid renewable energy system for power-quality enhancement and evaluated its performance for a real-time domestic-grid application. The research investigated the integration of photovoltaic and wind generation with electrical-network operation, focusing on improving renewable utilization and power-quality characteristics. The study demonstrates the importance of coordinated renewable-source operation and suitable power-conditioning techniques when variable renewable energy is connected to electrical loads. Their work also indicates that hybrid solar–wind systems can provide improved energy availability compared with individual renewable sources. The research provides a useful reference for the proposed prototype, particularly for understanding how multiple variable renewable sources can be integrated and regulated before supplying AC and DC loads.

Zhao et al. 2023, comprehensively reviewed piezoelectric footwear energy-harvesting technologies for converting human walking energy into electrical power. The researchers examined piezoelectric materials, foot-ground interaction, force distribution, mechanical deformation, electrical conversion, and energy delivery to external circuits. Four major harvester structures—flat plate, curved, cantilever, and flextensional configurations—were discussed. The review showed that harvested power varies significantly according to piezoelectric material, mechanical structure, walking speed, excitation frequency, and placement. Reported power levels range from nanowatts to milliwatts, demonstrating that footstep harvesting is more suitable as a supplementary energy source than as a primary high-power source. This study directly supports the proposed footstep-based piezoelectric generation mechanism.

Gurpreet Singh et al. 2024, This review investigated recent developments in piezoelectric footwear prototypes designed to convert mechanical energy from human walking and running into useful electrical energy. The study examined piezoelectric materials, harvesting mechanisms, prototype configurations, applications, advantages, and limitations. It emphasized that human movement represents an available mechanical energy source that can be converted into electricity using piezoelectric materials. Different footwear designs and patented technologies were compared to identify methods for improving harvesting performance. The research highlighted the potential of piezoelectric footwear for powering portable electronics, wireless sensors, and other low-power devices. The findings support the use of a spring-loaded footstep platform in the proposed hybrid system to supplement solar and wind generation.

León Gómez, et al. 2023, reviewed research articles related to hybrid renewable energy systems published between 2018

and 2023. Their study classified HRES research according to system architecture, energy-storage technologies, auxiliary generation sources, software tools, optimization algorithms, reliability criteria, and economic considerations. The authors highlighted the importance of battery energy storage for managing the intermittent nature of renewable sources. Different optimization approaches were compared for improving system reliability and reducing costs. The review provides a broad foundation for designing hybrid renewable systems and emphasizes that source integration alone is insufficient; appropriate storage, control, sizing, and energy-management strategies are required for reliable operation.

M. Thirunavukkarasu et al. 2023, This review investigated optimization methodologies applied to different hybrid renewable energy systems. The study examined technical feasibility, economic performance, reliability, environmental impacts, and social considerations associated with HRES design. Particular attention was given to optimization methods used for component sizing, energy storage, and system operation. The researchers also evaluated the increasing application of artificial-intelligence techniques for solving complex renewable-energy optimization problems involving uncertainty and intermittent generation. The review concluded that effective optimization is essential for obtaining an appropriate balance between renewable generation capacity, storage requirements, reliability, and system cost. The findings provide a theoretical basis for selecting suitable source capacities and storage arrangements in the proposed solar–wind–piezoelectric hybrid prototype.

Bansal et al. 2022, reviewed sizing and forecasting methodologies for photovoltaic–wind hybrid renewable energy systems. The study compared different optimization techniques, forecasting approaches, and software tools used to determine suitable capacities of solar panels, wind turbines, storage systems, and other components. The authors emphasized that proper sizing is essential because excessive generation capacity increases investment cost, whereas insufficient capacity reduces reliability. The review also identified limitations in earlier research concerning the combined consideration of technical, economic, environmental, social, and reliability factors. Furthermore, the influence of weather forecasting on hybrid-system optimization was identified as an important research area. These findings are useful for determining suitable component ratings in practical hybrid renewable-energy prototypes.

