# PHASE POWER METERING AND MONITORING SYSTEM DEVELOPMENT.

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# OBJECTIVES

1. Develop a microcontroller-based system to meter, monitor, and control a 3-phase power output.
2. Display real-time power status on a screen.
3. Support multiple connectors for power outputs.
4. Utilize a 32-bit microcontroller (STM32F411CEU6) and develop firmware in C/C++.

# LITERATURE REVIEW

Accurate metering and monitoring of three-phase power systems are essential in smart grid and industrial applications due to the need for real-time data and efficient control strategies [1]. Embedded systems using high-performance microcontrollers like the STM32F4 series have been widely adopted for power metering applications because of their robust ADC modules and communication interfaces [2]. Modern designs often integrate OLED displays for user-friendly real-time visualization and employ multiple connectors to flexibly manage power outputs [3]. These systems help enhance energy management and fault mitigation by continuously monitoring voltage, current, and power across all phases [4].

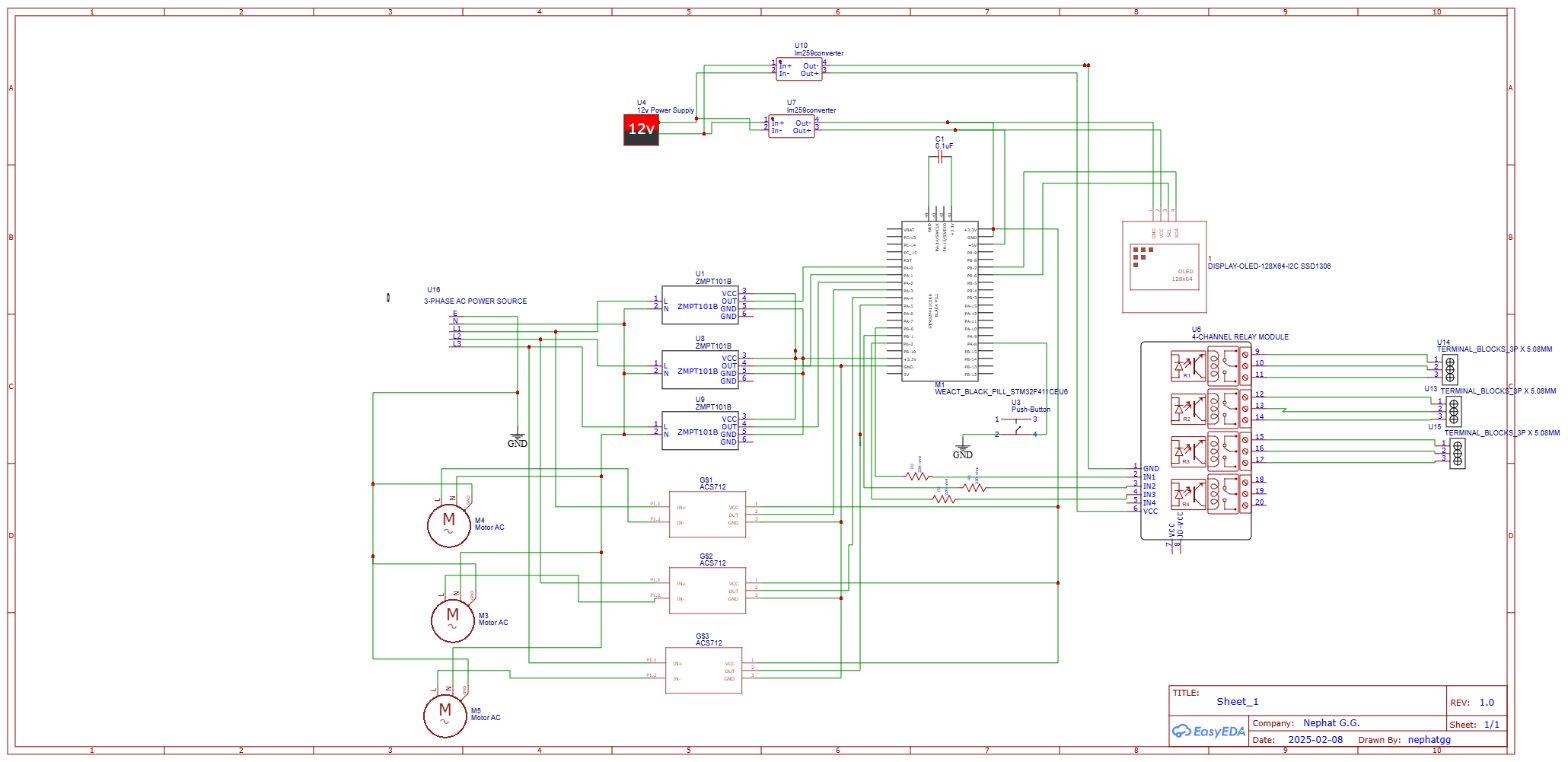
# COMPONENTS

1. **Microcontroller:** STM32F411CEU6 (Black Pill board)
2. **Display:** OLED display (SSD1306, 128×64, I2C interface)
3. **Voltage Sensors:** ZMPT101B voltage sensor modules (3 units, one for each phase)
4. **Current Sensors:**
   * Three ACS712 modules (3 units) for phases A, B, and C
5. **Relays:** 3-channel relay module (5V control, 250V AC rated)
6. **3-Phase AC Power Source:** 400V RMS (Nominal), connected through terminal blocks for safe testing and operation.
7. **Resistors:** 220Ω resistors for current-limiting in relay control lines
8. **Capacitors:**0.1 µF ceramic capacitor for high-frequency noise filtering near the microcontroller’s power pins
9. **Push Buttons:** For system reset and manual control.
10. **Power Supplies:**
    * 12V DC power supply for the relay module
    * Regulated 5 V supply (or 3.3 V as required by the STM32 and OLED) for sensors and microcontroller
11. **Terminal Blocks:** For secure connection to the three-phase power source.

# METHODOLOGY

1. **Microcontroller Setup:**
   * Configure the STM32F411CEU6 using STM32CubeMX to initialize GPIO, ADC, and I2C peripherals.
