# Solar Battery Project

The manual contains detailed information on the components of a solar battery system, a step-by-step procedure for a series solar panel configuration, and possible experiments.

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## Project Goals

This project will:

- Analyze how weather and sunlight intensity impact battery life and system efficiency.
- Determine system and charging efficiency loss due to ambient temperature.
- Design ideal operational performance scenarios based on observed and collected system power output and charging data.

## Key Concepts and Definitions

**Battery**

**Busbar**

**Disconnect Switches**

**Multiplus**

**Smart Battery Monitor**

**Smart Solar Charge Controller**

**Solar Panel**

**40-amp Fuse**

**200-amp Fuse**

**300-amp Fuse**

## Equipment Identification

- **Disconnect switch**: fig.1, a safety feature that stops electrical transmissions.
- **Fuse (200 amp)**: fig. 2, a safety device that protects the system from overcurrent.
- **Multiplus**: fig. 3, performs the function of an inverter and charger as needed.
- **Smart solar charge controller**: fig. 4, regulates charge flow between panel and battery.
- **Solar panel**: fig. 5, a device used to capture solar energy.
- **Busbars**: fig. 6, a power distribution hub that gathers electricity and routes it to various output lines.
- **Fuse (300 amp)**: fig. 2, a safety device that protects the system from overcurrent.
- **Smart battery monitor**: fig. 7, Bluetooth device that shows real time data.
- **Batteries**: fig. 8, a device that stores energy for future use.
- **Fuse (40 amp)**: fig. 2, a safety device that protects the system from overcurrent.

# Safety Procedures

Three possible safety scenarios:

- **Electrical Faults and Short Circuits**
  - The **NEC Article 690.9** requires **overcurrent protection** for PV systems to prevent damage from electrical faults and short circuits. It mandates that circuit protection devices, such as fuses or circuit breakers, be properly sized to handle fault conditions. **NEC Article 690.13** further emphasizes the need for **ground-fault protection** devices (GFPD) in PV systems, particularly for systems over 80V, to prevent ground faults, which could lead to electrical shock or fires.
- **Battery Storage Risks**
  - The **NEC Article 706** outlines safety requirements for **energy storage systems (ESS)**, including those integrated with PV systems. It mandates proper **disconnecting means**, **ventilation**, and **thermal management** to mitigate risks like fire or chemical leaks from batteries, particularly **lithium-ion** or **lead-acid** types. This article also requires **overcurrent protection** for battery systems to prevent overheating or fires caused by excessive current.
- **Overheating of Components**
  - To prevent overheating in a PV system, **NEC Article 690.31** specifies the use of proper **wiring methods** and correctly sized conductors to ensure that the system can handle the expected current without overheating. Additionally, **NEC Article 690.15** requires clear labeling of conductors and equipment with their ampacity and temperature ratings to prevent heat buildup. **NEC Article 110.14** addresses the **temperature limitations of electrical connections** and requires that connections be made in a way that avoids overheating and potential fire hazards.

Electrical hazards can cause personal injury or danger of fire. Electrical accidents are caused by unsafe installation, unsafe equipment, unsafe environment or unsafe work practices. The following can prevent electrical hazards on the job:

- Using properly grounded tools
- Work on circuits in a de-energized state
- Use electrical hazard (EH) rated foot protection
- Wear non-conductive Class E hardhat
- Maintaining an orderly job site
- Use protective eyewear that is impact resistant and **ANSI Z87.1** approved

When installing or servicing equipment, the appropriate safety gear should be used and a lockout and tagging process should be used. Extension cords that are used during installation or maintenance should be the 3-wire type (with ground) and designed for hard or extra-hard use. **[NFPA 70E-2015]**

# Standard Operating Procedures

## Purpose: Safely charge the solar battery system using solar panels

Estimated Time: 1-2 hours

### Materials:

- Solar battery system
- Solar battery manual
- Lab key
- Safety glasses
- Multiplus
- Thermometer gun

### Safety Precautions:

- Always wear safety glasses when handling electrical connections.
- Never touch exposed wires or connectors.
- Maintain clear communication with group partners.
- Keep bystanders at a safe distance.

