GNG5140

Design Project User and Product Manual

[SOLAR PANEL RECYCLING SORTER]

Submitted by:

[TEAM B – SOLAR VANGUARDS]

[SAHIL KHOKHAR, 300402910]

[El Ghali Filali El Garch, 8433572]

[Parsa Mohammadiafzal, 300425527]

[Abhay Champaneri, 300407769]

[Dec 11, 2024]

University of Ottawa

Table of Contents

List of Figures

List of Tables

1 Introduction

The need for sustainable solutions to address the growing issue of solar panel waste has driven us to develop innovative recycling methods. This project focuses on creating an energy-efficient and eco-friendly system to separate silicon and silver from discarded solar panels. The prototype uses electrostatic separation as an alternative to conventional chemical and thermal methods, which are often associated with byproducts and pollution. This document serves as a comprehensive guide to understanding and operating the electrostatic separation system prototype while ensuring its safe and effective use.

This User and Product Manual (UPM) is designed to provide the necessary information for diverse users, including researchers, engineers and non-technical personnel, to effectively understand, operate and improve upon the system. The document covers every aspect of the prototype, from setup and operation to troubleshooting and future development. It also provides detailed documentation of the design and construction process, enabling continuity in future iterations of the project.

The purpose of this manual is to:

- Explain the context and objectives of the electrostatic separation system.
- Provide step-by-step guidance for operating and maintaining the system.
- Document the design, construction and materials used in the prototype.
- Outline safety considerations and troubleshooting procedures.
- Recommend improvements and future development opportunities.

The scope of the document includes a detailed explanation of the system's mechanical and electrical components, setup and operation guidelines, and recommendations for testing and future work. The intended audience includes engineers, researchers and users with an interest in sustainable recycling technologies.

The document is organized into the following sections:

1. **Introduction:** Provides the context, purpose and structure of the document.
2. **Overview:** Highlights the key features and architecture of the prototype.
3. **Getting Started:** Offers a walkthrough of the system setup and operation.
4. **Using the System:** Explains system functions and features in detail.
5. **Troubleshooting & Support:** Details error recovery and maintenance procedures.
6. **Product Documentation:** Describes the construction and design considerations of the prototype.
7. **Conclusions and Recommendations for Future Work:** Summarizes lessons learned and proposes future improvements.

2 Overview

Discarded solar panels represent a growing environmental challenge, as their components often contain valuable materials like aluminum, silicon and silver that can be recycled but are difficult to separate efficiently and sustainably. Sunset Renewables is working to address this issue by developing methods to recycle these materials. The primary problem our team addressed was finding a sustainable and energy-efficient way to separate silicon from silver, a critical step in the recycling process. This challenge is important because it directly impacts the economic and environmental feasibility of large-scale solar panel recycling.

The client, Sunset Renewables, required a method to separate silicon from silver that was both energy-efficient and environmentally friendly, avoiding harmful byproducts and minimizing pollution. Existing methods like chemical leaching and thermal separation produce waste and environmental hazards. A sustainable alternative was needed to align with the renewable energy focus of the project.

Our electrostatic separation prototype is innovative in its energy efficiency and low environmental impact. Unlike chemical and thermal methods, electrostatic separation relies on electric fields to differentiate materials based on their electrical conductivity properties, eliminating the need for harmful chemicals or high temperatures. The system operates with minimal power, making it a highly sustainable solution when integrated into a renewable energy-powered facility.

The product's design emphasizes sustainability, with power supplied by renewable energy sources like solar and wind. The architecture is straightforward, relying on mechanical and electrical components.

The prototype operates in a controlled environment where the mixture of silicon and silver is fed through the machine. It includes:

- **Input Power**: Standard 120V outlet.
- **Mechanical Components**: A feeder tray, rotating drum, and collection tray.
- **Electrical Components**: A voltage multiplier circuit and high-voltage electrodes.

