Automatic Fire Extinguishing System for Electric Vehicle

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Abstract-- The main idea behind this paper is to propose a model focusing on cost effective design and application of an Automatic Fire Extinguishing System for Electric Vehicle. In this system the fire extinguisher activates on sensing of flame/smoke from the fire areas inside a vehicle & automatically extinguishes the fire. An electric vehicle has many reasons that can lead to fire accidents. The main reason behind the Electric Vehicle fires is the battery used in them. There have been numerous of incidents in which the cars caught fire because of the above reasons and ended up with the whole vehicle turned into ashes. The installation of the automatic fire extinguishing system can minimize the financial loss which could arise from a fire, as well as increasing the safety level for the vehicle, occupants and other traffic participants.

***Keywords*--** Arduino MEGA, Electric Vehicle safety, battery failure, overcharging, Electric Vehicles, ABC powder.

I. INTRODUCTION:-

In our country fire accident is a very common phenomenon. Many wealth and lives are fallen in danger. As a developing country we have no modern technology to solve this problem. The main sector of fire brigade has limitation to overcome it. Sometimes police, military come to the firing spot to help them. But this is not enough. Electric vehicle batteries bring new safety challenges to the vehicle development process, and rigorous testing must be carried out to ensure the minimal risk of fire. Research has shown that electrical system failures are among the top 4 causes of automobile related fires. Many people have the notion that only all-electric and hybrid vehicle battery packs are problematic and can start a fire. It is a significant challenge for the automotive industry to tackle, but car fires are not a new problem; around 900 car fires are said to occur on Indian roads for every billion miles travelled.

If an Automatic fire extinguishing system is available, it will offer greater flexibility. Several gas jetting nozzles are arranged at desired locations within a region. The gas jetting nozzles are connected through a valve and a pipe to the extinguishers. The fire sensors are arranged at desired locations within the region. In response to a fire signal from the fire sensors, the valve is opened to cause fire-extinguishing gas to jet from the gas jetting nozzles into the region so that automatic fire extinguishing can be achieved therein.

II. LITERATURE REVIEW:-

Anij Joseph John, et al. [01] has done an experimental study on **"**Automatic Fire Extinguishing Robotic Vehicle". This robot is defined as a mechanical design that is capable of performing human tasks or behaving in a human like manner. Building a robot requires expertise and complex programming. It's about building system and putting together motors, sensors, wires among other important components. A fire fighter robot is one that has a small fire extinguisher added to it. By attaching a small fire extinguisher to the robot, the automation put out the fire by human controlling.
Fire fighters face risky situations when extinguishing fires and rescuing victims, it is an inevitable part of being a fire fighter. In contrast, a robot can function by itself or be controlled from a distance, which means that fire fighting and rescue activity could be executed without putting fire fighters at risk by using robot technology instead.

Choton Kanti Das, et al. [02] has done a research on Design and Implementation of an "Automatic Fire Extinguishing System Based on Fault Secure Multi-Detectors"**.** The main objective of this paper was to provide an automatic fire-extinguishing system which eliminates the disadvantages of the prior arts, and to enable easy installation or removal of the system in or from a region wherein automatic fire-extinguishing should be effected and to allow a flexible arrangement of gas jetting nozzles according to the size and shape of the region. However, since such conventional automatic fire-extinguishing systems require a complicated system of gas pipes from a gas bomb to the gas jetting nozzles, the cost and installation of the pipes is expensive.

Andrzej Łebkowski [03] has done experimental studies on "Electric Vehicle Fire Extinguishing System". The presented fire extinguishing system for an electric vehicle, basing on data from temperature sensors, flame sensors and impact sensors, can alert the vehicle's driver about a fire in the vehicle and proceed with immediate preventive action. The fire system has an advantage over the other solutions, which are limited to disconnecting the battery, that it can react further, by actively trying to extinguish

the present fire. The fire extinguishing system for an electric vehicle can interact with other diagnostic and monitoring systems including remote notification of emergency services, and remote electric vehicles diagnostics.

B. Swetha Sampath [04] has done a research on Hardware based "Automatic Fire Extinguisher Robot". The Robot in this paper detects the temperature of about 300°C from the furnace, using a thermocouple. IC 741 has been used both as a comparator and an amplifier. The amplified DC voltage has been converted into AC using a DC to AC convertor. The AC voltage thus generated supplies power to the water pump. Generally water or other substitutes like foam and carbon dioxide can also be used to extinguish the fire. Obstacle avoider and motion sensor have been used to avoid the obstacles and move in all directions as per the fire intensity. The robot is shielded with calcium silicate boards to withstand very high temperatures.

