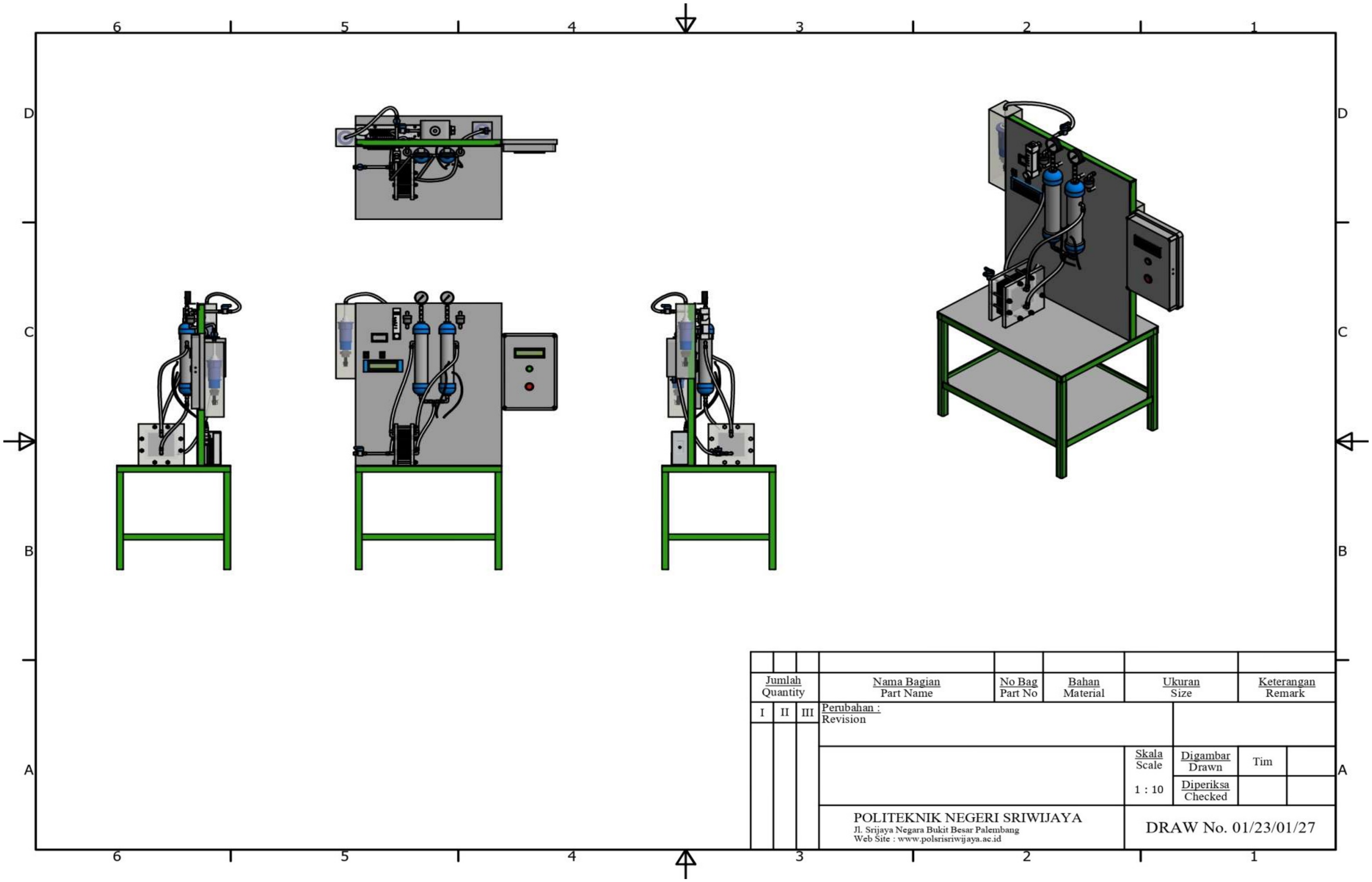
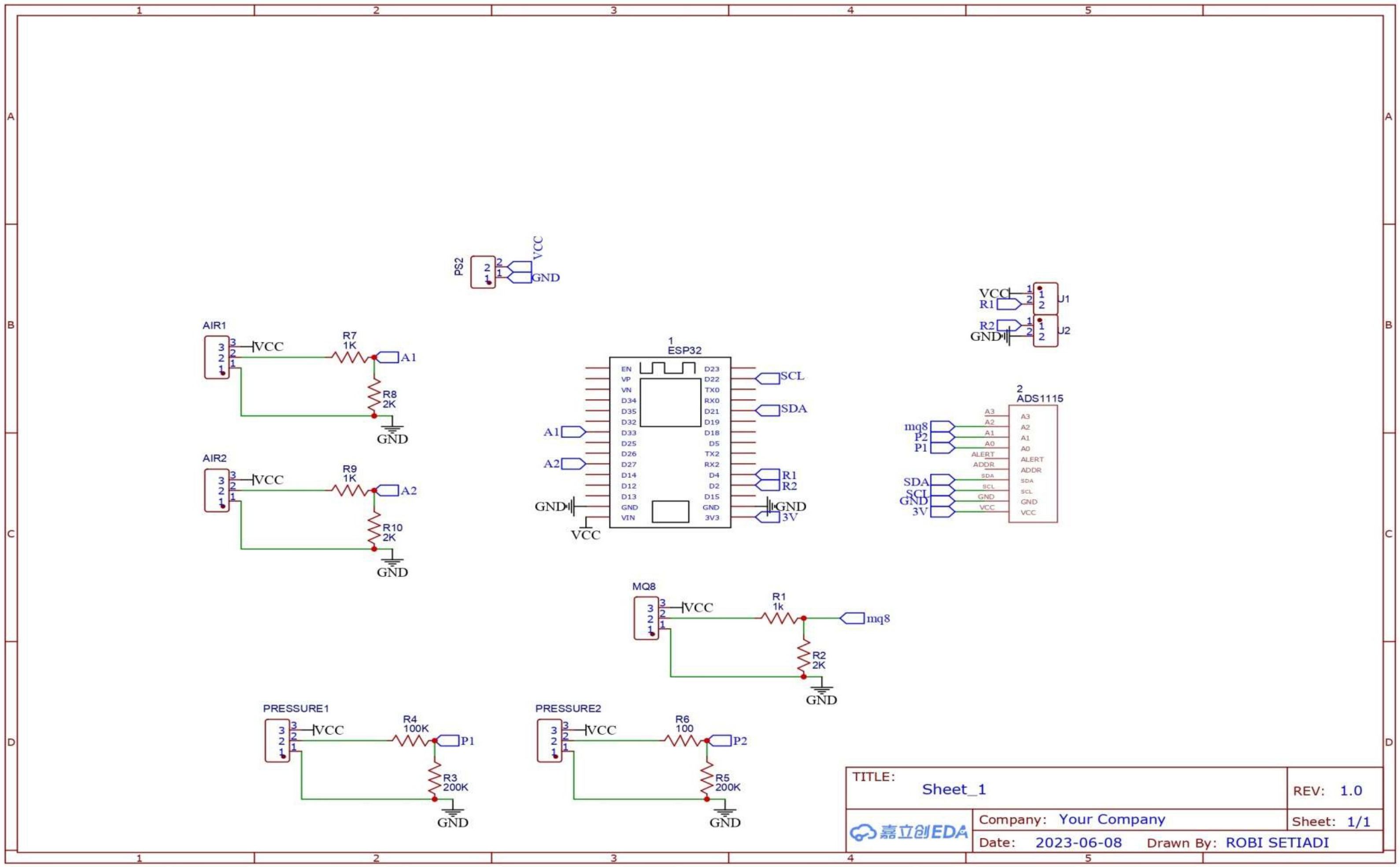
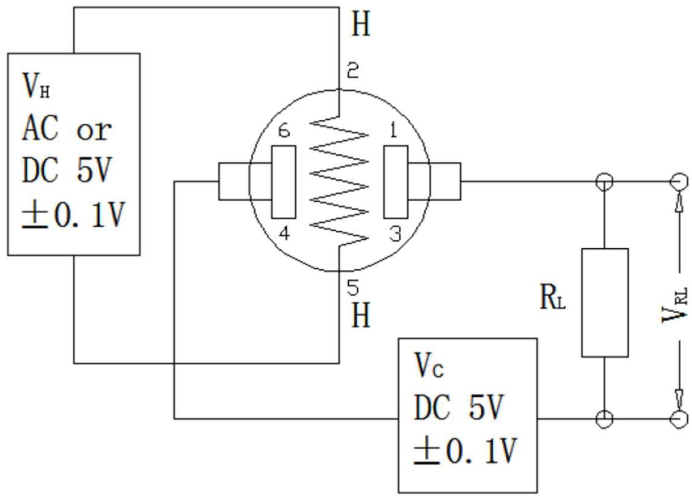
LAMPIRAN 1
DESAIN ALAT




