

CHAPTER 4 – RESULTS AND DISCUSSIONS

4.1. System Testing and Results

This section briefly summarizes the four primary experiments and testing done to confirm their reliability before being applied to the unified system.

4.1.1 Split HVAC Sensor Calibration

Due to the use of three temperature sensors in the split HVAC monitoring configuration, a calibration procedure was required during system implementation. The purpose of this process was to ensure that all sensors produced the same temperature reading when measuring at the same location. A two-point calibration method with an 8 °C temperature difference was performed using the DS18B20 sensor as the reference sensor, as shown in Figure 4.1.



Figure 4.1 Sensor Calibration

Based on the calibration data, linear regression equations were derived for each DHT22 sensor and implemented in the backend to calculate the calibrated temperature values.

To evaluate the calibration process, a data analysis was conducted. As shown in Figure 4.2, noticeable discrepancies can be observed among the sensor readings before calibration. The results indicate that the average error percentage reached up to 9.3%.

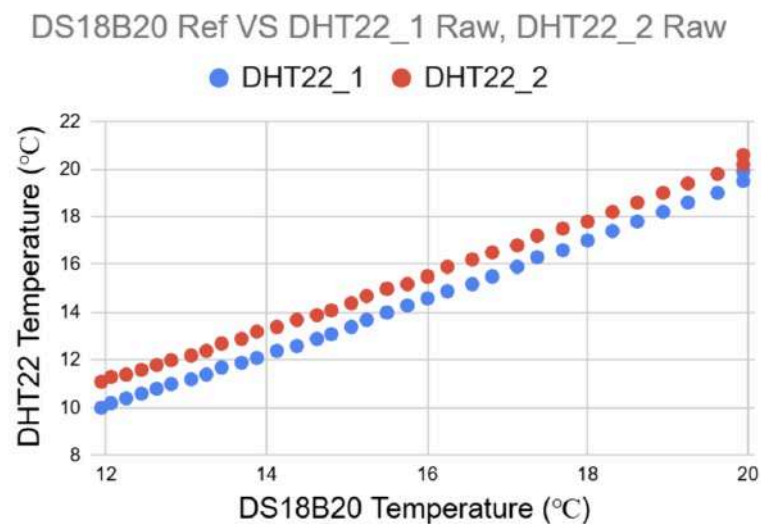


Figure 4.2 Sensor Graph Before Calibration

By selecting the initial and final calibration points, linear regression equations were obtained for each sensor, as presented in Table 4.1.

Table 4.1 Sensor Before Calibration

Sensor Comparison	Average Error (%)	Calculated Linear Regression
DS18B20 VS DH22_1	9.3	$Y = 0.83 * X + 3.59$
DS18B20 VS DH22_1	3.6	$Y = 0.87 * X + 2.2$

After applying the linear regression equations obtained from the calibration process, the results shown in Figure 4.3 indicate that the sensor readings became more closely aligned, with each sensor producing nearly identical values.

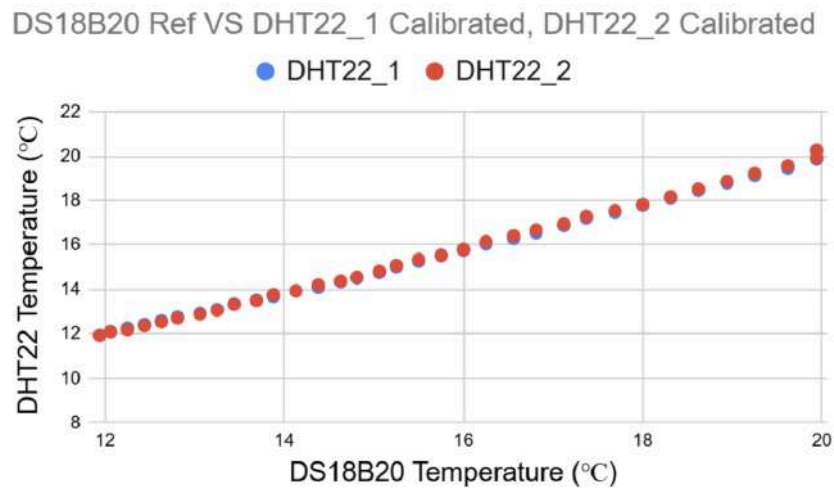


Figure 4.3 Sensor Graph After Calibration

The average error percentage decreased significantly from 9.3% to 1.04%, as presented in Table 4.2. These results demonstrate that the calibration process effectively improved the consistency and accuracy of the temperature measurements.

Table 4.2 Sensor After Calibration

Sensor Comparison	Average Error (%)
DS18B20 VS DH22_1	1.04
DS18B20 VS DH22_1	0.82

4.1.2 Current Transformer ZHT103C Test

The configuration and coding of the ZHT103C current transformer are evaluated under two load conditions, an electric stove (~2.6 A) (Table 4.3) and a hairdryer (~6 A). The measurements are compared against reference readings obtained from a Fluke meter and a Rigol MSO1074 oscilloscope (Figure 4.4) and readings can be seen on table 4.3 - 4.6.



Figure 4.4 Current Sensor Testing with Fluke Meter and Oscilloscope

Table 4.3 Current Sensor Test Result with an Electric Stove (~2.6 A)

Current Sensor Test (A)	Fluke Meter (A)	Oscilloscope (A)
2.62	2.56	2.64
2.62	2.56	2.64
2.618	2.56	2.64
2.618	2.56	2.64
2.619	2.56	2.64
2.619	2.56	2.64
2.619	2.56	2.64

2.618	2.56	2.64
2.617	2.56	2.64
2.618	2.56	2.64
2.617	2.56	2.64
2.618	2.56	2.64
2.618	2.55	2.64
2.616	2.55	2.64

On load testing with an electric stove (~2.6 A) the readings from the current sensor, Fluke meter, and oscilloscope were averaged (Table 4.4).

Table 4.4 Current Sensor Test Result with an Electric Stove (~2.6 A) Comparison

Average Current Sensor Test (A)	Average Fluke (A)	Average Oscilloscope (A)
2.618214286	2.558571429	2.64

The percentage error between the average current sensor reading and the Fluke meter is calculated using error percentage equation (Eq. 4.1) as:

$$\text{Error (\%)} = \frac{\text{Experiment Value} - \text{Reference Value}}{\text{Reference Value}} \times 100\% \quad (4.1)$$

$$\frac{2.618214286 - 2.558571429}{2.558571429} \times 100\% = 2.33\%$$

The percentage error between the average current sensor reading and the oscilloscope:

$$\frac{2.618214286 - 2.64}{2.64} \times 100\% = 0.82\%$$

Table 4.5 Current Sensor Test Result with a Hairdryer (~6 A)

Current Sensor Test (A)	Fluke Meter (A)	Oscilloscope (A)
5.993	5.96	5.911
5.986	5.95	5.911
5.977	5.94	5.911
5.975	5.93	5.911
5.973	5.92	5.911
5.975	5.92	5.911
5.973	5.91	5.911
5.973	5.91	5.911
5.979	5.91	5.911
5.981	5.91	5.911
5.973	5.91	5.911
5.973	5.9	5.911
5.961	5.9	5.911
5.951	5.9	5.911

Table 4.6 Current Sensor Test Result with an Electric Stove (~2.6 A) Comparison

Average Current Sensor Test (A)	Average Fluke (A)	Average Oscilloscope (A)
5.9745	5.919285714	5.911