Rafat Shams, et al. [05] has developed a model of "Automated Fire Extinguishing System with GSM Alarm". This paper demonstrates the requirements, specifications, design problems and solutions for the fire extinguishing system project fulfilling the requirements. Fire fighting is an important and hazardous job. A fire fighter can be able to extinguish fire quickly, averting the damages and reduce losses. Technology has joined the gap between fire fighting and machines using some effective method. The purpose of this thesis was to establish a system that can detect fire and extinguish it in the shortest time subject to a few effective factors. In this case, the system aims to put out the fire before it spreads increasing the security of home, laboratory, office, factory and building that is important to human life.

III. PROBLEM STATEMENT:-

Research has shown that electrical system failures are among the top 4 causes of automobile related fires. Many people have the notion that only all-electric and hybrid vehicle battery packs are problematic and can start a fire.
A Few years back, a Tesla Model S, which was awarded the title of the safest car in the world by the media, caught fire in late 2013. The concerns and risks associated with electric or hybrid cars go way back. There are even more risks with every new design or model that comes out. It may take a while for these high profiled incidents to ebb away from the mind of a lot of people. The common factors that lead to car fire in electric vehicles are given below-

i. Battery overcharging-

Every system has a limit of sustaining high loads on it and so the EV battery too. The electric vehicle battery also has some limit of electricity provided to it. This limit is stated by the manufacturer. If this limit is crossed, then some malfunctioning, damage to electrical system or in some cases the vehicle can also catch fire. This happens when excess of electric current flows though the battery.
Due to this excessive current the battery gets heated and it catches fire. This occurs normally when the owner or driver keeps the battery for charging overnight and forgets to remove it from charging.

Fig 01. Battery overcharging

ii. Battery electrolyte leakage-

The Lithium-ion battery also presents a risk of degradation by a violent and dangerous combustion reaction. This combustion can occur spontaneously as soon as the batteries intern temperature reaches 65 °C and is very likely to occur above 75 °C.
In case of burning of the battery, hydrofluoric acid is produced and released by thermal decomposition of the PF_6^- ions of the electrolyte contained inside the battery.
Concentration of released hydrofluoric acid is variable and depends on the quantity of electrolyte burnt in the combustion process and the combustion temperature. Other toxic gases are also produced and released during the electrolyte combustion (carbon oxides from combustion of ethylene and propylene carbonates). To prevent leaking or burning of the battery, very cautious manipulation of Li-ion batteries is recommended.

iii. Short circuit in electric components-

Short circuits occur due to overloading or when two bare wires touch. A circuit is said to be overloaded when too much current flows causing heat build up or wiring to break down. This can lead to sparks and fire. A short circuit is an electrical circuit that allows current to travel along an unintended path. Short circuits cause fire, especially when the positive wires get in contact with the flame; a spark is formed leading to fire. When the wires join together, a spark can be formed causing a blaze.

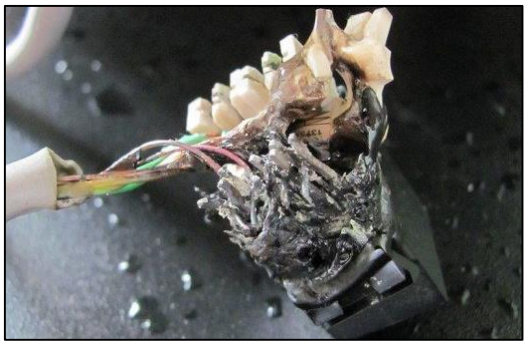


Fig 02. Short circuits in electric components

iv. Road crash-

Normally, a car isn't supposed to catch fire after a collision. But in an electric vehicle, the battery is the main reason for fires. The batteries in electric cars behave like any other battery, it ignites when punctured. So, if for example, an electric car travelling at top speed hit a small object or debris that punctures its battery, it would ignite. There are some cases that states how dangerous is this battery issue.

The Chevy Volt made headline in late 2011 and early 2012 when a couple of cars caught fire during impact testing. After a thorough investigation into the incidence, federal regulators determined that the fire may have been caused by the interaction between leaking coolant with damaged batteries during the test.