PS2
VCC
GND
VCC
R1
R2
GND
U1
U2
AIR1
VCC
R7
1K
A1
R8
2K
GND
1
ESP32
EN
VP
VN
D34
D35
D32
D33
D25
D26
D27
D14
D12
D13
GND
VIN
D23
D22
TX0
RX0
D21
D19
D18
D5
TX2
RX2
D4
D2
D15
GND
3V3
SCL
SDA
A1
A2
R1
R2
GND
3V
GND
VCC
2
ADS1115
A3
A2
A1
A0
ALERT
ADDR
SDA
SCL
GND
VCC
mq8
P2
P1
SDA
SCL
GND
3V
AIR2
VCC
R9
1K
A2
R10
2K
GND
MQ8
VCC
R1
1k
mq8
R2
2K
GND
PRESSURE1
VCC
R4
100K
P1
R3
200K
GND
PRESSURE2
VCC
R6
100
P2
R5
200K
GND
TITLE:
Sheet_1
REV: 1.0
Company: Your Company
Sheet: 1/1
Date: 2023-06-08
Drawn By: ROBI SETIADI

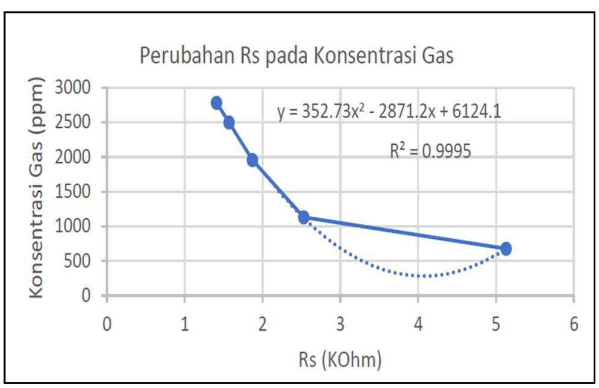
SENSOR HIDROGEN MQ-8

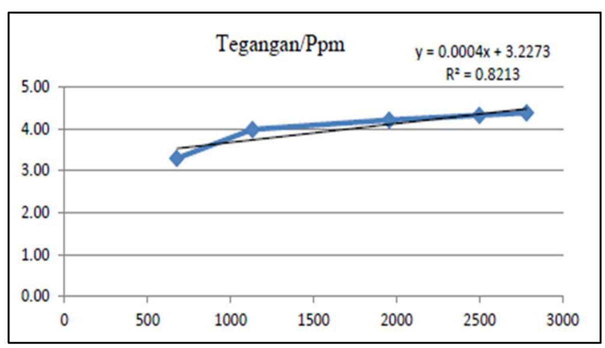
Rangkaian Proteksi



Data Kalibrasi Sensor MQ-8

Sampel (ml)	Rs (kOhm)	V_{LCD} (Volt)	Konsentrasi Hidrogen Gas *Chromatograph* (ppm)
1	5.15	3.30	677
2	2.53	3.99	1132
3	1.87	4.21	1956
4	1.57	4.32	2499
5	1.41	4.38	2783





Secara statik dapat diketahui bahwa sistem ini mempunyai *zero offset* pada sensor sebesar 3,227 Volt. Sensitivitas alat yang dirancang dilakukan dengan melihat perbandingan perubahan tegangan yang dihasilkan sensor terhadap perubahan konsentrasi gas hidrogen didalam tabung percobaan, sehingga hasil dari analisis regresi linier diperoleh bahwa sensitivitas sensor sebesar 0,0004 Volt/ppm.

