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DESIGN AND DEVELOPMENT OF AIR CONDITIONER (AC) MONITORING AND MANAGEMENT SYSTEM

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Abstract— **Nowadays, Air Conditioner (AC) has become a more important appliance in our life. The primary reasons behind the AC explosion are gas leakage, blockage in the evaporator and compressor coil, pipelines, and dust in the air filters. Many people have been injured over the years due to AC blasts. This paper developed a system that uses sensor technology and intelligent devices to reduce AC blast. As a result, pipeline leaks or blockage fault detection system was planned and constructed using MQ-02, TTC 103, optical dust sensors for gas detection, temperature detection, and for detecting dust density, respectively. Also, bacteria can be detected through the MQ-3 sensor as it combines with AC refrigerant and produces ethanol. This system is also digitally connected to smart devices (cellphones) and a control device (RM MINI 3) so that users can receive a detection notification at any time and operate AC from any location. By implementing these sensors, the initial target was achieved. The work is low cost and environment friendly.**

Index Terms— **Explosions, blockage, leakage, RM MINI 3, cellphone, refrigeration cycle, sensor, safety**

I. Introduction

The first electrical air conditioning was invented by Willis Haviland Carrier in the year 1902, who was also known as the Father of Modern Air Conditioning. In 1824 the principles for the adsorption type of refrigeration were discovered by Michael Faraday. Refrigerant is the messenger of the heat exchange between the external environment and the internal components called by the name Freon. This Freon was discovered by Thomas Midgley, Jr., in 1928.

Air Conditioner (AC) users in Bangladesh are increasing day by day. Air conditioners are not made to explode. Although AC blasts appeared to be a common scenario with a few casualties in the country, no such disastrous blast was reported here in the last few decades as the number of users is overgrowing, so it is high time to detect the causes, aware the users about AC explosions and take immediate action. The blasts stem from compressor failure in the air conditioner in most cases. Taking good care of the air conditioners can help the users be safe from explosions. There are many reasons behind AC explosions like dirty coils, blocked suction lines, low refrigerant charge, incorrect suction line size, too much refrigerant, electrical problems, Contaminants in the system, Inadequate oil lubricant. However, this type of explosion can be easily avoided if a system is generated that detects the gas leakage of an AC, detects the blockage line, and monitors the refrigerant cycle system. On the other hand, if some steps are taken like AC compressor never stopping running, cleaning the air filter from time to time, identifying any unusual noise, unplugging during storms, etc. explosions can be avoided.

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II. Literature Review

Some previous literature works focused on the design and development of air conditioner (AC) monitoring and management systems, and some novel solutions to the problems were summarized in this section.

I S. Rahman, in March 2019 from the Iraqi Journal of Science, proposed about the detection of the bacterial population in an air conditioner. Air samples were taken from the house air conditioner for this proposed solution. According to the findings, gram-positive bacteria were found to be more prevalent in air conditioners than gram-negative bacteria [1].

Huan Hui Yan and Yusnita Rahayu, in 2014, proposed a design and development of a gas leakage monitoring system using Arduino and ZigBee. A combustible gas sensor (MQ9) was used to detect the presence of methane (CH4) and carbon monoxide gas using this proposed solution (CO). This sensor can detect the gas concentration based on the sensor's voltage output and will be used in an alarm system, autonomous control system, and monitoring system, with the Arduino Uno serving as the system's microcontroller. The data reading from the gas sensor was sent via Zigbee to the monitoring device, which displays "Gas Detected." This process was discovered by Huan Hui Yan and Yusnita Rahayu [2].