Figure 1 shows what our prototype looks like, while highlighting the electrodes, the rotating drum and the motor. Figure 2 shows us the voltage multiplier circuit, made out of capacitors and diodes.

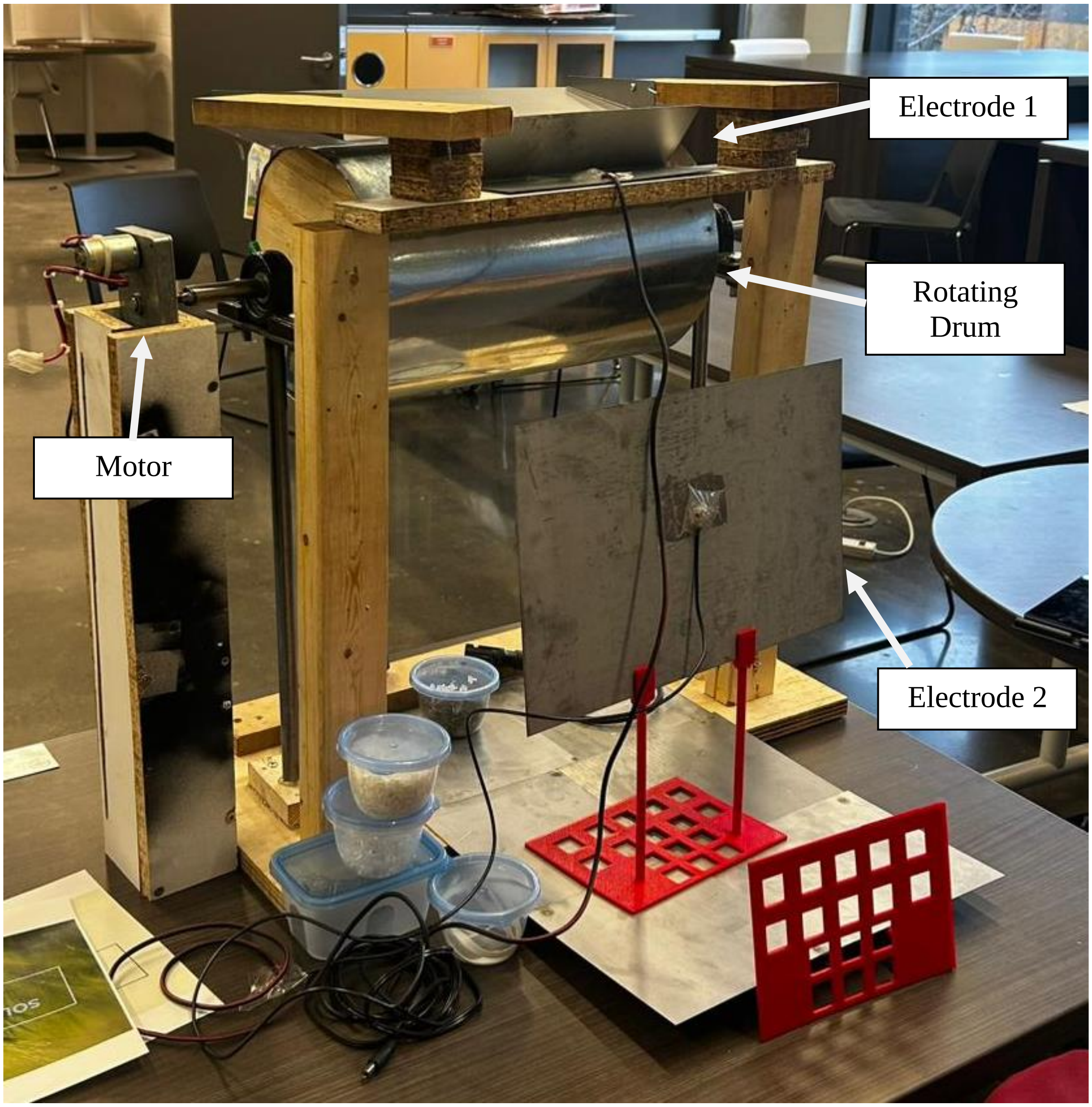

Figure 1: Labelled Diagram of the Prototype

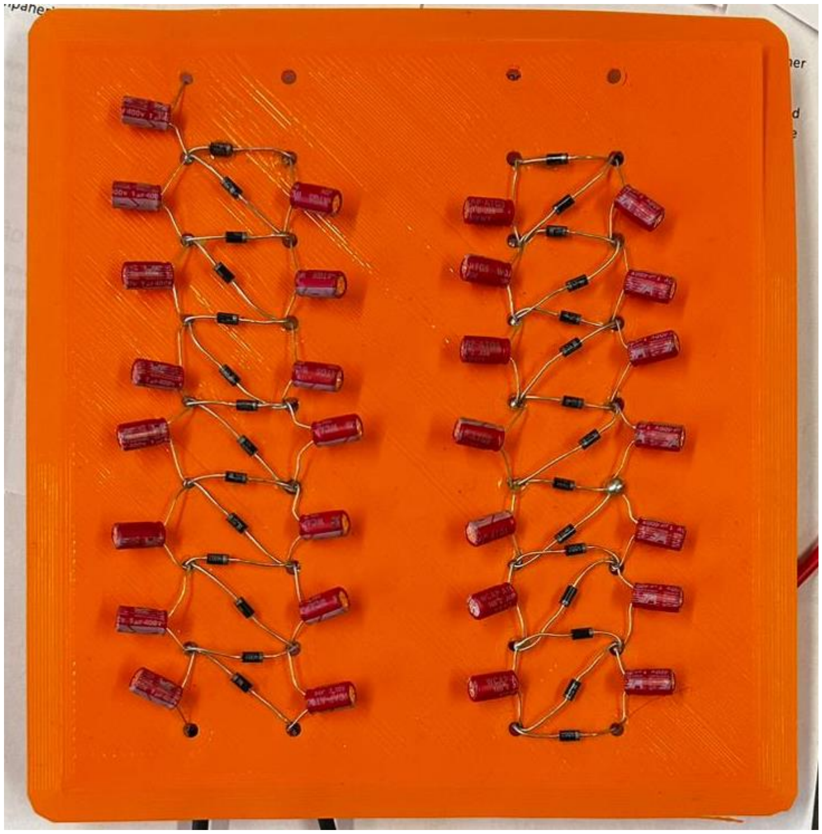

Figure 2: Voltage Multiplier Circuit.

2.1 Cautions & Warnings

Due to the high-voltage components (approximately 2000V DC), the system poses potential fire and safety risks. It is critical that the system be operated only in a controlled environment and by trained personnel. Testing must adhere to strict safety protocols to avoid hazards. Ensure the area is free from flammable materials during operation.

3 Getting started

This section provides a step-by-step walkthrough of how to set up, operate, and shut down the electrostatic separation system. Each stage is designed to ensure that even non-technical users can follow the process without difficulty.

3.1 Set-up Considerations

To set up the system, the following components and configurations are required:

1. **Equipment**:
   - Feeder tray for loading the silicon-silver mixture.
   - Rotating drum powered by a 20W gear motor.
   - Electrodes connected to the voltage multiplier circuit.
   - Collection tray to gather separated materials.

2. **Power Source**:
   - A standard 120V electrical outlet.

3. **Work Area**:
   - Ensure a clean, dry and well-ventilated space free of flammable materials.
   - The system must be positioned on a stable surface.

Setup Steps:

1. Position the system on a flat, stable surface.

2. Attach the feeder tray and collection tray securely.
3. Verify that all connections are tight and components are free from obstructions.
4. Connect the voltage multiplier circuit to the 120V power outlet.

3.2 User Access Considerations

The system is designed for controlled access, primarily for trained personnel. Access restrictions include:

- Authorized Users Only: Due to the high-voltage nature of the system, only trained individuals are permitted to operate it.
- Safety Gear Required: Operators must wear insulating gloves and safety goggles during use.

