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Construction and Performance Test of an Automatic GSM Based Fire Alarm System with Water Sprinkler

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ABSTRACT

Generally fire accidents occur more in areas like houses, factories, shopping malls, hospitals and so forth, which cause more misfortune to human life and properties. To reduce this overwhelming misfortune, automatic fire alarm system is very effective. An automatic fire alarm system detects the fire, convey message to fire control department and also will buzz alarm to the attendants. Sometimes, it may include water spraying system to extinguish the fire. In the present work, a low cost, portable, microcontroller based automatic fire alarm system has been developed for cautioning the fire occurrences in household or industrial premises. The aim of this system is to alert the remote property-owner and fire control department by sending a short message (SMS) via GSM network. This automatic fire alarm system will respond in time, when the presence of fire is detected and will also save goods or lives by sprinkling water on the fire. The system is included with a buzzer that could alert the guards or residents when fire incident is detected. The primary target of this project was to develop a fire alert system with minimal cost. The system has three fundamental components that are the detection system, the monitoring system and the controlling framework. This system would also diminish the correspondence time with the fire control department. A model fire alarm system was designed, constructed and tested. While testing it detects the fire, send SMS to two mobile numbers and sprays water to extinguish the fire. Thus, it performed satisfactorily. In order to prevent malfunction of the system a regular or periodical checking of the system by skilled operator should be necessary.

Keywords: Microcontroller, GSM module, Solenoid valve, Sensors, Automation.

1. Introduction

Fire is the effect of chemical reaction during which a carbon based material blends with O_2 (generally a part of air) is heated somewhere and combustible fumes are delivered. It originates from a response between O_2 within the atmospheric air and a couple of some sort of fuel. There are many potential fuel sources which can cause fire. Libraries, archives, exhibition halls, cafe, structures, industries and special structures frequently contain various types of burnable materials. These incorporate books, manuscript, records, antiquities, interior decorations, cupboards, goods and furnishings, and laboratory chemicals also. It is perceived that anything containing wood, plastic, paper, fabric or ignitable fluids could be a potential source of fire [1]. They contain a few basic potential ignition sources including anything, activity or procedure which produces heat. These envelop covers electric lighting and power system, heating and cooling equipment, heat producing conservation and maintenance activities and electric office appliances. Flame producing development works like welding, brazing and cutting are frequent sources of ignition. So, there are many fields wherever from the fire accident may occur. Fire accident is an unfortunate event that would bring a decent loss of social wealth and human life. Fire risks might be deadly and maligning for industrial and residential security, additionally alarming for life and properties. With the advancement of human progress, fire security has been an essential concern.

The best possible way to reduce these losses is to report to the concerned authority in emergency situation as quickly as possible. So, there is a need for a system that may automatically detect the fireplace and might alert people living in that area. The system may incorporate self-controlled smart fire control system which may be combined with multiple sensors, actuators and operated by micro-controller unit. This automatic fire control system will respond in time, when the presence of fire is detected and will save goods or lives by sprinkling water on the fire.

Although varieties of developed frameworks are utilized in this modern age, a reliable, easily implementable and low cost automated fire alarm system with water sprinkler is rarely available in the developing countries. Therefore, in the present work a system will be designed which could automatically detect the fire incidents and can alert the people living in that area and finally water might be sprinkled over the fire. This framework would be furnished with a gas sensor, a temperature sensor and a fire sensor to recognize horrible coincidental circumstances, since it occurs and with the help of microcontroller can alarm in a fraction of second to undertake careful measures like informing fire control department by a SMS, cautionary signals to the inhabitants by a buzzer. The system would automatically control a solenoid valve that could permit the flow of water to the sprinkler and hence water is sprayed over the fire areas by the assistance of sprinkler.

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The system may include LCD display by which the temperature, humidity and conditions of the area may be monitored.

2. Background Study

From the starting of written history individuals have discovered that early reaction to flames had positive outcomes in controlling those flames. At the point when somebody found a fire, the fire units and local groups of fire-fighters were alarmed by wandering guardians utilizing hand chime ringers or church sextons ringing, church ringers or production line steam whistles. Tragically these frameworks did not give particularly detail and frequently guided the local group of fire-fighters to an appropriate area. With the emergence of broadcasting system, designed in the mid 1840's by Samuel F. B. Morse, firemen were given a quicker and progressively precise fire reporting systems [2].

