Power Generation Using a Parabolic Mirrors

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Abstract

This research paper presents a comprehensive review of power generation using parabolic mirrors, a promising technology in the field of solar thermal energy. Parabolic mirrors, due to their ability to concentrate sunlight onto a single focal point, significantly enhance the efficiency of thermal energy collection. The concentrated solar energy is used to heat a working fluid, which can then be converted into electricity through various energy conversion systems such as Stirling engines or steam turbines. This method offers a clean, renewable, and sustainable alternative to conventional fossil fuel-based power generation. The paper analyses different configurations, materials, and design parameters of parabolic mirror systems, evaluates their performance under various climatic conditions, and highlights recent advancements and challenges in implementation. Emphasis is also placed on the potential of such systems for decentralized and off-grid power solutions, especially in sun-rich regions. The study aims to contribute to the development and optimization of solar concentrator technology for enhanced energy security and environmental sustainability. A basic study about an advance mirror technology has been carried at J D College of Engineering & Management, Nagpur in order to validate the results. The total solar power generation incremented due to advanced mirror technology and discussed and this will help in taking for future upgradation.

Keywords: - Mirror, Diffusion, Albedo, Tilt angle, Maximum Power

Introduction

As the global demand for electricity increases, so does the need for clean and sustainable energy sources. Traditional methods of power generation, such as coal and fossil fuels, are not only limited but also harmful to the environment due to greenhouse gas emissions and pollution. Solar technology plays significant role in the evolution of power generation, given that the sun is an abundant source of renewable energy worldwide. The rate of receiving sunlight is approximately 1300 watts of power per hour per meter on Earth every day. Although 30 percent of this potency is reflected, it still results in a staggering 4.2 kilowatt-hours of energy per meter each day.

This usable solar energy can be harvested by using solar panels worldwide (photovoltaic generation). These processes are eco-friendly and renewable; therefore, they are safe. In contrast, **solar energy** offers a renewable, eco-friendly, and widely available solution. Among various solar technologies, **concentrated solar power (CSP)** using **parabolic mirrors** is one of the most promising methods for converting solar energy into usable electrical power. A **parabolic mirror** is a curved reflector that concentrates sunlight onto a single point known as the **focus**.

When sunlight is focused at this point, it generates very high temperatures. This heat is transferred to a **working fluid** (such as water, oil, or molten salt), which is then used to produce steam. The steam can drive turbines or **Stirling engines** to generate electricity. This process is called **solar thermal energy conversion**.

Parabolic mirror systems are classified as **line-focus** (like parabolic troughs) and **point-focus** (like parabolic dishes), depending on how the sunlight is concentrated. These systems are ideal for regions with high solar radiation and can be implemented for both **centralized power plants** and **decentralized or off-grid applications**, such as in rural areas or small industries.

This research paper focuses on studying the design, working principle, components, materials used, efficiency, and energy output of parabolic mirror systems. It also discusses their advantages, limitations, recent technological developments, and real-world applications. The goal is to provide a deeper understanding of how parabolic mirrors can be effectively used for clean power generation, contributing to energy sustainability and environmental protection.

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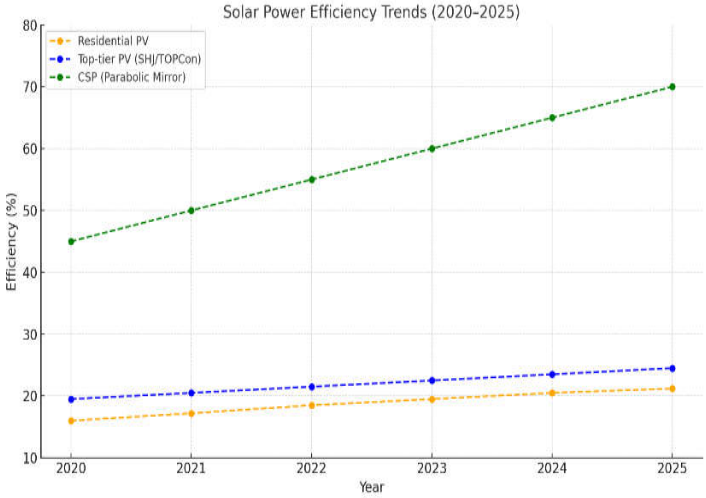