LAMPIRAN 2
LISTING PROGRAM

```
#include <Adafruit_ADS1X15.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <DHT.h>
#include <MQUnifiedsensor.h>
Adafruit_ADS1115 ads;
#include "DFRobot_OxygenSensor.h"

#define BLYNK_TEMPLATE_ID "TMPL60LlfLaBb"
#define BLYNK_DEVICE_NAME "REAKTOR H2O"
#define Oxygen_IICAddress ADDRESS_3
#define COLLECT_NUMBER  10            // collect number, the collection range is 1-
100.
DFRobot_OxygenSensor oxygen;

#define BLYNK_FIRMWARE_VERSION        "0.1.0"

#define BLYNK_PRINT Serial
//#define BLYNK_DEBUG

#define APP_DEBUG

#define DHTTYPE DHT11
#define DHTPIN 18
DHT dht(DHTPIN, DHTTYPE);
// Uncomment your board, or configure a custom board in Settings.h
#define USE_ESP32_DEV_MODULE
//#define USE_ESP32C3_DEV_MODULE
//#define USE_ESP32S2_DEV_KIT
//#define USE_WROVER_BOARD
//#define USE_TTGO_T7
//#define USE_TTGO_T_OIm

float humidity, temp;
unsigned long previousMillis = 0;
const long interval = 15000;

const int pressureZero = 429.5; //analog reading of pressure transducer at 0psi
const int pressureMax = 3686.4; //analog reading of pressure transducer at 100psi
const int pressuretransducermaxPSI = 174; //psi value of transducer being used
const int baudRate = 9600; //constant integer to set the baud rate for serial monitor
const int sensorreadDelay = 250; //constant integer to set the sensor read delay in
milliseconds
```

```
float pressureValue1 = 0; //variable to store the value coming from the pressure
transducer
float pressureValue2 = 0;
 float pressure1, pressure2, mq8;
float ppm ;

#define     Board         ("ESP-32") // Wemos ESP-32 or other board, whatever
have ESP32 core.
#define     Pin          (39)  //IO25 for your ESP32 WeMos Board, pinout here:
https://i.pinimg.com/originals/66/9a/61/669a618d9435c702f4b67e12c40a11b8.jpg
/***********************Software Related
Macros************************************/
#define     Type          ("MQ-8") //MQ3 or other MQ Sensor, if change this
verify your a and b values.
#define     Voltage_Resolution    (3.3) // 3V3 <- IMPORTANT. Source:
https://randomnerdtutorials.com/esp32-adc-analog-read-arduino-ide/
#define     ADC_Bit_Resolution    (12) // ESP-32 bit resolution. Source:
https://randomnerdtutorials.com/esp32-adc-analog-read-arduino-ide/
#define     RatioMQ8CleanAir     (70) // Ratio of your sensor, for this example an
MQ-3

#define Sensor_Amax 33
#define Sensor_Amin 5

int airMax;
int airMin;


MQUnifiedsensor MQ8(Board, Voltage_Resolution, ADC_Bit_Resolution, Pin, Type);
LiquidCrystal_I2C lcd(0x27, 16, 2);

#include "BlynkEdgent.h"

BLYNK_WRITE(V0){
  if (param.asInt()==HIGH){
    digitalWrite (2, LOW);
  }
  else{
    digitalWrite (2, HIGH);
  }
 }

   BLYNK_WRITE(V1){
  if (param.asInt()==HIGH){
    digitalWrite (4, LOW);
  }
  else{
    digitalWrite (4, HIGH);
```

```
 }
  }

void setup()
{
  Serial.begin(115200);
  delay(100);
  BlynkEdgent.begin();
lcd.begin();
dht.begin();
  lcd.backlight();
  lcd.clear();
  pinMode(2, OUTPUT);
  pinMode(4, OUTPUT);
  digitalWrite (2, HIGH);
  digitalWrite (4, HIGH);
  pinMode(Sensor_Amax, INPUT_PULLUP);
  pinMode(Sensor_Amin, INPUT_PULLUP);
  MQ8.setRegressionMethod(1);
  MQ8.setA(976.97); MQ8.setB(-0.688);
  MQ8.init();
  Serial.println("Getting single-ended readings from AIN0..3");
  Serial.println("ADC Range: +/- 6.144V (1 bit = 3mV/ADS1015,
0.1875mV/ADS1115)");

  while(!oxygen.begin(Oxygen_IICAddress)){
    Serial.println("I2c device number error !");
    delay(1000);
  }
  Serial.println("I2c connect success !");


    if (!ads.begin())
  {
    Serial.println("Failed to initialize ADS.");
    while (1);
  }

  Serial.print("Calibrating please wait.");
  float calcR0 = 0;
  for(int i = 1; i<=10; i ++)
  {
    MQ8.update(); // Update data, the arduino will read the voltage from the analog pin
    calcR0 += MQ8.calibrate(RatioMQ8CleanAir);
    Serial.print(".");
  }
  MQ8.setR0(calcR0/10);
  Serial.println("  done!.");
```

```
  if(isinf(calcR0)) {Serial.println("Warning: Conection issue, R0 is infinite (Open circuit detected) please check your wiring and supply"); while(1);}
  if(calcR0 == 0){Serial.println("Warning: Conection issue found, R0 is zero (Analog pin shorts to ground) please check your wiring and supply"); while(1);}
  /***************************** MQ CAlibration ********************************************/
  MQ8.serialDebug(true);
  BlynkEdgent.begin();
}

void loop() {
  BlynkEdgent.run();
  lcd.clear ();
gettemperature();

  float oxygenData = oxygen.getOxygenData(COLLECT_NUMBER);
  Serial.print(" oxygen concentration is ");
  Serial.print(oxygenData);
  Serial.println(" %vol");

Serial.print(airMax);
Serial.print(airMin);
  airMax = digitalRead(Sensor_Amax);
  airMin = digitalRead(Sensor_Amin);

  int16_t adc0, adc1, adc2;
  float volts0, volts1, volts2, volts3;

  MQ8.update(); // Update data, the arduino will read the voltage from the analog pin
  ppm = MQ8.readSensor(); // Sensor will read PPM concentration using the model, a and b values set previously or from the setup


  adc0 = ads.readADC_SingleEnded(0);
  adc1 = ads.readADC_SingleEnded(1);
  adc2 = ads.readADC_SingleEnded(2);
 // adc3 = ads.readADC_SingleEnded(3);

pressure1 = map(adc0, 0, 18325, 0, 4096);
pressure2 = map(adc1, 0, 18325, 0, 4096);

  volts0 = ads.computeVolts(adc0);
  volts1 = ads.computeVolts(adc1);

  Serial.println("-----------------------------------------------------------");
  Serial.print("AIN0: "); Serial.print(pressure1); Serial.print("  "); Serial.print(volts0);
Serial.println("V");
```

```
  Serial.print("AIN1: "); Serial.print(pressure2); Serial.print("  "); Serial.print(volts1);
Serial.println("V");

  pressureValue1 = ((pressure1-
pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero); //conversion
equation to convert analog reading to psi
  Serial.print(pressureValue1, 1); //prints value from previous line to serial
  Serial.println("psi"); //prints label to serial
  lcd.setCursor(0,0); //sets cursor to column 0, row 0
  lcd.print("Pressure:"); //prints label
  lcd.print(pressureValue1, 1); //prints pressure value to lcd screen, 1 digit on float
  lcd.print("psi"); //prints label after value
  lcd.print("   "); //to clear the display after large values or negatives

  pressureValue2 = ((pressure2-
pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero); //conversion
equation to convert analog reading to psi
  Serial.print(pressureValue2, 1); //prints value from previous line to serial
  Serial.println("psi"); //prints label to serial
  lcd.setCursor(0,1); //sets cursor to column 0, row 0
  lcd.print("Pressure:"); //prints label
  lcd.print(pressureValue2, 1); //prints pressure value to lcd screen, 1 digit on float
  lcd.print("psi"); //prints label after value
  lcd.print("   "); //to clear the display after large values or negatives

if (pressureValue1 <1 ) {
  pressureValue1 = 0;
}

if (pressureValue2 <1 ) {
  pressureValue2 = 0;
}
  Serial.print(ppm);
  Blynk.virtualWrite(V2, pressureValue1);
  Blynk.virtualWrite(V3, pressureValue2);
  Blynk.virtualWrite(V4, ppm);
  Blynk.virtualWrite(V5, temp);
  Blynk.virtualWrite(V6, humidity);
  Blynk.virtualWrite(V7, oxygenData);


 if (airMax == 0 && airMin == 0) {
     lcd.setCursor(0, 1);
     digitalWrite (2, HIGH);
     lcd.print("-----");
     lcd.print(" FULL ");
     lcd.print("-----");
   }
```

```
    if (airMax == 1 && airMin == 0) {
      lcd.setCursor(0, 1);
      lcd.print("-----");
      lcd.print("  LOW ");
      lcd.print("-----");
    }

    if (airMax == 1 && airMin == 1) {
      lcd.setCursor(0, 1);
      digitalWrite (2, LOW);
      lcd.print("-----");
      lcd.print(" EMPTY ");
      lcd.print("----");
    }

  delay(1000);
}

void gettemperature() {
  unsigned long currentMillis = millis();

  if (currentMillis - previousMillis >= interval) {
    previousMillis = currentMillis;


    humidity = dht.readHumidity();
    temp = dht.readTemperature();
    Blynk.virtualWrite(V5, temp);
    Blynk.virtualWrite(V6, humidity);
   // Serial.print (temp,humidity);


    if (isnan(humidity) || isnan(temp)) {
      Serial.println("Sensor Tidak Terbaca");
      return;
    }
  }
}
```

