

**DESIGN AND DEVELOPMENT OF AN OPTICAL SENSOR-BASED SOILING
SCANNER FOR SOLAR PANELS**

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ABSTRACT

Soiling is the accumulation of dust on the surface of solar panels that reduces power output, while conventional monitoring methods are subjective and inefficient. This study designed, built, and tested an optical sensor-based Soiling Scanner system to detect Soiling levels in real time. The system uses three pairs of LED-photodiode sensors, an ESP32 microcontroller, and a NEMA 17 stepper motor to scan the surface of the test glass in a 3×3 grid configuration; the data is transmitted via the MQTT protocol and visualized on a Python dashboard. Tests were conducted using four different amounts of wheat flour (0, 5, 10, and 15 grams) to simulate contaminants. The results showed that the Soiling index increased consistently from 0.05% under clean conditions to 9.12% under the 15-gram condition. Statistical analysis on the 3×3 grid configuration (average, minimum, maximum, and standard deviation) successfully mapped the heterogeneous characteristics of Soiling distribution, proving that this multi-point scanning method is more representative than single-point measurement.

Keywords: *Soiling, optical sensor, ESP32, MQTT, solar panel*