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# Air Handling Unit Monitoring and Control System Based on Internet of Things

**Mustafa Saied, A. M. Bassiuny, A. S. Ali**

***Abstract*****: *The Internet of Things (IoT) contributed to developing new concepts of monitoring and control systems for Air Handling Units (AHU). This paper proposes a modification of the traditional temperature monitoring and controlling system in AHU to a system based on the principles of the IoT. This is to take advantage of the features and characteristics of the Internet of things in accessing the system, following it up, and modifying it, Also evaluate the extent of reliance on software instead of hardware if the physical controller is replaced with a cloud controller in terms of data transfer rate and security of communication between the controller and field devices. The proposed system is applied to a real AHU. In the proposed system, the existing traditional temperature sensor and actuator are modified to be connected to the internet. With this modification, data can be received and sent with the IoT platform. So, the physical controller is replaced by a cloud controller on the IoT platform to receive the sensor readings and send the control signals to the actuator. Moreover, it configures a temperature alarm mails system to be sent to the authorized people in case of the temperature value is out of limits. The proposed system gives remote access to display the temperature readings and the controller's output. Thus, the performance of the system can be monitored with the ability to modify the controller to suit the system's needs.***

***Keywords: Internet of Things, Air-Handling Unit, Cloud, Remote Monitoring and Control***

## I. INTRODUCTION

The AHU is a part of the airside in the heating, ventilating, and air conditioning system (HVAC) that supplies the building with fresh, clean, and conditioning air. AHU is a composition of elements mounted in large, accessible box-shaped units called modules, which Contain dampers, filters, fan blower, heating and cooling elements, chambers, and sound attenuators. AHU is used to control air temperature, humidity, pressure, and quality by using a monitoring and control system integrated with the AHU mechanical and electrical elements [1]. New and innovative methods of collecting and analyzing air data improve building's profitability, quality and reliability. Developing a monitoring and control AHU system by coupling with the IoT is a recent trend and becomes more popular around the world with each passing day for its feature, option. It offers the following advantages: (I) Tracking the performance is very easy. (II) Reduction in the amount of time spent for monitoring. (III) Easy to make the right decision. (IV) Flexible operations. (V) Make the process faster, easier, cheaper, and more comprehensive [2].

The internet of things (IoT) shortly means connecting devices to the internet and allowing them to communicate with each other [3]. Together, IoT and Smart AHU have a bright and efficient future [4]. A properly designed AHU equipped with the Internet of Things allows seamless data collection, filtering, and sharing. This paper focused on developing a real temperature monitoring and control system applied to an industrial AHU by modifying the existing temperature sensor and valve actuator, using ThingSpeak as an IoT platform, and creating a cloud-based controller.

## II. RELATED WORK

In the field of AHU monitoring and control systems, there is a substantial amount of literature. Most of the recent works are concerned with the transition from wired and centralized control to wireless, distributed, and user-driven control, as well as the impact of IOT on the development of system performance as well as the enhancement of monitoring and control methods. In the power saving sector, Dhanalakshmi et al [5] built an automation system that takes care of energy conservation, user comfort, and indoor air quality with the help of various sensors and IoT to save energy and control the HVAC system. The key highlights of this HVAC system are: (1) monitor the CO2 level, temperature, and detect the motion, (2) Occupancy-based light & fan automation system, (3) Indoor Air Quality (IAQ) real-time monitoring and controlling of indoor air quality and temperature to improve user comfort and health along with the conservation of energy by automizing ventilation and air conditioning system. In performance monitoring and control sector, Sridharan et al [2] proposed IOT system capable of monitoring heat exchanger performance via inaccessible (private) firmware running on the cloud. The system can identify deviation of such input and output parameters from normal operating mean. The proposed IoT-based monitoring system in this study can identify, sensing, computing, and networking process parameters associated with operations of heat exchangers. AYRTON et al [6] describe the development, assembling, and configuration of a system for sensor data acquisition and cloud-based monitoring. The acquisition system allows the usage from one to six sensors.

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* Correspondence Author
**Mustafa Saied***, Department of Mechanical Engineering, Faculty of Engineering, Helwan University, Cairo, Egypt. E-mail: mustafasaied91@gmail.com
**A. M. Bassiuny**, Dean Faculty of Engineering, Heliopolis University, Cairo, Egypt. E-mail: abdelhalim.bassiuny@hu.edu.eg
**A. S. Ali**, Head of Electronics and Communications Engineering Department, Faculty of Engineering, Helwan University, Cairo, Egypt. E-mail: ahmed_ali9@h-eng.helwan.edu.eg

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Temperature sensor readings uploaded and processed to cloud platform by a microcontroller board. The monitoring system displays temperatures as charts with several different search modes and options to facilitate and give more accuracy for sensor monitoring.