LAMPIRAN 3
TABEL PENGAMBILAN DATA

Pengujian Performa Pembacaan Sensor

Waktu (s)	Temperatur (^oC)	Kelembaban (%)	Oksigen (%)	Hidrogen (ppm)	*Pressure* (Hidrogen) (psi)	*Pressure* (Oksigen) (psi)
1	32,8	93	19,6	128,64	0	0
2	32,8	93	19,6	128,64	0	0
3	32,8	93	19,5	127,24	0	0
4	32,8	93	19,5	142,76	0	0
5	32,8	93	19,5	142,76	1,23	1,07
6	32,8	93	19,5	182,79	1,23	1,07
7	32,8	93	19,5	193	1,5	1,39
8	32,8	93	19,6	193	1,5	1,87
9	32,8	93	19,6	213,94	1,82	1,87
10	32,8	93	19,6	213,94	2,03	2,14
11	32,8	93	19,7	244,65	2,03	2,14
12	32,8	93	19,8	303,72	2,19	2,19
13	32,8	93	19,8	303,72	2,19	2,62
14	32,8	93	19,9	421,54	2,62	2,62
15	32,8	93	19,9	421,54	2,88	2,88
16	32,8	93	20	565,77	2,88	2,88
17	32,8	93	20	712,75	3,15	3,15
18	32,8	93	20,2	712,75	3,53	3,47
19	32,8	93	20,3	875,42	3,53	3,47
20	32,8	93	20,3	875,42	3,79	3,69
21	32,8	93	20,5	1236,06	3,79	3,69
22	32,8	93	20,5	689,39	4,06	3,95
23	32,8	93	20,7	527,55	4,33	4,22
24	32,8	93	20,7	527,55	4,33	4,22
25	32,8	93	20,8	451,1	4,59	4,49
26	32,8	93	20,8	451,1	4,81	4,81
27	32,8	93	20,9	411,67	4,81	4,81
28	32,8	93	20,9	382,62	5,13	5,02
29	32,8	93	21	382,62	5,13	5,02
30	32,8	93	21,1	373,65	5,34	5,34
31	32,8	93	21,1	373,65	5,34	5,34
32	32,8	93	21,2	365,36	5,34	5,72
33	32,8	93	21,2	360,95	5,98	5,93
34	32,8	93	21,2	360,95	5,98	5,93
35	32,8	93	21,3	362,57	6,3	6,2

36	32,8	93	21,3	362,57	6,3	6,2
37	32,8	93	21,4	349,88	6,52	6,41
38	32,8	93	21,4	460,99	6,73	6,68
39	32,8	93	21,5	460,99	6,73	6,68
40	32,8	93	21,5	396,87	6,46	6,79
41	32,8	93	21,5	396,87	6,46	6,79
42	32,8	93	21,6	390,32	7,21	7,27
43	32,8	93	21,6	376,78	7,48	7,48
44	32,8	93	21,6	376,78	7,48	7,48
45	32,8	93	21,6	405,78	7,75	7,69
46	32,8	93	21,6	405,78	7,75	7,69
47	32,8	93	21,6	501,96	7,75	7,96
48	32,8	93	21,6	501,96	8,39	8,17
49	32,8	93	21,6	398,7	839	8,17
50	32,8	93	21,6	384,88	8,55	8,49
51	32,8	93	21,6	384,88	8,55	8,81
52	33,3	92	21,6	407,02	8.81	8,81
53	33,3	92	21,6	415,42	9,08	9,03
54	33,3	92	21,6	415,42	9,08	9,03
55	33,3	92	21,5	410,58	9,3	9,35
56	33,3	92	21,5	403	9,3	9,46
57	33,3	92	21,5	403	9,3	9,46
58	33,3	92	21,5	410,27	9,78	9,72
59	33,3	92	21,5	410,27	10,1	9,99
60	33,3	92	21,4	414,32	10,1	9,99

International Journal of Research In Vocational Studies (IJRVOCAS)
VOL. 3, NO. 2, August 2023, PP. 16~22
Print ISSN 2777-0168| Online ISSN 2777-0141| DOI prefix: 10.53893
https://journal.gpp.or.id/index.php/ijrvocas/index

Implementation of the Internet of Things for Monitoring and Protecting Hydrogen Production in Dry Cell HHO Generators

Robby Setiadi[1,2,*], Ahmad Taqwa[3] & Yohandri Bow[4]

[1]Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia
[2]Department of Electrical & Instrument Maintenance, PT Semen Baturaja Tbk. , Ogan Komering Ulu, Indonesia
[3]Electrical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia
[4]Chemical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia

Email address:

robsetiadi@gmail.com (Robby Setiadi)
[*]Corresponding author

To cite this article:

Robby Setiadi, Taqwa, A., & Bow, Y. Implementation of the Internet of Things for Monitoring and Protecting Hydrogen Production in Dry Cell HHO Generators. International Journal of Research in Vocational Studies (IJRVOCAS), 3(2), 16–22. https://doi.org/10.53893/ijrvocas.v3i2.203

Received: 07 18, 2023; **Accepted**: 07 28, 2022; **Published**: 08 25, 2023

Abstract: In the last few decades, researchers have been conducting various studies in search of alternative energy sources to reduce dependence on fossil fuels and anticipate future energy scarcity. One such alternative energy is hydrogen, which can be obtained through various methods, including electrolysis of water. Hydrogen possesses the characteristics of being flammable, odorless, colorless, and tasteless, necessitating the development of a rigorous monitoring and protection system to mitigate potential hazards. In this study, a monitoring and protection system was designed for the operation of an electrolyzer using a Dry Cell type HHO Generator. The system employs the concept of the Internet of Things, where data is connected through the internet network. The data received includes hydrogen concentration readings, electrolyzer operation automation, electrolyzer operating status, and hydrogen gas leak detection in the system. The research results obtained showed that the higher the concentration of electrolyte and the voltage supplied to the electrolysis process, the faster the production of hydrogen gas is accelerated, accompanied by an increase in temperature. If a leakage occurs in a system, the occurrence of the fire triangle will be faster when the concentration of electrolyte and the voltage supplied are greater.

Keywords: *Electrolysis, Hydrogen, Monitoring, Protection, Internet of Things*

1. Introduction

The need for energy continues to increase along with the increasing activities carried out by humans over time. However, this demand is not aligned with the supply of currently available non-renewable energy sources, such as fossil fuels. There are several examples of natural energy sources that are considered alternative, as they are clean, non-polluting, safe, and have unlimited supplies. These sources can serve as substitutes for the limited availability of fossil fuels. One such example is hydrogen.

It is important to note that hydrogen is not an energy source in itself; it differs from the energy derived from fossils. Energy derived from fossils is abundant in nature and can be extracted. On the other hand, hydrogen is an energy carrier. It cannot be extracted like energy from fossil sources. Instead, hydrogen gas must be produced, and one method of production is through the process of electrolysis.

Electrolysis occurs when an electric current flows through an ionic compound, causing a chemical reaction to take place. The electrolyte solution facilitates electrical conduction, creating a direct current source and imparting different charges to the two electrodes. The cathode, or negatively charged electrode, is connected to the negative pole, while the anode, or positively charged electrode, is connected to the positive pole. Electrolysis reactions are classified as non-spontaneous redox reactions, meaning they occur under the influence of electrical energy [1].