The absolute first alarm framework was developed by W. F. Channing and M. Farmer [3] in 1852 and their unique structure was two alarm boxes, each containing a transmitted key with a handle connected. At the point when somebody identified a fire, they would wrench the handle, which would then transfer the subtleties of the alarm box number to a central alarm station. The administrator at the station would get the message, which would then be sent to the local groups of fire-fighters. In mid-1900s, American District Telegraph (ADT) Security Company, Holmes Electric Protective Company, Grinnell Security Services and Automatic Fire Protection (AFP) built up contracts with one another to supply detection, sprinkler frameworks, sprinkler framework supervisory hardware and central station observing administrations. As businesses in the alarm and observing fields were developed, so did the improvement of the gadgets utilized for fire detection. As mentioned in [4] George Smith was the first to patent a pneumatic framework in 1907 which was later known as the Aero Automatic Fire Alarm.

A cheap automotive localization framework utilizing GPS and GSM-SMS administrations were used to predict the situation of the vehicle on the driver's or proprietor's cell phone as a short message (SMS) on his solicitation. The framework could be interconnected with the vehicle caution framework which alarms the proprietor about the occasions that were occurred with his vehicle when it is left. The framework is made by a GPS recipient, a processing unit and a GSM telephone. In addition the framework could be agreed to securing and transmitting the data, at the point mentioned about car status and alarms the client about the vehicle turned over motor. The framework could be utilized as a minimal effort to answer for car position restricting just as in vehicle-following framework application [5].

A GSM based fire alarm system is developed where smoke sensor is used to detect the fire. A SIM card is added with the GSM module to send SMS to the predefined emergency phone number when the microcontroller gets the signal from the smoke sensor. This system is useful to notify the occurrence of fire accident in a specific place [6]. In another work, Teja and Angadi [7] developed a fire alarm system to reduce the death loss because of fire in trains. Fire accident on running train is very dangerous because the passengers cannot escape from the train. The project consists of a microcontroller, a GPS module, a GSM module, fire sensor and buzzer. The GPS module helps to determine the latitude and longitude position of the train and the GSM module with a SIM card sends this position to the emergency number. Buzzer is used to alert the passengers when fire is detected by the fire sensors.

3. Methodology

The different processes of the present fire alarm system have three main stages: the fire detection, the notification and fire protection stages. As it has been mentioned earlier that the main function of the fire alert system is to identify the presence of fire and it could be detected by three different means: heat, flame and leakage of some specific gases. The microcontroller, used in the system, identifies the occurrence of fire if any of the sensor sends signal to the microcontroller. The schematic of the operation of the fire alarm system, introduced in the form of block diagram, is shown in Fig.1.

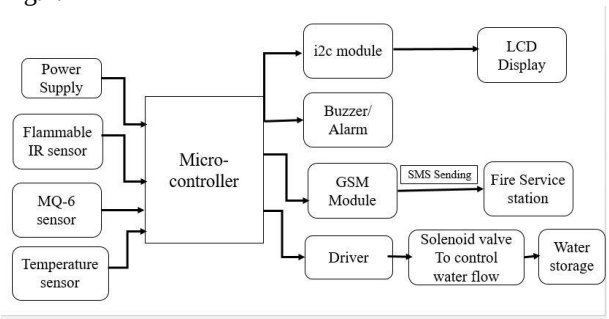

Fig.1 Schematic of the proposed design.

It comprises of a power supply unit (PSU) which supplies the required power to the microcontroller, a GSM module (SIM900), a gas sensor (MQ-6), a temperature sensor (LM36), a buzzer, a solenoid valve and the liquid crystal display (LCD). The microcontroller is associated with the power supply unit, LCD, gas sensor, solenoid valve and temperature sensor. The LCD shows the status of the framework when there is a presence of fire or gas which may prompt fire outbreak. The information which is displayed in the LCD is appeared when fire or any form of leakage of specified gas is detected. The solenoid valve is controlled by the microcontroller and the valve is connected with the main water line of the installation. The main purpose of the sprinkler system is to put off the fire by spraying water over the fire as much as possible.