Figure 1. Efficiency graph of solar power as per worldwide data

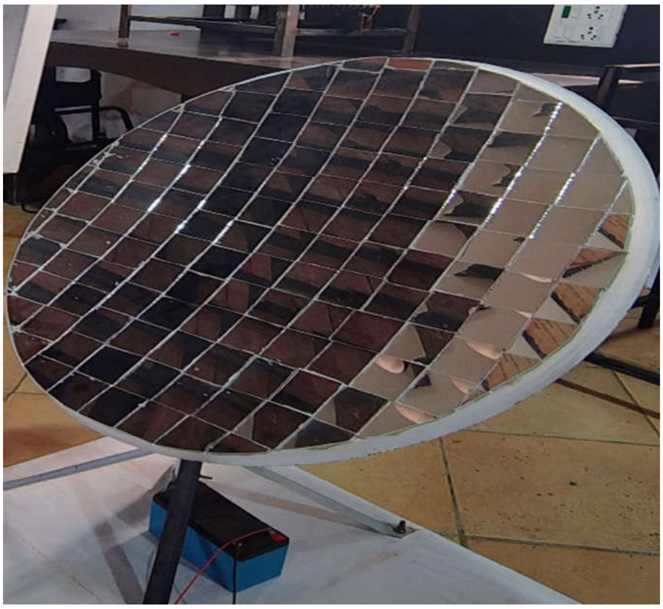
Here is a **dotted line graph** showing the **efficiency trends** of different solar power technologies from **2020 to 2025**, based on worldwide data:

Residential PV Panels have steadily improved from around **16% to over 21%**.

Top-tier PV technologies like **SHJ** and **Topcon** have increased from **~19.5% to 24.5%**.

Concentrated Solar Power (CSP) systems, such as those using **parabolic mirrors**, have shown a significant rise from **45% to 70%** in efficiency due to better designs and materials.

A. Concentrating Collector



B. Solar Panel

Solar panels are devices that convert sunlight into electricity using photovoltaic (PV) cells. These cells are made of semiconductor materials that generate excited electrons when exposed to sunlight, producing direct current (DC) electricity. Solar panels can also be called solar cell panels or PV modules. Typically arranged in groups known as arrays, a photovoltaic system includes solar panels, an inverter to convert DC to alternating current (AC), and other components like controllers and meters. The efficiency of solar panels relies on converting photons at the PN junction into electricity. When sunlight hits the solar cells, it generates free charge carriers, creating a potential difference that allows electric current to flow. For instance, a solar panel with a 12V, 25W rating is designed to produce 25 watts of power at a nominal voltage of 12 volts under optimal sunlight conditions.

SPECIFICATIONS OF SOLAR PANEL

Parameters	Ratings
Rated Maximum Power (Pmax)	25W
Voltage at Pmax (Vmax)	12V
Dimensions	450*350*22 mm

C. Charge Controller

A solar charge controller manages the charging of the battery from the solar panels and regulates the voltage supplied to the connected load. It ensures proper charging and discharging of the battery, preventing overcharging or excessive discharge. By controlling the power flow from the solar panels and battery to the load, it ensures the system operates efficiently. The charge controller is a vital component in maintaining the overall functionality of the solar power system.

a. Battery

A battery converts chemical energy into electrical energy by storing it. The process occurs between the cathode and anode, where chemical reactions generate a potential difference that allows electrons to flow, producing direct current (DC) electricity. Batteries play a crucial role in energy storage, particularly in renewable energy systems, by storing electricity generated by wind turbines and solar panels. The two most common types of batteries used in these applications are lead acid and lithium-ion batteries. In the context of a hybrid solar wind system, a 12V 14AH battery is typically used to store the energy produced.

SPECIFICATION OF LEAD ACID BATTERY

Current	2.0A
Dimensions	151*98*94mm
Voltage	14.1– 14.4V

b. Load and Display

A. Lighting

B. Motor

DC motor is a widely used electrical device designed to operate on a 12-volt direct current supply. These motors convert electrical energy into mechanical motion and are commonly found in solar power systems, electric vehicles, home appliances, robotics, and automation projects.