The previous research work reveals that the IoT model is based on the integration of different processes such as identifying, sensing, computing and networking. With the shift from wired and centralized control to wireless monitoring and control there is an opportunity to develop lightweight and low-cost solutions.

Such a system can work independently or in conjunction with the various systems. The rest of this paper is structured as follows: The proposed system design and resources is described in Section III while the system implementation is demonstrated in Section IV. The experimental evaluation and analysis are done in Section V. Finally, Section VI provides the concluding remarks.

## III. PROPOSED SYSTEM DESIGN

This section shows the temperature process control in the traditional and proposed system.

### A. Temperature monitoring and control system

Temperature monitoring and control system is the main process in the AHU. Observe and Maintain the zone temperature at the setpoint as the aim of temperature control. The difference between the actual temperature and the desired defined as error depends on the error value controller determine the control output signal to modulating valve actuator whether cooling or heating as shown in fig. 1.

The temperature control process in AHU depends on the heat exchange between the chilled or the hot water and the air. The actuator controls the chilled or hot water flows through the coil that contacts the air.

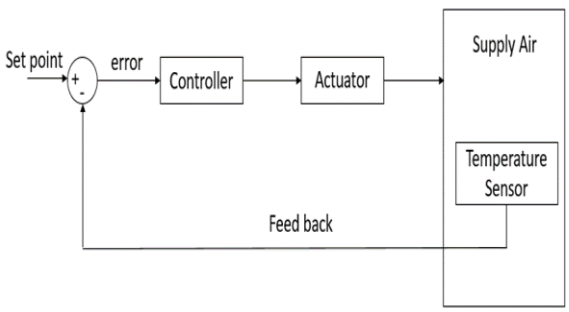



**Fig 1. Temperature Closed Loop Control system**

### B. Traditional system archenteric

The traditional system depends on the wiring connection between the system components. The traditional existing system in the real AHU as shown in Fig. 2 includes the following:

1. Temperature and humidity sensor
2. Modulation valve actuator
3. Direct digital controller
4. Inputs outputs modules
5. 220/24 transformer
6. Graphical user interface
7. Connection cables for power and signals
8. Cables carrier