Bhimaraju et al. 2024, reviewed recent developments in photovoltaic and wind hybrid renewable energy systems. The study highlighted that solar and wind sources are individually intermittent because their generation depends on climatic conditions. Combining them can improve reliability and reduce overall system cost. The authors examined hybrid-system configurations, optimal sizing, energy-storage technologies, demand-response methods, and renewable-energy integration. The review emphasized that proper sizing of solar, wind, and storage components is essential for achieving reliable operation. It also identified energy storage and intelligent control as important areas for future development. The findings strongly support combining multiple renewable sources rather than depending on a single source.

Giedraityte et al. 2025, reviewed optimization techniques for hybrid renewable energy systems incorporating solar, wind, biomass, geothermal, hydropower, and tidal resources. The study emphasized that HRES design involves multiple technical, economic, environmental, and social objectives. Advanced optimization techniques such as Multi-Objective Particle Swarm Optimization, NSGA-II, Grey Wolf Optimizer, and other metaheuristic methods were discussed. The authors highlighted the importance of optimal component sizing, system resilience, cost reduction, and efficient energy utilization. The research indicates that intelligent optimization can improve hybrid-system performance while reducing unnecessary generation and storage capacity. It provides a useful theoretical foundation for future intelligent energy-management systems.

Nikolas G. Chatzigeorgiou et al. 2024, This study reviewed battery energy-storage systems and their integration with renewable-energy installations, particularly photovoltaic-battery systems. The research identified battery storage as an important technology for overcoming the intermittent nature of renewable generation. Major research areas included techno-economic analysis, operational control, system sizing, and demand response. The authors explained that batteries can store excess renewable electricity and release it during periods of insufficient generation, thereby improving energy flexibility and supply reliability. The review also discussed battery-management requirements, operational scheduling, and integration with energy-management systems. These findings are directly relevant to the proposed project because the 12 V, 5 Ah battery provides energy storage and supports continuous DC and AC load operation.

Emrani et al. 2024, investigated the technical and economic aspects of energy-storage systems integrated with renewable energy. Their review compared different storage technologies and examined their performance, cost, sizing, and integration requirements for hybrid photovoltaic-wind systems. The researchers emphasized that renewable generation is variable, making energy storage essential for maintaining reliability and controlling unpredictable load demand. Optimal storage sizing was identified as an important factor because oversized systems increase investment cost while undersized systems reduce reliability. The study also highlighted the need to evaluate both technical and economic performance during system design. These findings support the use of appropriately sized battery storage and power-conditioning circuits in the proposed hybrid renewable prototype.

Roy et al. 2024, evaluated eleven hybrid renewable energy configurations for supplying electricity to remote communities in India. Their study considered photovoltaic panels, wind turbines, batteries, converters, diesel generators, biogas generators, and electrolyzers. Both techno-economic analysis and life-cycle assessment were used to compare the alternatives. The researchers found that hybrid PV/wind systems with battery and converter components can significantly improve renewable-energy utilization and reduce dependence on conventional generation. The study also showed that appropriate component sizing is essential for achieving acceptable cost and environmental performance. Their findings demonstrate the practical value of combining

renewable sources and storage for locations where conventional grid electricity is unreliable or unavailable.

Yemeli Wenceslas Koholé et al. 2024, This research compared battery, hydrogen, pumped-hydro, and thermal energy-storage technologies for photovoltaic-wind hybrid renewable systems. Twelve hybrid configurations were optimally sized using technical, economic, and environmental considerations. The study showed that the choice of storage technology strongly influences system cost, reliability, renewable-energy utilization, and carbon emissions. Different storage technologies have different response times, capacities, investment requirements, and operational characteristics. The researchers concluded that storage selection should be based on the renewable-resource characteristics and required reliability of the application. The findings demonstrate why battery storage is particularly suitable for compact systems requiring relatively simple energy management, fast response, and direct integration with DC renewable sources.

Selim et al. 2024, investigated piezoelectric sensors subjected to human footsteps for mechanical-energy harvesting. The study demonstrated that human footsteps can be converted into electrical energy using piezoelectric materials. The researchers examined the electrical response of piezoelectric elements under different mechanical loading conditions and considered their suitability for energy harvesting applications. The work demonstrates the potential of integrating piezoelectric elements into floors, platforms, or other locations with repeated human movement. However, the harvested energy from individual footsteps is relatively limited, making energy accumulation and appropriate power conditioning important. The findings support the use of a footstep mechanism as a supplementary renewable-energy source in the proposed solar-wind piezoelectric hybrid system.