3.3 Accessing the System

To turn on the system:

1. Verify that all components are securely connected.
2. Activate the motor control switch to start the rotating drum.
3. Plug the voltage multiplier circuit into a standard 120V outlet.
4. Switch on the main power supply for the system.
5. Load the silicon-silver mixture into the feeder tray.

3.4 System Organization & Navigation

The system consists of a straightforward workflow. First, the mixture of silver and silicon is loaded in the feeder tray. Then, while falling off the rotating drum, an electrostatic charge is applied to the silver particles. After that, while falling, the materials separated under the influence of the strong electrostatic field produced by second electrode. At last, the separated materials are collected in respective trays.

Each component operates automatically once the system is powered on. No digital interfaces or software configurations are required.

3.5 Exiting the System

To properly shut down the system:

1. Turn off the voltage multiplier and motor control switch to stop the rotating drum.
2. Disconnect the voltage multiplier circuit from the power source.
3. Allow the system to discharge any residual voltage by leaving it unplugged for at least 10 minutes.
4. Remove and clean the feeder and collection trays if necessary.

Warning: Do not touch the electrodes or internal components immediately after use, as residual charge may still be present.

4 Using the System

This section provides a comprehensive guide on how to operate each function of the electrostatic separation system. It includes step-by-step instructions, descriptions of the required input and output, and considerations for user safety and efficiency.

4.1 Loading the Mixture

To begin, ensure the system is properly set up, and the feeder tray is securely attached. Gradually pour the silicon-silver mixture into the feeder tray, taking care not to overload it. This ensures an even flow of material into the system, which is essential for efficient separation. This can be done by integrating this prototype, with the existing prototype where the mixture from the rollers with sharp teeth is fed directly to the feeder tray. Figure 3 highlights the feeder tray.

Figure 3: The feeder tray.

4.2 Electrostatic Charging

Once the mixture enters the system, the electrostatic charging mechanism starts. The voltage multiplier circuit generates a high-voltage field of approximately 2000V DC, which charges the particles. The electrodes are designed to separate the materials based on their charges. Ensure the power supply is stable and that the circuit is functioning correctly. Any irregularities in voltage or field strength could affect the efficiency of the separation process.

4.3 Rotating Drum Operation

The rotating drum ensures the silicon-silver mixture is evenly distributed as it moves through the system. Activate the motor to start the drum, which rotates at a consistent speed powered by a 20W gear motor. This uniform motion is crucial for maintaining a steady flow of charged particles into the separation zone. The motor and the rotating drum are highlighted in figure 4.

Do not attempt to touch or adjust the drum while it is operating. If any issues arise, pause the system and inspect the drum for obstructions or debris before restarting.

4.4 Collection of Separated Materials

Separated materials are collected in designated trays beneath the electrodes. Ensure these trays are correctly aligned before starting the process to avoid cross-contamination. The silicon and silver particles will naturally fall into their respective trays.

Once the process is complete, carefully remove the trays and label them for identification. If necessary, clean the trays to prepare them for the next cycle. Handle the separated materials with care, as they may still carry residual charges.