On load testing with a hairdryer (~6 A) the readings from the current sensor, Fluke meter, and oscilloscope were averaged. The percentage error between the average current sensor reading and the Fluke meter is calculated as:

$$\frac{5.9745 - 5.919285714}{5.919285714} \times 100\% = 0.93\%$$

The percentage error between the average current sensor reading and the oscilloscope:

$$\frac{5.9745 - 5.911}{5.911} \times 100\% = 1.07\%$$

4.1.3 Current Transformer SCT-013-015 Test

Another current transformer test was conducted using the SCT-013-015 with the same circuit configuration. Using the SCT-013-015 specifications, the calculated calibration factor becomes (Eq 3.13):

$$\begin{aligned} \frac{1}{R_{\text{totalburden}}} &= \frac{1}{100} + \frac{1}{123,15} \\ R_{\text{totalburden}} &= 55,18\Omega \\ CF &= \frac{1800}{55,18} = 32,62 \end{aligned}$$

Initial testing was performed using a heat gun with current consumption of 3.6 A and 6.4 A. Using the calculated calibration factor of 32,62 the testing result is shown on table 4.7 - 4.10.

Table 4.7 Current Sensor Test Result with a Heat Gun (~3.6 A) CF 32.62

Current Sensor Test (A)	Fluke Meter (A)	Oscilloscope (A)
3.591	3.68	3.7
3.575	3.68	3.7
3.575	3.67	3.7

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3.575	3.67	3.7
3.575	3.67	3.7
3.575	3.66	3.7
3.578	3.65	3.7
3.575	3.65	3.7
3.575	3.64	3.7
3.575	3.64	3.7
3.575	3.64	3.7
3.575	3.64	3.7
3.575	3.64	3.7
3.575	3.64	3.7

Table 4.8 Current Sensor Test Result (~3.6 A) CF 32.62 Comparison

Average Current Sensor Test (A)	Average Fluke (A)	Average Oscilloscope (A)
3.576583333	3.655	3.7

The percentage error between the average current sensor reading and the Fluke meter is calculated as:

$$\frac{3.576583333 - 3.655}{3.655} \times 100\% = 2.14\%$$

The percentage error between the average current sensor reading and the oscilloscope:

$$\frac{3.576583333 - 3.7}{3.7} \times 100\% = 3.33\%$$

Table 4.9 Current Sensor Test Result with a Heat Gun (~6.4 A) CF 32.62

Current Sensor Test (A)	Fluke Meter (A)	Oscilloscope (A)
6.318	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.315	6.36	6.4
6.318	6.36	6.4

Table 4.10 Current Sensor Result with a Heat Gun (~6.4 A) CF 32.62 Comparison

Average Current Sensor Test (A)	Average Fluke (A)	Average Oscilloscope (A)
6.31525	6.395714286	6.4

The percentage error between the average current sensor reading and the Fluke meter is calculated as:

$$\frac{6.31525 - 6.395714286}{6.395714286} \times 100\% = 1.26\%$$

The percentage error between the average current sensor reading and the oscilloscope:

$$\frac{6.31525 - 6.4}{6.4} \times 100\% = 1.32\%$$

To improve measurement accuracy, a new calibration factor was calculated using the following empirical correction formula:

$$CF_{\text{new}} = CF_{\text{old}} \times \frac{\text{Actual Value}}{\text{Measured Value}} \quad (4.2)$$

Using this approach, the experiment was conducted twice for each load condition using different current sensors. For every test, the measured output is then inserted to equation 4.2 to calculate a new calibration factor (Figure 4.5)

Test No	Average Measured Value	Average Actual Value	Calculated New CF
1	3.576583333	3.655	33.3147557
2	6.31525	6.395714286	33.0153653
3	3.612333333	3.656666667	33.00009228
4	6.315571429	6.381428571	32.93994436
Average New CF			33.06753941

Figure 4.5 New Calibration Factor Calculation

From Figure 4.5, the new calibration factor was obtained as 33. Using this updated calibration factor, the current sensor testing was conducted again to evaluate the measurement accuracy. The testing result is shown on table 4.11 - 4.14.

Table 4.11 Current Sensor Test Result (~3.6 A) CF 33

Current Sensor Test (A)	Fluke Meter (A)	Oscilloscope (A)
3.7	3.72	3.7
3.684	3.71	3.7
3.681	3.71	3.7
3.684	3.7	3.7
3.684	3.69	3.7
3.677	3.69	3.7
3.684	3.69	3.7
3.684	3.69	3.7
3.684	3.68	3.7
3.684	3.67	3.7
3.674	3.67	3.7
3.575	3.67	3.7
3.575	3.65	3.7
3.575	3.67	3.7

Table 4.12 Current Sensor Test Result with a Heat Gun (~3.6 A) CF 33 Comparison

Average Current Sensor Test (A)	Average Fluke (A)	Average Oscilloscope (A)
3.674583333	3.686428571	3.7

The percentage error between the average current sensor reading and the Fluke meter is calculated as:

$$\frac{3.674583333 - 3.686428571}{3.686428571} \times 100\% = 0.32\%$$

The percentage error between the average current sensor reading and the oscilloscope:

$$\frac{3.674583333 - 3.7}{3.7} \times 100\% = 0.68\%$$

Table 4.13 Current Sensor Test Result with a Heat Gun (~6.4 A) CF 33

Current Sensor Test (A)	Fluke Meter (A)	Oscilloscope (A)
6.489	6.47	6.4
6.463	6.46	6.4
6.53	6.45	6.4
6.43	6.44	6.4
6.43	6.43	6.4
6.433	6.42	6.4
6.433	6.41	6.4
6.43	6.41	6.4
6.436	6.41	6.4
6.426	6.4	6.4
6.43	6.4	6.4
6.315	6.4	6.4
6.315	6.4	6.4
6.318	6.4	6.4

Table 4.14 Current Sensor Test Result with a Heat Gun (~6.4 A) CF 33 Comparison

Average Current Sensor Test (A)	Average Fluke (A)	Average Oscilloscope (A)
6.430666667	6.421428571	6.4

The percentage error between the average current sensor reading and the Fluke meter is calculated as:

$$\frac{6.430666667 - 6.421428571}{6.421428571} \times 100\% = 0.14\%$$

The percentage error between the average current sensor reading and the oscilloscope:

$$\frac{6.430666667 - 6.4}{6.4} \times 100\% = 0.47\%$$

The difference between the theoretical and experimentally corrected calibration factors may be caused by several practical factors, including variations in the actual number of coil turns inside the current transformer, manufacturing tolerances in the built-in sensor resistance.

4.1.4 HVAC System Test

For the HVAC system, the monitoring configuration utilizes two DHT22 sensors and one DS18B20 temperature sensor. After the device pairing process is completed, the system requires a calibration procedure to improve sensor accuracy before normal operation. Following calibration, the sensor node was installed on the appliance and allowed to continuously monitor operational data for approximately four hours, from 12:30:39 PM to 04:15:24 PM on May 16, 2026.