3.Block Diagram

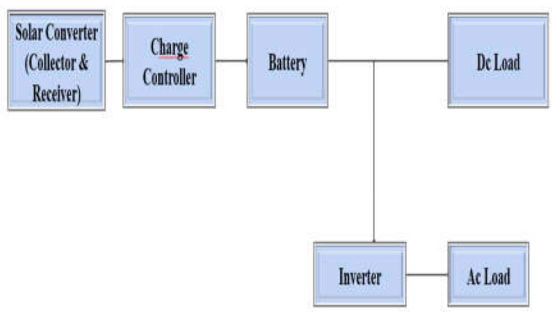


Figure 2. Block Diagram of The System

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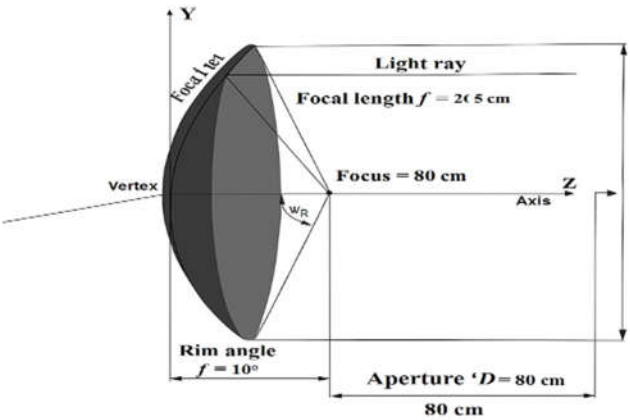
4. Rating

Sr. No	Components	rating
1	Concentrating Collector	Rim Angle: 10°
2	Solar Panel	12V, 25W
3	Solar Charge Controller	20A
4	Lead Acid Battery	V_{max}=14.2V
		V_{Min}=11v
5	Load (Light, Motor)	-

5. Structure



Design Parameters of The Solar Parabolic Dish Concentrator

Focal Length (f): 25 cm

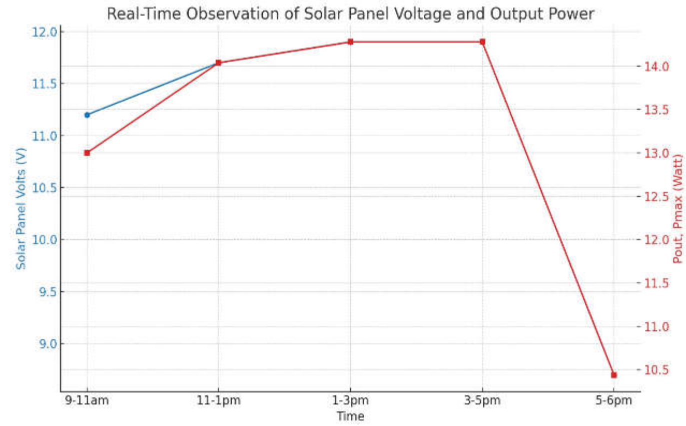
Aperture Diameter (D): 60 cm

Focus (Z-axis position): 80 cm

Rim Angle: 10°

6. Observation Table

OBSERVATION OF REAL-TIME CALCULATION				
S.NO	TIME	OUTPUT SOLAR PANEL VOLTS (v)	SOLAR POWER RATING VOLTAGE 12 V	Pout, Pmax 15Watt
1	9-11am	11.2	12	13
2	11-1pm	11.7	12	14.04
3	1-3pm	11.9	12	14.28
4	3-5pm	11.9	12	14.28
5	5-6pm	8.7	12	10.44



The Observation Graph Based on Your Data. It Shows

- **Blue Line:** Output Solar Panel Volts Over Different Time Intervals.
- **Red Line:** Corresponding Power Output (Pout, Pmax) In Watts.

7. Conclusion

Power generation using parabolic mirrors represents a promising and sustainable solution for meeting the growing global energy demand while reducing environmental impact. The fundamental principle of concentrating sunlight onto a focal point using a parabolic reflector allows for achieving significantly higher temperatures compared to flat-plate collectors, enabling efficient thermal-to-electric energy conversion through steam turbines, Stirling engines, or other heat-based power cycles. This approach not only maximizes the utilization of the abundant solar resource but also minimizes greenhouse gas emissions, making it an attractive alternative to fossil fuel-based energy systems.

From a technological perspective, parabolic mirror systems offer several advantages, such as high optical efficiency, scalability for diverse applications ranging from decentralized rural electrification to large-scale solar power plants, and compatibility with thermal energy storage systems, which can extend power supply beyond daylight hours. Furthermore, their relatively simple design compared to other concentrated solar power (CSP) technologies makes them easier to manufacture and maintain in many regions.