### Procedure:

Step #1: Collect lab key, safety and recording material (e.g. glasses, multimeter, thermometer gun) from Dr. Ravi and make sure they are in working condition.

Step #2: Go to lab to collect the solar battery system.

Step #3: Verify that the solar battery system is secure, nothing loose and ready for safe transportation.

Step #3: Transport solar battery system outside.

Step #4: Determine an appropriate location with direct sunlight.

- This location should be clear of high student traffic areas, shadows of buildings, and uneven terrain.

Step #5: Setup system.

1. Put on safety glasses.
2. Cautiously remove the solar panels from the cart.
3. Fully extend solar panel kickstands.
4. Determine the configuration: series or parallel.

a. If you choose series configuration, go to step #6.
b. If you choose parallel configuration, go to step #7.

Step #6: Series configuration.

1. Ensure the disconnect switch is off.
2. Take wires out of the cart.
3. Connect the positive wire of the first panel to the negative wire of the second panel.
4. Connect the negative wire of the first panel to the negative wire of the battery.
5. Connect the positive wire of the second panel to the positive wire of the battery.
6. Proceed to step #8.

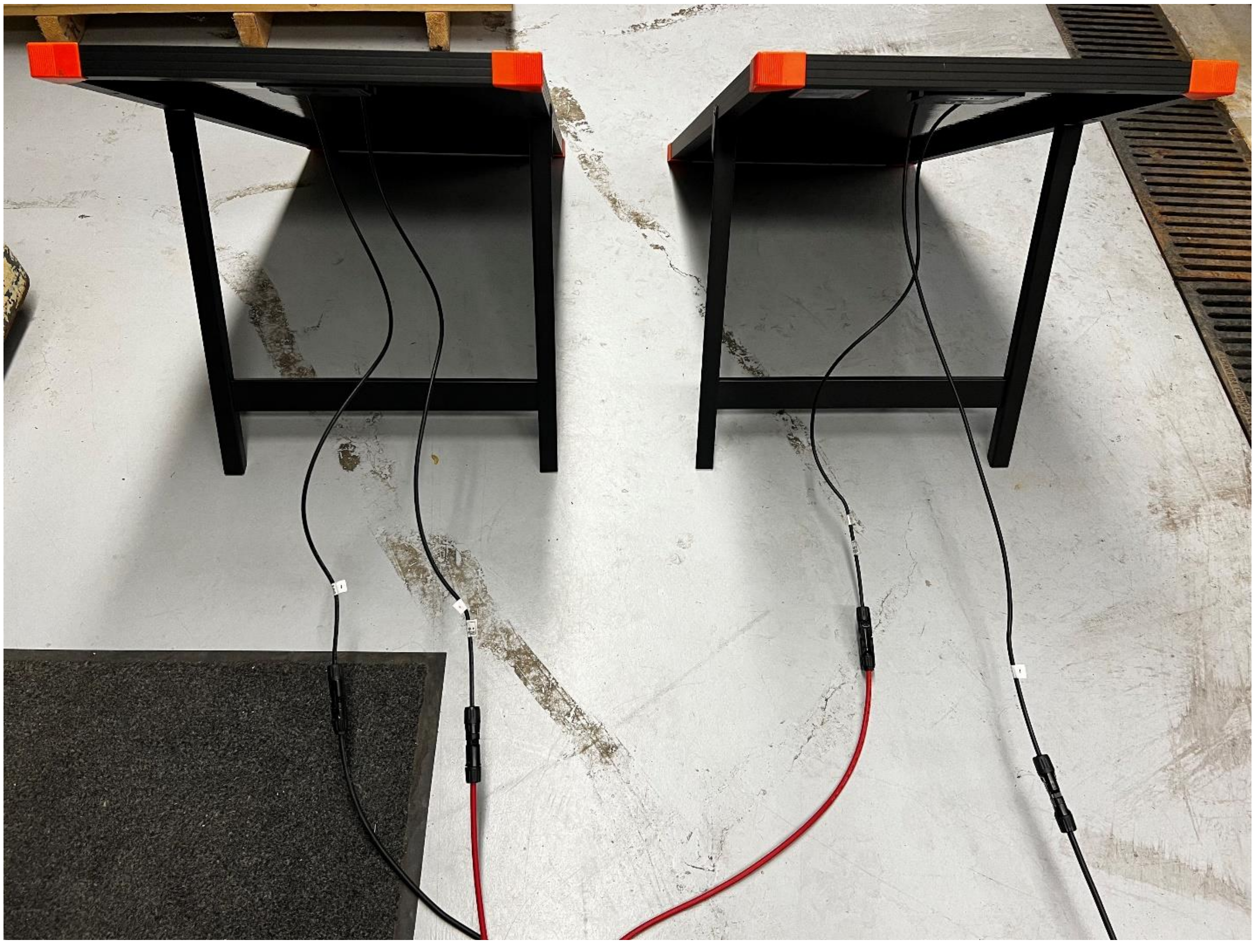
Should look like this:

Step #7: Parallel configuration.

1. Ensure the disconnect switch is off.
2. Take wires out of the cart.
3. Connect the positive wire of the first panel to the positive wire of the battery.
4. Connect the positive wire of the second panel to the positive wire of the battery.
5. Connect the negative wire of the first panel to the negative wire of the battery.

6. Connect the negative wire of the second panel to the negative wire of the battery.
7. Proceed to step #8.

Should look like this:



Step #8: Turn on system.

1. Turn the disconnect switch on (twist knob to the right).
2. Switch the multiplus to charge (the switch is located on the bottom of the device).

Step #10: Collect data and monitor the system.

1. Download the VitronConnect App from the app store to monitor system.
2. Enter app and select the device: MPPT 100/30.
3. Enter passcode for Bluetooth pairing: 00000
4. Record start time and initial readings (e.g. time, voltage, temperature).
5. Collect data in intervals of 10 minutes.

Step #11: System clean up.

1. Turn the disconnect switch off (twist knob to the left).
2. Switch the multiplus off.

3. Disconnect wires from solar panels.
4. Neatly place the wires back in the bottom of the cart.
5. Secure the solar panels to the cart with straps.
6. Return the cart to the lab.
7. Return lab key, safety and recording material to Dr. Ravi.

## Purpose: Safely drain solar battery using a lamp

Estimated Time: 1-2 hours

### Materials:

- Lamp
- Solar battery system
- Solar battery manual
- Lab key
- Safety glasses
- Multiplus

### Safety Precautions:

- Always wear safety glasses when handling electrical connections.
- Never touch exposed wires or connectors.
- Maintain clear communication with group partners.

### Procedure:

Step #1: Obtain lab key, safety and recording material (e.g. glasses and multimeter) from Dr. Ravi and make sure they are in working condition.

Step #2: Go to lab to begin battery draining.

Step #2: System setup.

1. Put on safety glasses.
2. Record initial battery voltage.
3. Verify lamp is in working condition.
4. Connect lamp to the outlet attached to the battery system.

Step #3: Turn on system.

1. Turn the disconnect switch on (twist knob to the right).
2. Switch the multiplus on (the switch is located on the bottom of the device).
3. Switch on the lamp.

Step #7: Collect data and monitor the system.

1. Record start time and initial readings (e.g. time and voltage).
2. Collect data in intervals of 10 minutes.

Step #7: System clean up.

1. Turn disconnect switch off (turn knob to the left).
2. Switch off multiplus (the switch is located on the bottom of the device).
3. Turn off lamp.
4. Unplug lamp from outlet.
5. Store equipment properly.
6. Return lab key, safety and recording material to D. Ravi.