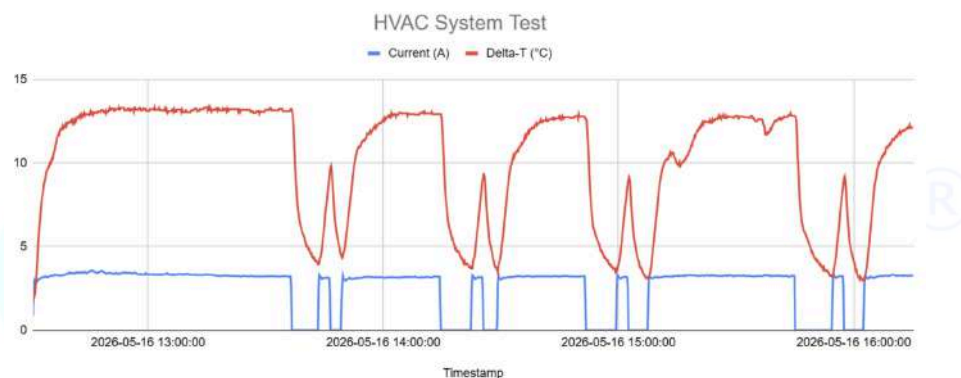


Figure 4.6 Split HVAC Test Current & Delta-T

Based on the collected data, the behavior of each parameter over time can be evaluated. From Figure 4.6, it can be observed that the Delta-T value reaches its highest point shortly before the compressor turns off. This occurs because the cooling process becomes most effective after the system has operated for a certain duration, causing the supply air temperature to decrease significantly compared to the return air temperature. As the room approaches the target temperature, the compressor eventually shuts off, resulting in the peak Delta-T value appearing near the end of the cooling cycle.

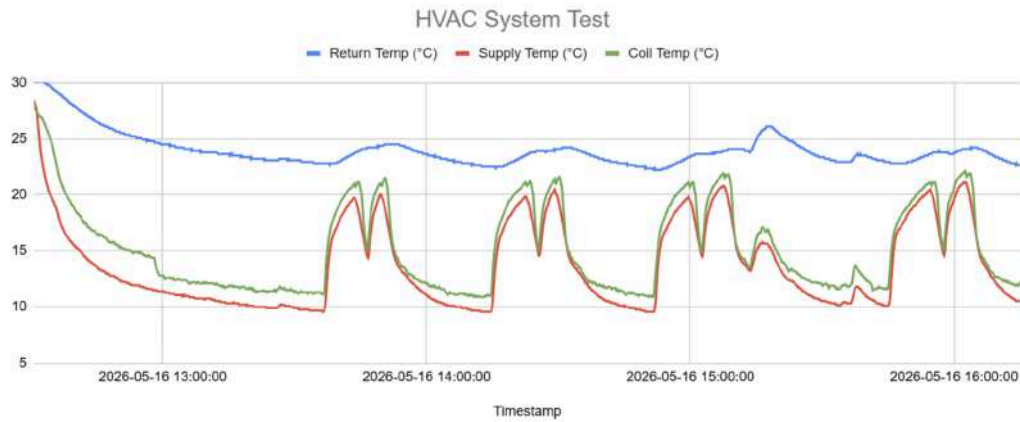


Figure 4.7 Split HVAC Test Current & Delta-T

From the observations in Figure 4.7, the DS18B20 sensor was unable to capture the actual evaporator coil temperature accurately, as the measured coil temperature remained higher than the supply air temperature. Although the sensor was positioned near the original thermocouple location of the air conditioning unit, this limitation is caused by the stainless-steel casing of the DS18B20 probe, which has lower thermal conductivity compared to the original indoor unit copper-based thermocouple, resulting in a slower thermal response as shown in Figure 4.8 (Maeno, Mori, and Fujimoto, 2009). In addition, the contact surface between the sensor and the evaporator coil was not optimal because the sensor was mounted only using cable ties, which may have further reduced heat transfer accuracy.

	Stainless steel	Copper
Thermal conductivity	15 [W/m·K]	393 [W/m·K]

Figure 4.8 Thermal Conductivity

Because of this limitation, the fault detection method was shifted to focus mainly on the temperature difference (ΔT) between the return and supply air.

4.1.5 Gas Dryer System Test

For the gas dryer system, testing was conducted over an extended operational period from 07:58:54 AM on April 14, 2026, until 11:47:58 AM on May 8, 2026. During this testing phase, the system continuously monitored exhaust temperature, relative humidity (RH), pressure, and motor current throughout multiple dryer operating cycles.

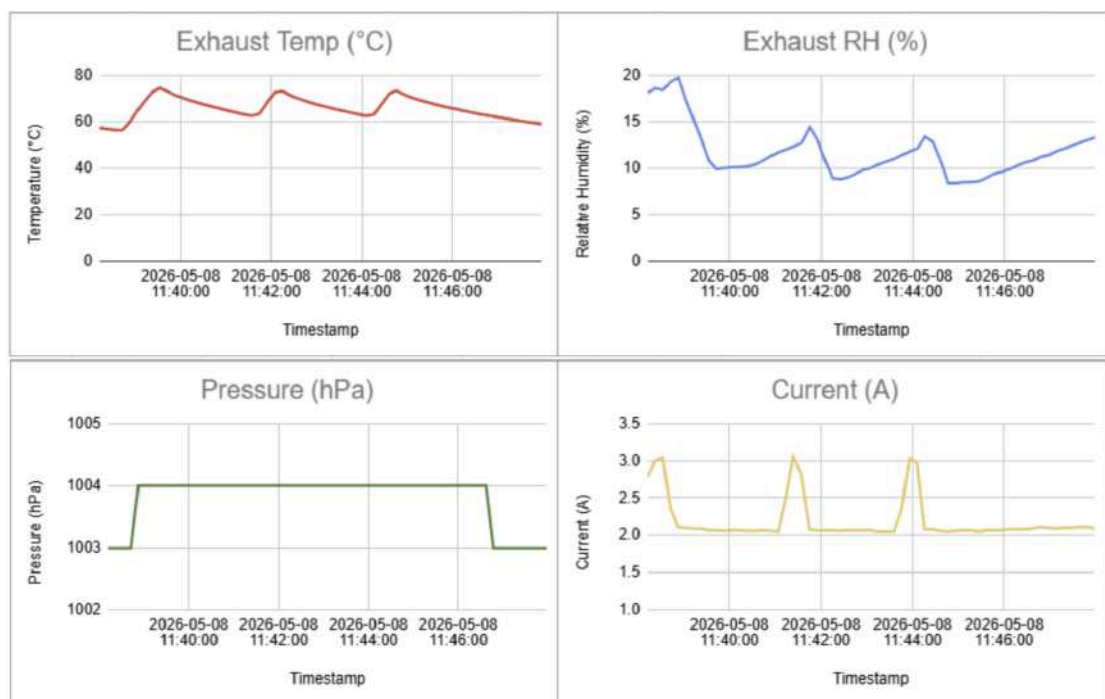


Figure 4.9 Gas Dryer No Load Cycle Test

Based on the collected data (Figure 4.9), it was observed that the system was capable of clearly detecting changes in temperature and relative humidity during each drying cycle. These parameters showed distinguishable fluctuations corresponding to the operational stages of the dryer, indicating that they could be effectively utilized for monitoring dryer behavior and performance.