James E. Farnsworth and his team developed a method for bacteria and virus recovery from heating, ventilation, and air conditioning (HVAC) filters in a journal on September 6, 2006. The research aimed to see whether building air handling units (AHUs) could be used as high-volume sampling devices for bacteria and viruses in the air. The bacteria and viruses were nebulized in separate samples and inserted into the research facility's test duct upstream of a MERV 14 filter. Upstream and downstream of the test filter, SKC Bio-samplers acted as reference samplers. The findings suggested that analyzing the material collected on HVAC filter media may be used to assess the airborne concentration of spore-forming bacteria in building AHUs, but culture-based analytical techniques were impractical for virus recovery. Techniques like PCR, which were based on molecular biology, may be used even though the results were appropriate but made the system much more complicated and more expensive [3].

In Alexandria, Egypt, O. Srour, E. Saber, and H. A. Elgamal of the Arab Academy for Science Department of Mechanical Engineering proposed a technique for detecting pipeline blockages based on wall shear stress prediction. A minor sinusoidal disturbance inflow was artificially added at pipe entry to the original flow to have time shifts in velocity distribution and wall shear stress capable of sensing the presence of blockage in the pipe. As compared to the wall shear stress in the non-blocked portion of the pipe, the shear stress at the blockage surface remained higher. Partial blockage of the pipeline was investigated by Pressure-Induced Blockage analysis. The research paper was published by the International Journal of Engineering Research & Technology (IJERT) on 06, June-2016 [4].

The blockage in the pipes was the first problem with the Air Conditioning system. Since pipeline blockages trigger most explosions, Nan Bu, Naohiro Ueno, and Osamu Fukuda developed a pipeline blockage detection device using a versatile piezoelectric film sensor on January 18, 2021 [5].

Rafeeq, Mohammed & Afzal, Asif & Rajendra, Sree designed and developed an automated and manual AC system working in remote and local mode to increase the level of comfort and faults occurring in the system. The Programmable Logical Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) system were used for remote supervision and monitoring of AC systems using series ninety protocol and remote terminal unit Modbus protocol as communication module to operate in remote mode. PLC was used as a remote terminal for continuous supervision and control of the AC system. SCADA software was used to design a user-friendly graphical user interface. The proposed SCADA AC system was successfully monitored and controlled following the parameter limits like temperature, pressure, humidity, and voltage [6].

That literature works helped to find out the main aspects or causes of AC explosion in our works and how to deal with the problem through optimal solutions. The solution must be within our reach. The device should be easy to install.

III. MODELLING AND SIMULATION

The system was built to save the user's life in every possible accident that can happen related to Air Conditioner. The entire system was Arduino-based, and a series of sensors were used with Arduino, such as a wi-fi module, gas detector sensor, blockage detector sensor, bacteria detector sensor, dust detector sensor, temperature sensor, and pressure sensor. Gas, Dust, Bacteria sensors were placed in the indoor and temperature, pressure sensors were placed in the pipeline of an Air Conditioner and Compressor pipeline to detect the blockage. The system was also able to locate the fault, which will help the user manage the regular operation of an Air Conditioner. It was coded based on some pre- defined standard temperature values and pressure to detect any abnormalities if they crossed the limits. If any abnormalities occurred in Air Conditioner, then it would be sensed by sensors and shown in the monitor through Arduino Board. By any chance, if the user did not notice the monitor or that time the user was not at home, then the wi-fi module which was connected with Arduino Board will send the notification to the user's mobile, which was saved there before. After getting a notification from mobile, the user can take proper steps like turning the Air Conditioner off using the RM MINI 3 device to avoid unwanted accidents and can save lives.

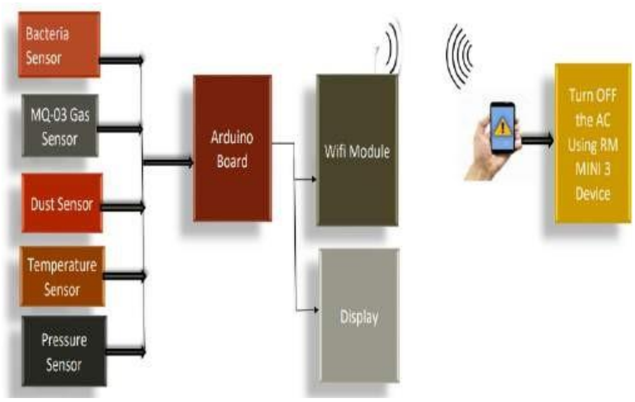

Fig.1. Block diagram of the system

A. Simulation of the work

Proteus 8 Professional software was used to complete this simulation. Since the MQ-3 sensor was not available in the library, the MQ-2 gas sensor was used to detect gas during the simulation. The numbers 0's and 1's on the button indicated that there was no gas present and that there was gas present, respectively.

