Automated Dissolved Gas Analysis for Oil Filled Transformers

TEAM 69 - Mountaineers

EE		ME		CS	ISE
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INTRODUCTION

The project aims to develop an Automated Online Dissolved Gas Analysis (Online-DGA) device to automate transformer fault detection and provide real-time insights. The device will detect methane (CH4), ethylene (C2H4), acetylene (C2H2), hydrogen (H2), carbon monoxide (CO), and carbon dioxide (CO2) with ±20 ppm precision, issuing alerts within seconds when gas thresholds exceed safe limits. Meeting specifications like early warning alerts, detecting multiple gases, and real-time monitoring. This project also addresses constraints such as junction box size, harsh environmental conditions, safety standards, and limited data storage. The impact of this project will enable proactive maintenance, extend transformer lifespan, and reduce reliance on manual sampling and expensive contracts.

OPTIMIZING POWER USAGE

By using operations research methods

Objective function

Minimize $P(x,y) = ax + by^2$

Decision Variables

$x = Vvolume\ of\ oil\ being\ transferred$

$y = Presuure\ applied\ for\ gas\ separation$

Parameters

a = power required to transfer a unit volume of oil (kWh/liter)

b = unit of pressure (kWh/KPa) respectively.

Constraints

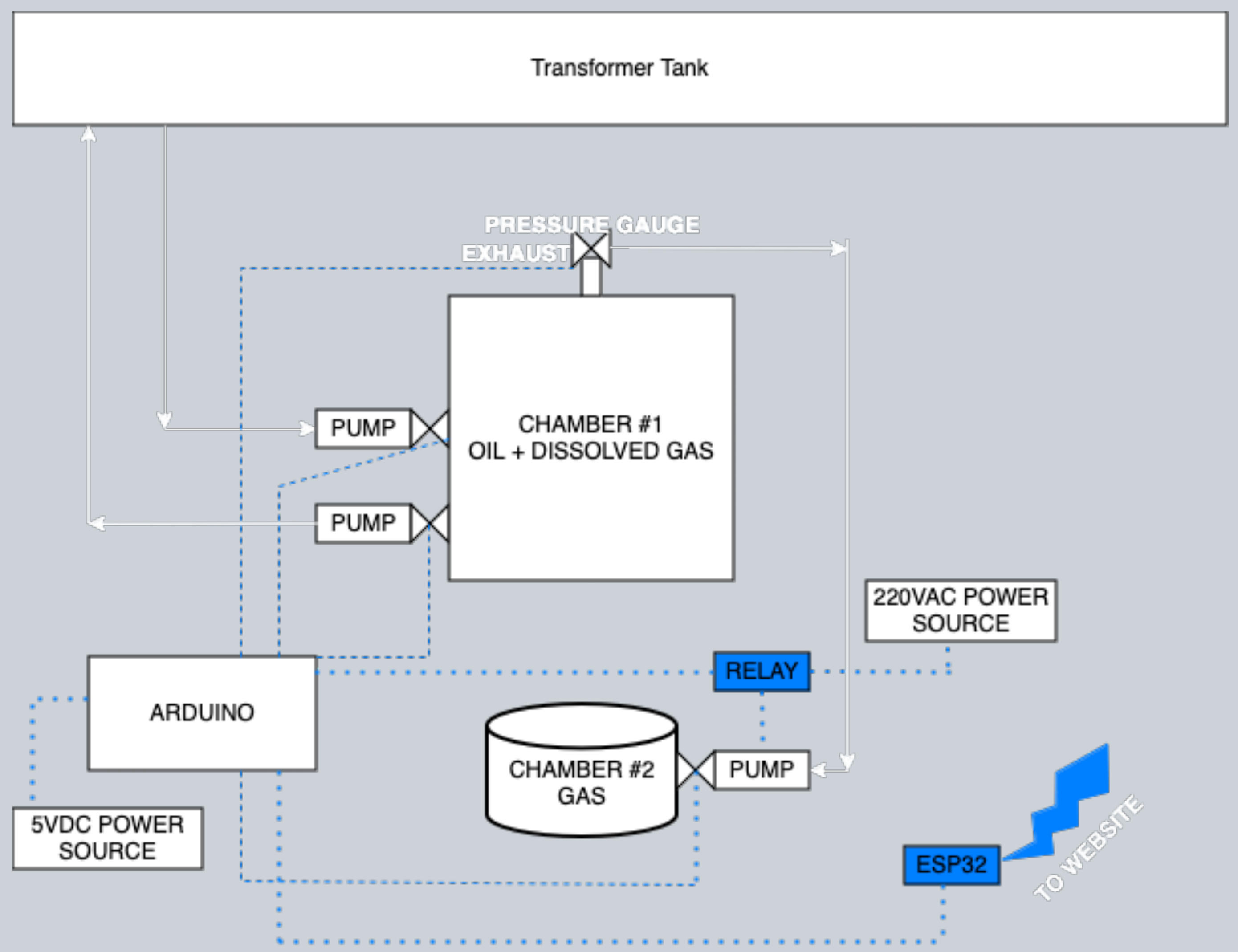
$0 \leq x \leq 2$ Liters Chamber capacity.