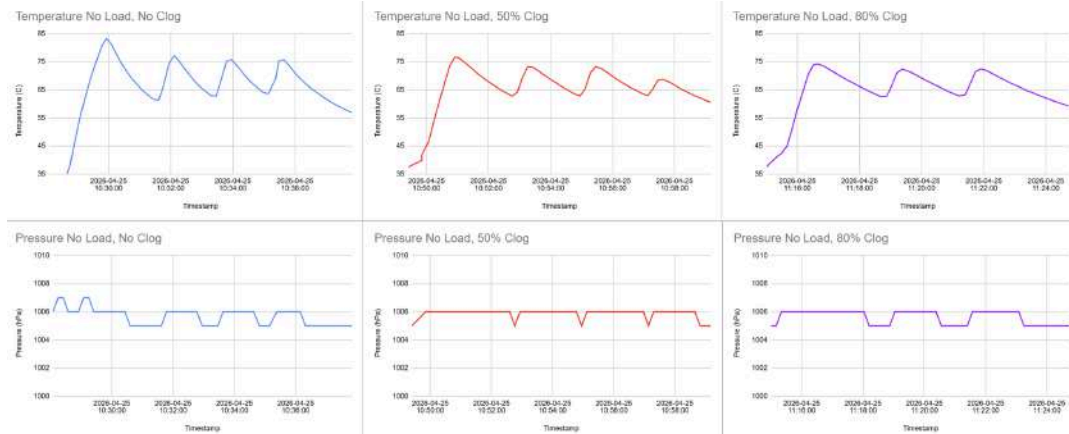


Figure 4.10 Gas Dryer Clog Test

Due to the limited magnitude of these pressure changes, the original sensor resolution was considered insufficient for detailed monitoring and analysis (Figure 4.10). Therefore, the system resolution for pressure data recording was increased to retain two digits after the decimal point. This adjustment improved the visibility of minor pressure fluctuations and allowed the monitoring system to capture more detailed operational characteristics of the dryer (Figure 4.11).

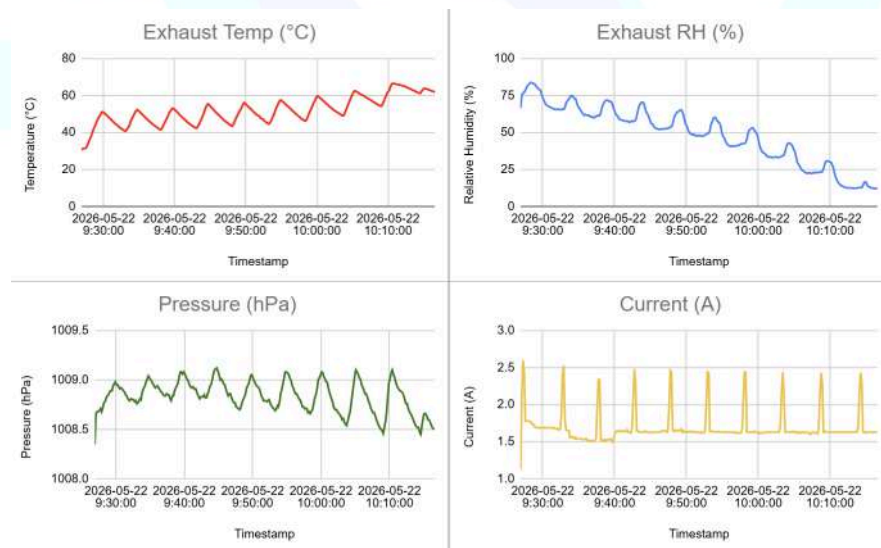


Figure 4.11 Gas Dryer Test

To evaluate the accuracy of the gas dryer analytical table logic, three gas dryer cycles were conducted between 20 May 2026 at 10:04:09 PM and 22 May 2026 at 10:16:35 AM. Manual calculations were then performed and compared with the results generated by the system.

Metric		Manual	System	Result
Total Cycle		3	3	Match
Cycle 1	Duration (Minute)	49.83	49.8	Match
	Ignition	10.00	10	Match
	Minimum Temp (°C)	44.90	44.9	Match
	Maximum Temp (°C)	73.10	73.1	Match
	Begin RH (%)	36.28	36.28	Match
	End RH (%)	11.85	11.85	Match
	Ignition Spike (A)	2.46	2.46	Match
	Motor Current (A)	1.66	1.659	Match
	Energy Consumption (kWh)	0.32	0.3157	Match
Cycle 2	Duration	48.66	49.7	Match
	Ignition	10.00	10	Match
	Minimum Temp (°C)	32.90	32.9	Match
	Maximum Temp (°C)	72.10	72.1	Match
	Begin RH (%)	69.50	69.5	Match
	End RH (%)	9.20	9.2	Match
	Ignition Spike (A)	2.43	2.44	Match
	Motor Current (A)	1.63	1.629	Match
	Energy Consumption (kWh)	0.31	0.3069	Match
Cycle 3	Duration	49.80	49.8	Match
	Ignition	10.00	10	Match
	Minimum Temp (°C)	30.80	30.8	Match
	Maximum Temp (°C)	66.40	66.4	Match
	Begin RH (%)	75.78	75.78	Match
	End RH (%)	12.37	12.37	Match
	Ignition Spike (A)	2.46	2.46	Match
	Motor Current (A)	1.63	1.629	Match
	Energy Consumption (kWh)	0.31	0.3092	Match

Figure 4.12 Analytical Table Manual vs. System Comparison

As shown in Figure 4.12, the manually calculated data closely matches the system-generated results, with only minor differences caused by rounding. This demonstrates that the system is able to accurately calculate the gas dryer cycle and its operating parameters.

4.2. Sensor Node

The electrical schematic diagram (Figure 3.9) is converted into PCB and manufactured by JLCPCB. The PCB dimensions are 7.3 cm × 6 cm and include three mounting holes that are used to secure the PCB inside the sensor node housing (Figure 4.13).



Figure 4.13 Printed Circuit Board (PCB)

Creating a user-friendly enclosure while reducing operational errors during system usage and maintenance is the primary goal of the casing design (Figure 4.14). Several design considerations were implemented, including dedicated label slots to differentiate between sensor nodes, labeled ports with numbered indicators for easier wiring identification, and directional labels for the switches to improve usability. The casing also includes slots for LED status indicators, allowing users to visually monitor the operational condition of the sensor node based on the indicator behavior described in Table 3.3. The flexible casing section itself acts as the button cap for button 2 and can be pressed directly by the user. This hidden button is used for HVAC calibration requests. The separation of button types was designed to reduce the possibility of incorrect button presses during operation by the user.



Figure 4.14 Printed Sensor Node Housing

4.3. Website UI

4.3.1 Login & Sign Up Page

Figure 4.15 shows the login screen, where users enter their credentials to access the system.

The image shows two side-by-side screenshots of a web application interface. The left screenshot is the 'Member Login' page, which has a purple background. It features a user icon, the title 'Member Login', and the instruction 'Sign in to your IoT monitoring dashboard'. There are input fields for 'Username / Email' and 'Password', a 'Remember me' checkbox, a 'Forgot password?' link, a blue 'LOGIN' button, and a 'Don't have an account?' link at the bottom. The right screenshot is the 'Create Account' page, which has a white background. It features the title 'Create Account' and the instruction 'Start monitoring your appliances'. There are input fields for 'Full Name', 'Email', 'Password' (with a note 'At least 6 characters'), and 'Confirm Password' (with a note 'Re-enter password'). There is a blue 'Sign Up' button and a link 'Already have an account? Login' at the bottom.

Figure 4.15 Login and Create Account Page

If a user does not have an account, they can click the “Don’t have an account?” option at the lower left, which redirects them to the sign-up screen. On the sign-up screen, users must provide their full name, email address, password, and password confirmation to create a new account.