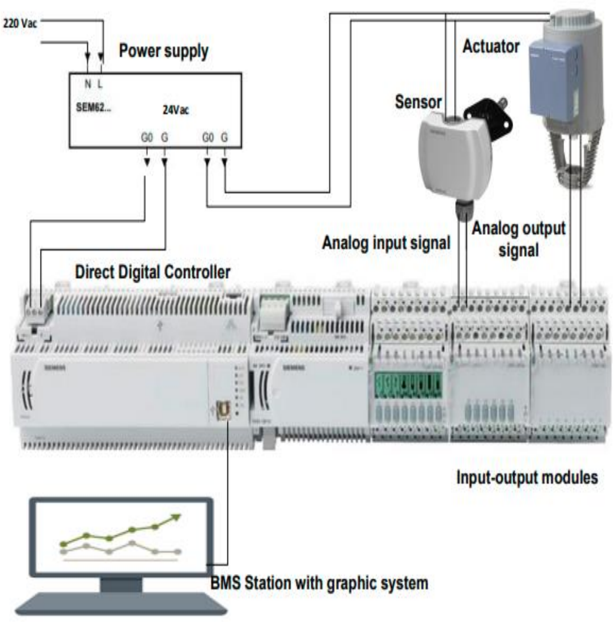



**Fig 2. Traditional temperature control system**

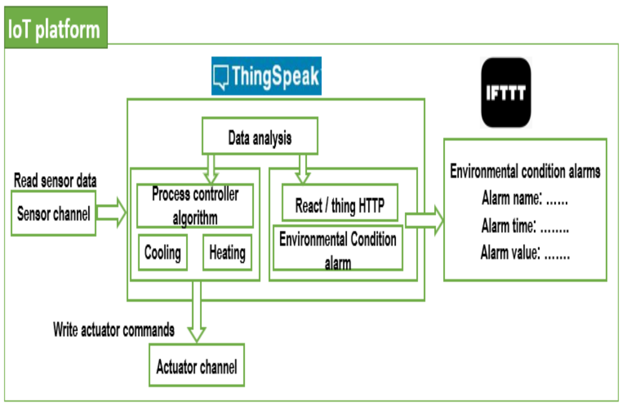
### C. Proposed System Design

In the proposed system, a cloud controller and wireless communication technology based on IoT replace the physical hardware controller and wired connection system. Different control algorithms are built and edited remotely (online) from everywhere at any time. Complete remote monitoring system for temperature with alarm mail trigger notifies authorized people in case of temperature readings out of limits.

The system design as presented in figure 3 shows the temperature monitoring and control system. The sensor and actuator are connected to the ThingSpeak cloud platform using signal conditioning circuits and a Wi-Fi chip to upload the sensor reading and get the actuator commands.

The proposed system using HTTP communication protocol. HTTP is the most common protocol stack on the internet offers ubiquitous connectivity without any hassle of network programming or administration. cloud platform includes:

- Channels for sensor and actuator.
- P control algorithm.
- Temperature Alarm mails react application

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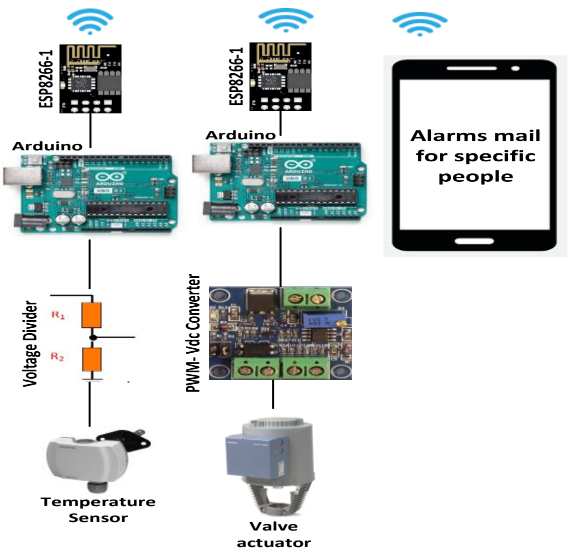


Fig 3. Proposed System Schematic

## IV. RESOURCES

The resources used in the development of the proposed system are:

*1) Siemens Temperature & Humidity Sensor*

QFM2160 Siemens temperature and humidity duct sensor is used. It has the following characteristics: temperature measure range 0-50 °C and humidity measure range 0-100 %rh, operating voltage 24 V-ac, two analog output 0-10 VDC signals one for temperature and the other for humidity [7]. Only, the temperature readings are uploaded.

*2) Siemens valve actuators*

SKC62 Siemens actuator is used to move the mechanical valve for cooling and heating coil. The valve is 24 V-ac operating voltage, 0-10 control signal, spring return in 20 sec and 120 sec opening running time [8].

*3) Arduino Uno with ESP8266 Wi-Fi module*

The Arduino Uno microcontroller is used to send and receive data. It is a microcontroller board based on ATmega328. It has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connector, a power jack, an ICSP header, and a reset button [9].

Start by connecting to your computer with a USB cable or powering on with an AC to DC adapter or battery. The ESP8266 is a Wi-Fi module, that provides Arduino with access to Wi-Fi networks. ESP module contained SOC with a built-in TCP / IP protocol. Operating voltage 3.3V, flash memory 4 MB, RAM 8MB command and 12MB data, clock frequency 80 MHz, Wi-Fi 802.11 b / g / n 2.4 GHz, wakeup time <2 ms [10].

*4) Signal Conditioning*

Signal conditioning is the manipulation of a signal in a way that prepares it for the next processing stage. The proposed design uses two different types of signal conditions.

### A. Voltage divider

As the sensor output signal is 0-10 V-dc, and Arduino accepts only 0-5 Vdc, the sensor signal needs to adjust for suitable range for Arduino. A voltage divider is used for this purpose. The voltage divider is a simple and basic circuit used to get a fraction output voltage from the input. In the proposed system the voltage divider is two 1K series thermal resistors. The voltage divider reduces the output voltage to the half of the input using the following relation:

v_0ut=v_in [R_2/(R_1+R_2 )]

where the maximum Vin = 10 Vdc, R1=R2= 1 K ohm.