In the process of electrolysis, which produces hydrogen (H2) and oxygen (O2), the generation of these gases typically begins when an electric current of more than 4 Amperes is applied [1]. One way to obtain hydrogen is by breaking down the compound water (H2O) into hydrogen and oxygen gases, also known as HHO gas or Brown's gas. This is achieved through an electrolysis process with the assistance of a direct electric current. The resulting gas is highly flammable, making it a suitable alternative to conventional fuels in engine applications.

Research on how to produce hydrogen has been carried out to produce efficient hydrogen gas production. The electrolysis process is influenced by various factors that can affect the amount of hydrogen production produced and the efficiency of the electrolysis system, including electric current, electrolyte, temperature, pressure and the electrical voltage that is delivered. One of the most popular ways to increase hydrogen production is to use an electrolyte. Some of the electrolytes commonly used to help the process of electrolysis include NaCl, NaOH and seawater. In the electrolysis process using NaCl as electrolysis, it was found that the hydrogen gas content can be produced as much as 78.45% at a NaCl concentration of 50% [2]. The production of hydrogen gas is found to be directly proportional to the NaCl concentration given, resulting in an increased production capacity. However, at a certain point, the production capacity of hydrogen gas will cease to increase as the hydrolyzed hydrogen level reaches a saturation point [3]. Electrolysis using NaOH at a concentration of 50% produces a hydrogen gas content of 78.34% [4], In addition, the electrolysis process using NaOH at a concentration of 50% achieves an electric current efficiency of 89.13% [5]. The efficiency obtained by using NaOH is significantly higher compared to using seawater, which is only around 12.99% [6] [7]. Brackish water is converted into an electrolyte with a remarkably high efficiency, reaching 93.33% [8]. The concentration of the electrolyte significantly influences the quantity of hydrogen gas produced. In addition to the electrolytes mentioned above, KOH exhibits similar characteristics when used as a catalyst in the electrolysis process. Increasing the concentration of KOH in the electrolysis process results in a higher production of hydrogen gas [9] [10].

Hydrogen possesses flammable, odorless, and colorless characteristics, which raise safety concerns in the production process. Both in its liquid and gas phases, hydrogen is considered a hazardous chemical substance. It has flammability within a range of 4-75% flammability limits in air and requires an energy of 0.02 MJ to ignite, making it flammable when exposed to sparks caused by static electricity. The U.S. Department of Energy (DOE) has reported 208 accident cases worldwide related to hydrogen plants from 1995 to 2013 [11].

The focus on security regarding hydrogen began 40 years ago, particularly in the industrial sector. Since then, infrastructure has been developed to safely produce, store, and transport hydrogen gas. [12]. The diffusivity of hydrogen gas is 3.8 times faster than that of natural gas. Furthermore, its liquidity is twice as fast as Helium gas and six times faster than natural gas, which has a speed of 20 m/s. [12]. Therefore, if there is no structure to contain the rising gases, such as a roof or ventilation openings, hydrogen will not accumulate around the source of the leak. Additionally, it is crucial to restrict hydrogen to non-dangerous concentrations. [12]. The effect of a leak in an enclosed space can create a hazardous situation, potentially causing severe damage to property, posing risks to human health, and even leading to fatalities [11].

To mitigate the potential risks of leakage, it is essential to analyze safety factors associated with the production and storage processes of hydrogen gas. One critical aspect that influences the safety factor of hydrogen production is the storage and gas flow management [13]. Currently, the most prevalent methods for storing hydrogen gas are through compressed gas and in liquid form. In the future, there will be further advancements in solid-state storage methods, which are anticipated to become more widely used. However, the main obstacle at present is the relatively high cost associated with these storage technologies [14], [15].

With the rapid advancement of technology, various technologies are emerging to enhance the level of security in high-risk production processes like hydrogen gas production. One such technology is sensors. Sensors have the capability to convert physical quantities into electrical signals. The readings from these sensors can be processed through computer programs, providing valuable monitoring information and supporting decision-making processes for protection measures. Sensors play a crucial role in improving safety and enabling efficient monitoring and control in industrial operations [16]. This research focuses on developing a monitoring and protection system for hydrogen gas production, specifically designed for a prototype of a Dry Cell type HHO Generator. By utilizing existing technology, the system will gather data from sensors that monitor the condition of the equipment. The researchers aim to detect and supervise any leaks in the hydrogen gas production system. The collected data will be processed and presented in real time, utilizing internet of things technology [17]. The aim of this research on monitoring and protection systems is to provide users with rapid information regarding the status of hydrogen gas production conditions. By doing so, it is expected to support the uninterrupted supply of environmentally friendly and safe new energy sources.

2. Experimental Design

The research process is divided into two stages: hardware design and software design.

2.1. Hardware Design of The Equipment

The hardware design activities include fabricating acrylic boxes, assembling all components on the PCB, installing sensors at designated locations, and integrating the monitoring and protection system equipment onto the HHO Generator equipment that will be monitored and safeguarded.

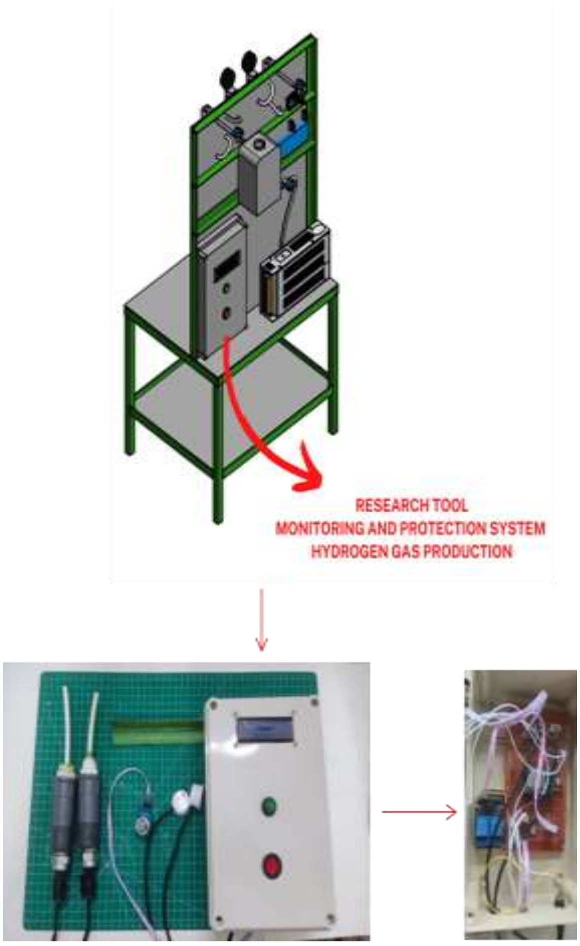


Figure 1. *Hardware Design for Monitoring and Protection System Equipment in HHO Generators for Hydrogen Production*

2.2. Software Design of The Equipment

The software design aims to enable programming and coding for the installed sensors, allowing them to provide data to the user, including gas concentration, pressure, temperature, humidity, and the status of water flow in the electrolyzer. A program was developed in this study to function as a hydrogen gas leak detector and equipment automation, based on the water level in the bubbler. The water level in the bubbler serves as an indicator for the water reservoir to open the faucet and maintain sufficient water levels for the operation of the electrolyzer. The monitoring system, which has been created and integrated, operates through the Internet of Things.