4.3.2 Dashboard Page

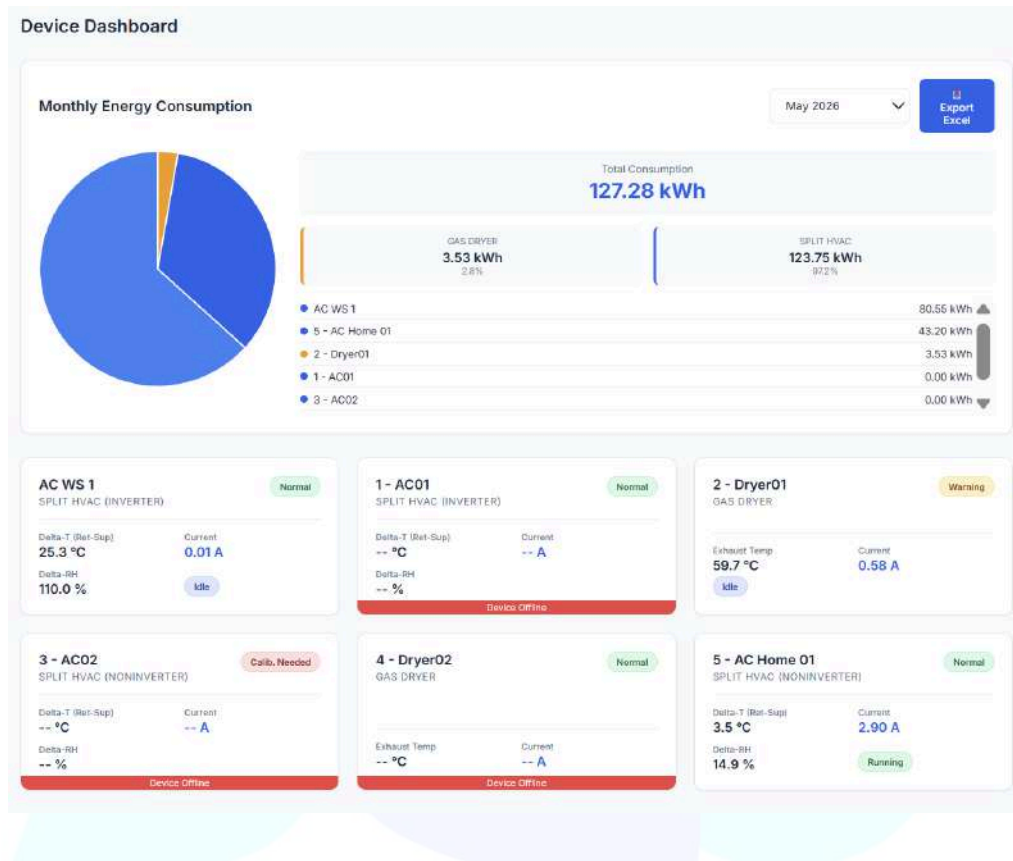


Figure 4.16

The dashboard page consists of a monthly power consumption report that displays the percentage of energy consumption and the paired device card and the status of each appliance (Figure 4.16). The dashboard also provides information regarding the total monthly energy consumption and the individual energy usage of each appliance. This feature allows users to easily monitor appliance power consumption on a monthly basis. On the right side of the dashboard, users can select the monitoring month and export the energy consumption data into an Excel file for reporting and analysis purposes (Figure 4.17).

Monthly Energy Consumption Summary		
Month: 2026-05		
Export Date: 2026-05-22 16:21:33		
Appliance Type	Appliance Name	Energy Consumption (kWh)
Gas Dryer	2 - Dryer01	4.5794
Gas Dryer	4 - Dryer02	0
Split HVAC	1 - AC01	0
Split HVAC	3 - AC02	0
Split HVAC	5 - AC Home 01	53.3114
Split HVAC	AC WS 1	105.9527
Total		163.8435

Figure 4.17 Generated Monthly Summary Excel File

4.3.3 Add Device Page

Looking for New Sensor Nodes?

Make sure your ESP32 is powered on. Click scan to discover unpaired MAC addresses.

Scan for Unpaired Nodes

1C:DB:D4:C4:66:14

1. Appliance Name

AC Test 1

2. Select Appliance Type

Air Conditioner (Split HVAC)

HVAC Technology

Inverter (Variable Speed)

Hardware Wiring for Split HVAC

- DHT22 (Port 1): AC Return (Top intake)
- DHT22 (Port 2): AC Supply (Cold output)
- DS18B20 (Port 3): Evaporator coil
- ZHT103C (Port 6): Compressor live wire

After pairing, for HVAC press BOTH buttons 5s on Device to calibrate. For dryer, instantly begin baseline training.

Save & Link Appliance

Figure 4.18 Add Device Page Filled

Figure 4.18 shows the screen that is used during the initial pairing of a sensor node with its corresponding appliance. First, the system scans for active and unpaired sensor nodes. Once detected, the user can assign a name to the device (e.g., Living Room AC) and select the appliance type it will monitor (Split HVAC or gas dryer). If Split HVAC is selected, the user is further prompted to specify whether the unit is inverter or non-inverter.

4.3.4 Discord Registration

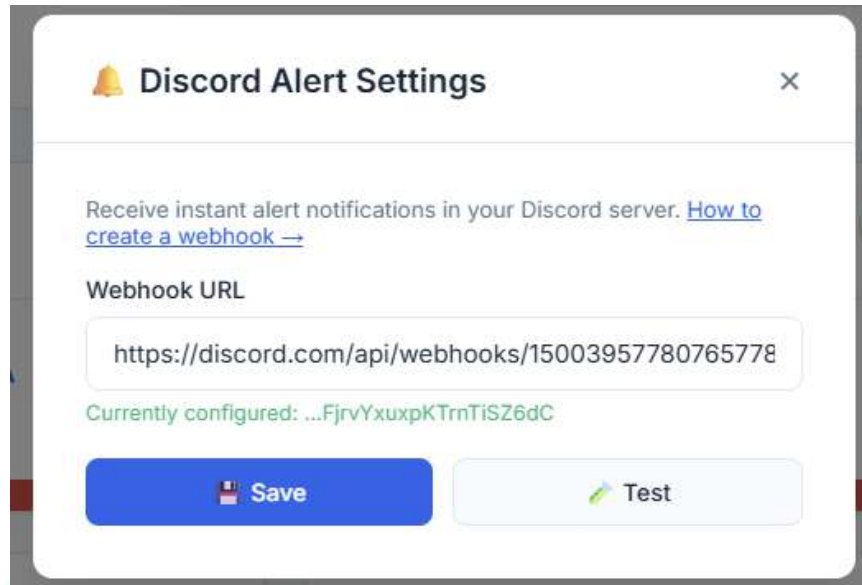


Figure 4.19 Discord Webhook Insert

On the Discord registration page, users are required to enter their own Discord webhook URL (Figure 4.19). To assist users who may be unfamiliar with the setup process, a tutorial link is also provided that directs them to a Discord guide on creating a webhook. This feature is included to minimize difficulties in configuring the Discord-based alert system. After entering the webhook URL into the provided text box, users can test the webhook connection to verify proper integration by clicking the “test” button or save the webhook URL for future fault alert notifications (Figure 4.20).