### B. PWM to Voltage Converter module

The valve actuator is controlled by voltage signal 0-10 Vdc, but Arduino Analog Output pins do not generate a true analog output. Instead, pulse-width modulate (PWM) a digital signal to achieve some of the functions of an analog output the output voltage is proportional to the duty ratio of the PWM. The output signal either 0 or 255 and have a frequency of approximately 980 Hz So, we use a PWM voltage converter to adjust the Arduino signal to be suitable for the valve actuator. You can select the pulse width signal voltage level using a jumper [11].

*5) Thing Speak IOT Platform*

ThingSpeak platform is used as a cloud storage, analysis and processing platform. It is an IoT analytics platform service that allows the user to aggregate, visualize, and analyze live data streams in the cloud [12].

Once the data is sent to ThingSpeak, instant visualization of live data is created and send alerts. The platform acts as a system of "channels" that functions like the tables from a database with every channel has a maximum of eight fields for storage. The data is sent and received by Arduino and ESP8266. In the proposed system three channels are used: one channel for reading temperature and two channels for writing control commands in the cooling coil and the heating coil.

## V. SYSTEM IMPLEMENTATION

The proposed system is applied using the modified SIEMENS field devices and installed on an industrial Air Handling Unit (AHU).

In the AHU temperature control process, the temperature sensor measures the actual air temperature and sends it to the controller. The controller calculates the error between the actual and desired temperature.

The controller objective is to make the error equal to zero or as minimum as possible. Depending on the error value, the controller outputs the proper control signal to the cooling or heating coil valve actuator. The cooling and heating coils transfer the heat between the chilled or hot water flows through the coils and the air. The implementation procedure of the proposed system is as follows:

### A. Create channels for the sensor and actuator on the ThingSpeak platform

Create channels steps:

1. Sign in to the ThingSpeak account
2. Click Channels > My Channels.
3. On the Channels page, click New Channel.
4. set the channel name, description, check the first field box and set the field name as show in Fig .4.

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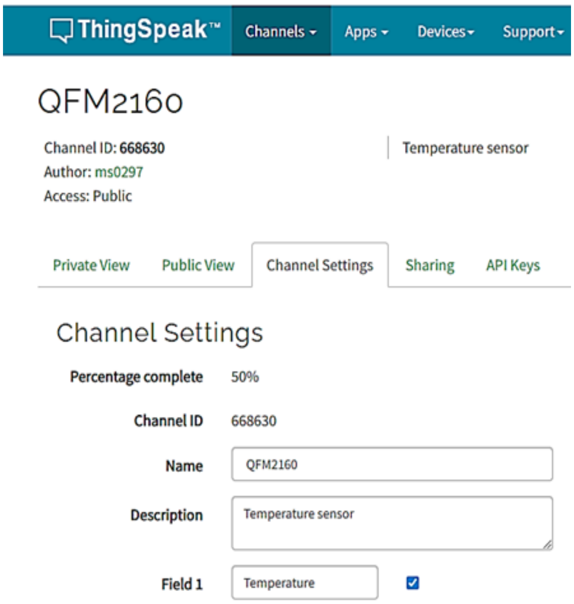


**Fig 4. Sensor Channel Setting**

For the sensor channel:

- Name: QFM2160,
- Description: Temperature sensor,
- Field 1: Temperature

For the actuator:

- Name: SKC62
- Description: Cooling valve (For cooling channel)
  : Heating valve (For heating channel)
- Field 1: Cooling coil
  : heating coil