IV. FIRE SAFETY REQUIREMENTS IN ELECTRIC VEHICLE:-

Electric vehicle batteries bring new safety challenges to the vehicle development process, and rigorous testing must be carried out to ensure the minimal risk of fire. Engineering consultancy AVL employs benchmarking programmes that test and analyse battery cells, modules and packs to optimize total battery systems. The Austria-headquartered firm has recognized various factors that can put an Electric Vehicle battery at risk of what is known as a 'thermal runaway', and believes computer simulation can provide vital insight into the problem.

So-called 'battery abuse' can occur during a crash, for instance, with a part of the vehicle's body structure piercing the battery cell. Batteries can also be electrically abused through excessive vibration or torsion, which could damage electrical connections. The battery pack can be thermally abused, and brought to an unsafe temperature. In theory, overcharging is also a risk.

It is a significant challenge for the automotive industry to tackle, but car fires are not a new problem; around 900 car fires are said to occur on Indian roads for every billion miles travelled. However, the risks of prolonged and excessive thermal runaway that can occur post-crash means automakers must strive to keep EV batteries intact no matter what.

V. METHODLOGY:-

1. **Recognition of need-** First of all, makes a complete statement of the problem, indicating the need, aim or purpose for which the system is to be designed.
2. **Design of structure**: Decide the size and shape of the structure by considering the installation of all the electronic and mechanical components/parts. Draw the detailed plan of each component of the structure with complete specifications and dimensions.
3. **Modification**: Modify the size of the member to agree with the past experience and judgment to facilitate manufacture. The modification may also be necessary by considering of manufacturing to reduce overall cost.
4. **Selection of components-** Select the possible components and decide the proper number of components, which will be used in the project.
5. **Programming the Micro-Controller-** The micro-controller is nothing but an Arduino Mega board. The Arduino board is feed with a program that is used for the actual project application. As per the program feed, the fire sensed by the sensors is processed and signals are sent to the actuators that will extinguish the fire.
6. **Production& Assembling**: The components, as per the drawing, are assembled in the frame. After assembling all the components, the project is ready.

VI. COMPONENTS USED:-

1. Arduino-

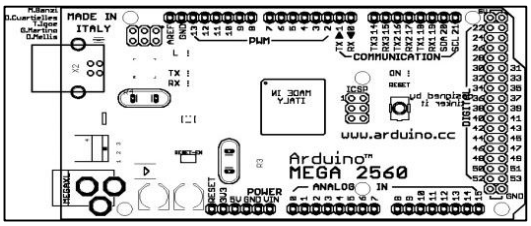
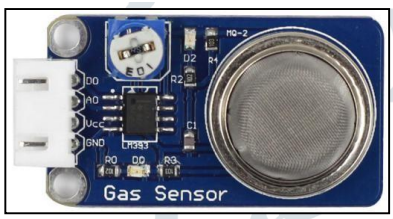


Fig 03. Arduino Board

Arduino is an open-source project that created microcontroller based kits for building digital devices and interactive objects that can sense and control physical devices. The project is based on microcontroller board designs, produced by several vendors, using microcontrollers. The Arduino project provides an integrated development environment (IDE) based on a programming language named processing which also supports the languages C and C++.

2. Sensors-

A smoke detector is a device that senses smoke, typically as an indicator of fire. Commercial security devices issue a signal to a fire alarm control panel as part of a fire alarm system, while household smoke detectors, also known as smoke alarms, generally issue a local audible or visual alarm from the detector itself or from a number of detectors if there are multiple smoke detectors interlinked. A flame-sensor is one kind of detector which is mainly designed for detecting as well as responding to the occurrence of a fire or flame. The flame detection response can depend on its fitting.



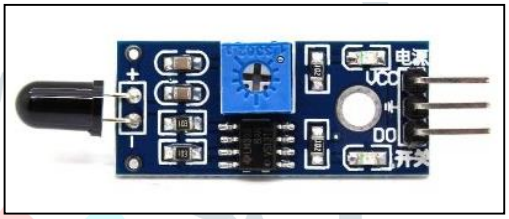


Fig 04. Smoke & fire sensors

3. Power supply-

As per the power requirement of the hardware of the density based traffic light control system, supply of +5V with respect to GND is developed. The complete circuitry is operated with TTL logic level of 0V to 5V. It comprise of 0V to 9V transformer to step down the 220V AC supply to 9V AC. Further a bridge rectifier converts the 9V into 9V√2 DC. It is further filtered through a 1000uF capacitor and then regulated using 7805 to get +5V. To isolate the output voltage of +5V from noise further filtering 220uF capacitor is used.