3.1 Hardware

The major components requierd for the proposed fire alarm system are listed in Table 1.

Table 1. The requierd major components for this project.

Sl. No.	Name of the component	Rating/ Specification	Quantity
01	Arduino UNO	STM32F103C8T6	1
02	LCD Monitor AC Adapter	12V 5.0A	1
03	Vero Board	Double Size (7×9 cm)	1
04	Buzzer	SFM- 27	1
05	DC-DC Buck converter step-down	LM2596	1
06	Relay Module	1 channel, 12V	1
07	Smoke Sensor	MQ6	2
08	SPI OLED Display	0.96 inch	1
09	Flame Sensor	5 way	1
10	Digital Tempera-ture humidity sensor module	DHT22	1
11	Al cloud inside	ESP-8266	1
12	Toggle switch		1
13	GSM module	SIM 900A	1
14	I2C module	ESP 8266	1
15	Solenoid Valve	12V, 0.75 inch	1
16	Shower head		1
17	Pipe fittings & Thread tape		1

3.2 Software

The Arduino IDE has been used to write the code and upload the code into the microcontroller. The Arduino programing is very much compatible with C and C++ language. The Arduino UNO is a cross-platform application developed by Java programming language [8]. For drawing the circuit diagram of the system the Fritzing software was used which is very easy and free to draw circuit diagram. Fritzing is an open-source initiative to create circuit diagram for the beginner or side interest CAD programming for the structure of electronics hardware, to help creators and craftsmen prepared to move from trying different things with a model to building a permanent circuit [9].

3.3 Program Algorithm

A highly efficient algorithm is essential for a programed autonomous system. Being an autonomous system, some decisions and work should be done by the system itself. Sensing the values from the input and to return the decision to the output, all the commands are executed by the program installed in the microcontroller [10]. The algorithm dictates the micro-controller what to do, when it senses an input. The activity of the sensors is a common operation for this system. The whole system algorithm is shown in a system flow chart in Fig.2.

The control system works on a feed forward system because the system is an open loop. Here the output depends on the input signal which is initiated from the sensors. The output does not depend on the generated feedback signal. In this system, the signal is passed to the microcontroller and the microcontroller controls the output and the feedback signal does not further act as input to the system.

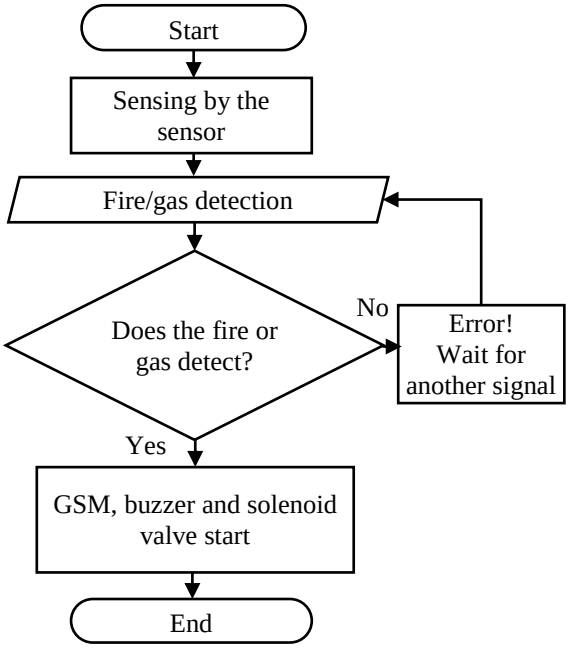

Fig.2 The System Flow chart of the program algorithm.

4. Circuit Diagram

The circuit diagram of the whole fire alarm system is shown in Fig.3.

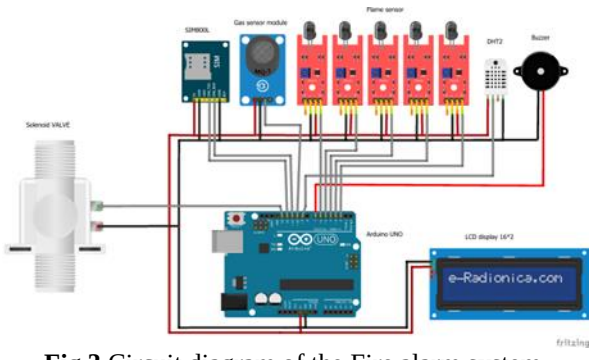

Fig.3 Circuit diagram of the Fire alarm system.