5. Click Save Channel at the bottom of the settings. Now you can see the different channel tabs.

6. Click the API key tab to get the unique read and write channel API key to can access thee channel.

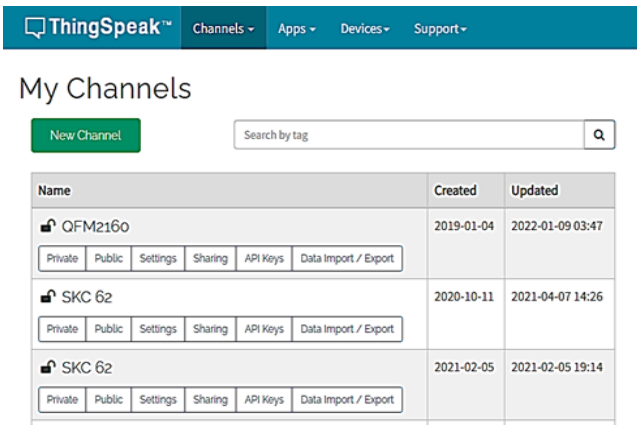


**Fig. 5. Proposed system channels**

### B. Create cloud control system algorithm to act as the physical controller in temperature control process

1. Click (APP tab) MATLAB analysis.
2. On the MATLAB analysis page (APP tab), click new and choose custom from a template to get started
3. Click create at the bottom of the page
4. On the code page, build a control code for temperature control depends on the flow chart show in Fig. 7. Set the name of the code as Cooling control and heating control as show in Fig. 6.
5. At the bottom of the same page, click on time control option in the action schedule. The time control schedules your saved code to run at a specified time.
6. Set the time control setting as follows:

- Name: new time control
- Frequency: recurring
- Recurrence: minutes
- Every: 5 minutes (less time)
- Action: MATLAB analysis
- Code to Execute: the name of the created code

7. Click save "Time control" at the bottom of the page
8. Back to the code page, click save and run.

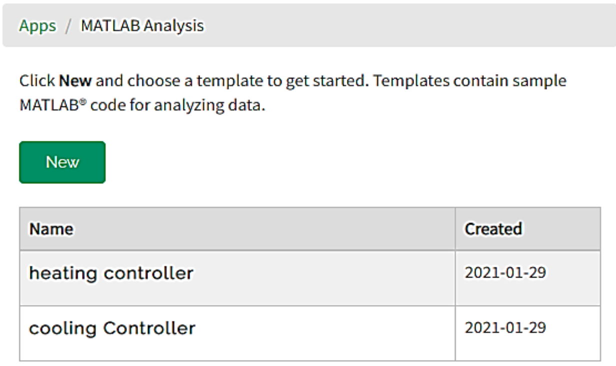


**Fig. 6. control codes names**

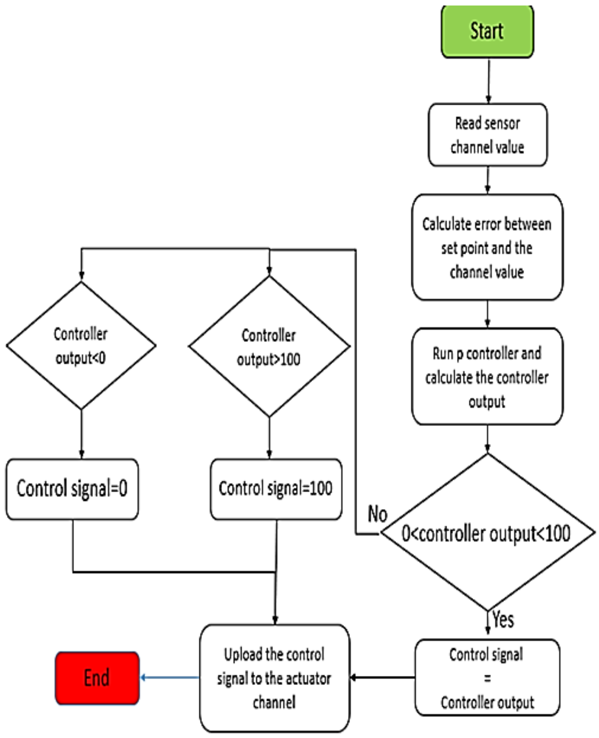


**Fig. 7. Temperature control process flow chart**

### C. Field devices modification

In this step the required circuits and procedure to connect the sensor and the actuators to the internet are illustrated.

#### 1) Sensor modification

The sensor modification circuit is shown in Fig. 8. and the procedure is as follows:

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1. Connect the sensor 0-10Vdc output signal to the voltage divider input. The voltage divider outputs 50% of the input voltage
2. Connect the voltage output to the Arduino analog input the Arduino receive the analog input 0-5 Vdc analog signal.
3. Create Arduino code using Arduino IDE software to receive the sensor output and send the temperature readings to the ESP8266-1 Wi-Fi module via serial.
4. Connect the ESP8266-1 Wi-Fi module to the Arduino.
5. Program the ESP to receive and upload the temperature readings using write API key to the sensor channel.

**2) Actuator modification**

1. The ESP8266-1get the control command from the actuator channel.
2. Connect the ESP to the Arduino via serial to transfer the control command
3. Arduino outputs PWM signal to the PWM to voltage converter module, the converter module function is supplying the actuator with the suitable form of the control signal. The actuator control signal from is 0-10Vdc

The output of the converter module connects o the actuator control signal terminal.