VII. CONSTRUCTION OF MODEL:-0

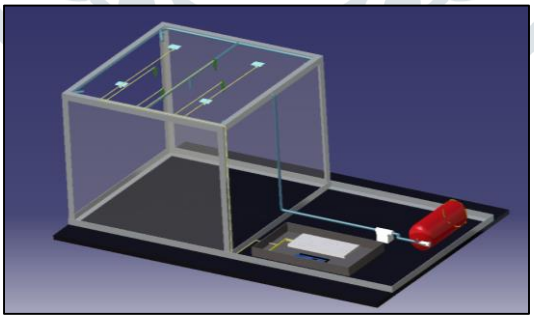


Fig.06- Design of structure

The figure below shows the design of demo model of Automatic Fire Extinguishing System. It consists of Fire Extinguisher, Motor, Actuators & Sensors and structural members. The actuators consist of solenoid valve (12 volt DC) and DC motor (high torque 3.5 rpm). The sensors consist of flame sensor module and smoke sensor module (MQ-2). Four flame sensors and four smoke sensors which will cover the whole area for more accuracy and effectiveness.

The base of this model is the wooden board of size 4×2.3square foot. The Aluminum angles are fitted on the wooden board with the help of nut bolts and washers. This aluminum angles are used to form the rectangular structure of the model. The size of the aluminum angles is 20×20 mm and thickness is 2 mm. A rectangle of size 4×2 square feet is formed with the help of aluminum angles at the floor. The upper portion is of size 2×2 square feet. The height of box is 1.5 feet. On the upper portion acrylic sheet (Fiber glass) is placed an also on the left and right side of the model. On the acrylic sheet at the upper side sensors are placed.

The fire extinguisher is placed at one side of the wooden board with the help of clamps. The pneumatic pipes with internal diameter of 10 mm are split all over the rectangular section in which the extinguishing powder gases are flowing. One end of the pneumatic pipes is connected to the outlet of the fire extinguisher with the help of brass extension. Five nozzles are used to spray the powder gases and four of them are located at the corner of the rectangular section & one at the middle of it.

The Arduino MEGA 2560 and bread board (PCB) are placed on a side of the wooden board.
The Arduino MEGA is feed with the programme that will be used for operating the actuators. Sensors are connected at the input section and actuators are connected at the output section of the Arduino board with the help of jump wires. Sensors are attached to the upper acrylic sheet.

Working of model-

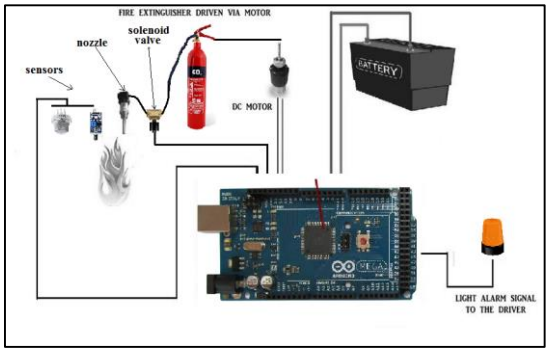


Fig.07- Circuit diagram

1. When fire occurs, the sensors placed at the top of the model senses the fire. The smoke sensor senses the smoke of the fire and the flame sensor senses the actual fire by determining the temperature around and its range area.
2. Then the sensors send signal to the Arduino (Microprocessor). Then the microprocessor reads the information given by the sensors and processes it.
3. With the help of programme fed to the microprocessor, according to the information taken from the sensors the microprocessor gives command to various actuators.
4. If the information is taken from the smoke sensor, then the microprocessor gives command only to the buzzer and the LED. And if the information is taken from flame sensor, then the microprocessor gives command to the buzzer, LED & also to the DC motor and solenoid valve.
5. When the DC motor turns ON, its shaft starts rotating in clockwise direction. The motor's shaft is connected to the handle of fire extinguisher with the help of steel cable.
6. When the shaft rotates, the lever of fire extinguisher is pressed and the extinguishing powder gases are released into the pneumatic pipes.
7. The pneumatic pipes are further connected to the solenoid valve. When the solenoid valve is turned ON by the command of microprocessor, the gases will pass through it.
8. Then the gases will further pass forward in the pipes into the rectangular section of the model.
9. The gases then will get released from the nozzles connected to the top of the model and will get spread all over the area of the model. And this will extinguish the fire at bottom of the model.

