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Improving Passive Safety in Electric Vehicles by Developing a Prototype of Automatic Fire Extinguishing System

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Abstract*— Electric vehicles (EVs) are becoming increasingly popular due to their eco-friendliness and fuel efficiency. However, they pose a potential fire hazard due to their high-voltage battery packs. In this paper, we present a prototype of an automatic fire extinguisher system for EVs using an Arduino UNO board, a fire sensor, and a wiper motor. The proposed system consists of a fire sensor that is fixed near the battery pack to detect any signs of fire. The sensor sends a signal to the Arduino UNO board, which in turn triggers the wiper motor. The motor is connected to a gear system that opens the cylinder of the fire extinguisher, releasing the extinguishing agent onto the fire. The prototype was tested in a simulated environment, and the results showed that the system was able to detect the fire and trigger the extinguisher in less than 5 seconds. The system can also be easily installed in any EV, as the sensors can be fixed at desired locations depending on the vehicle's design. The proposed system has several advantages over traditional fire extinguishing systems, such as being fully automated and requiring minimal human intervention. It can also help reduce the risk of fire-related accidents in EVs, ensuring the safety of passengers and the vehicle. In conclusion, the prototype of an automatic fire extinguisher system for EVs presented in this paper has the potential to improve the safety of electric vehicles and can be further improved by integrating additional sensors and safety features.

Index Terms- Arduino UNO, battery firing, CO2 fire extinguisher, electric vehicles.

I. INTRODUCTION

Electric vehicles (EVs) are becoming increasingly popular due to their environmental benefits, including reduced greenhouse gas emissions and improved air quality [1]. However, concerns over their safety have also emerged, particularly with respect to the risk of fire. EV fires can be caused by a range of factors, including battery overheating, electrical faults, thermal runaway, and collisions [2]. These fires can pose a serious threat to passengers and the environment as they emit poisonous gases like hydrogen fluoride into the atmosphere [3] and can be difficult to control and extinguish due to the unique characteristics of EV batteries. Current passive safety measures in EVs are not always sufficient to prevent or mitigate fires, highlighting the need for new and innovative approaches to improve EV safety. One promising solution is the development of automatic fire extinguisher systems that can detect and extinguish fires quickly and effectively. However, the design and implementation of such systems is complex, requiring careful consideration of factors such as system weight, power consumption, and compatibility with existing EV systems.

In this paper, we present a new approach to improving the passive safety of EVs by developing and testing a prototype of an automatic fire extinguisher system. Our study builds on previous research in automatic fire extinguisher systems in the area of EV safety [4] and introduces a novel solution to address the problem of EV fires. Specifically, our objectives are to design and develop a prototype of the automatic fire extinguisher system, evaluate its effectiveness in reducing the risk of EV fires, and assess its potential for implementation in commercial EVs.

To achieve these objectives, we conducted a series of experiments and simulations to evaluate the system's ability to detect and extinguish fires electric vehicles and compared its performance to existing passive safety measures which include multi secure fault detection [5]. Our results demonstrate the effectiveness of the system in reducing the risk of EV fires and provide insights into the design and implementation of automatic fire extinguisher systems for EVs. Overall, our study represents a significant contribution to the field of EV safety and highlights the potential for automatic fire extinguisher systems to improve the passive safety of EVs. By providing a detailed analysis of the system's design and performance, we aim to inform future research and development in this area and contribute to the ongoing efforts to improve the safety and sustainability of EVs.

II. LITERATURE REVIEW

In terms of control systems, the existing automatic fire extinguisher system uses an Arduino MEGA as the microcontroller to monitor for signs of a fire and trigger the release of the extinguishing agent. Which was done by Manas Kulkarni, et al. (April 2020). While effective, this system could potentially be improved using more sophisticated

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sensors and algorithms that can more accurately detect and respond to fires. There is a need for further research and development of automatic fire extinguisher systems that are more effective and suitable for use in confined spaces such as electric vehicles. This could include the development of new fire suppression agents, as well as more sophisticated control systems that can better detect and respond to fires. Because the extinguisher that had been used is an ABC powder which will cause visibility problems when in use [4].

Smoke and fire sensors are critical components of any automatic fire extinguisher system. These sensors are designed to detect the presence of smoke or fire and send signals to the microcontroller. Dr. (Mrs.) Saylee Gharge, et al. (July 2014), developed a system to detect fire and smoke which are being captured by a camera. There are several types of sensors used in fire detection systems, including optical, ionization, and heat detectors. Each type of sensor has its own strengths and limitations, and the choice of sensor will depend on the specific application and the level of sensitivity required [6].

Arduino UNO is a popular micro-controller board that can be used for IoT projects which has come into the Indian market in the recent years it has numerous applications especially in development of VLSI test bench especially of sensors which was tested by Leo Louis. (July 2018) [7]. In the context of an automatic fire extinguisher system for electric vehicles, the Arduino can be connected to smoke and fire sensors to detect the presence of a fire. When a fire is detected, the Arduino UNO can trigger the fire extinguisher system to activate and put out the fire before it spreads. This can potentially save lives and prevent damage to the vehicle. Additionally, the Arduino can also be programmed to send notifications to the vehicle owner or emergency services in case of a fire.

