

INTISARI

Penggunaan perangkat listrik di lingkungan laboratorium membutuhkan sistem *monitoring* dan pengendalian energi yang dapat bekerja secara real-time, terjadwal, dan aman. Pada Smart Laboratory EcoLab, sistem tersebut diperlukan untuk memantau konsumsi energi dan mengendalikan beban listrik melalui antarmuka yang mudah digunakan. Proyek Akhir ini bertujuan untuk merancang dan mengimplementasikan *Smart Socket* berbasis *Internet of Things* (IoT), mengembangkan fitur pengendalian terjadwal, serta menerapkan mekanisme keamanan komunikasi MQTT.

Sistem yang dikembangkan terdiri atas lima perangkat *Smart Socket* dengan ESP32-C3 sebagai pengendali utama, sensor PZEM-004T sebagai pembaca parameter energi, RTC DS1302 sebagai sumber waktu lokal, TRIAC BTA24 sebagai pengendali beban AC, dan EcoLab Dashboard berbasis Python/PySide6 sebagai antarmuka *monitoring* dan kontrol. Pengujian dilakukan terhadap fungsi *monitoring* energi, kontrol relay, validasi sensor, *timer*, penjadwalan mode *daily* dan *onetime*, serta komunikasi MQTT dengan TLS, autentikasi, CA certificate, dan rancangan *Access Control List*.

Hasil pengujian menunjukkan bahwa EcoLab Dashboard mampu menampilkan parameter energi berupa tegangan, arus, daya, energi, frekuensi, dan power factor secara *real-time* serta mengontrol kondisi relay *Smart Socket*. Validasi sensor menunjukkan *percentage error* tegangan sebesar 1,01% pada skenario beban blower dan 1,07% pada skenario beban blower dan kipas angin, sedangkan *percentage error* arus sebesar 2,36% dan 1,81%. Fitur *timer* dan *schedule* berhasil mengendalikan *Smart Socket* sesuai waktu yang ditentukan. Selain itu, pengujian komunikasi menunjukkan bahwa koneksi MQTT hanya berhasil ketika konfigurasi *broker*, port, autentikasi, TLS, dan CA certificate sesuai. Dengan demikian, sistem yang dikembangkan telah mampu mendukung *monitoring* energi, pengendalian ON/OFF beban terjadwal, dan komunikasi MQTT yang lebih aman pada Smart Laboratory EcoLab.

Kata kunci: *Smart Socket*, IoT, *monitoring* energi, MQTT, TLS

ABSTRACT

The use of electrical devices in a laboratory environment requires an energy monitoring and control system that can operate in real time, on a scheduled basis, and safely. At the Smart Laboratory EcoLab, such a system is needed to monitor energy consumption and control electrical loads through an easy-to-use interface. This final project aims to design and implement an Internet of Things (IoT)-based Smart Socket, develop scheduled control features, and implement MQTT communication security mechanisms.

The developed system consists of five Smart Socket devices with an ESP32-C3 as the main controller, a PZEM-004T sensor as the energy parameter reader, a DS1302 RTC as the local time source, a BTA24 TRIAC as the AC load controller, and an EcoLab Dashboard based on Python/PySide6 as the monitoring and control interface. Testing was conducted on energy monitoring functions, relay control, sensor validation, timers, daily and one-time mode scheduling, as well as MQTT communication with TLS, authentication, CA certificates, and Access Control List (ACL) design.

Test results show that the EcoLab Dashboard is capable of displaying energy parameters such as voltage, current, power, energy, frequency, and power factor in real-time, as well as controlling the relay status of the Smart Socket. Sensor validation showed a voltage percentage error of 1.01% in the blower load scenario and 1.07% in the blower and fan load scenario, while the current percentage error was 2.36% and 1.81%. The timer and scheduling features successfully controlled the Smart Socket according to the specified times. Additionally, communication testing showed that the MQTT connection was successful only when the broker, port, authentication, TLS, and CA certificate configurations were correct. Thus, the developed system has been able to support energy monitoring, scheduled load control, and more secure MQTT communication in the EcoLab Smart Laboratory.

Keywords: Smart Socket, IoT, energy monitoring, MQTT, TLS