VIII. APPLICATIONS:-

The same concept will be used for the actual application in the car. For the actual car application, we have to make three sections in the car i.e. engine section, passenger section and luggage/dickey section as shown in the fig. below. The microcontroller used in the car will be the Electronic Control Unit (ECU) instead of the Arduino board. So as well the same program will be fed to the Electronic Control Unit.
The sensors will be placed at the top of the hood, roof and dickey for engine section, passenger section and the dickey section respectively. The sensors are connected to the ECU with respect to the program into the specific pin connections.
The fire extinguisher is placed is between the passenger section and dickey section. The pipes are spread all over the car in each compartment and are connected with sprinkling nozzles. The pipes are passed through the foam inside the car.
One solenoid valve for each section is provided to control to flow of the fluid through the pipes. Each solenoid valve is connected to the Electronic Control Unit which will operate it as required through a relay.

The working will be the same as the demo model except the sections created in car for actual application.

1. When fire occurs, the sensors placed at the top of each section sense the fire. The smoke sensor senses the smoke of the fire and the flame sensor senses the actual fire by determining the temperature around and its range area.
2. Then the sensors send signal to the Electronic Control Unit. Then the ECU reads the information given by the sensors and processes it.
3. With the help of programme fed to the ECU, according to the information taken from the sensors it gives command to various actuators.
4. If the information is taken from the smoke sensor, then the ECU gives command only to the buzzer and the LED in dashboard as a warning signal. So that the driver could check for whether it is fire or some other smoke.
5. The smoke sensor will also sense the smoke from cigarette. But it will not actuate the fire extinguisher.

6. And if the information is taken from flame sensor, then the ECU gives command to the buzzer, LED & also to the DC motor and respective solenoid valve according to the section.
7. When the fire is sensed in particular section then ECU will actuate the respective solenoid valve to flow the extinguishing fluid. (For example, if the fire is sensed in the engine compartment then the solenoid valve connected to the pipes going to the engine compartment is actuated. And the remaining two valves will be in OFF condition.)

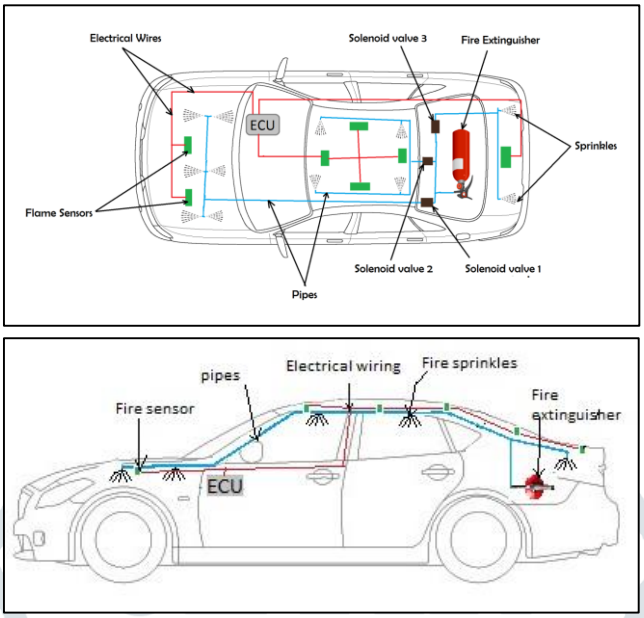


Fig.08- Actual application in car

IX. CONCLUSION:-

- This invention of Automatic Fire Extinguishing System is effective and it is well within the reach of every person.
- If considerable amount of time is spent on its further research and development, it could really prove to be an effective product in the fire safety department.
- This system is applicable to the different sizes of fire extinguisher and high controlling capability over them.
- The simple design of it allows minimum of maintenance work.
- After installation of this system, there will not be any disturbance and uneasiness to the driver and also to the passengers.
- The results shows that, after the application of the system the risk of fire in Electric Vehicle is reduced by 80% (Approx.)

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