Arish et al. 2025, explored harvesting ambient mechanical energy from human footsteps using piezoelectric materials and electromagnetic induction. The research considered applications in high-traffic urban environments such as railway stations and other public locations where repeated pedestrian movement is available. The authors emphasized that the energy generated from one individual step is small, but large numbers of footsteps can collectively provide useful energy. The study investigated the potential environmental and economic benefits of converting otherwise wasted human mechanical energy into electricity. The findings suggest that footstep energy harvesting can complement other renewable sources and could contribute to smart-city energy systems when combined with suitable storage and power-conditioning technologies.

Salman et al. 2025, proposed a control approach for improving power generation in a hybrid solar-wind energy system using a doubly fed induction generator. The study focused on controlling renewable generation while considering wind conditions, photovoltaic generation, and maximum-power-point-tracking requirements. The research demonstrates that suitable control strategies can improve energy extraction from variable renewable sources and enhance overall system performance. The authors investigated the interaction between solar generation and wind-turbine operation and emphasized the importance of efficient power conversion. Although the proposed approach is more complex than a small prototype

system, its findings support the general requirement for appropriate controllers and converters when integrating variable renewable sources into a common energy system.

Zhou et al. 2024, conducted a bibliometric analysis of more than 1,500 publications concerning standalone hybrid solar photovoltaic and wind-energy systems. The research mapped major research trends, system configurations, application areas, and future development directions. The analysis showed that solar-wind hybrid systems are considered more reliable and efficient than individual renewable sources because the two resources can complement each other. Standalone applications, particularly for remote locations, were identified as an important research area. The study also showed strong research interest in system optimization, energy storage, and hybrid-system design. These findings reinforce the proposed project's concept of combining different renewable sources to improve energy availability and reduce dependence on conventional electricity

B) Literature Summary

- Recent studies show that solar–wind hybrid systems improve renewable power availability by combining complementary energy sources and reducing dependence on a single source.
- Researchers have emphasized battery energy storage, power converters, and energy-management strategies for maintaining stable output under variable environmental conditions.
- Optimization and forecasting techniques have been widely investigated to achieve appropriate component sizing, reduce operating costs, and improve system reliability.
- Piezoelectric energy-harvesting studies demonstrate that human footsteps and mechanical movement can be converted into electrical energy for low-power applications.
- Overall, existing research confirms the technical feasibility of hybrid renewable generation but generally investigates solar–wind and piezoelectric systems separately.

C) Research Gap

- Most existing hybrid systems concentrate on solar–wind integration, while practical integration of solar, wind, and piezoelectric footstep generation remains comparatively limited.
- Piezoelectric research primarily focuses on footwear, sensors, and low-power electronic devices rather than integrating harvested footstep energy into a common battery-based power system.
- Many studies emphasize simulation, optimization, and theoretical analysis, with fewer low-cost hardware prototypes demonstrating real-time operation.
- Limited work combines multiple renewable sources with microcontroller-based monitoring, voltage sensing, LCD display, battery storage, and DC boost conversion in one compact system.
- Therefore, the proposed work addresses this gap by developing an integrated solar–wind–piezoelectric hybrid prototype capable of supplying both DC and 220 V AC loads.

