PROJECT ABSTRACT

Three-Phase Power Quality Analyzer with THD Logging

ESP32-based three-phase analyzer measuring Vrms, Irms, THD and power factor per phase with CT clamps and on-device FFT, SD-card logging and a dashboard — built-to-order with calibration procedure, report, PPT and viva kit.

01. Title

Three-Phase Power Quality Analyzer with THD Logging

02. Introduction / Background

Nonlinear loads — VFDs, SMPS chargers, LED drivers — inject harmonic currents that distort the mains waveform, overheat neutrals and nuisance-trip protection. Utilities care about total harmonic distortion, but commercial power-quality analyzers cost more than a student budget. This project builds an educational alternative: an ESP32 analyzer that clamps onto the three phase conductors with SCT-013 split-core CTs, senses voltages through ZMPT101B isolation modules, samples each channel at roughly 2 kS/s, and computes a 512-point FFT per phase for THD and the harmonic spectrum to the 15th harmonic. Results log to SD card as timestamped CSV while a dashboard renders live readings, waveforms and trends against the IEEE 519 guidance line.

03. Problem Statement

Students learn THD as a formula but never measure it on a real distorted waveform. The project addresses this with a buildable instrument: per-phase voltage, current, THD and power factor measured on real conductors, logged over time, and analyzed against the IEEE 519 5% guidance — with accuracy established by the buyer's own calibration against a reference meter, stated honestly as ±2% typical after calibration.

04. Objectives

- Sense three-phase voltage and current non-invasively with ZMPT101B modules and SCT-013 split-core CT clamps.
- Compute per-phase THD and harmonic spectra on-device with a 512-point FFT (Hann window, to the 15th harmonic).
- Log Vrms, Irms, THD and PF per phase to SD card as NTP-timestamped CSV.

- Deliver a dashboard (live cards, waveform, spectra, 24-h trend), a reference-meter calibration procedure, report, PPT and viva Q&A.

05. Proposed Methodology

The ESP32 ADC samples each voltage and current channel at roughly 2 kS/s, synchronized to the mains cycle. A 512-point FFT with Hann windowing extracts the fundamental and harmonic magnitudes to the 15th harmonic per phase; THD is the RMS of harmonics over the fundamental. Vrms, Irms and displacement power factor come from the time-domain samples. Results update the local TFT immediately and append to the SD CSV once per minute. During commissioning the buyer runs the calibration procedure against a reference meter and stores ratio/phase correction factors.

06. System Architecture / Working

The system has four blocks. (1) Sensing: 3x SCT-013 CTs on R/Y/B conductors, 3x ZMPT101B isolated voltage taps. (2) Processing: ESP32 sampling engine + FFT + THD/PF computation. (3) Storage/display: SD-card CSV logging with NTP timestamps; local TFT showing Vrms/THD/PF per phase. (4) Presentation: web dashboard with live cards, reconstructed waveform, harmonic bar charts, 24-hour THD trend with IEEE 519 guidance line, and CSV export.

07. Hardware / Software Requirements

- ESP32 DevKit development board
- 3x SCT-013 split-core current transformers (0–100 A)
- 3x ZMPT101B voltage transformer modules (isolated, 230 V nominal)
- SD-card module (FAT32), TFT display, 5 V supply
- Arduino IDE / ESP32 Arduino core firmware; reference meter for calibration
- Single-file HTML/CSS/JS dashboard

08. Expected Outcomes

The student receives a working analyzer: per-phase Vrms, current, THD and PF on the display and dashboard, harmonic spectra identifying dominant harmonics (e.g. the 5th), and minute-resolution CSV logs. Accuracy of ±2% typical on V/I applies after the buyer's reference-meter calibration — uncalibrated error is larger, and the report documents both states. The instrument is educational, not a certified revenue meter.

09. Applications

- Electrical lab teaching: THD, FFT, CT instrumentation, IEEE 519
- Small-industry power-quality surveys (advisory, non-certified)
- VFD and nonlinear-load harmonic studies

- Base build for neutral-current or sag/swell monitoring

10. Future Scope

- Neutral-current and voltage sag/swell event capture
- Cloud upload of daily logs for multi-site comparison
- Automatic load-identification from harmonic signatures
- Calibration against a higher-class reference for tighter accuracy claims