4.1 Construction of the Project

In this project flame sensor module, temperature sensor module and MQ-6 sensor module are used to detect the presence of flame, to measure the temperature and to detect leakage of gas respectively. An Arduino UNO board is used with auxiliary circuit components as

control unit and GSM module is used for sending the text messages.

At first Arduino UNO board with loaded control program is placed in a wooden board to construct the controlling unit for fire alarm system. MQ-6 sensor is fixed with the wooden board which can detect leakage of LPG and butane gas. Many fire accidents occur due to the leakage of gas from gas cylinder. This sensor can sense the leakage of that kinds of gas. The sensor has 6 pins. Three of them are known as A, H, A pin and another three are known as B, H, B pin. Three pin A, H, A are connected with 5V pins of the Arduino. Another three pins are connected with Arduino AO pin with a register and a ground. Photographic view of the MQ-6 sensor connection is shown in the Fig. 4.

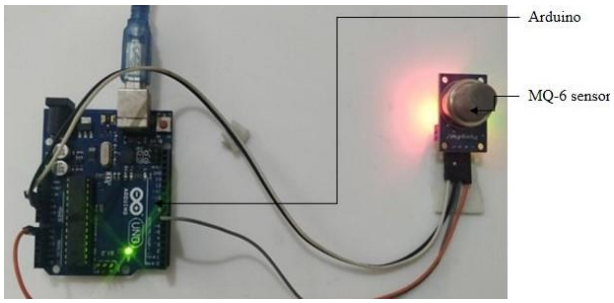

Fig.4 Photographic view of MQ-6 sensor connection.

The fire sensor recognizes the nearness of flame or the fire dependency on the Infrared (IR) frequency produced by the fire. It gives logic ‘1’ as output, if fire is identified, else it gives logic ‘0’ as output. Arduino UNO checks the logic level on the output pin of the sensor and performs further assignments, for example, enacting the signal and LED, sending an alarm message. These kinds of sensors are utilized for short range fire recognition and can be utilized to screen ventures or as a wellbeing precautionary measure. A 5-way fire sensor module is utilized in this project. The connection of the fire sensor module is shown in the Fig. 5.

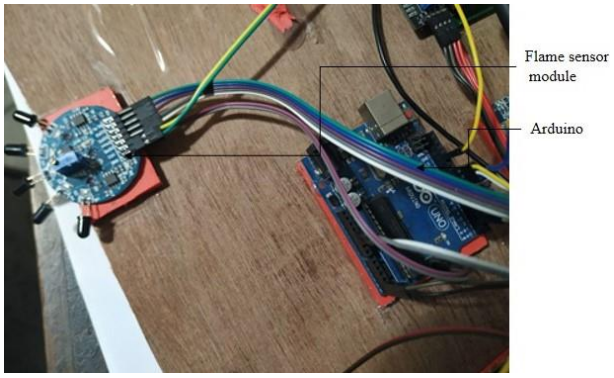

Fig.5 Photographic view of the flame sensor connection.

The digital temperature-humidity sensor module is added to the framework to show the temperature and moistness of air in the LCD. The LCD shows 'No Fire' when there is no occurrence of fire and shows 'Fire occurred' when the sensor recognizes the nearness of the fire or leakage of gas (LPG and butane). The connection of the flame and MQ-6 sensors is shown in Fig. 6.

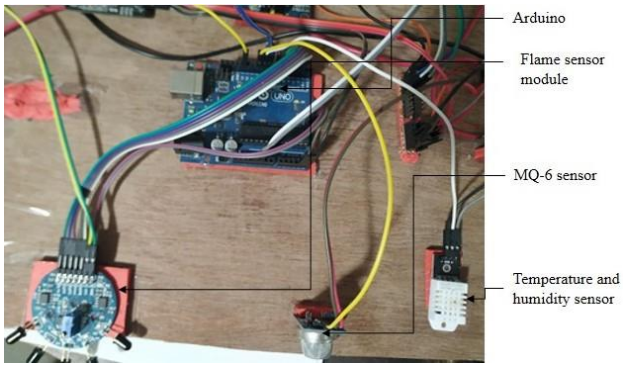

Fig. 6 Photographic view of flame and MQ-6 sensor connection.