Since the temperature sensor we used was not in the Proteus software library, a variable thermistor was used instead to show that when the temperature is above/below as per the required condition, it will show on the 20x4 LCD that the temperature was high/low.

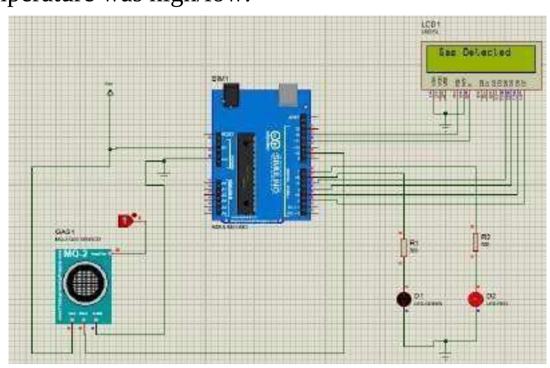

Fig.2. Gas detection result in simulation

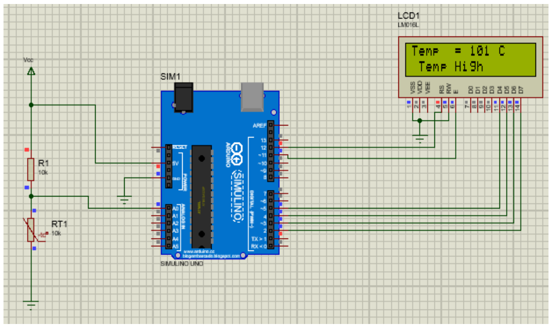

Fig.3. Compressor coil temperature detector showing high temperature in simulation (when temperature above 100degree Celsius)

IV. DESCRIPTION OF THE HARDWARE

The whole work was designed for multipurpose operation. There were basically some sensors and wi-fi module collaboration with Arduino. In the implemented circuit, there was an LCD showing the result of each detection as well as this circuit gave us notification.

A. Implementation of pressure sensors

This work used three pressure sensors to detect the pipeline's blockage. These three pressure sensors were placed as follows, one was connected to the evaporator coil, one was connected to the pipeline (gas pipeline) of indoor to outdoor, and one was connected to the compressor coil.

B. Implementation of temperature sensors

Three temperature sensors were used to detect the high temperature of the compressor and the low temperature of the evaporator and pipeline. They were placed into the evaporator coil, pipeline, and compressor coil. The expected value was defined in the code so that after crossing that pre-defined standard value, it detects and notifies us about the detection.

C. Implementation of Dust Sensor

A dust sensor was used to detect the dust in the indoor of an Air Conditioner. This sensor can detect any particles of dust that are present in the air. This was placed in the indoor of an Air Conditioner. GP2Y1010AU0F Compact optical dust sensor was suitable for our work.

D. Implementation of RM MINI 3 Device

Broad Link RM Mini 3 was an intelligent IoT remote control that could be easier to install and use. With the Broad Link Remote Control skill and Alexa, interaction can be done with a/V device such as TVs, DVDs, STBs through Broad Link RM pro universal remote by voice. The device should be set and connected with the Air Conditioner to implement this feature.

After making the connection, the device should be kept near to Air Conditioner and keep the connection all time. Now, for any detection, notification will be sent through the system, and after getting notification, the user can turn the Air Conditioner off using this device through an app.