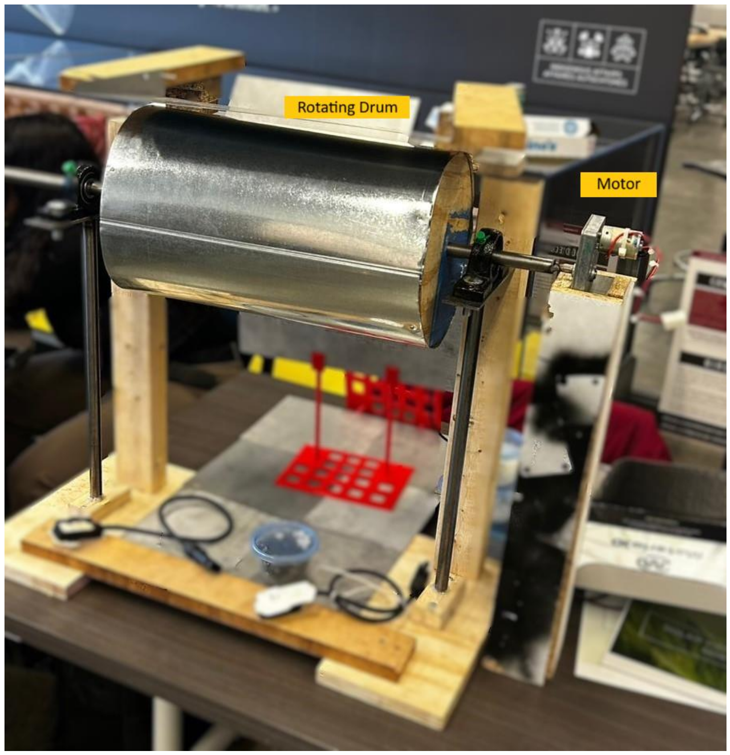

Figure 4: The motor and drum assembly.

5 Troubleshooting & Support

This section provides users with detailed instructions to address potential errors or issues that may arise while using the electrostatic separation system. It includes information on identifying common error conditions, resolving issues, and maintaining the system for optimal performance.

5.1 Potential Points of Failure

Common issues that users may encounter can be the system failing to power on, the rotating drum not moving, the electrostatic charge not activating or the feeder tray clogging. If the system does not turn on, check the power cable and outlet to ensure proper connections and functionality. For a non-functioning rotating drum, inspect it for obstructions or debris and verify that the motor connections are secure. If the electrostatic charge is not activating, the voltage multiplier circuit or electrodes may be faulty and should be inspected or replaced. Feeder tray clogs typically result from overloading. Users should remove excess material.

5.2 Special Considerations

Safety is paramount during troubleshooting. Always turn off the system and allow it to fully discharge before making any adjustments or repairs. Failure to follow this precaution could result in electrical shock. The system should only be operated in a clean, dry and well-ventilated environment to prevent issues caused by dust or moisture. Additionally, ensure that the silicon-silver mixture is free from contaminants or debris, as these can interfere with the separation process.

5.3 Maintenance

Regular maintenance is essential to ensure the system operates efficiently and reliably. Regular inspections should be performed to check for wear and tear to components such as the feeder tray, rotating drum, electrodes and collection trays. Clean these parts as necessary to avoid material buildup. Test the voltage multiplier circuit and motor to confirm they are functioning correctly and replace any worn components. Conduct a thorough system review, including recalibration of the electrodes and cleaning of all mechanical and electrical components.

5.4 Support

For urgent issues, disconnect the system from its power source and notify the support team immediately. If a security-related incident occurs, such as unauthorized access or a breach, follow emergency protocols and contact the designated security officer.

By adhering to these troubleshooting steps, maintenance guidelines and support procedures, users can ensure the safe and effective operation of the electrostatic separation system.

6 Product Documentation

This section outlines the construction, design considerations and testing of the electrostatic separation system prototype. It details how materials were selected for their specific roles, ensuring both safety and functionality and includes a combined Bill of Materials (BOM) summarizing all components.

6.1 Bill of Materials

Table 1: Detailed Bill of Materials

Item Name	Description	Quantity	Unit Cost ($)	Extended Cost ($)
Batteries	9V Alkaline	2	8.11	16.22
Steel Round Pipe	8-in x 30-in Galvanized Steel Round Pipe, 28 Gauge	1	22.00	22.00
Keyed Shafting	POWERFIST Keyed Shafting to rotate the drum	2	34.99	69.98
Motor	Gear 12VDC	1	9.99	9.99
Block Bearing	Standard Duty Pillow Block Bearing Assemblies	2	14.99	29.98

Capacitors	1uF – 400V	30	0.23	6.90
Diodes	1N4007	30	0.081	2.43
Prints and Miscellaneous				12
Shipping and Taxes	(8+2.25+3.41+13+2.53)			29.19
Total				198.69

6.2 Mechanical Subsystem

The mechanical subsystem provides the structural integrity and functional framework for the prototype. The base of the stand, constructed from plastic and wood, serves as a stable and insulated base. This prevents high-voltage electricity from traveling to unintended parts of the system. The rotating drum, made of metal, facilitates the movement and even distribution of the silicon-silver mixture. Wooden drumheads isolate the drum from the motor, ensuring that the motor and its wiring are protected from high-voltage exposure.