## Experiment One

Date:

Members:

Configuration:

Purpose:

Notes:

## Experiment Two

Date:

Members:

Configuration:

Purpose:

Notes:

## Experiment Three

Date:

Members:

Configuration:

Purpose:

Notes:

## Data collection

## Data Analysis

1. **Identify the different ways by which the stored energy in the battery can be used and how the energy can be replenished.**
    a. **Show theoretically how you can use the stored energy in the battery for one or more application(s) Plot graphs of energy captured, stored, used. Analyze**

**Used:**

- Lighting

    Battery: 1200WH

    Lamp uses 20W

    Amps: 20W / 12V = 1.67 amps

    ___(usable capacity)__ / 1.67 amps = ___(runtime)___

- Charging
- Transportation

**Replenished:**

- Solar panels

2. **Demonstrate the use of the stored energy for one practical condition with appropriate calculations.**
    a. **This is a practical demonstration.**
        i. **Show that you can repeated power an application (floor lamp provided) with the stored energy.**

NEEDS TO BE ANSWERED

**Scenario**: Two 100 Ah, 12 V batteries power a 200 W floor lamp.

1. **Total Stored Energy** $= 2 \times 100\,\text{Ah} \times 12\,\text{V} = 2400\,\text{Wh}$
2. **Daily Energy Consumption** $= 200\,\text{W} \times 5\,\text{hours} = 1000\text{Wh}$
3. **Days of Operation** $= 2400\,\text{Wh} \,/\, 1000\,\text{Wh} = 2.4\text{days}$

The batteries can power the lamp for 2 full days and part of the third.

ii. **Identify scenarios for operation and demonstrate the consumption of energy for your scenario.**

NEEDS TO BE ANSWERED

**Scenario**: Camping trip with a 100 W lamp used for outdoor activities.

1. **Usage**: Lamp is used for 3 hours every evening.
2. **Energy Consumption** $= 100\text{ W} \times 3\text{ hours} = 300\text{ W}$
3. **Days of Operation** $= 2400\text{ Wh} / 300\text{ Wh} = 8\text{ days}$

The batteries can power the lamp for 8 days during the camping trip.

3. **Identify the scale-up criteria for the system. -Evelyn**
   a. **This is a theoretical demonstration.**
      i. **You have the following: cooking range, TV, water heater, 3 lights (40W,100W, 150W), small refrigerator, microwave, and dishwasher.**

Cooking range: 30-Inch 5 Burner Electric Double Oven Convection Range

- Right Rear Element-Burner Power: 1,200W

TV: LED TV

- 15W

Water heater: A.O. Smith Signature 100

- 4500W

Lights

- 40W
- 100W
- 150W

Small refrigerator: Whirlpool 4.3-Cu.-Ft. Mini Refrigerator WH43S1E

- 62W

Microwave: Solwave Stainless Steel Commercial Microwave

- 1000W

Dishwasher: average dishwasher

- 1800W

      ii. **Identify the power requirements, show how this need will be met using solar battery.**

Cooking range: (used from 6-7 pm) 1200W x 1hr = 1200Wh

TV: (used from 6-10 pm) 15W x 4hrs = 60Wh

Water heater: (used from 7-8 am) 4500W x 1hr = 4500Wh

Lights

- 40W x 5hrs = 200Wh
- 100W x 5hrs = 500Wh
- 150W x 5hrs = 750Wh

Small refrigerator: 62W x 24hrs = 1488Wh

Microwave: 1000W x 0.5hr = 500Wh

Dishwasher: 1800W x 4hrs = 7200Wh

**Total Wh: 16398Wh**

iii. **What scale-up criteria is required (How many PV panels, how many batteries).**

NEEDS TO BE ANSWERED

iv. **How long can you operate on an average day.**

NEEDS TO BE ANSWERED

# Conclusion

4. **Identification of the key components of the prototype Solar Battery System. Write 1 statement (definition) of each of the key components of the systems identified as A, B, C, D...etc.**