   * Set up I2C for OLED communication and ADC channels for reading voltage and current sensor outputs.
2. **Voltage and Current Measurement:**
   * Connect the ZMPT101B voltage sensors to each phase (Phase A to PA0, Phase B to PA1, Phase C to PA2) with their analog outputs connected to the ADC pins of the microcontroller.
   * Connect the ACS712 current sensors analog outputs to PA3, PA4, and PA5 respectively.
3. **Relay Control:**
   * Connect relay control inputs to digital pins PB0, PB1, and PB2 of the STM32.
   * Use 220Ω resistors in series for current limiting.
4. **Display Integration:**
   * Interface the OLED display with the STM32 via I2C (SCL to PB6, SDA to PB7) to show real-time voltage, current, and power values.
5. **Multiple Power Connectors:**
   * Provide terminal blocks connected to each relay output to support multiple loads.
6. **Power Supply:**
   * Provide a common ground between the microcontroller and sensor modules.
   * Use 0.1µF capacitors across power lines for stability.
7. **3-Phase AC Power Source:**
   * Connect each phase line to its respective voltage and current sensor module.
   * Ensure proper grounding and use protective enclosures to prevent accidental contact with high-voltage lines.
8. **Firmware Development:**
   * Develop code to read ADC values, calculate power parameters, and display them on the screen.
   * Implement relay control logic for load management.

# DIAGRAM



# CODE 1: STM32CUBEIDE (C CODE)

#include "main.h"

#include "ssd1306.h"// Assume an SSD1306 driver is available

#include <stdio.h>

#define ADC\_MAX 4096.0

#define VREF 3.3

// Calibration factors for voltage divider (example: divider ratio = 11)

#define VOLTAGE\_SCALE 11.0

// ACS712 calibration for 5A variant: sensitivity 185 mV/A, with mid offset ~1.65V (assuming 3.3V system may require adjustment)

#define CURRENT\_OFFSET (VREF/2) // 1.65V (if using 3.3V reference)

#define CURRENT\_SENSITIVITY 0.185 // V per A

ADC\_HandleTypeDef hadc1;

I2C\_HandleTypeDef hi2c1;

uint32\_t adcValues[6];

void SystemClock\_Config(void);

static void MX\_GPIO\_Init(void);

static void MX\_ADC1\_Init(void);

static void MX\_I2C1\_Init(void);

float readVoltage(uint32\_t adcValue) {

float voltage = (adcValue \* (VREF / ADC\_MAX)) \* VOLTAGE\_SCALE;

return voltage;