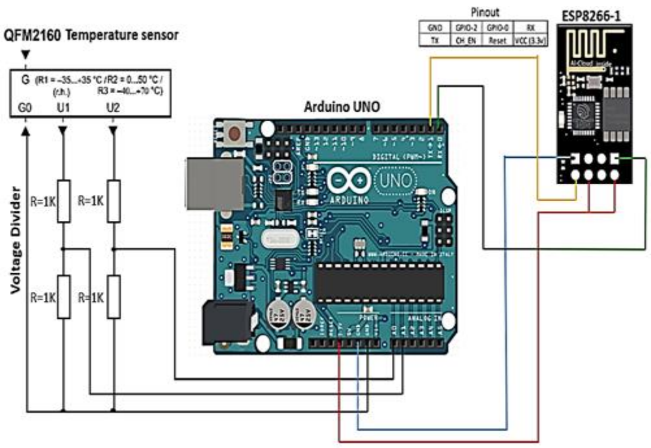


**Fig. 8. Sensor modification**

## D. Alarms mails trigger

The ThingSpeak and IFTTT platforms integrated together to activate and send temperature alarm emails. In case of the temperature is more than 25°C an email alarms sent to authorized people.

Three stages to full integration between the ThingSpeak and IFTTT are as follows:

1. Create new React in ThingSpeak to perform trigger when temperature is more than 25 °C. as shown in Fig. 9.
2. Create Webhooks with Gmail service in IFTTT to send alarm email. The IFTTT gives the choice to write the mail body and the mail subject plus the mail recipient.
3. Create new Thing HTTP in Thing Speak. That enables communication with IFTTT without having to implement the protocol on the device level.

The steps to create new react as follows:

1. Click Apps > React
2. On the react page, click new react
3. Set the react setting as follows:

- React Name: Temperature alarm
- Condition Type: numeric
- Test Frequency: on data insertion
- Condition: If channel QFM2160
  : Field1
  : Is greater than 25 °C
- Action: Thing HTTP
- Options: Run action each time condition is met

4. Click save React at the bottom of the page

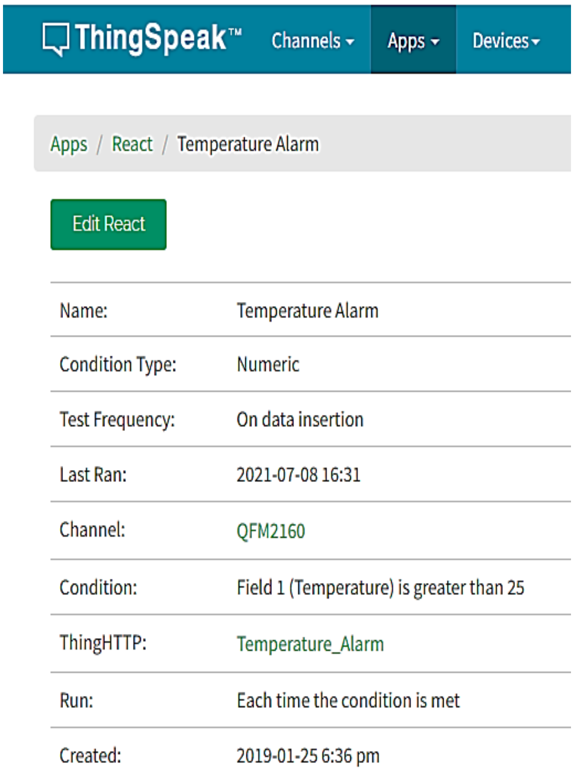


**Fig. 9. React setting**

The steps to create the IFTTT service are as follows:

1. On the home page click create then add
2. Search for webhooks service
3. Open webhooks and choose receive a web request
4. Set the event name then create trigger
5. In THEN THAT tab click add
6. Search for Email and click on send me an email
7. Set the Email subject and body then click on create action
8. Click continuo then finish. The final result show in Fig. 10.