Carbon dioxide (CO2) fire extinguisher is being used in this experiment which is commonly used in indoor environments as they are effective in extinguishing fires without leaving residue or causing visibility issues. The 2-4 kg gas inside CO2 extinguishers is stored in a high-pressure container and released as a cold gas that displaces oxygen, thereby suppressing electrical fires explained by Anirudha Kulkarni. (September 2020) [8]. Several studies have explored the efficacy and safety of CO2 fire extinguishers, including their impact on human health and the environment.

III. EXPERIMENTAL PROCEDURE

The creation of an automatic cap opening and closing mechanism for a CO2 fire extinguisher cylinder involved several steps that were critical to the success of the project.

3.1 Welding

Two gears have been customized, one for the cap and one for the motor. A ring gear with a diameter of 40 mm has been selected for the welding process because removing the cap is essential during the refilling process. So, the experiment was carried out while satisfying necessary conditions like refilling. To create the gear setup, welding equipment was used to attach another gear with a diameter 56 of onto a bolt with clearance, which would be connected to the motor's shaft caliper because in that way if the motor is busted then a new motor can be replaced. During the welding process of motor gear, thin aluminum rods have been used. Copper rods were used for the gas welding process of cylinder gear, as they provided a high level of durability and strength. Gas welding was done using both oxygen and carbon dioxide gases, which were chosen for their ability to weld various types of metals [9]. Two metal washers, one is aluminum and another one is made of iron with diameters 20 and 40mm respectively have been sandwiched between copper valve and the gear of cylinder for gas welding during the customization of the cap. The final gear assembly is shown in fig 1.

Figure 1. Gear assembly of wiper motor and CO2 fire extinguisher

3.2 Grinding

After the process of welding, it is common that it leaves rough edges and metal granules on the welded surfaces. An angle grinder machine was used to smooth out any rough edges or imperfections on the welded surfaces [10]. Fig 2. shows the final grinded part of ring gear used for cylinder cap.

Figure 2. side and top view of grinded ring gear

3.3 Soldering

After the gear setup was completed, the hardware connections were made using soldering process for a strong metal bond between joints [11]. This ensured a secure connection between the various components, including the

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fire sensors, dc-dc step down voltage regulator, a two-dimensional relay and a bread board for all the connections that were connected to Arduino UNO in fig 3.

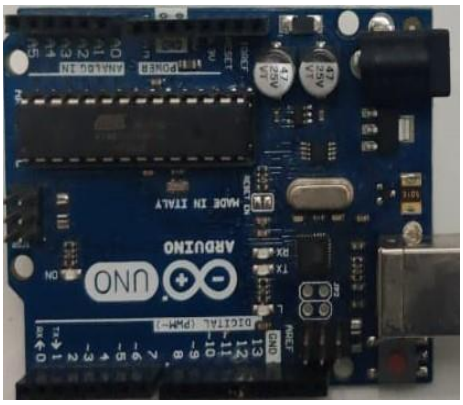

Figure 3. Arduino UNO

3.4 Control algorithm

A code of 58 lines using embedded C has been integrated into the Arduino UNO. An inbuilt library called 'serial' has been used to enable communication between Arduino UNO and the computer using a USB cable. Several functions have been used to build the code like 'setup()' it initializes the serial communication, sets the input/output pins, and sets the initial state of the relays, 'loop()' it checks the sensor data and triggers the wiper motor and relays based on the sensor readings, 'sensor data()' this function reads the data from the fire sensor and updates the fire-value variable based on the sensor readings. 'Fmotor() and Rmotor()' functions are used to run the wiper motor in forward and backward directions and 'allmotorclose()' is used to stop the wiper motor rotation after the demonstration is done. While in real live scenarios the motor doesn't have to rotate in reverse direction until the fire is totally extinguished, this can be achieved with some changes to the code which is embedded in the microcontroller. These sensors would trigger the automatic mechanism to activate the wiper motor which cranks the cylinder's gear allowing the cylinder to open in the event of a fire with a torque of 5Nm.

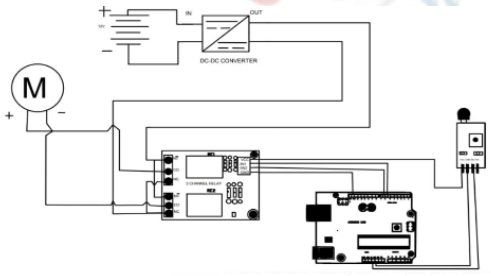

Figure 4: circuit diagram of Arduino UNO with motor and sensor

In fig 4, the circuits connections between Arduino UNO, dc-dc converter, a wiper motor, fire sensor, battery and a 2-channel relay. The NO and NC pins of the relay are connected together with battery positive and negative terminals respectively. The common (CO) pins are connected with wiper motor's positive and negative terminals. The voltage is regulated as it flows through buck converter. The VCC pins of relay and sensor are connected. The inputs of the relay are connected to 5 and 6 volts of digital analog of Arduino UNO. The analog input's ground and 5 V pins of Arduino UNO are connected to the fire sensor.