To understand the functionality of the developed program, a flowchart is created to illustrate the system's operations and ensure its proper functioning. The flowchart serves to determine the step-by-step sequence of processes to be executed by the application and the microcontroller. It forms a fundamental part of the system, laying the initial foundation before the actual development of the system or device. If the mapped flowchart is incorrect, it is certain that the resulting system or device will not function as intended. Therefore, it is crucial to follow these basic procedures to understand the system's components and create an improved system [18].

The flowchart of the designed monitoring and protection system for hydrogen production can be seen in the figure below:

Figure 2. *Flowchart of Water Level Detection and Electrolyzer Operation Automation*

The logic for the valve conditioning signal for water flow to the electrolyzer can be described in the table below:

Table 1. *Water Level Signal Conditions For Electrolyzer Automation*

Water Level Condition		**Solenoid Valve**
High	**Low**	
0	0	Close
0	1	Close
1	0	*Error*
1	1	Open

Figure 3. *Flowchart of Hydrogen Gas Leak Detection*

The programming involves two software components: Arduino, which acts as a microcontroller to process data from sensors and provide instructions based on specific conditions, and the Blynk Application, which serves as an Internet of Things platform for users to monitor the operating status of the HHO Generator.

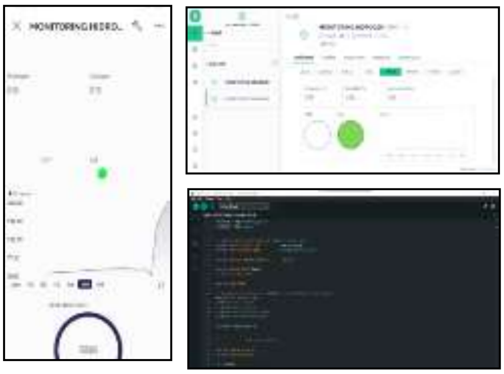


Figure 4. *Display of the Hydrogen Production Monitoring and Protection System Program for the HHO Generator on the Blynk Application, Arduino Application, and Websites*

3. Result And Discussion

3.1. Automation System Testing

The testing activity of the water filling automation system for the electrolyzer involves testing the response of the sensor to the water level inside the bubbler. The sensor sends a signal to the microcontroller to be processed in a program and executed based on the conditions specified in Table 1. To observe changes in signal conditions, the water level sensor can be monitored. The level sensor detects the water level in the bubbler and sends a signal response to instruct the solenoid valve to open or close based on the water level conditions. The solenoid valve receives commands from the relay, which serves as an automatic switch, based on the signal received from the microcontroller.

(a)

(b)

Figure 5. *(a) Sensor and Relay Responses When the Water Level is Full (b) Sensor and Relay Responses When the Water Level Decreases*

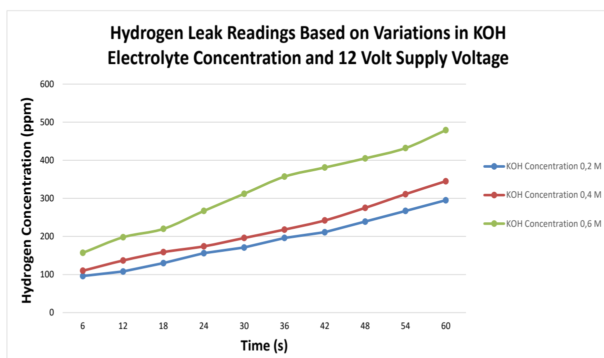
The results of testing the sensor response for the automation of water filling in the bubbler for the electrolyzer are as follows:

1. When both the high and low level sensors detect the water level, the solenoid valve is closed
2. When the high level sensor does not detect the water level but the low level sensor detects the water level, the solenoid valve is closed
3. When both the high and low level sensors do not detect the water level, the solenoid valve is open

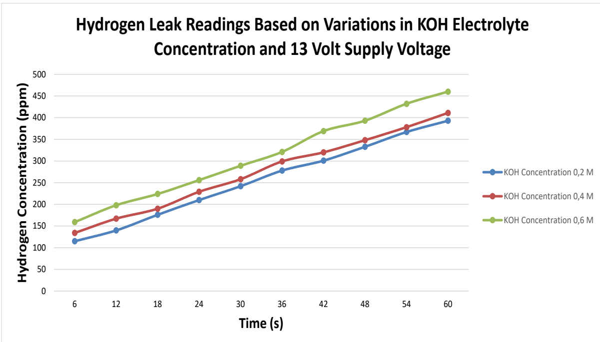
3.2. Hydrogen Gas Leak Detection Test

The hydrogen gas leak detection testing activities involve intentionally leaking the gas hose during the charging process for storage. The sensor's response to the leaking gas is examined to analyze how quickly it can provide a signal to notify the user of a leak. This prompt notification allows the user to take immediate action to stop the operation of the electrolyzer. To conduct the test, a hydrogen sensor is placed inside an acrylic box with a hole at the top. The purpose of the acrylic box is to contain any leaking hydrogen gas, preventing it from escaping into the surrounding air. The sensor, attached to the top of the box, can detect the presence of the gas. This setup is necessary because hydrogen, being lighter than air, tends to rise and evaporate upwards [19]. By conducting these tests and analyzing the sensor's response time, the effectiveness of the hydrogen gas leak detection system can be evaluated. It ensures the safety of the production process by promptly notifying the user of any leaks, enabling them to take immediate action to prevent further risks.

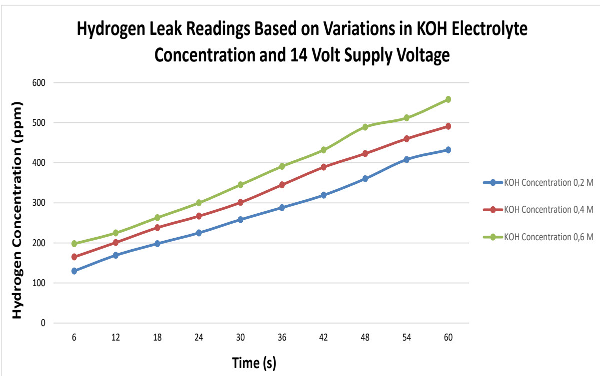
Observations were conducted by varying the concentration of the KOH electrolyte (0.2 M, 0.4 M, and 0.6 M) and the supplied electric voltage (12 Volts DC, 13 Volts DC, and 14 Volts DC) during a 60-second electrolysis operation. The purpose of this test was to simulate a leak scenario and assess the system's response. The duration of the operation was intentionally kept brief to mitigate any potential risks, such as equipment damage or the accumulation of hydrogen gas, which could pose a risk of explosion inside the acrylic box.