The final stage will be creating new Thing HTTP. Creation steps will be as follows:

1. Click Apps > Thing HTTP
2. On the app page, click new Thing HTTP
3. Set Thing HTTP parameter as follows:

- Name: Temperature_ Alarm
- URL: Copy the URL of your service on IFTTT from documentation tab. The URL titled as “Make a POST or GET web request to:”

4. Method: POST
5. At the end of the app page click save Thing HTTP. As shown in Fig. 11.

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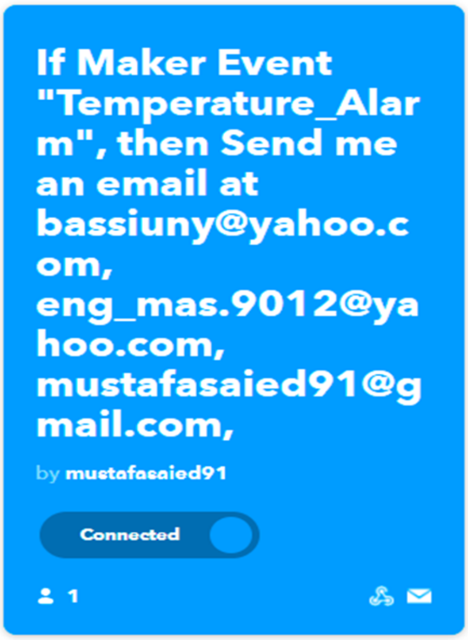


**Fig. 10. IFTT Mails service example**

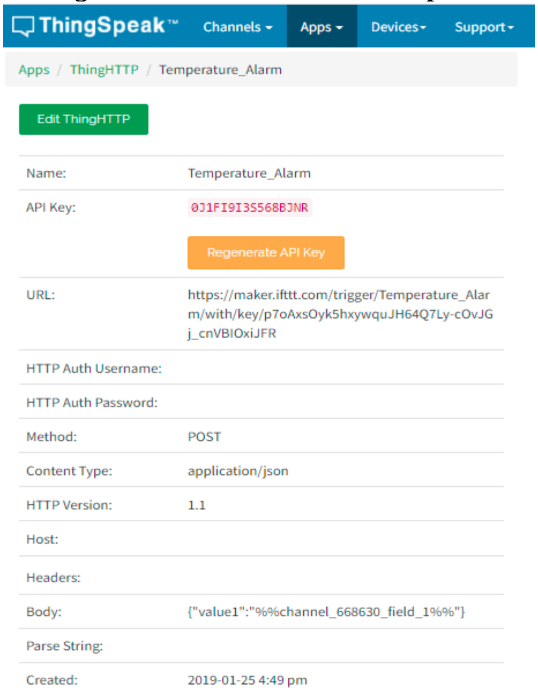


**Fig. 11. Thing HTTP parameters set**

## VI. RESULTS

The results of the proposed work can be described in 3 parts.

### A. Uploaded temperature readings

The uploaded temperature reading is shown in Fig. 12. The channel received 22120 readings uploaded form the sensor. The channel saves all uploaded data plus, the availability to export all uploaded data. The sensor upload reading every 60 seconds and it is adjustable in the programming.

### B. Temperature alarms notification

Temperature alarms mail, Fig. 13, shows that the recorded temperature is 57 °C which is greater than 25 °C. More than 600 mails for the temperature alarms from the system startup.

### C. Control process code output

The Control process code output is represented in the actuator channels graphic visualization, Fig. 14. The figure shows the values written from the control algorithm to the heating and cooling actuators. The control algorithm run and outputs control value every 5 minute.