SIM900 GSM module is utilized to send SMS to the recipients in this project. The SIM card is embedded to the GSM module and locked into it. At that point the adapters are associated and turned the module on. After some time it displays the blinking rate of 'status LED' or 'system LED' (GSM module will set aside some effort to build up association with mobile network). When the association is set up effectively, the status of the system will be flicked in LED persistently at regular intervals.

There are two different ways of associating GSM module to Arduino UNO. Regardless of the occurrence, the correspondence among Arduino UNO and GSM module is sequential. Sequential pins of Arduino UNO (Rx and Tx) is utilized to associate with the GSM module. The Tx pin of GSM module is associated with Rx pin of Arduino UNO and Rx pin of GSM module is associated with Tx pin of Arduino UNO. At that point the ground pin of Arduino UNO is associated with ground pin of GSM module. The complete connection of all the sensors and buzzer is shown in Fig. 7.

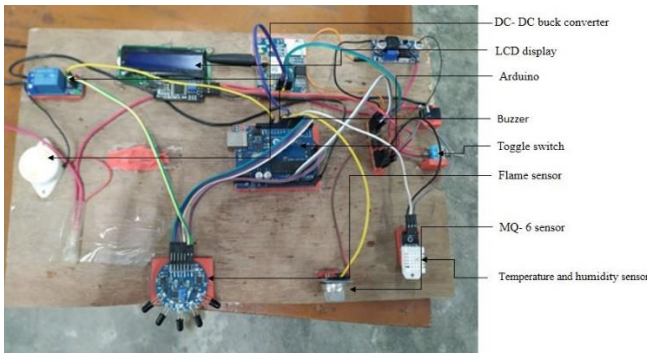

Fig. 7 Photographic view of the complete connection.

After completing the construction of the circuit unit, water sprinkler is fabricated. For this purpose, a bypass line is added to the main water pipeline as shown in the Fig. 8. The solenoid valve is added to the bypass pipeline to control the water flow. When the microcontroller receives signal from the sensor (when

fire is detected), it opens the solenoid valve to enable water flow through the sprinkler.

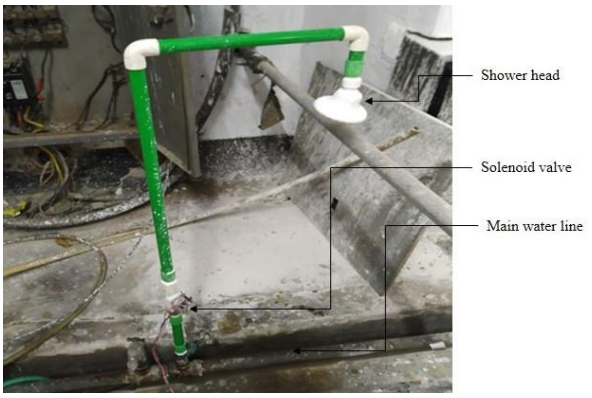

Fig.8 Photographic view of the solenoid valve connection with pipeline.

5. Experimentation and Performance Test

For testing the performance of the constructed fire alarm system, fire was created by a gas lighter, match stick, burning paper and burning wood. Because of cost constrain, the flame sensor used in this project to sense the presence of fire/flame was of very short range. When the gas lighter was turned on, both flame sensor and MQ-6 sensor got activated. Flame sensor was activated when fire was created by burning wood, by burning paper and by using a match stick. These sensors sent signals to the Arduino. The Arduino sent signals to the buzzer, GSM module and solenoid valve. GSM module sent text messages in two mobile numbers. Two numbers were used because if one person is not available in that case the other could receive the text message and act accordingly. Another reason of using two numbers were if one person denied about the receipt of the message then the other person could prove the authenticity of the message. When the Arduino sent signals to the buzzer, it began to ring loudly so that people in the nearby area could be notified about the danger of fire accident and the relevant persons could take necessary steps to minimize losses. The Arduino also sent signals to the solenoid valve. The solenoid valve was attached to the waterline which controls the flow of water. The purpose of water spray was to put out the fire.