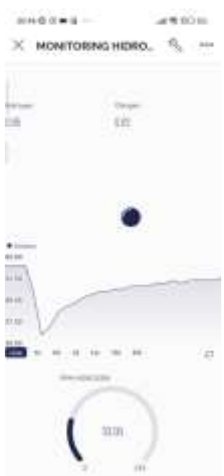
(a)



(b)



(c)



(d)

Figure 6. *Graph of Hydrogen Readings Based on Variations in KOH Electrolyte Concentration and Supply Voltage (a) 12 Volts (b) 13 Volts (c) 14 Volts (d) Hydrogen Concentration Readings in the Monitoring System*

Based on the experimental results, it was found that the electrolyte concentration and supply voltage have an impact on the amount of hydrogen concentration produced. The increase in electrolyte concentration is accompanied by an increase in voltage, which leads to an increase in the electric current flowing during the electrolysis process [20]. As a result, a higher electric current increases the rate of electric charge in the solution, leading to a greater number of electrons being transferred per unit time and an increased volume of hydrogen being formed [21], [22]. This can be observed from the graph depicted in Figure 6. The production rate of hydrogen, whether due to system leakage or intentional gas production, is higher when the electrolyte concentration and supply voltage are increased. Therefore, it is crucial to promptly respond to any leaks to prevent the conditions for fire occurrence, as per the fire triangle theory (heat, air, and fuel). One of the challenges in researching protection against hydrogen gas leaks is the gas's nearly invisible nature to the naked eye. This is because the combustion products resulting from the reaction between pure hydrogen and oxygen mainly emit ultraviolet waves [23]. So, when designing a protection system capable of detecting hydrogen gas at the smallest possible concentration scale, it is important to consider the cost implications of the sensor. Ensuring the system's sensitivity to detect even low levels of hydrogen gas concentration in order to address potential leaks may require more advanced and expensive sensors.

In this study, the MQ-8 sensor was used, which is an affordable sensor suitable for research-scale purposes. The sensor has a reading scale ranging from 100 to 1000 ppm. If the hydrogen concentration falls within this range, the sensor will detect it and send a signal to the program to stop the operation of the electrolyzer. During the experiment, one sensor replacement was required due to overheating caused by prolonged exposure to gas and the increasing temperature inside the acrylic box. The temperature increase was a result of the rising hydrogen concentrations and the supplied electric voltage. As the temperature rose, the sensor's voltage value also increased [24]. This resulted in the sensor being damaged due to the surrounding temperature conditions exceeding the threshold characteristic of the MQ-8 sensor.

Figure 7. *Condition of MQ-8 Hydrogen Sensor after Overheating*

Sensors must be selected based on their characteristics when determining the suitable type of hydrogen sensor for use in production activities. For a leak detection protection system in industrial-scale hydrogen production, it is important to choose a sensor that can read a wide range of concentrations and can withstand high ambient temperatures. Sensors designed for industrial applications are often priced higher compared to those available for research purposes or for use with microcontrollers. The standard characteristics of hydrogen sensors suitable for industrial-scale use are defined by the specifications set by the U.S. Department of Energy (DOE) [12].

Table 2. *Specifications For Hydrogen Sensors According To Department Of Energy (DOE) Industrial Scale Standards* [12]

Parameter	Performance Requirement	DOE Requirement
Sensitivity range	< 0.1 to > 4%	Measuring range 0 – 4 vol% H2 in air; Stationary: Measuring range Up to 1 vol% H2 in air (alarm limit) Lower detection limit < 0.1 vol%
Survivability limit	100%	100%
Response time	< 30s	< 30s
Recovery time	< 30s	< 30s
Temperature range	-20˚C	Ambient temperature -40 to 125˚C
Pressure range	80-110 kPa	-
Humidity range Ambient (relative humidity range)	20 - 80%	Ambient humidity: 0 – 100% relative humidity
Power consumption	< 1W	-
Lifetime	> 5 years	Durability/lifetime : 3 – 5 years
Accuracy and repeatibility	10%	Accuracy: 10%

In a monitoring system, the availability and stability of the internet network are crucial for real-time data receiving and sending. Therefore, it is important to ensure the condition of devices that support database delivery on the Internet of Things network, such as the ESP12E WiFi communication protocol module and the Blynk application as an interface. When using the Blynk application, the database display is limited to one week for free accounts, but with a premium account, the Blynk application can record databases for up to three months. Considering the need for data archives and the stability of the internet connection, especially during the operation of the electrolyzer, becomes essential. This ensures that any hazardous conditions, such as a hydrogen gas leak, can be detected and prevented promptly. Establishing a robust internet network infrastructure in the electrolyzer operating area is crucial to ensure continuous information flow from users regarding the safety conditions of hydrogen gas production.

4. Conclusion

The monitoring and protection system designed for hydrogen gas production can provide users with information regarding the safety status of the electrolyzer operation. Through observations, it was found that higher electrolyte concentration and supply voltage in the electrolysis process result in increased hydrogen gas concentrations within a shorter time. Therefore, to ensure safety in the hydrogen production process using electrolysis and to implement a monitoring and protection system, it is essential to have a sensor that can quickly respond to system leaks and accurately measure hydrogen concentrations, particularly for industrial purposes. The incorporation of internet connectivity within the electrolyzer system environment is necessary to maintain stable data transmission and provide users with continuous and real-time information.

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SURAT PENCATATAN
CIPTAAN

Dalam rangka pelindungan ciptaan di bidang ilmu pengetahuan, seni dan sastra berdasarkan Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta, dengan ini menerangkan:

Nomor dan tanggal permohonan	:	EC00202360112, 27 Juli 2023
Pencipta		
Nama	:	**Robby Setiadi, S.Tr.T, Dr. Ing. Ahmad Taqwa, M.T. dkk**
Alamat	:	Jalan Ki Merogan Lr.Ngabehi No.707 RT.12 RW.03 Kelurahan Kemas Rindo, Palembang, Sumatera Selatan, 30258
Kewarganegaraan	:	Indonesia
Pemegang Hak Cipta		
Nama	:	**Robby Setiadi, Dr. Ing. Ahmad Taqwa, M.T. dkk**
Alamat	:	Jalan Ki Merogan Lr.Ngabehi No.707 RT.12 RW.03 Kelurahan Kemas Rindo, Palembang, Sumatera Selatan, 30258
Kewarganegaraan	:	Indonesia
Jenis Ciptaan	:	**Program Komputer**
Judul Ciptaan	:	**Sistem Monitoring Dan Proteksi Produksi Hidrogen Pada Generator HHO Dry Cell**
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Nomor pencatatan	:	000493052

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No	Nama	Alamat
1	Robby Setiadi, S.Tr.T	Jalan Ki Merogan Lr.Ngabehi No.707 RT.12 RW.03 Kelurahan Kemas Rindo
2	Dr. Ing. Ahmad Taqwa, M.T.	Jalan Hokky Kampus, Blok C/12A RT 20 RW 006, Lorok Pakjo
3	Dr. Yohandri Bow	Vila Sukajaya Indah Blok D-1, Sukabangun
4	Prof. Rusdianasari	Vila Sukajaya Indah Blok I-4, RT 46, Sukabangun

LAMPIRAN PEMEGANG

No	Nama	Alamat
1	Robby Setiadi	Jalan Ki Merogan Lr.Ngabehi No.707 RT.12 RW.03 Kelurahan Kemas Rindo
2	Dr. Ing. Ahmad Taqwa, M.T.	Jalan Hokky Kampus, Blok C/12A RT 20 RW 006, Lorok Pakjo
3	Dr. Yohandri Bow	Vila Sukajaya Indah Blok D-1, Sukabangun
4	Prof. Rusdianasari	Vila Sukajaya Indah Blok I-4, RT 46, Sukabangun

KESEPAKATAN BIMBINGAN TESIS

Kami yang bertanda tangan dibawah ini:

Pihak Pertama

Nama	: Robby Setiadi
NPM	: 062150443040
Program Studi	: Teknik Energi Terbarukan

Pihak Kedua

Nama	: Dr. Ing. Ahmad Taqwa, M.T.
NIDN	: 0004126802
Program Studi	: Teknik Energi Terbarukan

Pada hari ini Kamis, tanggal 04 Agustus 2022 telah sepakat untuk melakukan konsultasi bimbingan tesis.