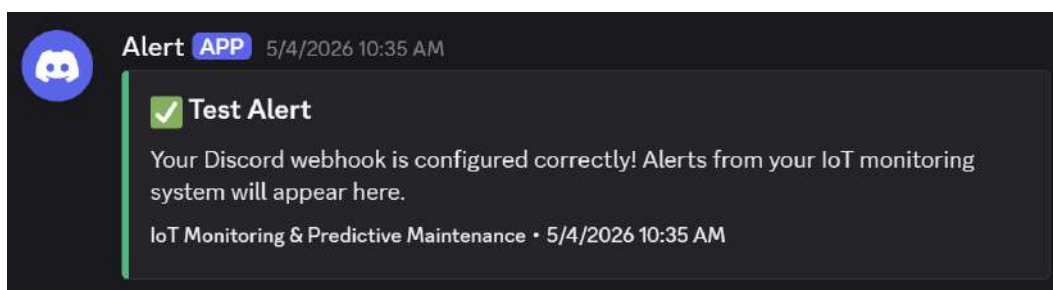


Figure 4.20 Discord Webhook Test Output

4.3.5 Device Card and Data Characteristics

When a device card on the dashboard page is selected, a detailed view of the monitored appliance is displayed (Figure 4.21), (Figure 4.23). Each device card contains the appliance name, appliance status, and connection status.

The detailed page provides graphical visualization of all monitored parameters along with their latest recorded values, which can be viewed either from the most recent 1080 data points or based on a user-defined time range.

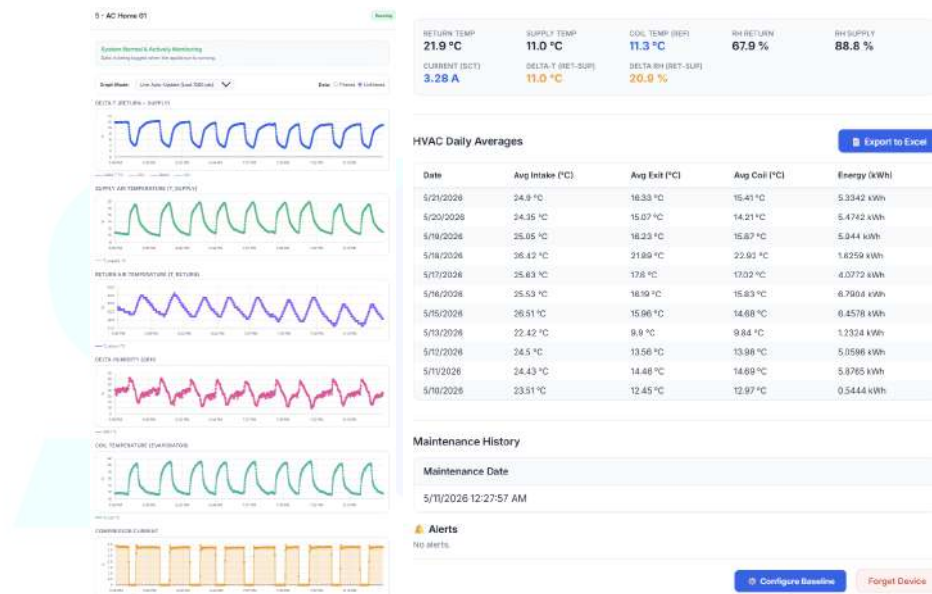


Figure 4.21 HVAC Device Card Page

The collected monitoring data can be used to analyze the operating characteristics of the monitored appliance. As shown in Figure 4.22 for split HVAC non-inverter, the primary parameter observed is the delta temperature (ΔT), which is calculated from the return air temperature minus the supply air temperature. When the compressor is running, indicating that the HVAC system is actively cooling, the ΔT value increases as the temperature difference between the return and supply air becomes larger. Once the desired room temperature is reached, the ΔT gradually decreases.

However, a decrease in ΔT does not immediately trigger an alert. Alerts are generated only when the compressor is operating while the ΔT value falls below the lower control limit (LCL), indicating a potential reduction in cooling performance.

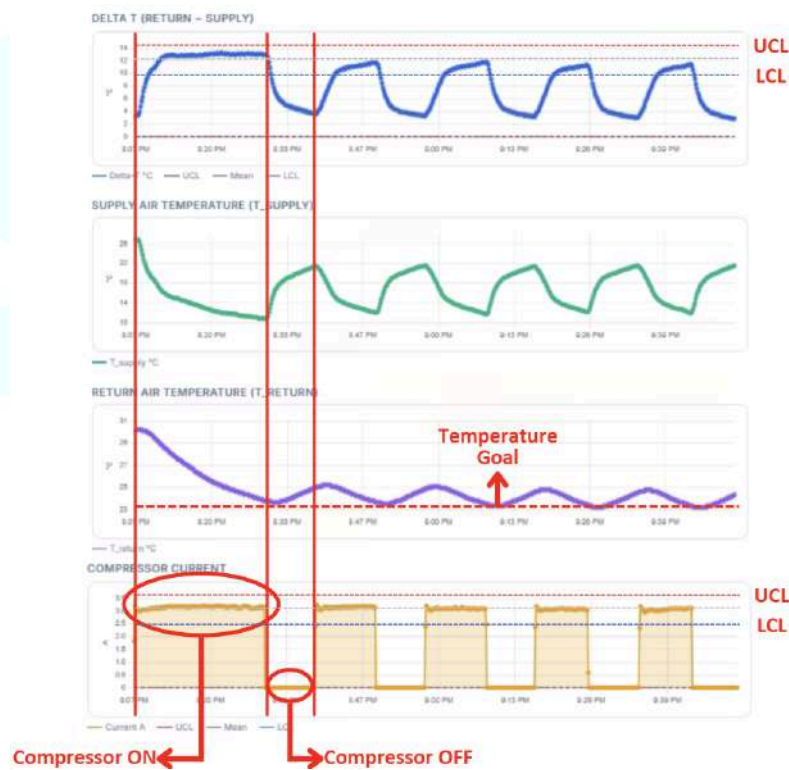


Figure 4.22 Split HVAC Data Characteristics

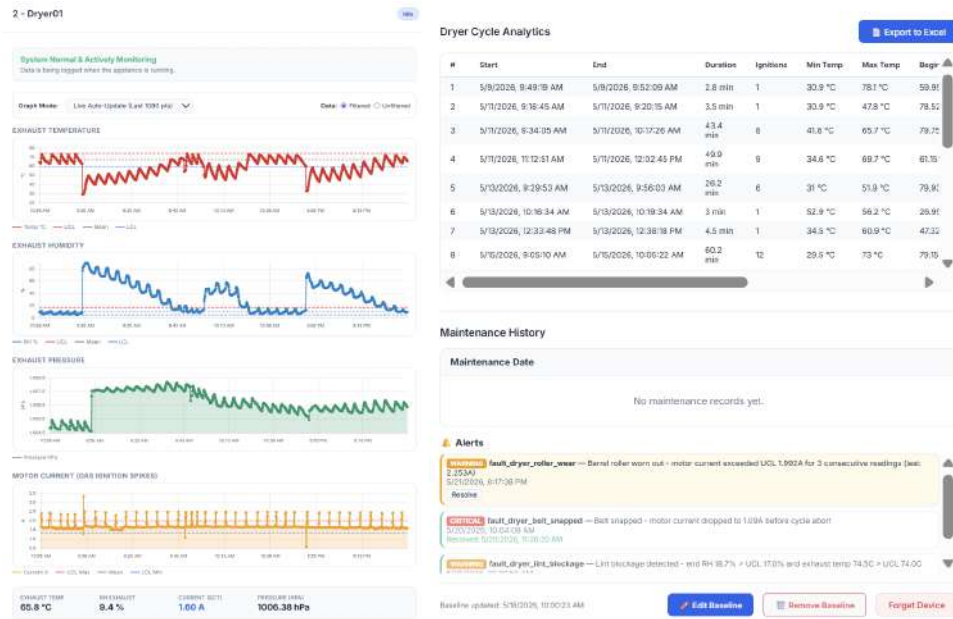


Figure 4.23 Gas Dryer Device Card Page

Because the gas dryer is using an electric ignitor, there are ignitions in the current usage from the data from figure 4.24 as there is ignition which indicates the flame turn on the temperature gradually increases, and the humidity comes down meaning that the cycle is drying the load.