**Disconnect switch**: a safety feature that stops electrical transmissions.

**Fuse (200 amp)**: a safety device in an electrical circuit to provide protection.

**Multiplus**: performs the function of an inverter and charger as needed.

**Smart solar charge controller**: regulator of charge flow between panel and battery.

**Solar panel**: device used to capture solar energy and generate electrons.

**Busbars**: a power distribution hub that gathers electricity and routes it to various output lines.

**Fuse (300 amp)**: a safety device in an electrical circuit to provide protection.

**Smart battery monitor**: Bluetooth device that shows real time data.

**Batteries**: device that stores electrons for future use.

**Fuse (40 amp)**: a safety device in an electrical circuit to provide protection.

5. **Familiarize with all the technical terms and relevant calculations associated with the main components of the system. Show (by theoretical calculation ONLY):**
    a. **The calculation to generate 200W of power from the two PV panels.**

    Assuming each solar panel has a power output of 100W, the total power for two panels is 200W. The calculation formula is:

    **Power = Voltage × Current**

    If the output voltage of each panel is 20V, the required current would be:

    **200W/20V = 10A**

    b. **How long will one battery be able to operate 10 200W bulbs, 50 1000W bulbs. Assume the battery capacity is 100Ah, and the power of the lights is 200W and 1000W.**

    Power demand for operating 10 lights of 200W each:

    **10 × 200 = 2000W**

    Power demand for operating 50 lights of 1000W each:

    **50 × 1000 = 50000W**

    If the battery voltage is 12V, the battery capacity is:

    **100Ah × 12V = 1200Wh**

Calculate the runtime based on power demand and battery capacity:

**Runtime for 2000W = 1200Wh/2000W = 0.6 hours**

**Runtime for 50000W = 1200Wh/50000W = 0.024 hours**

c. **A scenario where the total capacity of the two batteries is consumed in a 4 hour period**

Assume each battery has a capacity of 100Ah, so the total capacity for two batteries is 200Ah. If the battery voltage is 12V, the total energy is:

**200Ah × 12V = 2400Wh**

If the energy is consumed in 4 hours, the system power demand is:

**2400Wh/4hr = 600W**

6. **Understand the fundamental operational principles of each of the system components.**
   a. **For components A-J, write 2-3 statements, why they are needed.**

**Disconnect switch:** safety (creating a safe environment for the operator to complete any necessary repairs, maintenance, or inspections / guarantee that a particular electrical circuit is de-energized in the case of an emergency stoppage, service, or maintenance.)

**Fuse (200 amp)**: It protects the system from overcurrent, preventing damage to expensive components. It acts as a sacrificial device, breaking the circuit if current exceeds safe levels.

**Multiplus**: do not need to separate inverter and battery charge, so it provides to be easy to switch, and reduces installation complexity.

**Smart solar charge controller**: It optimizes solar panel output by adjusting voltage and current for maximum power point tracking, It prevents overcharging of batteries, extending their lifespan. It provides system monitoring and data logging capabilities for performance analysis.

**Solar panel**: It can operate employing the solar energy that is available from the sun. Each solar panel has multiple solar cells or silicon cells which are the key building blocks. These are absorb the energy from the sun and convert them into electricity for powering both houses and a variety of businesses.

**Busbars**: They provide a central point for power distribution, simplifying system wiring and maintenance. They allow for easy expansion of the system by providing multiple connection points. They help maintain system organization and reduce the risk of wiring errors.

**Fuse (300 amp)**: It provides protection for high-current sections of the system, such as between batteries and inverter. It helps prevent fire hazards by interrupting excessive current flow.

**Smart battery monitor**: It provides real-time data on battery state of charge, helping optimize system performance. It alerts users to potential battery issues, allowing for proactive maintenance. It aids in system troubleshooting by providing detailed battery performance data.

**Batteries**: It can be common in portable electronics devices such as TV, household stuffs, flashlights etc...

**Fuse (40 amp)**: It protects smaller circuits or individual components from over current. It allows for targeted protection of specific system sections, enhancing overall safety.