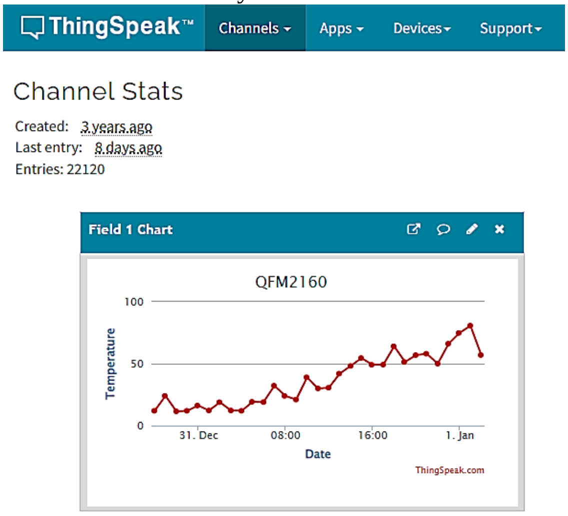


**Fig. 12. Temperature readings in the sensor channel**

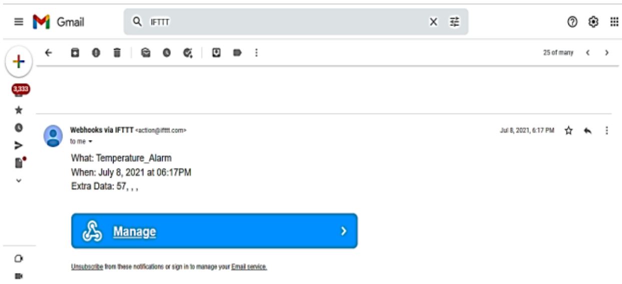


**Fig. 13. Temperature alarm mail**

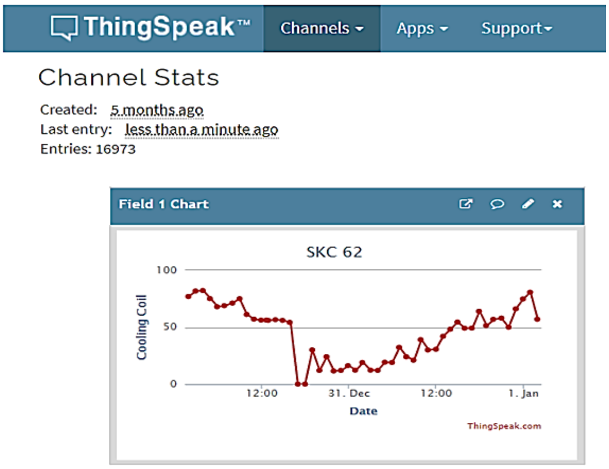


**Fig. 14. Cooling actuator channel**

## VII. CONCLUSION

This paper proposes a modification of the traditional monitoring and control system in an industrial AHU to a system based on the principles of the IoT.

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The system focuses on changing the traditional vision of the control system and the usage of the IoT in monitoring and control. The proposed system doesn't need a physical controller, human operator presence, or even a wiring connection. This system may be adapted and customized according to needs. SIEMENS industry-level temperature sensor and actuator are modified and connected to the ThingSpeak IoT platform successfully. Temperature readings uploaded to the sensor channel on the IoT platform. The cloud controller reads the temperature from the sensor channel and writes the suitable control action to the heating and cooling actuator channels according to the temperature set point. The temperature readings and the controller outputs are displayed and stored in the ThingSpeak channels. Moreover, the system notifies alarms mail when reading is out of the limits without human interaction. Features of such newly designed IoT based monitoring and control system are:

1. Reduced installation time, cost, and workers.
2. Operations monitoring and control in the absence of operators.
3. Less hardware components and the ability to create a new controller with new characteristics and features.

Despite the advantages of the developed system, some modifications are still required, especially:

a) There is no backup connection way in the case of internet interruption, which means system failure in case of internet down.

b) Relatively high operational and running costs.

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## AUTHORS PROFILE

**Professor. A. Halim M. Bassiuny** is the professor of Mechatronics and Control Engineering. Since 1979, he joined the faculty of Engineering at Helwan, Helwan University, Egypt as a teaching staff. During his Ph.D. research program, he was granted a DAAD scholarship, during the interval 1986-1989, at the Group of Automatic Control and Technical Cybernetics, Wuppertal University, Germany. Currently, he is the Dean of faculty of engineering, Heliopolis University, Egypt. His research interests include intelligent control systems, mechatronic systems and their applications, machine tool dynamics and control, condition monitoring of machinery as well as smart systems.

**Ahmed S. Ali,** Professor at Faculty of engineering, Helwan University. Head of Electronics and Communications Department Director of Center of Excellence for smart Educational Systems (CESES) Ahmed S. Ali received the B.Sc., M.Sc., and Ph.D. degrees in electronics and communications engineering from Helwan University, Cairo, Egypt, in 1992, 1998, and 2003, respectively. He is currently working as a professor in the department of electronics and communications, Faculty of Engineering, Helwan University, Egypt. His current research interests include the area of 5G mobile networks, wireless networks, IoT, wireless sensor networks, smart grid communication systems, and optical networks. E-mail: ahmed_ali9@h-eng.helwan.edu.eg

**Mustafa Saeed,** Building Management Systems Engineer. Master's student and holder of a Bachelor's degree in Mechatronics, Faculty of Engineering, Helwan University. The field of research and interest includes the monitoring and control system using the principles of the Internet of Things.


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