}

float readCurrent(uint32\_t adcValue) {

float voltage = adcValue \* (VREF / ADC\_MAX);

// Subtract offset and calculate current (A)

float current = (voltage - CURRENT\_OFFSET) / CURRENT\_SENSITIVITY;

return current;

}

void updateDisplay(float vA, float iA, float pA,

float vB, float iB, float pB,

float vC, float iC, float pC) {

char buffer[32];

SSD1306\_Clear();

sprintf(buffer, "A:%.1fV %.1fA", vA, iA);

SSD1306\_GotoXY(0, 0);

SSD1306\_Puts(buffer, &Font\_7x10, 1);

sprintf(buffer, "PA:%.1fW", pA);

SSD1306\_GotoXY(0, 12);

SSD1306\_Puts(buffer, &Font\_7x10, 1);

sprintf(buffer, "B:%.1fV %.1fA", vB, iB);

SSD1306\_GotoXY(0, 24);

SSD1306\_Puts(buffer, &Font\_7x10, 1);

sprintf(buffer, "PB:%.1fW", pB);

SSD1306\_GotoXY(0, 36);

SSD1306\_Puts(buffer, &Font\_7x10, 1);

sprintf(buffer, "C:%.1fV %.1fA", vC, iC);

SSD1306\_GotoXY(0, 48);

SSD1306\_Puts(buffer, &Font\_7x10, 1);

sprintf(buffer, "PC:%.1fW", pC);

SSD1306\_GotoXY(0, 60);

SSD1306\_Puts(buffer, &Font\_7x10, 1);

SSD1306\_UpdateScreen();

}

int main(void)

{

HAL\_Init();

SystemClock\_Config();

MX\_GPIO\_Init();

MX\_ADC1\_Init();

MX\_I2C1\_Init();

// Initialize the OLED display

SSD1306\_Init();

while (1)

{

// Start ADC conversion for all 6 channels (3 voltage sensors: PA0, PA1, PA2 and 3 current sensors: PA3, PA4, PA5)

HAL\_ADC\_Start(&hadc1);

for (int i = 0; i < 6; i++) {

HAL\_ADC\_PollForConversion(&hadc1, HAL\_MAX\_DELAY);

adcValues[i] = HAL\_ADC\_GetValue(&hadc1);

}

HAL\_ADC\_Stop(&hadc1);

// Calculate for Phase A (Voltage on PA0, Current on PA3)

float vA = readVoltage(adcValues[0]);

float iA = readCurrent(adcValues[3]);

float pA = vA \* iA;

// Calculate for Phase B (Voltage on PA1, Current on PA4)

float vB = readVoltage(adcValues[1]);

float iB = readCurrent(adcValues[4]);

float pB = vB \* iB;

// Calculate for Phase C (Voltage on PA2, Current on PA5)

float vC = readVoltage(adcValues[2]);

float iC = readCurrent(adcValues[5]);

float pC = vC \* iC;

updateDisplay(vA, iA, pA, vB, iB, pB, vC, iC, pC);

// Relay control logic (example: if power exceeds a threshold, disable output)

// Assume threshold values and GPIO control are implemented as needed.

HAL\_Delay(1000);

}

}

# CODE 2: ARDUINO IDE (C++ CODE)

#include <Wire.h>

#include <Adafruit\_GFX.h>

#include <Adafruit\_SSD1306.h>

// OLED display settings

#define SCREEN\_WIDTH 128

#define SCREEN\_HEIGHT 64

#define OLED\_RESET -1

Adafruit\_SSD1306 display(SCREEN\_WIDTH, SCREEN\_HEIGHT, &Wire, OLED\_RESET);

// Pin definitions (adjust according to your board mapping)

const int voltagePinA = A0; // Voltage sensor for Phase A

const int voltagePinB = A1; // Voltage sensor for Phase B

const int voltagePinC = A2; // Voltage sensor for Phase C

const int currentPinA = A3; // Current sensor for Phase A

const int currentPinB = A4; // Current sensor for Phase B

const int currentPinC = A5; // Current sensor for Phase C

// Relay control pins

const int relayPinA = 9;

const int relayPinB = 10;

const int relayPinC = 11;