IV. RESEARCH METHODOLOGY

A) Proposed System

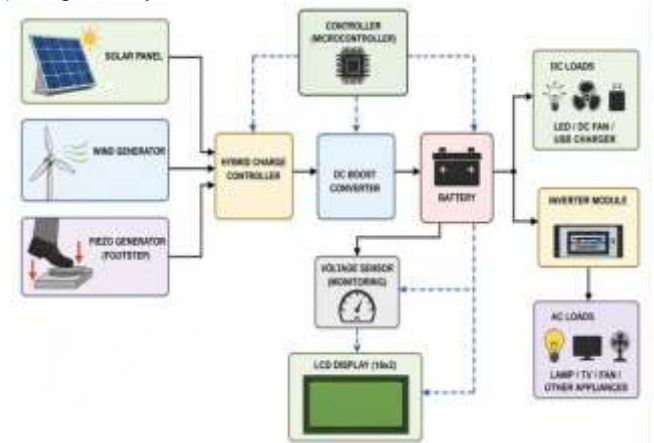


Figure 1. Block Diagram



Figure 2. Model

- Solar Power Generation:** The 12 V, 60 W solar panel converts solar radiation into electrical energy. The generated DC power is supplied to the power conditioning circuit for further processing.
- Wind Power Generation:** The 12 V, 10 W wind generator converts available wind energy into electrical power. Its output supplements solar generation when sufficient wind is available.
- Piezoelectric Power Generation:** The footstep mechanism applies mechanical pressure to piezoelectric elements. The resulting electrical energy is collected from repeated footsteps and used as an additional renewable input.
- Power Conditioning:** The outputs from the renewable sources are regulated through suitable charging and protection circuits. The DC boost converter helps maintain the required voltage level for efficient energy transfer.
- Battery Storage:** The conditioned electrical energy is stored in a 12 V, 5 Ah rechargeable battery. The battery provides continuous energy when renewable sources produce insufficient power.
- Monitoring and Control:** The microcontroller receives voltage-sensor readings and monitors source voltage, battery

condition, and load operation. The LCD displays important electrical parameters in real time.

- Load Supply: Stored energy directly supplies 12 V DC loads. For AC applications, a 12 V DC-to-220 V AC inverter converts battery power into AC electricity, enabling operation of suitable AC loads.

B) Hardware Used

- Solar Panel (12 V, 60 W): Converts sunlight into DC electrical energy and serves as the primary renewable energy source for the hybrid system.
- Wind Generator (12 V, 10 W): Converts wind energy into electrical power and provides supplementary generation when suitable wind conditions are available.
- Piezoelectric Generator (12 V, 10 W): Converts mechanical stress produced by footsteps into electrical energy through piezoelectric elements.
- Footstep Power Generation Mechanism: A spring-loaded platform transfers human weight and mechanical pressure to the piezoelectric elements for repeated energy harvesting.
- Hybrid Charge Controller: Combines and regulates electrical energy from the renewable sources and controls safe battery charging.
- DC Boost Converter: Increases and regulates the available DC voltage to the required level for efficient energy transfer and battery charging.
- 12 V, 5 Ah Battery: Stores generated electrical energy and supplies backup power when renewable generation is temporarily unavailable.
- Controller: Processes sensor information and manages monitoring and control functions of the prototype.
- Voltage Sensor: Measures voltage from renewable sources and the battery for real-time system monitoring.
- 16×2 LCD Display: Displays source voltage, battery voltage, charging condition, and operating status.
- 12 V DC Loads: LEDs, DC fans, and USB charging units utilize stored DC power directly.
- 12 V to 220 V AC Inverter: Converts battery DC power into 220 V AC for operating suitable AC loads.
- Protection Components: Fuses, switches, connectors, and wiring provide safe electrical connections and protection against overloads and short circuits.

V. CALCULATION

Solar panel = 12 V, 60 W

Wind generator = 12 V, 10 W

Piezoelectric generator = 12 V, 10 W

Battery = 12 V, 5 Ah

Inverter = 12 V DC to 220 V AC

1. Solar Panel Current

$$I_s = \frac{P_s}{V_s}$$

$$I_s = \frac{60}{12} = 5 \text{ A}$$

The solar panel can theoretically provide 5 A at 12 V under rated conditions.

2. Wind Generator Current

$$I_w = \frac{P_w}{V_w}$$

$$I_w = \frac{10}{12} = 0.83 \text{ A}$$

The wind generator provides approximately 0.83 A at 12 V.

3. Piezoelectric Generator Current

$$I_p = \frac{P_p}{V_p}$$

$$I_p = \frac{10}{12} = 0.83 \text{ A}$$

The piezoelectric arrangement is rated at approximately 0.83 A at 12 V.

4. Total Rated Generation

$$P_{total} = P_s + P_w + P_p$$

$$P_{total} = 60 + 10 + 10 = 80 \text{ W}$$

The maximum theoretical combined generation is 80 W when all three sources operate at their rated outputs simultaneously.