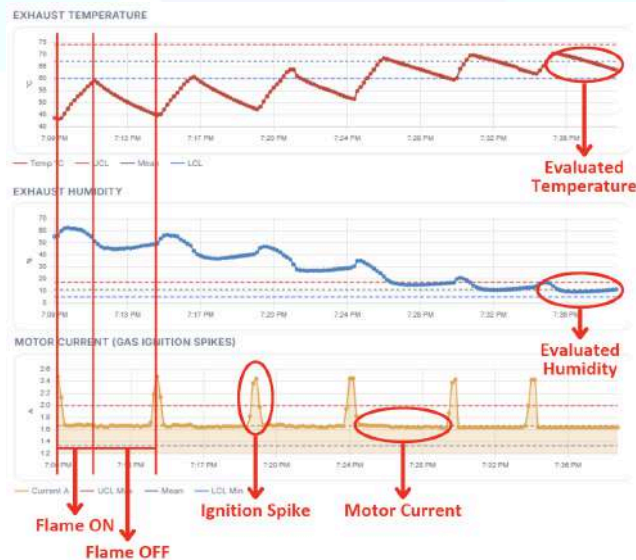


Figure 4.24 Gas Dryer Data Characteristics

In addition, an analytical table classified according to Table 3.7 and Table 3.8 is provided, with an Excel export feature that allows users to export data within a selected time range or all recorded data since the initial pairing process (Figure 4.25). The page also includes maintenance history, alert history, baseline configuration settings, edit and removal functions, as well as an option to disconnect or forget the sensor node.

Device: 2 - Dryer01

Type: Gas Dryer

Export Date: 2026-05-23 14:00:27

Data Points: 4351

Timestamp	Exhaust Temp (°C)	Exhaust RH (%)	Pressure (hPa)	Current (A)
2026-05-09 09:49:19	30.9	61.2	1006	2.75
2026-05-09 09:49:29	30.9	60.8	1006.53	1.78
2026-05-09 09:49:39	31	59.1	1006.58	2.17
2026-05-09 09:49:49	31.1	58.3	1006.58	2.44
2026-05-09 09:49:59	31.3	58.2	1006.58	1.97
2026-05-09 09:50:09	33.9	62.1	1006.55	1.64
2026-05-09 09:50:19	39.8	55.7	1006.59	1.64
2026-05-09 09:50:29	45.1	47.6	1006.66	1.66

Figure 4.25 Generated Appliance Data Excel Export

4.4. Multi Node Testing

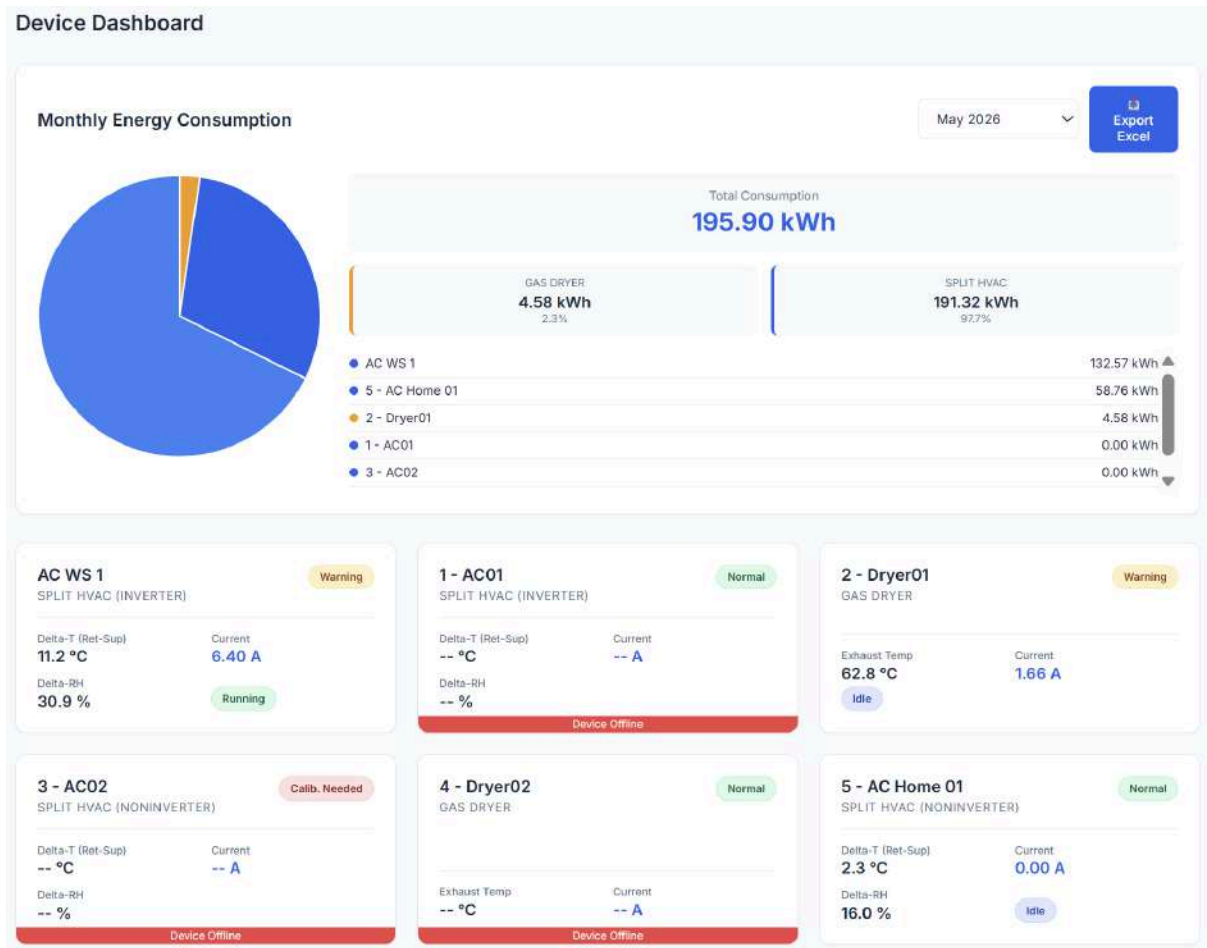


Figure 4.26 Generated Appliance Data Excel Export

Multiple node testing was conducted in parallel to evaluate the scalability of the proposed system (Figure 4.26). At the time of this research, six sensor nodes had been successfully paired with the system, with three nodes actively monitoring appliances consisting of two split HVAC units and one gas dryer. The system was able to monitor appliance status and operating conditions in near real time, while also generating monthly energy consumption data that provided both total energy usage and per-appliance energy consumption information.

