A Study on High-Efficiency Operation of a Competition Solar Car

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Introduction

Photovoltaic (PV) systems have attracted considerable attention as Japan strives to achieve carbon neutrality by 2050 and to introduce 36–38% renewable energy by fiscal year 2030. In fiscal year 2021, solar power accounted for a substantial portion of Japan's renewable energy capacity. In the automotive sector, competitions featuring vehicles powered by solar energy have been held annually in Australia since 1987. Despite this progress, the power generation capacity of current solar cells remains insufficient for practical use in automobiles. Nevertheless, the challenge of maximizing vehicle travel distance under limited power supply has become a major motivation for solar car racing. Building upon this context, the present research aims to contribute to the advancement of sustainable electric vehicle technology.

Improvement Plan for a Competition Solar Car Aimed at High-Efficiency Operation

This study investigates the design and performance enhancement of an electrical system for achieving high-efficiency operation in a competition solar car. The solar car used in this experiment is shown in Figure 1. The vehicle is equipped with monocrystalline silicon solar cells, lithium-polymer batteries, and in-wheel brushless DC motors (BLDCs). Key features include the adoption of lithium-polymer batteries and reduced current consumption through system voltage boosting, which minimizes wiring losses and improves transmission efficiency. For energy management, maximum power point tracking (MPPT) control is implemented. In the developed system, MPPT devices are attached to each PV module to enable individual control, thereby improving power generation efficiency. Each MPPT module is realized using a high-performance switching IC [1] capable of low-voltage operation. The design adopts a boost-type DC–DC converter with PWM control and synchronous rectification. Based on MPPT calculation results, the PWM duty ratio (5–90%, with 2% control steps) is adjusted to optimize output voltage and current. [2] This design allows simple replacement of conventional bypass diodes while maintaining high efficiency, enabling effective utilization of generated power even under partial shading conditions. Building upon this system, we plan to replace the lithium-polymer batteries with cylindrical lithium-ion batteries beginning this fiscal year, thereby aligning the design with storage batteries more commonly used in electric vehicles. To verify improvements in efficiency and reliability, driving tests will be conducted at the former runway in Shirahama Town, Wakayama Prefecture in November 2025, during which data on power consumption, voltage behavior, motor output, and related parameters will be collected.

Discussion

The proposed distributed MPPT system is expected to enhance photovoltaic energy utilization by reducing power losses and enabling effective operation even under partial shading. The high-voltage configuration should minimize wiring losses and improve motor performance, contributing to more efficient driving in competition settings. Furthermore, replacing lithium-polymer batteries with cylindrical lithium-ion batteries is anticipated to improve system reliability and bring the design closer to practical electric vehicle applications. These expected outcomes indicate the potential of the proposed approach to support sustainable electric vehicle technologies and efficient renewable energy utilization.

Figure 1 solar car

References

[1] K. Yamashita, "STMicroelectronics launches boost DC–DC converter IC with MPPT function for photovoltaic power generation," Nikkei Technology, Jun. 2010.

[2] T. Matsuyama et al., "Experimental Introduction of Distributed Maximum Power Point Tracking Systems for PV System and Effect Applied to Solar Car," Research Paper , pp. 1, Feb. 14, 2014.