Konsultasi bimbingan sekurang-kurangnya 1 (satu) kali dalam satu minggu, Pelaksanaan bimbingan pada setiap hari Senin Pukul 15.00 WIB, tempat di Kampus Politeknik Negeri Sriwijaya.

Demikianlah kesepakatan ini dibuat dengan penuh kesadaran guna kelancaran penyelesaian Tesis.

Palembang, 04 Agustus 2022

Pihak Pertama,

Robby Setiadi
NPM. 062150443040

Pihak Kedua,

Dr. Ing. Ahmad Taqwa, M.T.
NIDN. 0004126802

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Laman : http://polsri.ac.id, Pos El : info@polsri.ac.id

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Kami yang bertanda tangan dibawah ini:

Pihak Pertama

Nama	: Robby Setiadi
NPM	: 062150443040
Program Studi	: Magister Terapan Teknik Energi Terbarukan

Pihak Kedua

Nama	: Dr. Yohandri Bow, ST., MS.
NIDN	: 0023107103
Program Studi	: Magister Terapan Teknik Energi Terbarukan

Pada hari ini Kamis, tanggal 04 Agustus 2022 telah sepakat untuk melakukan konsultasi bimbingan tesis.

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Demikianlah kesepakatan ini dibuat dengan penuh kesadaran guna kelancaran penyelesaian Tesis.

Palembang, 04 Agustus 2022

Pihak Pertama,	Pihak Kedua,
Robby Setiadi	Dr. Yohandri Bow, ST., MS.
NPM. 062150443040	NIDN.0023107103

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Jalan Srijaya Negara, Palembang 30139
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REKOMENDASI UJIAN TESIS

Pembimbing Tesis memberikan rekomendasi kepada:

Nama	: Robby Setiadi
NPM	: 062150443040
Program Studi	: Magister Terapan Teknik Energi Terbarukan
Judul Tesis	: Rancang Bangun Sistem *Monitoring* Dan Proteksi Produksi Hidrogen Pada *Generator* HHO *Dry Cell*

Mahasiswa tersebut telah memenuhi persyaratan dan dapat mengikuti Ujian Tesis pada Tahun Akademik 2022/2023.

Palembang, 24 Juli 2023

Pembimbing I,

Dr. Ing. Ahmad Taqwa, M.T.
NIDN. 0004126802

Pembimbing II,

Prof. Dr. Yohandri Bow, ST., MS.
NIDN. 0023107103

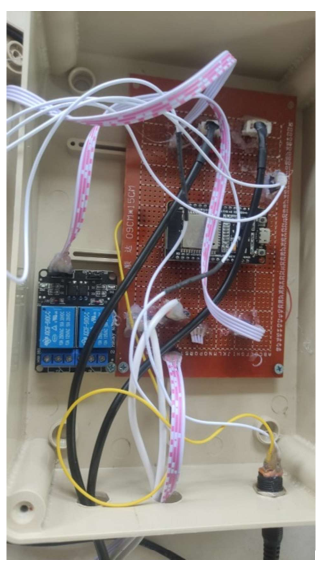
LAMPIRAN 9
DOKUMENTASI

Proses Perancangan Program

Proses Perakitan Peralatan

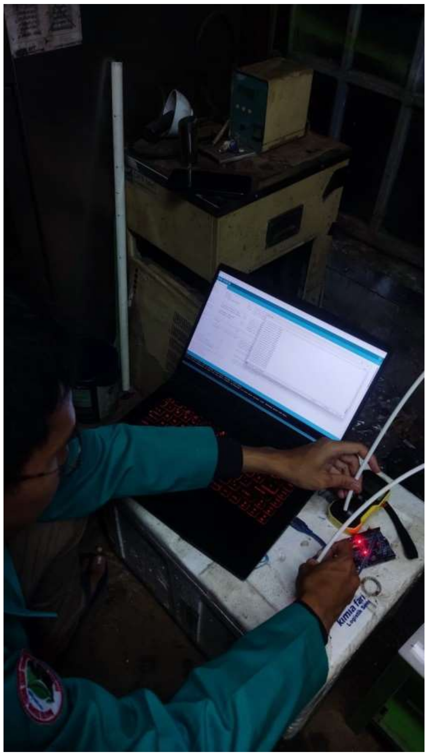
Proses Testing Peralatan ke *Generator*

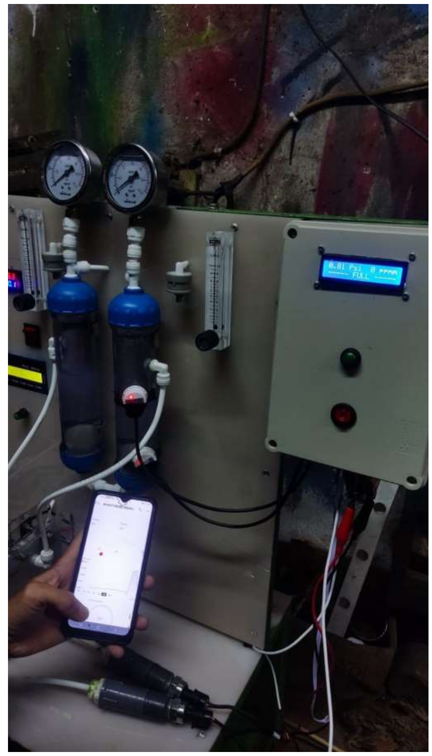
Pengujian Pengoperasian Peralatan



Rangkaian Alat Sistem *Monitoring* dan Proteksi (Tampak Bagian Dalam)

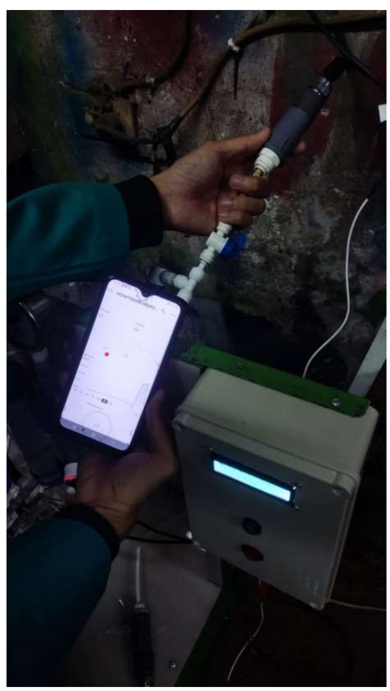
Rangkaian Alat Sistem *Monitoring* dan Proteksi (Tampak Bagian Depan)





Pengujian Performa Sensor Hidrogen

Pengujian Performa Sensor *Level*



Pengujian Performa Sensor Pressure

Pengujian Pembacaan Oksigen Dengan Alat Ukur

Pengujian Pembacaan Temperatur Dengan Alat Ukur

Pengujian Pembacaan Tekanan Dengan Alat Ukur