Fig.4. RM MINI 3 Device with the system

E. Implementation of Gas and Bacteria sensor

Gas detection sensor: Some research papers clearly mentioned that a gas leak occurred in the evaporator coil most of the time. So, in the implementation, a detector (MQ-02) was kept in the inlet of the evaporator coil. Therefore, if any gas leakage occurred, it would show in the LCD. Moreover, from the control panel, the user can easily monitor the performance of the Air Conditioner.

Bacteria detection sensor: Bacteria consist of carbohydrates in their cell, and when it reacts with AC refrigerant, it produces ethanol. At room temperature, ethanol exists as a liquid or a gas. Hence alcohol gas sensor (MQ-3) was used, which detects the presence of alcohol gas (ethanol) at concentrations from 0.04 mg/L to 4mg/L.

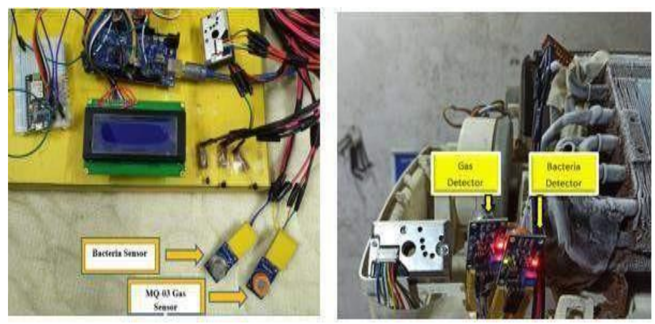

Fig.5. For gas and bacteria detection

V. ECONOMICAL ASPECT OF THE WORK

Cost is an essential parameter for all kinds of work. If any work's outcome is less than the cost, it cannot be considered as a successful work. The cost of the work was tried to minimize. A table is provided with the cost of the work below:

Table I: Total expenses and component lists of the prototype

Serial No	Component's name	Quantity	Cost (BDT)
1	Arduino Uno	01	500
2	LCD 20*4	01	260
3	Wi-fi Module	01	560
4	Dust Sensor	01	160
5	Temperature Sensor	03	240
6	Piezoelectric sensor	03	210
7	Capacitor	01	10

8	Gas sensor	01	100
9	Bacteria sensor	01	100
10	Breadboard	01	70
11	Wires	01	70
12	RM MINI 3 Device	01	1100
13	AC Rent		5000
		Total (BDT)	8380

The cost of our device may seem high because it was a prototype. It was assumed that if this device goes for production in huge amounts, the cost will be reduced significantly. Then the price of this device can be affordable for AC users. This work was all about a life-saving device.

VI. RESULT ANALYSIS

The work was reviewed several times after it was implemented. This multifunctional device has undergone several studies. The experiments were carried out independently.

A. Result of the temperature detection system

In this work, thermistor temperature sensors were used for measuring the temperature of three-part of the air conditioner; the first one was in the evaporator coil, the second one was in the connection line (gas pipeline) of indoor to outdoor, and the last one was in the compressor coil. The first one measured the temperature of the evaporator; if it can detect any low temperature, it will notify us; the second one measured the temperature of the pipeline; if there were a low temperature, it would notify us. The pipeline temperature should be 7 or near to 8 degrees Celsius [7]. The last temperature sensor measured the temperature of the compressor coil in the outdoor unit.

B. Result of Gas Detection System

An MQ-02 gas detection sensor was used in this work. The sensor was placed near the indoor unit. If it found any gas or smoke, it would send a message. As the sensor detected gas, and it was showing results in LCD and giving notification in mobile phone as well.

C. Result of Bacteria Detection System

A bacteria detection sensor was used to detect the bacteria in the surrounding air as there were no bacteria in that area; that is why the display showed “No Bacteria”.

Fig.6. The bacteria Detection system is displayed on the monitor

D. Result of Dust Detection System

As mentioned earlier, GP2Y1010AU0F Compact optical dust sensor was used to detect the air particles. This sensor will help us to measure the accurate ratio of air particles and easily detect dust. A system was generated that will notify us if it detects any kind of detection through a message. As shown in the pictures, dust was detected can be seen and the ratio was 0.10 and tested for a few more times, and sometimes ratio was high such as 0.9, and got notification as "Dust Density is HIGH." Users can monitor this from anywhere using their cellphone. That is because this system was reliable and easy to use for everyone.

