# 1U LEO CUBESAT EPS

The electrical power system of a 1U cubesat (10\*10\*10 cm small satellite) is the subsystem in the satellite which is tasked with **Generating, storing, regulating, and distributing electrical power** to all other subsystems (e.g., OBC, ADCS, communications, payload).

Each of the tasks above are performed by different components which may include;

* **Solar array**
* **maximum power point tracking (MPPT)** for solar panels.
* **Battery pack**
* **Charge controllers**
* **DC-DC converters**
* **Switching circuits**
* **Microcontroller for monitoring**

Each of the tasks above are discussed below;

## Power generation

The primary source of power in the satellite is the sun. Harvesting of solar energy is done by the use of solar panels. Recommended solar panels are the **Triple-junction GaAs (Gallium Arsenide) cells** which have an efficiency of 26 – 30% but a cheaper option is the **Monocrystalline Si** whose efficiency can range from 18 - 22%.

The solar panels in the cubesat will be placed on four or five sides to ensure continuous power generation regardless of the satellite’s orientation towards the Sun, leaving a side for payload or/and mounting. Deployable panels, which extend after launch to increase surface area, are not commonly used in 1U cubesats but instead used in power-hungry missions.

The solar cells are connected in series at manufacturer level, forming a string (panel), hence voltages add up but current remains constant. Us as the system designers will connect the panels in parallel, obtaining a constant voltage output and the currents summing up to provide higher current levels.

From the panels, power goes to a maximum power point tracker/ charger (**MPPT**). We can choose to use an MPPT for each two panels before connecting all the panels to a common power bus instead of having only one MPPT for all the panels. This helps to reduce **mismatch losses** since their voltages differ under sunlight due to the panels facing different directions.

Blocking diodes, preferably the Schottky diode can be used to prevent the flow of current from the batteries back to the solar panels, mainly due to its low voltage drop. These can be ideally placed at the positive terminal of each panel to prevent the reverse current flow.

The MPPT extracts the maximum possible power from a solar panel under any light condition. It continuously samples voltage and current from the panel, calculates power and adjusts the load (via DC-DC converter) to find the V at which P is maximum. Maximum power point is reached which is the point with an ideal voltage at which the maximum power is delivered to the loads, with minimum losses. This is also commonly referred to as peak power voltage.

Current and voltage sensors should be put in place to protect the from short circuit current and overvoltage. The readings from these sensors can then be fed into the microcontroller chosen for the EPS and actuators used for control in case of any power issues.

If the output is higher than what is needed to charge the batteries, a buck converter is used for step down and if lower, a boost converter is used for step up.

The following is a comparison of features that can guide on the choice of solar panel;

| **Feature** | **Triple-junction GaAs** | **Monocrystalline Silicon** |
| --- | --- | --- |
| Efficiency | 28–30% | 18–22% |
| Cell Voltage (per cell) | ~2.3 V | ~0.5–0.6 V |
| Current (per cell @ AM0) | ~120 mA/cm² | ~40 mA/cm² |
| Area per face | ~85 cm² usable (per 10×10 cm side) |  |
| Power per face (sun-facing) | ~2.5–3.0 W | ~1.5–2.0 W |
| Power (5 sides total in orbit) | ~8–12 W | ~5–7 W |
| Radiation tolerance | Very High | Moderate |

*Table 1. Comparison between Triple-junction GaAs and Monocrystalline Silicon solar panels*

## Power Storage

The solar panels can be used as the primary sources of power when the sun is present but during an eclipse, they produce barely enough energy to keep the subsystems active and operational hence the need for energy storage. Also, if the energy produced is not enough or in the presence of fluctuating loads, the batteries can be used together with the solar panels to supply needed energy.

Energy is usually stored in **Lithium-ion (Li-ion)** or **Lithium-polymer (Li-Po)** cells. The connection of the batteries, either series or parallel, depends on the systems voltage and capacity specifications.