7. **Learn to perform safe assembly (connect) and disassembly (disconnect) the solar panel from the rest of the components.**
    a. **Before the system is powered on, when dealing with the actual battery bank we could be electrocute.**

While handling the battery or other electrical component, wear protective clothing to move them around. A poorly installed solar panel could create a solar panel fire when powered on, making sure the right connections have been made is important to the safety of the students. One safety concern unique to solar panels is called an arc flash. If you have several solar panels connected together, this could cause a high DC voltage that can electrocute you or create an electrical arc, which could be bright enough to blind you. Making sure to take the proper precautions is important, making sure you are connecting everything correctly and making sure you have the proper protective gear, like gloves and safety goggles.

b. **Identify at least 3 scenarios where a safety issue can arise BEFORE the system is powered on. How will you deal with it?**

NEEDS TO BE ANSWERED

Scenario 1: Improper Wiring or Connections

Problem: Bad polarity or loose connections during the connection of solar panels or batteries may result in electrical arcing and/or component damage.

Solution: Verify all wiring and connections to the system diagram before advancement. Ensure to check the voltage and polarity with a multimeter at each point of connection.

Scenario 2: Wires Exposed or Damaged

Problem: Exposed or damaged wires may result in accidental contact, causing electric shock or system failure.

Solution: Check all cables for wear, damage, or exposed conductors. Replace any damaged wires with insulated and correctly rated cables.

Scenario 3: Unsafe Handling of the Battery Bank

Problem: Improper handling of batteries without protection may result in exposure to toxic materials, electric shock, or dropping heavy batteries.

Solution: Always wear protective gloves, goggles, and clothing when handling batteries.

8. **Understanding the risks associated with the operation of the system.**
    a. **AFTER the system is connected and operating, identify at least 3 operational risks.**

After the solar battery system is connected and operational, three primary risks need to be managed.

First, overcharging the battery can occur if the charge controller malfunctions or is improperly set, leading to overheating or battery damage. This can be mitigated by ensuring proper controller settings, using a controller with an automatic cut-off feature, and regularly monitoring battery voltage levels.

Second, a short circuit or overcurrent can happen due to faulty wiring or improper connections, posing fire hazards and potential component damage. To address this, use appropriately rated fuses and circuit breakers, ensure proper wiring practices, and perform regular inspections for any signs of wear or damage.

Third, improper load management can result in inverter overload if too many appliances are connected, causing shutdowns or damage. This can be prevented by monitoring power consumption with a battery monitor, implementing a load management plan, and educating users on the system's capacity limits. These measures will help maintain the safe and efficient operation of the system.

9. **Identify different configurations that are possible for operating the photovoltaic panel with the battery system.**
    a. **You did your calculations for #2. Now show how you will practically assemble the system with different configurations.**

**Series configuration:**

Step 1: connect the positive wire of the first panel to the negative wire of the second panel

Step 2: connect the negative wire of the first panel to the negative wire of the battery

Step 3: connect the positive wire of the second panel to the positive wire of the battery

**Parallel configuration:**

Step 1: connect the positive wire of the first panel to the positive wire of the battery

Step 2: connect the positive wire of the second panel to the positive wire of the battery

Step 3: connect the negative wire of the first panel to the negative wire of the battery

Step 4: connect the negative wire of the second panel to the negative wire of the battery

10. **Gather data for various aforementioned configurational changes related to both solar energy capture as well as battery storage.**

a. **By now, you have calculated (#2) and assembled (#5, #6) the system. Now prove it works. Gather real data.**

NEEDS TO BE ANSWERED

11. **Identify the different ways by which the stored energy in the battery can be used and how the energy can be replenished.**
    a. **Show theoretically how you can use the stored energy in the battery for one or more application(s) Plot graphs of energy captured, stored, used. Analyze**

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12. **Demonstrate the use of the stored energy for one practical condition with appropriate calculations.**
    a. **This is a practical demonstration.**
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NEEDS TO BE ANSWERED

ii. **Identify scenarios for operation and demonstrate the consumption of energy for your scenario.**

NEEDS TO BE ANSWERED

13. **Identify the scale-up criteria for the system.**
    a. **This is a theoretical demonstration.**
        i. **You have the following: cooking range, TV, water heater, 3 lights (40W,100W, 150W), small refrigerator, microwave, and dishwasher.**

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NEEDS TO BE ANSWERED

### iv. How long can you operate on an average day.

NEEDS TO BE ANSWERED