Fig.7. Dust detection notification received in user mobile display (when dust ratio was 0.9)

The result of the dust detection system was correctly worked. By using this technique, the dust can be detected easily.

E. Result of Pressure Detection System

To detect the blockage, piezoelectric sensors were used, and those were placed in the pipeline of an Air Conditioner. If the pipeline had any blockage, the gas pressure would increase on that portion, and the system would detect that and notify users. Three sensors were placed on three different portions of the pipeline. If the blockage occurred, our system would detect it correctly in any portion.

F. Result of Broad links RM MINI 3 Device.

Broad Link RM Mini 3 was an intelligent IoT remote control that was easy to install and use. Various home appliances were remoted control with it, such as Air Conditioner, TV, STB, Lighting, Audio, etc [8]. After any kind of detection, to avoid the explosions of the Air Conditioner, turning the Air Conditioner off should be the top priority. Only for that reason was this device used. This feature would work even if the users were not present at home.

Fig.8. Broad link RM MINI 3 device result after connecting with the system

G. Result analysis of temperature sensor

The temperature T1, T2, and T3 were observed in seven days consecutively. Ideally, T1 temperature should be greater than 3- degrees Celsius and T2 temperature should be greater than

5-degree Celsius. On the other hand, T3 should be less than 100 degrees; it will show a high temperature if more. The expected notification had been obtained whereas implemented on different days. In addition, for the ideal case, any notification did not obtain, and for the strange case, the notification was obtained respectively to that temperature in AC.

Table II: Temperature Analysis

Day	Temperature T1 (degree Celsius)	Temperature T2 (degree Celsius)	Temperature T3 (degree Celsius)	Result	Time to detect HIGH/LOW temperature (seconds)
1	2	4	90	Notification sent (T1 low temperature T2 low temperature)	2.45
2	1	3	97	Notification sent (T1 low temperature T2 low temperature)	3.3
3	7	11	84	No Notification	5 (Observation Time)
4	4	8	92	No Notification	5 (Observation Time)
5	8	13	96	No notification	5 (Observation Time)
6	7	9	88	No notification	5 (Observation Time)
7	4	7	105	Notification sent (T3 high temperature)	2.7

