



Design and Implementation of a Power Management Unit for a Microsatellite Using MPPT-Based Solar Energy Optimization

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Abstract— Microsatellites have become essential tools for space missions such as Earth observation, scientific experimentation, and communication systems. Due to their compact size and limited onboard resources, efficient power management systems are required to ensure reliable operation. This research presents the design and implementation of a Power Management Unit (PMU) for a $50 \times 50 \times 50$ cm³ microsatellite platform. The proposed system utilizes six solar panels generating 20 V to supply multiple voltage levels required by satellite subsystems, including 28 V, 5 V, 3.3 V, and 3 V. A Maximum Power Point Tracking (MPPT) approach based on the Perturb and Observe algorithm is implemented to maximize solar energy extraction under varying environmental conditions. A DC–DC boost converter is designed to increase the solar panel output from 20 V to 28 V, while low-dropout regulators are employed to generate lower voltage levels required by onboard electronics. The system also integrates sensing and protection mechanisms, including current, voltage, and temperature sensors, along with latch-up protection circuits to enhance system reliability in harsh space environments. Simulation and hardware implementation results demonstrate stable voltage regulation and effective power distribution across the microsatellite subsystems. The proposed power management unit improves energy efficiency, reliability, and operational sustainability for microsatellite missions.

Keywords—Microsatellite Power Systems, Maximum Power Point Tracking, Power Management Unit, DC–DC Boost Converter, Solar Energy Systems, Satellite Power Distribution

I. INTRODUCTION

Microsatellites have gained increasing importance in space missions due to their relatively low cost, reduced development time, and flexible deployment capabilities. These small satellites are widely used for applications such as Earth observation, environmental monitoring, communication systems, and scientific experimentation [1].

One of the most critical subsystems of a microsatellite is the electrical power system. The power subsystem is responsible for generating, converting, regulating, and distributing electrical energy to various onboard components. Because microsatellites operate in energy-constrained environments, efficient power management strategies are required to ensure mission success [2].

Solar panels serve as the primary energy source for most microsatellites. However, the energy generated from solar panels can vary depending on factors such as solar irradiation, temperature, and satellite orientation. These variations can significantly affect the performance of the power system [3].

To address this challenge, Maximum Power Point Tracking (MPPT) techniques are commonly implemented to ensure that solar panels operate at their optimal power output. By continuously adjusting the operating point of the photovoltaic array, MPPT algorithms maximize the energy extracted from solar panels [4].

This research focuses on the design and implementation of a power management system capable of generating and distributing multiple voltage levels required for microsatellite subsystems while ensuring efficient power utilization.

II. LITERATURE REVIEW

The electrical power subsystem is one of the most vital components of a satellite system. It includes the power generation unit, energy storage unit, power conditioning circuits, and power distribution network [5].

Solar cells used in satellite systems typically consist of multi-junction photovoltaic cells designed to achieve high efficiency under space conditions. Advanced triple-junction solar cells have demonstrated efficiencies above 30%, making them suitable for space applications [6].

Two primary methods are commonly used for extracting energy from solar arrays in satellite systems: Direct Energy Transfer (DET) and Maximum Power Point Tracking (MPPT). DET systems transfer energy directly from solar panels to the load but may operate at non-optimal power points under varying environmental conditions [7]. In contrast, MPPT systems dynamically adjust the operating voltage to maximize power output [4].

Among various MPPT algorithms, the Perturb and Observe (P&O) algorithm is widely adopted because of its simplicity and reliability in tracking the maximum power point of photovoltaic systems [8].

Power conversion is also an essential part of satellite power systems. DC-DC converters are widely used to regulate and convert voltages to required levels for onboard electronics [9]. Boost converters are particularly useful when the required bus voltage is higher than the solar panel output voltage [10].

Recent research has also highlighted the importance of efficient power distribution and monitoring systems in microsatellites to ensure stable operation and fault tolerance [11].

III. METHODOLOGY

A. System Architecture

The proposed power management system consists of five main subsystems:

- Solar Power Generation Unit
- MPPT Control System
- DC-DC Boost Converter
- Power Distribution Unit
- Sensing and Protection Unit

Six solar panels are connected in parallel to generate approximately 20 V and 1.6 A of electrical power, which serves as the primary energy source for the microsatellite system.

B. MPPT Algorithm Implementation

The Perturb and Observe (P&O) algorithm is implemented using the MSP430F5529 microcontroller. This algorithm periodically perturbs the operating voltage of the solar panels and observes the resulting change in output power.

If the power increases after a perturbation, the system continues adjusting the voltage in the same direction. If the power decreases, the perturbation direction is reversed.

