PROJECT ABSTRACT

# Capacitor Bank Health Monitor with Dashboard

A per-stage capacitor bank health monitor: scheduled self-tests estimate each stage's effective capacitance from its current draw, with degradation trending, temperature watch, watch/fail thresholds and a web dashboard. Delivered built-to-order with demo bank panel, firmware, dashboard, report, PPT and viva kit.

## 01. Title

Capacitor Bank Health Monitor with Dashboard

## 02. Introduction / Background

Power-factor-correction capacitor banks degrade quietly. Metallized-film capacitors lose capacitance as their self-healing events accumulate, cans run hotter as losses rise, and one failed stage silently shifts the whole bank below its design kVAr — until the utility's power-factor penalty arrives to announce it on the bill. Most plants discover this at billing time because nobody measures individual stages, and manual checks need shutdowns plus an LCR meter per can. This project makes bank health visible: a monitoring add-on that self-tests each stage, estimates effective capacitance from the stage current it actually draws, watches temperature per stage, and presents degradation trends with watch/fail alerts on a dashboard.

## 03. Problem Statement

Students study power-factor correction and contactor switching in theory but rarely see how capacitor ageing announces itself electrically — falling stage current, rising can temperature, shrinking effective kVAr. Without per-stage measurement there is no way to demonstrate condition monitoring on an APFC bank. The project addresses this with automated per-stage self-tests that estimate capacitance electrically, trend it over time, and hold failed stages off — showing the full sense-judge-act maintenance loop on a low-voltage demo bank.

## 04. Objectives

- Estimate each stage's effective capacitance during an isolated self-test from $C = I / (2\pi fV)$, using measured stage current and bus voltage — no LCR meter needed.
- Trend per-stage deviation against a buyer-calibrated nameplate baseline in a deviation chart.
- Raise a watch alert at −15% deviation (plan replacement) and mark fail/hold-off at −25% deviation, automatically excluding failed stages from the switching sequence.
- Monitor per-stage can temperature with NTC sensors and flag thermal anomalies against the bank mean.

- Compute a 0–100 bank health index from stage deviations, temperatures and failed-stage count.
- Deliver the complete student kit: demo bank panel, ESP32 firmware, dashboard, calibration procedure, report, PPT and viva Q&A.;

## 05. Proposed Methodology

The system is developed in three stages. (1) Demo bank: six capacitor stages (10 / 15 / 15 / 20 / 20 / 20 kVAr, 100 kVAr total, scaled demo cans) wire through contactors, each with an ACS712-class current sensor and an NTC thermistor. (2) Self-test sequencer: at the scheduled test (design 06:00 daily, or on demand) the ESP32 switches each stage in alone while other loads are steady, measures the stage's reactive current and the bus voltage, and estimates capacitance from $C = I / (2\pi fV)$. (3) Judgement and display: each estimate is compared with the buyer-calibrated nameplate baseline; −15% raises a watch alert, −25% marks the stage failed and holds its contactor off while the bank's effective kVAr is recomputed. Temperatures are sampled continuously against the bank mean, and everything publishes over MQTT to the dashboard with a timestamped event log.

## 06. System Architecture / Working

The 6-stage demo panel provides the power hardware; per-stage current sensors and NTC thermistors feed the ESP32, which runs the self-test sequencer, the capacitance estimator and the threshold/hold-off logic, with local status on a 16x2 LCD plus buzzer alerts. The telemetry path is MQTT to the web dashboard, which renders the per-stage deviation chart, stage cards with temperature, the 0–100 health index and the 24-hour alert log. A failed stage is excluded from the switching sequence and the dashboard notes the rebalanced effective kVAr — demonstrating automatic derating of the bank.

## 07. Hardware / Software Requirements

- ESP32 development board (controller)
- 6-stage capacitor bank demo panel with contactors (100 kVAr scaled demo)
- ACS712-class current sensors, one per stage (6)
- NTC thermistors, one per stage (6)
- 16x2 character LCD + buzzer for local alerts
- MQTT broker + web dashboard (HTML/CSS/JS)
- Arduino IDE (C/C++ firmware)
- LCR meter access (for the buyer-run nameplate-baseline cross-check at commissioning)

## 08. Expected Outcomes

- A working demo bank whose per-stage health is self-tested, trended and dashboarded.
- Demonstrated watch and fail behavior, including automatic failed-stage hold-off and effective-kVAr recomputation.
- Buyer-verified estimation accuracy against an LCR cross-check (design target within ±10%).

- A complete report, PPT and viva Q&A; on capacitor ageing, reactive power and the estimation method.

## 09. Applications

- Teaching APFC and capacitor-bank maintenance concepts in electrical labs.
- Demonstrating condition monitoring and threshold engineering.
- Prototype platform for plant power-quality and derating studies.

## 10. Future Scope

- Harmonic-content compensation in the capacitance estimator.
- Detuned-reactor health channel.
- Automatic stage rotation for even ageing.
- Integration with a plant SCADA over Modbus-TCP.