$Y_{min} \leq y \leq Y_{max}$ Pressure within operational limits.

$y \geq Y_{eff}$ Pressure must be sufficient to separate gas.

$y \leq Y_{saftey}$ The applied pressure must not exceed safety limit.

PROTOTYPE DESIGN



BLUE DOTTED LINES = ELECTRICAL CONNECTIONS
WHITE ARROWS = MECHANICAL CONNECTIONS

PROTOTYPE DEVELOPMENT: EE

4 Voltage sources

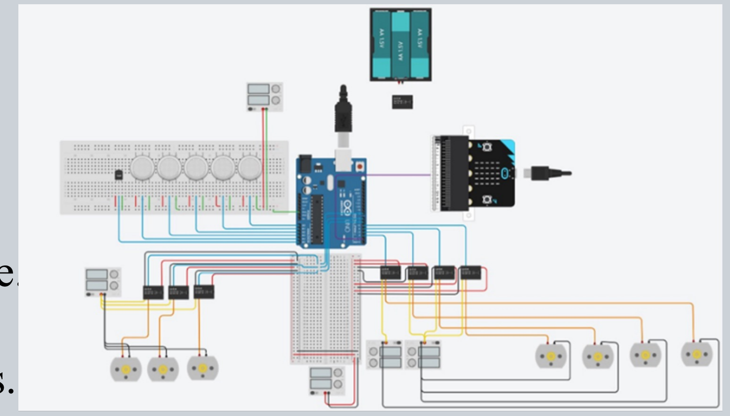
- 3 - 3.7 V_{DC} lithium batteries = 11.1V_{DC} (UPS System)
- 5 V_{DC} (6 Sensors + Arduino + ESP)
- 12 V_{DC} (2 Valves + 2 Fluid pumps)
- 220 V_{AC} (Vacuum pump)

6 Sensors

- For gas analysis: MG 811, MQ-2, MQ-6, MQ-7, and MQ-8. These sensors will be used to measure the concentration of the gases that was mentioned earlier.
- Temperature sensor: LM35. This sensor will be used to measure the temperature of the oil sample.

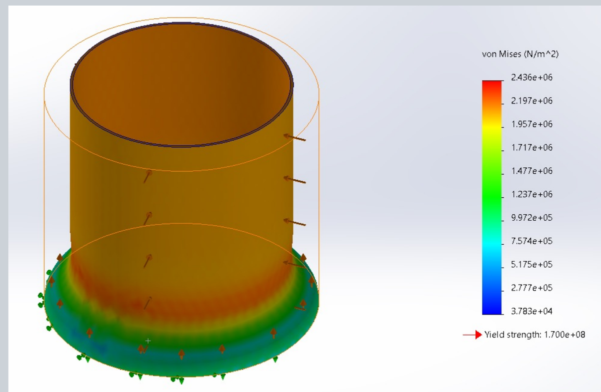
Circuitry

As can be seen in the adjacent circuit, the arduino is connected to a relay, which in turn receives the signal from the arduino and switches to either the 12 V_{DC} power source, or the 220 V_{AC} power source The arduino sends signals to valves, pumps, and the UPS, it also receives signals from all 6 sensors.



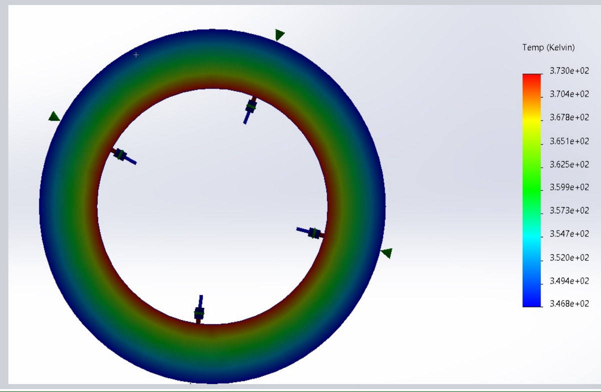
ANALYSIS

– The Von-Mises Stress Analysis on Vacuum Chamber can be seen in the adjacent figure , this analysis ensures that the chamber could withstand the expected mechanical stresses without risk of failure.



– Heat Transfer Analysis on the polyurethane pipe:

$$q = h * A\left(T_{oil} - T_{pipe}\right) = 17.6\ W$$

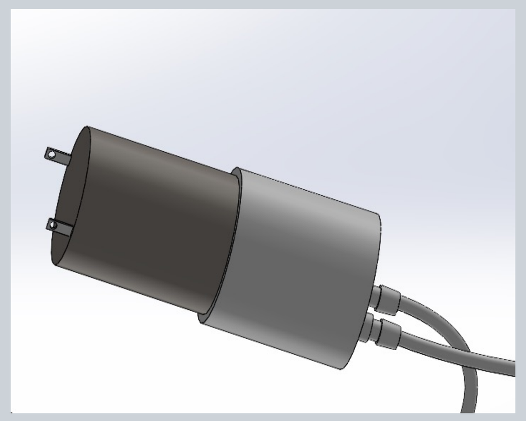


PROTOTYPE DEVELOPMENT: ME

– $Q_{oil\ pump} = \frac{v}{t} = 1.25L/min$

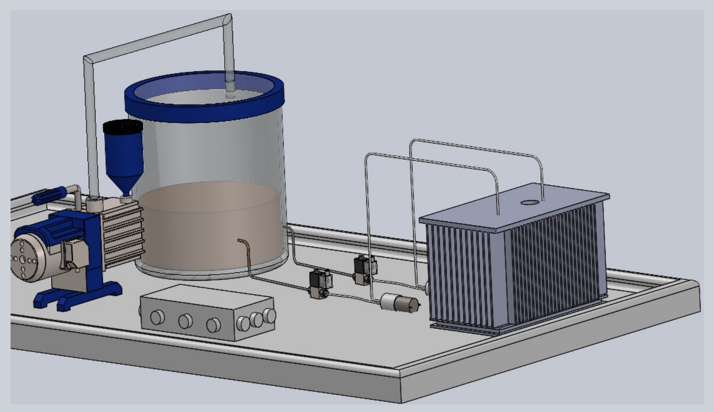
– Actual head of the pump:

$$H_{actual} = z_2 - z_1 + \sum h_{minor\ losses} + \sum h_{major\ losses} = 1.013\ m$$



Oil pump design

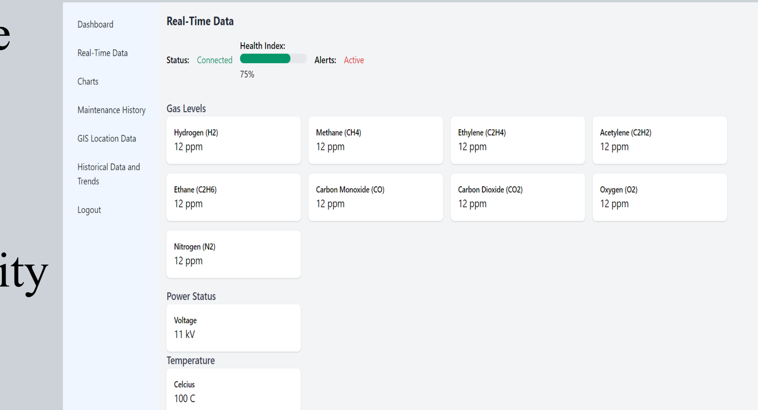
The SolidWorks design presents the entire Automated Dissolved Gas Analysis system, featuring a vacuum pump, oil pumps, vacuum chamber, junction box, valves, and a 3D- Printed oil-filled transformer Prototype



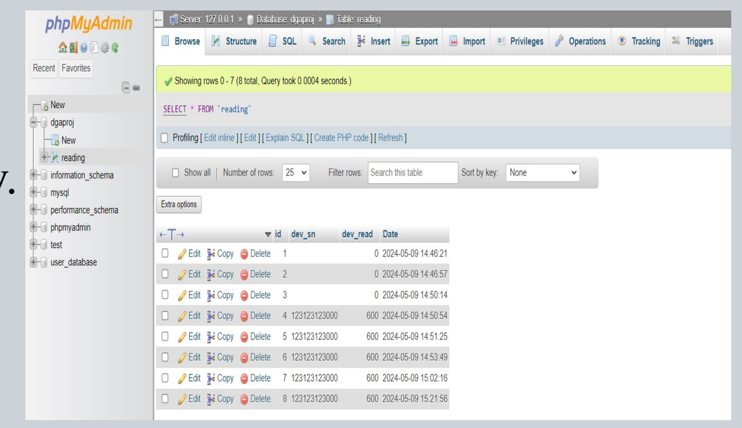
SolidWorks design for our project

SOFTWARE INTEGRATION

- Security mechanisms implemented on the client side through defensive coding mechanisms, including Sanitization and Input Validation.
- The Web App meets the global accessibility standard of the "3 Click Rule".
- Consistent and Fluent design principles.
- Integration of an **ESP32** Module using multiple APIs.
- Developed a stand-alone app to configure specific modules for the ESP on connectivity.
- Developed algorithms to ensure minimal connectivity issues.
- Additional algorithms were developed for further connectivity with the web App.



Full-stack web application that retrieves data sent by the sensors



Multiple database tables for back-end development. XAMPP, node.js, MySQL, and Apache for integration.

TESTING

We tested the electrical connections using a multimeter to ensure all components had sufficient power, carefully verifying voltage and continuity for each connection. Each mechanical component was examined to confirm proper functioning and verify the absence of gas/oil leaks. We also tested the sensors for accurate gas detection and the vacuum pump for proper operation. Finally, the entire prototype was thoroughly tested to ensure everything worked correctly and met our performance standards.

RESULTS

In conclusion, our prototype (as can be seen in the above figure) for our project met all requirements, ensuring accurate gas detection, efficient fault monitoring, and reliable data transmission. Testing confirmed seamless functioning and structural integrity, reducing the cost of transformer maintenance while providing proactive fault detection.