4.5. Baseline Setting and Fault Alert

This section explains the procedure for configuring the baseline values used as references for the fault detection logic and alert system. To configure the baseline, users must select the “Configure Baseline” button located at the bottom of the device card (Figure 4.27). Users are then required to define the Upper Control Limit (UCL) and Lower Control Limit (LCL) for the relevant monitoring parameters. For split HVAC systems, the parameters include Delta T and compressor current, while for gas dryers, the parameters include exhaust temperature, exhaust humidity, and motor current.

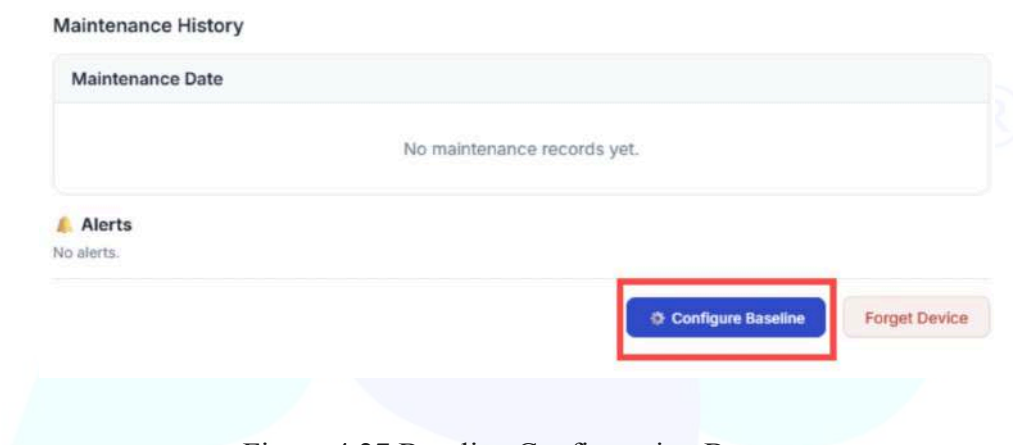


Figure 4.27 Baseline Configuration Button

To minimize incorrect baseline configuration and reduce false alerts, guidance is provided to help users determine appropriate UCL and LCL values (Figure 4.28), (Figure 4.29). For exhaust temperature and humidity, users define the UCL and LCL, and the system automatically calculates the mean value. In contrast, for motor current, users directly input the mean current value corresponding to the normal operating cycle of the gas dryer. This difference in input method is implemented to simplify the configuration process, as motor current values are generally easier to define based on the typical operating current of the dryer cycle.



Figure 4.28 Baseline Setting Guidance for Split HVAC



Figure 4.29 Baseline Setting Guidance for Gas Dryer

After the baseline configuration is completed, the monitored appliance data are evaluated using the fault alert logic defined in Table 3.5 and Table 3.6. Fault conditions are then simulated to verify that the alert system functions correctly and triggers notifications as intended. On a split HVAC system dirty indoor filter fault is simulated by blocking the indoor unit filter (Figure 4.30) and discord alert is generated (Figure 4.31).



Figure 4.30 Initial Indoor Filter Condition, Blocked Indoor Filter Condition



Figure 4.31 Generated Discord Indoor Filter Alert

After implementing the monitoring system on the gas dryer, a “clothes not properly dried” fault alert was generated. The alert was then evaluated to determine whether it corresponded to an actual operational fault or a false alarm and all generated alerts were confirmed to represent real faults (Figure 4.32).

Appliance Unit	Date	Time	Fault Alert	Is Fault Real
2 - Dryer 01	25/05/2026	10:28:48 AM	Clothes Not Dried	Yes
2 - Dryer 01	28/05/2026	8:13:30 AM	Clothes Not Dried	Yes
2 - Dryer 01	01/06/2026	9:02:28 AM	Clothes Not Dried	Yes

Figure 4.32 Generated Dryer Fault Evaluation

Users can later resolve the alert to restore the sensor node status back to normal (Figure 4.33). Detected fault alerts are sent to the user’s registered Discord webhook URL and are also stored in the alert history log (Figure 4.34), (Figure 4.35), (Figure 4.36), (Figure 4.37).



Figure 4.33 Alert History

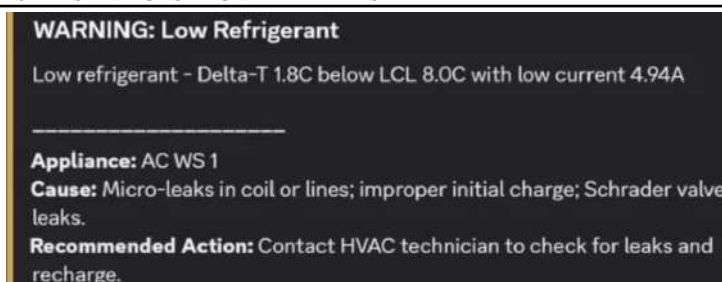


Figure 4.34 Discord Split HVAC Low Refrigerant Alert

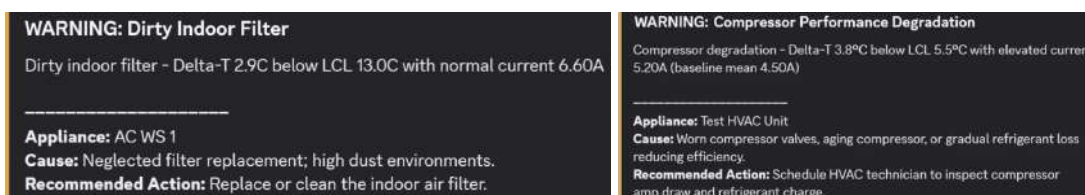


Figure 4.35 Discord Split HVAC Dirty Indoor Filter, Compressor Degradation

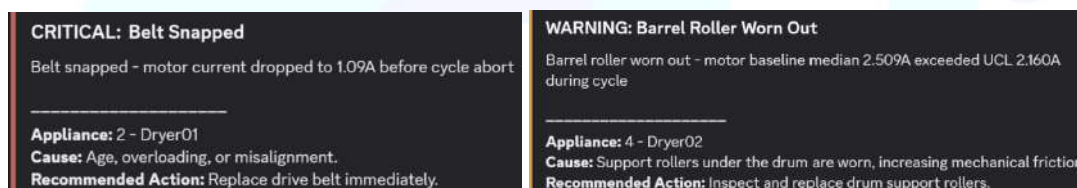


Figure 4.36 Discord Belt Snapped, Barrel Roller Worn Out Alert

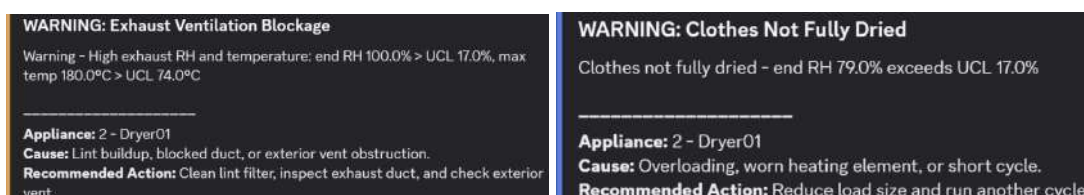


Figure 4.37. Discord Gas Exhaust Ventilation Blockaged, Clothes Not Dried Alert