5.1 Performance Test

The main target of this project was to design and construct a model of a fire control system using locally available materials. The control unit for this system was constructed by a microcontroller with auxiliary circuit components as described before. The model of the fire control system was tested at the Heat Engine Laboratory of the Department of Mechanical Engineering of Khulna University of Engineering & Technology, Khulna. A Grameen phone SIM card was used in the GSM module. The contact number of the SIM card was +8801709369031. Two SIM cards were used as dummy of the fire service contact number and owner's number. The contact numbers were +8801727629433 and +8801936256615. The flame was created using different sources as described earlier. When flame or leakage of gas were detected by the sensors, it sent signal to the microcontroller. The microcontroller processed that signal and sent it to the GSM module, solenoid valve and buzzer. After getting the signal the GSM module sent text messages to the above two mobile numbers. When there was existence of fire, the text message was "Fire occurred at HE lab, KUET". At the same time the solenoid valve was opened and water was discharged from the sprinkler. The buzzer was also buzzed loudly after getting the signal from the microcontroller to notify people about the fire incident.

6. Result and Discussion

The detection capability of the flame sensor and MQ-6 sensor as well as the overall performance of the fire alarm system were measured throughout the test. During the testing, it was noticed that the range of detection of the sensors is limited. The flame sensor could detect flame within a distance of maximum 245 cm. Within the range, the sensors were tested and observed to work satisfactorily. It was found to perform as per the design. Sensors were found to work without delay and also the GSM module, buzzer and solenoid valve reacted after getting the signal from the microcontroller. The solenoid valve responded immediately with respect to the signal/command but it could not detect the point of fire. It discharged water though the water sprinkler to the drain. In this test, the water sprinkler was set on a position where fire was initiated. In fact, no sensor to detect the fire was used in this work because of fund. A view finder might be used to eliminate this limitation. The sensors used in this project were relatively low priced one that is why the range of the sensor was limited. To apply in real system high performance sensors may be used. The test results are shown in Table 2.

Table 2 Variation of Sensing Capability of Flame sensor, GSM module and Solenoid valve.

Fire source	Maximum distance from sensor (cm)	Time taken from detection to SMS delivery (sec)	Time taken from detection to open solenoid valve (sec)
Gas lighter	150	1	1
Match stick	60	1	1
Burning wood	245	1	1
Burning Paper	110	1	1
Spirit lamp	25	1	1

The model fire alarm system was constructed for a fixed location. If the location was changed, it would

send wrong address. In that case, the text message programed within the microcontroller should be modified, otherwise it would send the text message what was already programed in it. No internet connection was used with the system, so this system was unable to locate its position by GPS. For that reason it was not possible for this system to send the latitude and longitude of that location to the fire control department.

It was observed that the sensing capability of the sensor varied according to the types of flame. When the flame was large enough, it radiated much IR. That is why a highly glowing flame could be detected from a comparatively large distance.

7. Conclusion

The aim of this project was to construct the model of an automatic fire alarm system comprising of fire sensor module, MQ-6 sensor, control unit, water sprinkler framework and GSM module. After developing and testing the model, the programed fire control framework has effectively furnished the tasks as expected. The structured alarm framework is basic, yet it has wide territory of use in family unit and modern security, particularly in developing countries. Utilizing this framework, fast and dependable alert response is conceivable to start preventive measures to turn away risk of fire perils and limit misfortunes of life and property. Modern industries or residential areas can be checked through the designed framework introducing multiple modules. The following conclusions could be made from the performance test of the model fire alarm system:

1. This is a cost-effective and cheap fire alert system that works dependably to guarantee security from fire accident and can be introduced in residents, ventures, workplaces, product houses and so forth.
2. It can also be utilized to recognize flammable gas like methane, propane, LPG or other combustible gases.
3. It is small in size and requires low power to operate. So, It can be used anywhere in the building.

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