// Calibration constants

#define ADC\_MAX 1024.0

#define VREF 3.3

#define VOLTAGE\_SCALE 11.0 // Voltage divider scaling factor

#define CURRENT\_OFFSET (VREF/2) // Assume mid-point offset ~1.65V

#define CURRENT\_SENSITIVITY 0.185 // ACS712 sensitivity in V/A

float readVoltage(int pin) {

int adcValue = analogRead(pin);

float voltage = (adcValue \* (VREF / ADC\_MAX)) \* VOLTAGE\_SCALE;

return voltage;

}

float readCurrent(int pin) {

int adcValue = analogRead(pin);

float voltage = adcValue \* (VREF / ADC\_MAX);

float current = (voltage - CURRENT\_OFFSET) / CURRENT\_SENSITIVITY;

return current;

}

void setup() {

Serial.begin(9600);

// Initialize OLED display

if(!display.begin(SSD1306\_SWITCHCAPVCC, 0x3C)) {

Serial.println(F("SSD1306 allocation failed"));

for(;;);

}

display.clearDisplay();

display.setTextSize(1);

display.setTextColor(SSD1306\_WHITE);

// Initialize relay pins

pinMode(relayPinA, OUTPUT);

pinMode(relayPinB, OUTPUT);

pinMode(relayPinC, OUTPUT);

digitalWrite(relayPinA, LOW);

digitalWrite(relayPinB, LOW);

digitalWrite(relayPinC, LOW);

}

void loop() {

// Read sensor values for each phase

float vA = readVoltage(voltagePinA);

float iA = readCurrent(currentPinA);

float pA = vA \* iA;

float vB = readVoltage(voltagePinB);

float iB = readCurrent(currentPinB);

float pB = vB \* iB;

float vC = readVoltage(voltagePinC);

float iC = readCurrent(currentPinC);

float pC = vC \* iC;

// Display the measurements on OLED

display.clearDisplay();

display.setCursor(0,0);

display.print("Phase A: ");

display.print(vA,1);

display.print("V ");

display.print(iA,1);

display.print("A ");

display.print(pA,1);

display.println("W");

display.print("Phase B: ");

display.print(vB,1);

display.print("V ");

display.print(iB,1);

display.print("A ");

display.print(pB,1);

display.println("W");

display.print("Phase C: ");

display.print(vC,1);

display.print("V ");

display.print(iC,1);

display.print("A ");

display.print(pC,1);

display.println("W");

display.display();

// Example relay control logic (if power > threshold, deactivate relay)

float powerThreshold = 100.0; // Example threshold in Watts

digitalWrite(relayPinA, (pA > powerThreshold) ? LOW : HIGH);

digitalWrite(relayPinB, (pB > powerThreshold) ? LOW : HIGH);

digitalWrite(relayPinC, (pC > powerThreshold) ? LOW : HIGH);

delay(1000);

}

# RESULTS AND DISCUSSION

The developed system successfully measures and displays real-time power parameters (voltage, current, and power) for all three phases. In the firmware implementations:

* Sensor Readings:  
  The ADC channels capture scaled-down voltage and current signals. The calibration factors in software convert these raw values into real-world units.
* Display Functionality:  
  The OLED display (via I2C) continuously shows updated power status for each phase, allowing for real-time monitoring.
* Power Output Control:  
  The relay outputs are controlled based on the computed power, providing a method to disconnect power outputs when the measured power exceeds predefined thresholds.

The STM32CubeIDE version leverages the HAL libraries for precise ADC and I2C handling, whereas the Arduino version benefits from simplified coding and readily available display libraries. Both implementations meet the system objectives and allow for further expansion, such as integrating network connectivity for remote monitoring.

# CONCLUSION AND RECOMMENDATIONS

The 3-phase power metering and monitoring system has been successfully designed and implemented using an STM32F411CEU6 microcontroller. The system accurately reads and computes power parameters for all phases, displays the results in real-time on an OLED screen, and controls power outputs via relays. Future work could include:

* **Enhanced Calibration:**  
  Improving sensor calibration for more accurate measurements.
* **Network Integration:**  
  Adding Wi-Fi/Ethernet modules for remote monitoring and control.
* **Safety Features:**  
  Incorporating overvoltage/overcurrent protection mechanisms for further reliability.

Overall, this system provides a robust foundation for advanced power monitoring applications in industrial and smart grid environments.

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