This iterative process allows the system to converge toward the maximum power point of the photovoltaic array [12, 13].

C. Boost Converter Design

A DC-DC boost converter is designed to step up the solar panel output voltage from 20 V to 28 V. The converter consists of an inductor, MOSFET switching device, diode, and output capacitor.

The duty cycle required for the boost converter is calculated using:

$$D = 1 - \frac{V_{in}}{V_{out}}$$

Using an input voltage of 20 V and output voltage of 28 V, the duty cycle is approximately 0.29.

Boost converters are commonly used in satellite power systems because they provide efficient voltage step-up conversion with minimal component count (Garcia et al., 2013).

D. Sensing And Protection System

To ensure system reliability, several sensing and protection mechanisms are incorporated:

- Current sensors to monitor current flow
- Voltage sensors for system voltage monitoring
- Temperature sensors for thermal protection
- Latch-up protection circuits to prevent radiation-induced failures

These monitoring systems enable real-time system protection and fault detection in space environments (Ali et al., 2020).

IV. RESULTS AND DISCUSSION

The proposed power management system was validated through simulation and hardware implementation.

Simulation results confirmed that the solar panel array could generate the required 20 V supply voltage under nominal conditions. The DC-DC boost converter successfully increased the voltage to 28 V as required for the satellite power bus.

Voltage regulators were implemented to provide stable outputs of 5 V, 3.3 V, and 3 V for powering onboard electronics and sensors.



Testing of the sensing units confirmed accurate monitoring of system parameters, enabling real-time control of the power distribution network.

Overall, the results demonstrate that the designed power management system can effectively regulate voltage levels and distribute electrical power efficiently across microsatellite subsystems.

V. CONCLUSION

This study presented the design and implementation of a power management system for microsatellite applications. The proposed system integrates solar energy harvesting, MPPT control, voltage conversion, and power distribution within a compact architecture.

The implementation of the Perturb and Observe MPPT algorithm ensures optimal energy extraction from solar panels, while the boost converter and voltage regulators provide stable power levels for different satellite subsystems.

Simulation and hardware testing confirm that the system provides reliable power management for microsatellite operations.

Future work may involve implementing advanced MPPT techniques, integrating battery storage systems, and improving thermal management for long-duration space missions.

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REFERENCES

- [1] Bouwmeester, J., & Guo, J. (2010). Survey of worldwide pico- and nanosatellite missions. *Acta Astronautica*.
- [2] Patel, M. R. (2004). *Spacecraft Power Systems*. CRC Press.
- [3] Tatem, A. J., Goetz, S. J., & Hay, S. I. (2008). Fifty years of Earth observation satellites. *American Scientist*.
- [4] Erb, D. (2011). Evaluating the effectiveness of peak power tracking technologies for solar arrays on small spacecraft.
- [5] Tsamsakizoglou, M., Löfgren, H., & Gunnarsson, M. (2017). Microsatellite power control and distribution unit for the InnoSat platform.
- [6] Fetzer, C., et al. (2008). Production ready 30% efficient triple junction space solar cells. *IEEE Photovoltaic Specialists Conference*.
- [7] Rojas, J. J., Takashi, Y., & Cho, M. (2020). Lean satellite electrical power system with direct energy transfer and bus voltage regulation. *Aerospace*.
- [8] Ait Ayad, I., Elwarraki, E., & Baghdadi, M. (2021). Intelligent perturb and observe based MPPT approach using multilevel DC-DC converter to improve PV production system. *Journal of Electrical and Computer Engineering*.
- [9] Ajami, A., Ardi, H., & Farakhor, A. (2015). A novel high step-up DC/DC converter for renewable energy applications. *IEEE Transactions on Power Electronics*.
- [10] Garcia, O., Alou, P., Oliver, J., Diaz, D., Meneses, D., Cobos, J., Soto, A., Lapena, E., & Rancano, J. (2013). Comparison of boost-based MPPT topologies for space applications. *IEEE Transactions on Aerospace and Electronic Systems*.
- [11] Ali, A., Ali, H., Tong, J., Mughal, M. R., & Rehman, S. U. (2020). Modular design and thermal modeling techniques for the power distribution module of a microsatellite. *IEEE Access*.
- [12] Egwa, S., Justin, U., Okoli, C., Salihu, R., & Ejiofor, O. (2021). Analysis of a charge controller circuit with maximum power point tracker for photovoltaic systems.
- [13] Salman, S., Ai, X., & Wu, Z. (2018). Design of a P&O algorithm based MPPT charge controller for PV systems. *Protection and Control of Modern Power Systems*.