However, despite these strengths, the technology still faces certain limitations. The initial capital cost for setting up a parabolic mirror power generation system remains high, and the performance is heavily dependent on geographical location, solar intensity, and clear-sky conditions. Additionally, precise solar tracking mechanisms are essential to maintain the alignment of the mirror with the sun, which adds to operational complexity. The efficiency can also be reduced by factors such as dust accumulation, reflector degradation over time, and thermal losses in the receiver system. Ongoing research and development are addressing these challenges by introducing cost-effective manufacturing techniques, advanced selective coating materials with higher reflectivity and durability, and innovative hybrid systems that integrate parabolic mirrors with photovoltaic panels or other renewable energy sources. Improvements in thermal energy storage technologies, such as molten salts and phase change materials, are further enhancing the dispatchability and reliability of such systems.

In conclusion, while there are practical and economic challenges to be resolved, parabolic mirror-based power generation remains a viable and environmentally friendly option for future energy systems. With continued technological advancements, supportive policies, and increased awareness of climate change impacts, this technology has the potential to make a significant contribution to the transition towards a cleaner, more sustainable, and decentralized energy future.

Result

In this section, the electrical harvested electrical energy (voltage and current) of the proposed system has been compared with the output of offset feed static parabolic dish and static solar panel without parabolic dish under natural environmental conditions, which is depicted in Fig. a and Fig. b respectively. The dynamic offset feed mirrored parabolic reflector dish is 88.05% more than static parabolic reflector dish and whereas average output power of static parabolic reflector dish is 44 % more than static solar panel.

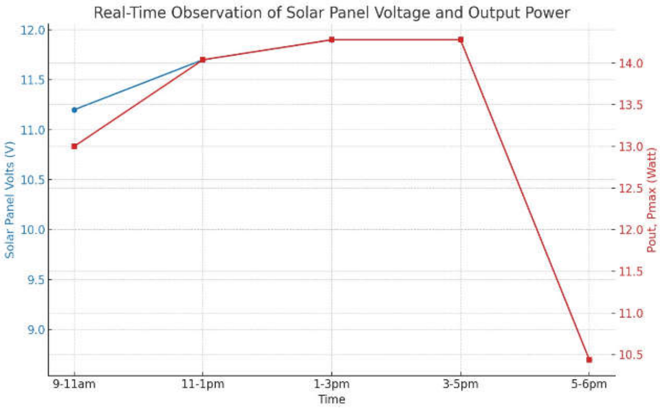


Fig A. Real-Time Observation of Solar Panel

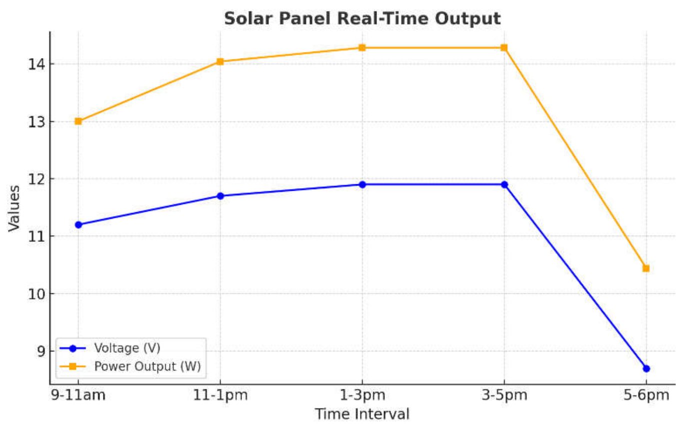


Fig B. Solar Panel Real-Time Output

Time	Pout (W)	Pmax (W)	Efficiency (%)
9-11am	13	15	86.67%
11-1pm	14.04	15	93.60%
1-3pm	14.28	15	95.20%
3-5pm	14.28	15	95.20%
5-6pm	10.44	15	69.60%

Calculate the total efficiency manually:

1. **Total Pout** = 13.00 + 14.04 + 14.28 + 14.28 + 10.44 = **66.04 W**
2. **Total Pmax** = 15 + 15 + 15 + 15 + 15 = **75 W**
3. **Total Efficiency** = (66.04 ÷ 75) × 100 = **88.05%**

The overall efficiency is **88.05%**.

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