The batteries need protection and for this purpose, different sensors are integrated.

To protect the batteries from overcharge or over-discharge, **voltage sensors** are used where if the cell voltage exceeds a certain maximum safe limit, charging is stopped by the help of a microcontroller and over-discharge is detected once the cell voltage exceeds a certain minimum safe limit.

**Current sensors** are used to monitor the charge/ discharge currents and can detect overcurrent, short-circuits and other unusual charge behaviours.

Monitoring the temperature of the batteries is also important and can be done by the use of **temperature sensors** such as digital temperature sensors and thermistors. They detect overheating during charging or discharging where the action can be reduced or stopped for some time and extremely cold eclipse conditions where a resistive heater can be used to warm the batteries. Charging Li-ion cells at temperatures below freezing point can lead to lithium plating of the graphite electrode of the battery, which in turn leads to battery performance degradation and cell safety issues.

A **battery charger** is incorporated to charge the battery from the MPPT during the charging phase when sunlight is available. It ensures that the battery is safe and increases its lifespan. The battery charger follows a specific profile depending on the battery type, for example **CC-CV** for Li-ion batteries, where the charger delivers a constant current until a certain voltage is reached, then the constant voltage is maintained as the current drops below a set threshold and the battery stops charging. The battery can be simultaneously used to power the load if the load demand is higher than what the solar is able to supply.

The different activities, including response to measurements from the voltage, current and temperature sensors can be handled by the microprocessor chosen for the EPS subsystem, where different actuators can be used for example solid state switches like MOSFETs can be used to disconnect the battery during overcharging or over-discharging or a resistive heater for warming the battery at extremely low eclipse temperatures.

The batteries’ state of charge can be determined by coming up with a suitable formula to be able to translate full charge to 100% and hence transmit the data as required, either to the ground station and/or to be easily determined by the microcontroller monitoring charging and discharging of the batteries.

## Power Distribution

Unregulated voltage from the battery can now be regulated into the different voltages required for the system’s operation. The battery voltage is converted to the required voltage by a dc-dc converter (buck or boost). If only one voltage level is required, say 4.2V, then only one voltage rail is fed into from the battery and is used to supply the load. Otherwise, different rails can be supplied each with its own voltage level to meet the different subsystems’ requirements. For example, when using RF transmitters, a voltage rail of 12V can be added, with another voltage rail of fewer voltages to power the microcontrollers.

The loads too need protection. Components like the different microcontrollers and payloads need to be protected. Switching and load control allows the microcontroller or EPS to enable or disable power to specific subsystems or components. This is critical for power budgeting, fault recovery, and mission safety.

This is critical for;

**Power saving** – Turn off non-critical loads during eclipse.

**Fault isolation** – Disable malfunctioning subsystems remotely.

**Mission control** – Schedule when payloads are active.

Each power rail should have its voltage and current monitored for the following reasons;

* Power usage tracking
* Fault detection
* Load shedding if needed

**Components & Methods Used**

**1. MOSFETs (Most Common)**

* Used as electronic switches.
* Controlled via microcontroller GPIO
* Fast, low-loss switching

**2. Load Switch ICs**

* Integrated MOSFET with control logic
* Features like:
  + Over-current protection
  + Soft start
  + Thermal shutdown

**3. Latching Relays (Less common in 1U CubeSats)**

* For mechanical switching.
* Uses pulse to latch or unlatch

**4. Solid State Relays (SSR)**

* Fully electronic, used in higher voltage designs

## Conclusion

The EPS of the cubesat is the subsystem which supplies the whole satellite with power.

Power can be effectively managed by using the power directly from the solar if sufficient sunlight is present, at the same time charging the batteries.

MPPTs are used to continuously adjust the voltage and current drawn from solar panels to operate at the point where the product of voltage and current (i.e., power) is maximized.

The EPS requires different protection mechanisms and intergrated sensors to protect the system from different power faults.