The cylinder with a height of 580mm and with a diameter 108mm [12] is installed because it's smaller compared to the other ones in the market. A hosepipe of diameter of 20 mm and of length 1200mm with nozzles was then installed to release the CO2 gas at desired locations. To hold the fire extinguisher cylinder in place, a wooden board of 600x320x10mm which contains 2KG gas was used, along with two U bolts of 3mm diameter bolted to the wooden board to secure the cylinder from moving around while operating. Regular testing and maintenance of the fire extinguisher is important to ensure that it remains in good working condition. This includes checking the mechanism, hose pipe, nozzles, and sensors periodically to ensure that they are functioning properly. A rubber hose pipe has been used for the circulation of gas throughout the battery pack.

IV. WORKING

Whenever there is a fire accident the fire sensors which are previously installed sense it and send signals to the controller, which in this case is an Arduino UNO. All the sensors and Arduino UNO receive an external voltage supply of 12 V after regulating to required voltage using a buck converter. It allows DC current to reach wiper motor which then cranks cylinder's gear through a 2 channel 5V relay so that the relay can act as both a switch and a fuse to save Arduino UNO from getting damage if there is an abnormal power supply [13]. The current supply is achieved with the help of a 15V battery. which finally allows the gas to flow into the hose pipe resulting in the stopping of further fire spread in battery compartment or any other desired locations. In summary, the creation of an automatic opening and closing mechanism for a CO2 fire extinguisher involved a careful design process of welding and soldering techniques to create the gear setup and hardware connections. With the automatic mechanism, the fire extinguisher can be activated quickly and efficiently, providing greater protection against potential damage or injury.

V. RESULT AND DISCUSSION

The effectiveness of this experiment depends on the sensing ability of the sensors used. In this experiment fire sensors have been used to detect the fire which usually emits infrared rays. Those rays can be detected with the help of an infrared light on the fire sensor. The sensitivity of the sensor can be adjusted by loosening or tightening a screw of the potentiometer of the fire sensor. Table.1 shows the sensor status at different temperatures.

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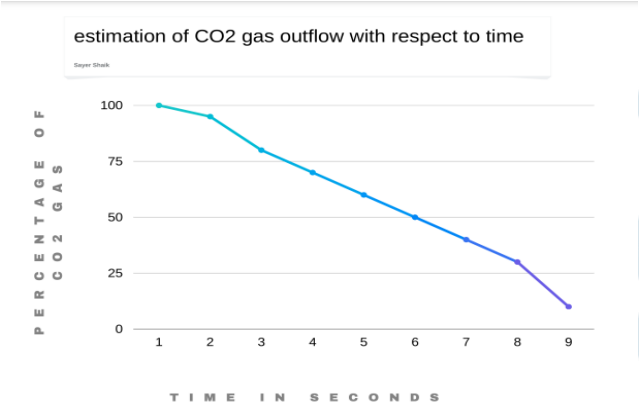
Table.1. status of sensor at different temperatures

Level	Temperature in degrees	Sensor status
Low (room temperature)	Below 30	Inactive
Medium	30-40	Inactive
High	40-50	Inactive
Firing	Over 50	Active

A ring gear with 21-teeth and with diameter 40 mm has been used for the cap of cylinder and a 24-teeth gear with a diameter 56 has been used for the wiper motor. The gear ratio of the two gears used in this experiment is 1.14 rpm.

It took 9 seconds to empty the fire extinguisher. Graph 1. is showing estimation of the rate of gas outflow with respect to time.



Graph 1. Estimation of CO2 gas outflow with respect to time

VI. CONCLUSION

In conclusion, the automatic fire extinguisher system for electric vehicles presented in this journal paper represents a significant step forward in ensuring the safety of passengers and drivers in the event of a fire. By integrating the code into the Arduino UNO, we have developed a system that can be easily integrated into the vehicle's ECU, providing an added layer of protection against fire hazards. The use of fire and smoke sensors, along with the gear setup for opening and closing the fire extinguisher cap, has enabled us to create a robust and effective fire extinguishing system that can detect fires quickly and extinguish them before they can spread, potentially saving lives and preventing significant property damage. Moreover, this prototype can be installed in a variety of electric vehicles, such as cars, buses, and vans, providing a much-needed safety measure for these increasingly popular modes of transportation. With the rise of electric vehicles, it is essential that we take steps to ensure their safety, and this automatic fire extinguisher system is an important step in that direction. In addition, this system can be further improved by incorporating machine learning algorithms, which can analyze the data from the sensors and provide more accurate and timely responses to potential fire hazards. This is particularly relevant given the increasing complexity of electric vehicle systems and the potential for multiple failure points. Overall, we believe that this automatic fire extinguisher system for electric vehicles represents a significant advancement in vehicle safety, and we hope that it will be widely adopted in the industry to ensure the safety of passengers and drivers alike.

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