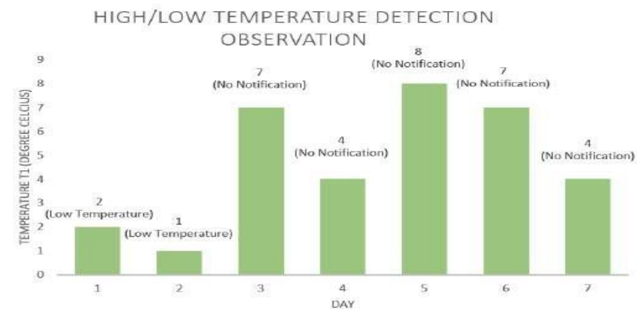

Fig.9. Observation of temperature (T1) via bar diagram

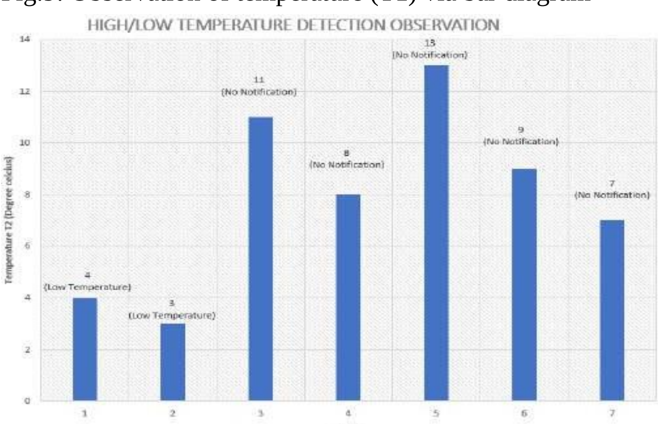

Fig.10. Observation of temperature (T2) via bar diagram

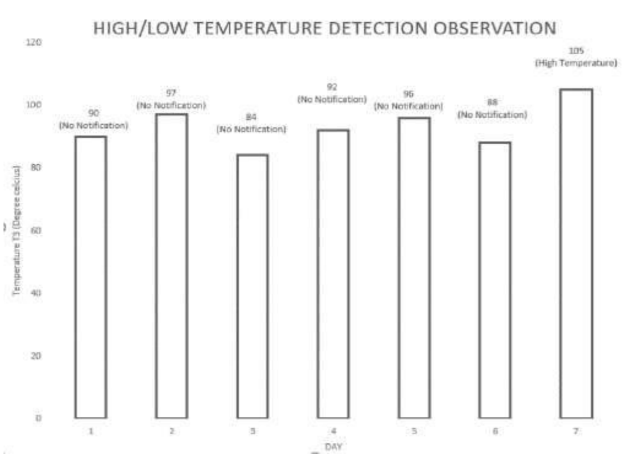

Fig.11. Observation of temperature (T3) via bar diagram

H. Result analysis of gas sensor

While implementing, gas detection was done for seven days consecutively. The observation time was taken five seconds. Gas was detected in the fourth, sixth, and seventh days in 2, 2.4, and 2.87 seconds respectively. Therefore, the gas detection in AC was successful as it could send a notification to the users.

Table III: Gas Detection Analysis

Day	Gas detection	Observation time (seconds)
1	No Notification	5
2	No Notification	5
3	No Notification	5
4	Notification (Gas detection)	2
5	No Notification	5
6	Notification (Gas detection)	2.4
7	Notification (Gas detection)	2.87

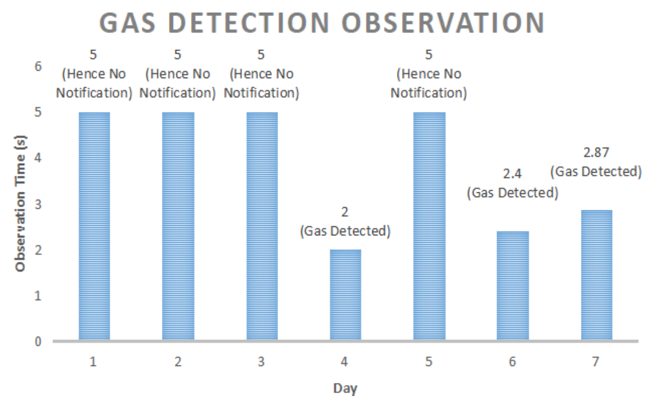

Fig.12. Observation of gas sensors via bar diagram

I. Result analysis of the dust sensor

At the time of implementation, the dust density sensor was observed for seven days. The reference value for the dust density sensor for the ideal case was 0.45. If the result is 0.1, it means the air was immaculate, and the dust density was very low. Most of the day, the dust density was better as we tested inside of the house.

Table IV: Dust Detection Analysis

Day	Dust Density	Results
1	0.1	Best
2	0.35	Good
3	0.45	Ideal
4	0.3	Good
5	0.2	Moderate
6	0.1	Best
7	0.35	Good

