UDC 621.316.727

OPTIMIZED CONTROL SYSTEM FOR WIRELESS CHARGING OF AUTONOMOUS UAVs

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Introduction: The rapid advancement of autonomous unmanned aerial vehicles (UAVs) has revolutionized industries such as logistics, smart agriculture, surveillance, and environmental monitoring. However, a significant limitation of these systems is their reliance on battery power, which restricts flight duration and operational range. Wireless charging technology offers a promising solution by enabling UAVs to recharge without physical connectors, enhancing their autonomy [1]. Efficient wireless power transfer (WPT) requires precise alignment between the UAV's receiver and the charging station's transmitter, a challenge compounded by the dynamic nature of UAV positioning [2]. Charge control systems address this by adjusting power delivery parameters to maintain efficiency despite misalignment or environmental variations [3]. This paper explores an optimized control system for wireless charging of autonomous UAVs, focusing on phase shift adjustments and wireless communication to optimize performance.

Main Part: The optimized control system for wireless charging of autonomous UAVs relies on real-time adjustments to maintain efficient power transfer. A key mechanism in this system is the shift of the phase angle between current and voltage, which directly influences the power delivered to the UAV's battery. In an ideal scenario, the transmitter and receiver coils are perfectly aligned, ensuring that the current and voltage are in phase, maximizing power transfer efficiency [1]. However, when the UAV is misaligned—due to hovering and landing inaccuracies or external factors like wind—the phase angle shifts, reducing efficiency and potentially causing power loss or instability [2]. To address this, the proposed system incorporates a wireless communication module based on the nRF protocol, a robust and low-power standard commonly used in IoT applications [4]. A current and voltage sensor on the UAV measures the current and voltage at the rectifier, which is present on the UAV, capturing deviations caused by misalignment. These readings are transmitted wirelessly via the nRF protocol to the charging station. The inverter section includes a microcontroller with high-resolution timers to control the switching process of the MOSFETs and it processes this received data to determine the extent of the phase shift. Based on this information, it adjusts the phase angle of the transmitted power signal to realign the current and voltage, restoring optimal charging conditions [5]. The adjustment process is governed by a variable proportional-integral-derivative (PID) control strategy. Unlike a static PID controller, the proposed variable version is optimized to continuously tunes its parameters—proportional, integral, and derivative gains—based on the range of incoming sensor data. When misalignment occurs, the controller calculates the necessary phase shift correction and applies it through changes in inverter switching, ensuring that the system responds swiftly and accurately. This dynamic tuning compensates for varying degrees of misalignment, maintaining stable and efficient power transfer without requiring manual intervention. By integrating phase angle control with wireless feedback, the system enhances the UAV's ability to charge autonomously, even under imperfect conditions.

Conclusion: The optimized control system described offers a practical approach to improving wireless charging for autonomous UAVs. By leveraging phase shift angle adjustments and the nRF protocol for real-time communication, the system effectively mitigates the challenges of misalignment, ensuring consistent power delivery. The use of a variable PID control strategy further enhances its responsiveness, making it suitable for the unpredictable environments in which UAVs operate. As UAV applications continue to expand, such innovations in charging technology will be critical to extending their operational capabilities. Future developments could explore integrating machine learning to predict misalignment patterns, further refining the system's adaptability and efficiency.

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