The collector plate, positioned beneath the electrodes, is made of metal to ground the separated particles effectively. This grounding prevents the accumulation of residual charges, which could disrupt the system's operation. The mechanical subsystem’s design emphasizes a balance of safety and efficiency, with each material chosen for its specific functional role.

6.3 Electrical Subsystem

The electrical subsystem generates the electrostatic field required for particle separation and powers the drum's motion. The voltage multiplier circuit was designed to convert a standard 120V AC input to approximately 2000V DC, enabling the electrodes to charge the particles effectively. This circuit was made up of 1N4007 diodes and 1uF capacitors with maximum voltage tolerance of 400V. Stainless steel sheets were selected for the electrodes due to its conductivity and availability, ensuring efficient particle charging.

The gear DC motor was chosen for its precision and accurate speed control, critical for maintaining a consistent feed rate and uniform distribution of particles on the rotating drum. The motor operates on 20W, making it energy-efficient while ensuring steady performance. The wooden drumheads act as isolators, protecting the motor and electrical components from potential high-voltage exposure.

6.4 Testing & Validation

The prototype could not be tested on campus due to potential fire and safety risks associated with operating high-voltage equipment. While the design and assembly followed established principles and specifications, actual performance validation was not conducted. This limitation highlights the need for future iterations to be tested in a controlled environment equipped to handle high-voltage systems safely.

The absence of direct testing does not diminish the rigor of the design process. Each subsystem was carefully planned and assembled to ensure functionality and safety. Future work should focus on testing the system in a secure facility to validate its operational effectiveness and identify potential areas for adjustments and improvement.

7 Conclusions and Recommendations for Future Work

The development of the electrostatic separation prototype provided valuable insights into the challenges and considerations involved in designing an efficient and safe recycling solution. While the project successfully addressed key design and construction goals, the inability to conduct testing due to fire and safety restrictions limited the evaluation of its performance. This highlights the need for specialized facilities equipped to safely test high-voltage systems.

The use of insulating materials like plastic and wood for isolation, combined with conductive materials like metal for key components, ensured a safe and effective design. The choice of a gear DC motor with precise speed control proved essential for achieving uniform material distribution, a critical factor for effective separation.

Thorough planning in high-voltage system design is direly needed, especially when addressing safety concerns. The inability to test the system underscored the significance of incorporating extensive simulations and partial validations during the design phase to anticipate performance under real-world conditions.

7.1 Recommendations for Future Work

Future iterations of this project can focus on the following areas:

1. Testing in a Controlled Environment: The prototype needs to be tested in a high-voltage facility equipped with proper safety measures. This will allow validation of the separation process and identification of any design flaws.

2. Integration of Safety Features: To enable testing in more general environments, additional safety features, such as high-voltage enclosures, emergency shutoff systems and grounded housings, can be integrated. These features would mitigate risks and expand testing opportunities.

3. Performance Optimization: With more time, the system's performance could be optimized by fine-tuning the alignment of electrodes, adjusting the drum's speed and exploring the optimum voltage to be produced and alternative voltage multiplier configurations for higher efficiency.

4. Modular Design: Developing modular components for easier assembly, maintenance, and scalability.

The foundation laid by this project provides a solid starting point for future work in sustainable recycling systems. By addressing the identified limitations and incorporating the recommended improvements, future teams can build upon this prototype to create a highly effective and scalable solution for recycling discarded solar panels.