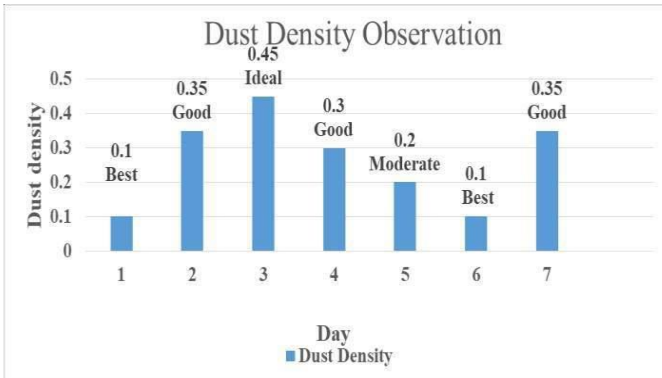

Fig.13. Observation of dust detection sensor

VII. DISCUSSION

Several research papers were studied to identify the cause behind AC explosion. The designed system is more effective compared to the previously developed systems. I S. Rahman [1] proposed the detection of bacterial populations by sampling. One of the contributions of the system proposed in this paper is that the system does not require air sampling. Small bacteria can be successfully detected by this system. Again, O. Srour [4] proposed a technique in which partial blockage of pipelines was investigated by pressure-induced blockage analysis. But a piezoelectric force sensor responds directly to an applied force. No analysis required. Although force is the primary quantity measured by a piezoelectric sensor, other quantities such as pressure, strain, and acceleration can be easily measured using proper construction. Moreover, Asif and Rajendra, Sri [6] designed an automatic and manual AC system where Programmable Logical Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) system were used. As the research aims to contribute to the AC manufacturing industries so the system is proposed without having such a powerful and expensive system. Only through an app, users can easily monitor their AC. In future further works can be done to integrate this into the AC remote control. As the number of sensors grows, the system becomes increasingly challenging to design and implement. Overall, the research can contribute hugely to the technological world as the no. of AC users are increasing rapidly so at the same time more safety measures need to be taken. The existing methods for the air conditioner's safety consist of circuit breakers. Gas leakage and a blockage in the pipeline, which has to be checked manually, is not so reliable. In the designed system, the blockage of the pipeline will be detected automatically by sensors, and the detection of gas leakage will also be detected automatically. Not only that, but the refrigerant cycle inside the AC will also be monitored automatically (such as temperature, pressure) so that refrigerant does not become ice inside the evaporator coil and lead to blockage. The work was based on sensors and electronic devices available in the market. No device can simultaneously detect gas leakage, pipeline blockage, and bacteria detection. So far, no AC manufacturing companies in Bangladesh have used such a safety monitoring device. There is no existing method that can send notifications about the problem related to AC blast. The main strength of using a sensor-based system is that it gives various information (like temperature, pressure, dust, and others) at a time, which is real-time data. This technique is not available in Bangladesh. A groundbreaking revolution will come in the air conditioning industry if it goes into mass production. Some detection rates came with a low confidence value for not having sensitive sensors.

Moreover, if more sensitive sensors are used, this prototype will be cheaper, and detection time will be less. This system can be controlled from anywhere. In the future, government and commercial company funding will aid in implementing our system across the country.

There is no research paper where all the causes are identified together, this system can easily identify all those causes behind AC explosion at one time and users can easily mitigate their hazards. Also, there are many other aspects which can be further researched, like this system works in case of split AC, but it can be verified whether this system will work or not in case of central AC. Again, by automatically reading the ambient temperature, the AC temperature can be adjusted more or less, further research is needed in this regard. In various restaurants, AC temperature can be adjusted by reading the number of customers through image scanning.

VIII. CONCLUSION

This air conditioning monitoring, safety, and management system will revolutionize Bangladesh's cooling system. Gas leakage, blockage in the evaporator coil, pipelines, and compressor coils, as well as dust-generating a blockage in the air filter, all contribute to

AC explosions. All of the problems listed above were discovered and addressed in this work. TTC 103 sensors were used in this work to continuously monitor the temperature of the pipelines and coils because this was one of the most common problems that led to AC explosion. Coils and pipeline leakage or obstruction due to high dust density also causes AC explosion, so a detection system was implemented. Also, the air conditioner can be regulated from anywhere at any time, and as a result, the system is not only a way but a vital way to reduce AC blasts and save human lives. Lastly, the complete system functions smoothly.

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