5. Total Equivalent Current at 12 V

$$I_{total} = \frac{P_{total}}{V}$$

$$I_{total} = \frac{80}{12} = 6.67 \text{ A}$$

6. Battery

Battery Capacity rating:

$$V_b = 12 \text{ V}, \quad Ah = 5 \text{ Ah}$$

$$E_b = V_b \times Ah$$

$$E_b = 12 \times 5 = 60 \text{ Wh}$$

Stored energy:

Therefore, the battery theoretically stores 60 Wh of energy.

7. Approximate Battery Backup Time

$$t = \frac{E_b}{P_L}$$

$$t = \frac{60}{20} = 3 \text{ hrs.}$$

For a 20 W DC load:

8. Solar Charging Time

Assuming the solar panel continuously delivers its rated 60

$$t = \frac{E_b}{P_s}$$

$$t = \frac{60}{60} = 1 \text{ hrs.}$$

9. Inverter Output Current

For an ideal 80 W AC output:

$$I_{AC} = \frac{P}{V_{AC}}$$

$$I_{AC} = \frac{80}{220} = 0.364 \text{ A}$$

Therefore, 80 W corresponds to approximately 0.36 A at 220 V AC.

VI. ADVANTAGES AND APPLICATIONS

A) Advantages

- Multiple Energy Sources: Combines solar, wind, and piezoelectric energy, improving overall energy availability.
- Renewable and Clean: Uses naturally available energy sources and reduces dependence on fossil-fuel-based electricity.
- Improved Reliability: When one source produces less energy, other sources can supplement power generation.
- Energy Storage: The 12 V, 5 Ah battery stores generated energy for later use.
- Dual Output: Supports both 12 V DC and 220 V AC loads.
- Real-Time Monitoring: Sensors and LCD provide continuous system-status information.
- Footstep Energy Recovery: Converts otherwise wasted human mechanical energy into useful electricity.
- Scalable Design: The prototype can be expanded for larger renewable-energy applications..

B) Applications

- Smart Buildings: Provides supplementary renewable electricity for lighting and small electronic devices.
- Railway Stations: Footstep harvesting can utilize energy from continuously moving passengers.
- Bus Stands: Solar, wind, and pedestrian energy can support lighting and information systems.
- Educational Institutions: Demonstrates practical renewable-energy generation and energy management.
- Public Walkways: Footstep mechanisms can generate supplementary electricity from pedestrian movement.
- Rural Areas: Provides decentralized power where grid electricity is limited or unavailable.
- Street Lighting: Battery-stored renewable energy can operate LED lighting systems.
- Remote Locations: Suitable for low-power monitoring, communication, and emergency electrical applications.

VII. CONCLUSION

The Hybrid Power Generation System Using Solar, Wind and Piezoelectric Energy Sources provides an effective approach for utilizing multiple renewable energy resources in a single integrated system. The 12 V, 60 W solar panel acts as the primary generation source, while the 12 V, 10 W wind generator and piezoelectric footstep mechanism provide supplementary energy under suitable operating conditions. The generated power is regulated through appropriate power-conditioning circuits and stored in a 12 V, 5 Ah battery for later utilization. The microcontroller, voltage sensor, and LCD display enable real-time monitoring of source voltage, battery condition, and load status. The stored energy can supply 12 V DC loads directly, while the inverter converts DC power into 220 V AC for suitable AC loads. The proposed system can achieve a theoretical combined generation capacity of approximately 80 W when all sources operate at their rated outputs. Overall, the system demonstrates the feasibility of combining solar, wind, and human-motion energy harvesting to improve renewable-energy utilization, reduce dependence on

conventional electricity, and support sustainable decentralized power applications.

VIII. FUTURE SCOPE

- Advanced Energy Management: AI-based controllers can optimize power flow, source selection, battery charging, and load distribution according to real-time generation and demand.
- Improved Piezoelectric Harvesting: High-efficiency piezoelectric materials and improved footstep mechanisms can increase energy generation from human movement.
- Large-Scale Implementation: The system can be expanded for smart buildings, railway stations, public walkways, and rural areas with IoT monitoring, larger battery storage, and grid integration.

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