



A DETAILED REVIEW ON CAUSES OF FIRING AND PREVENTION STRATEGIES IN ELECTRIC VEHICLES

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Abstract

As now and in near future electric vehicles are really making huge difference in automotive industry. It comes with its own limitations, one of the things to consider the most is safety. During the recent times there are some unfortunate situations like electric vehicles catching fire. In order to tackle this problem huge advancements and research are going on in Battery Management System (BMS) like cooling the battery from overheating, cutting of the power supply from battery to the drive motor. In this paper, the covered topics are causes for fire in battery packs, battery management system, methods to overcome battery overheating problems and mainly automation of fire extinguishing in electric vehicles. In this paper itself the prevention strategies to tackle firing problems are described. On the other hand, it is really necessary to ensure passive safety. It also can be achieved by installing an automatic fire extinguishing system. This project is hoping to improve the safety features of electric vehicles to reduce vehicle damage and human life.

Keywords: overheating, automatic, fire extinguisher, battery overcharging, CO₂ gas, electric fire, battery management system.

1.Introduction

With the present world moving towards the generation of electric vehicles we believe that it's mandatory to keep our sight on safety systems. In considering the status of road accidents which is over 1.5 lakh in which around 900 cars according to National Crime Records Bureau (NCRB) fire accidents is one of the major issues and the fire accidents are causing a panic in the public which is resulting in refraining the EVs to roll on roads [1]. So, it is best, until the electric vehicles reach a state where

It has an effective cooling system and a good battery management system. It's better to have a passive safety system too which can tackle the firing problems in electric vehicles.

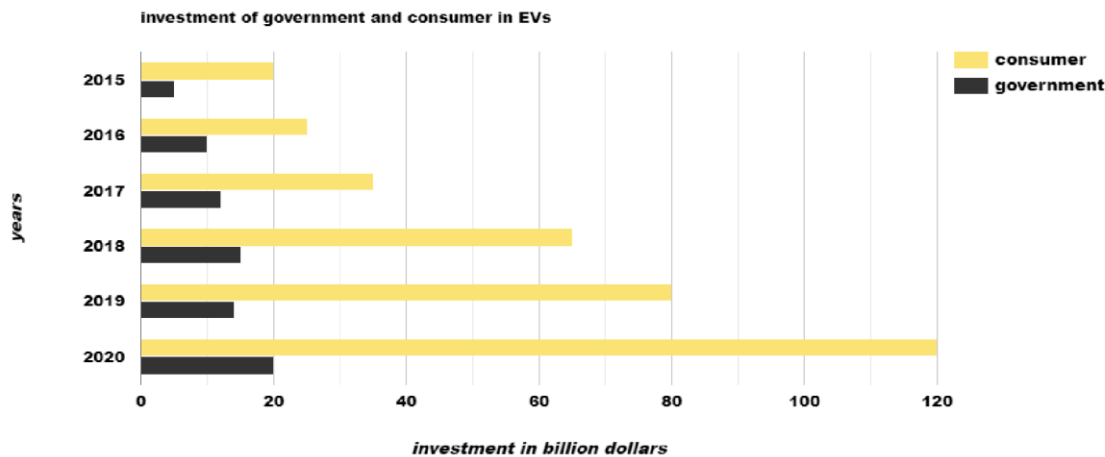


Figure.1. graph of investment of US dollars in electric vehicles from 2015-20.

The above graph shows the increase in the investment in EVs. There has been a gradual increase in the investment in electric vehicles from 2015 to 2020 [2].

Date	Place	Vehicle model	Incident	Comments
Jan	Chongqing China	Tesla, BEV	Fire in parked vehicle	Sudden ignition
March 18	Bangkok Thailand	Porsche Panamera PHEV	Fire while in charge	Absence of inbuilt safety system
March 25	Catalonia Spain	BMW i3 REx, PHEV	Fire while parking	Sudden ignition
March 23	California USA	Tesla model X, BEV	Accident	Fire Extinguisher but happened again
May 8	Florida, USA	Tesla model S, BEV	Accident	Fire exhausted but ignited while loading on tow truck
May 15	Ticino, Switzerland	Tesla, BEV	Accident	Bursted into flames after hitting a barrier
May 21	Hubei China	Zhong Tai, BEV	Fired while driving	Self-ignited
Dec 12	Gelderland Netherlands	Jaguar I-pace, BEV	Fire while parking	Front part was burned
Dec 18	California, USA	Tesla model S	Fire while parking	Fire reignited twice

Table.1 List of fire accidents that happened in 2018.

The above table shows the fire accidents that took place in different locations around the world in the same year. It includes certain types of vehicle models [3].

2. CAUSES OF FIRING IN LITHIUM-ION BATTERIES

2.1 Thermal runaway

Lithium-ion batteries are the most widely used batteries for cars and motorbikes in the present electric vehicle manufacturing field. One of the most common causes for a Li-Ion battery to explode is when it undergoes thermal runaway [4]. Thermal runaway is something that happens in a battery when there is no proper maintenance and short circuit internally. Because of that the battery cells go under a chain reaction in the battery internal which results in overheating in the end, it causes explosion.

2.2 Overcharging

Overcharging is also taken as a cause for explosion. A battery which crosses its prescribed max voltage (to prolong the distance an electric powered auto will run, for example) may lead the battery to be completely damaged. And it might lead to thermal runaway.

2.3 Rapid charging

One of the other factors is rapid charging. It can lead to thermal runaway due to the fact fast charging can lead to immoderate currents. DC Fast Charging covers all of the obstacles of the on-board charger and required conversion, as an alternative supplying DC electricity without delay to the battery, rate of charging has the plausible to be substantially increased. Charging instances are based on the battery dimension and the output of the dispenser, and different factors, however many automobiles are successful in getting an 80% cost in about or beneath an hour the use of most presently handy DC rapid chargers [5].

DC rapid charging is quite essential for excessive mileage/long distance riding and long-range driving. Without rapid chargers drivers have to recharge the vehicle overnight to get fully charged or it may take several hours. Older motors had boundaries that solely allowed them to cost at 50kW on DC devices (if they had been in a position to at all) however more recent cars are now coming out that can be given up to 270kW. Because battery measurement has accelerated notably in view that the first EVs hit the market, DC chargers have been getting steadily greater outputs to healthy – with some now being successful of up to 350kW.

2.4 Temperature and positioning of battery pack

Finally, temperatures outdoor of the secure location on both the low and excessive facet degrades a battery's performance. This leads to long-lasting harm, sometimes irreversible to the battery and feasible triggering of the reaction. While the risk of immoderate heat may additionally be obvious if it is positioned wrongly. The functioning of lithium-ion batteries relies upon chemical reactions. So, it's better to provide the battery with a safe working atmosphere.

2.5 Manufacturing defects

Due to the flaws in manufacturing can bring steel particles (impurities) seep into the lithium ion cells all through the process of manufacturing. That's why battery manufacturing companies wish to make certain rooms specified for the manufacturing process. Thinning of separators which may want to show unsafe in genuine use. Cells undergo strict validation and verification before they are released to market.

2.6 Design Flaws

Car companies try to make designs slimmest while achieving comfort and aerodynamics. Due to this the battery pack producers have to come up with designs which will suit the desired vehicle perfectly. Compromising on the design or blueprint can cause damage to the electrodes or the separator. Either of them may want to end the result in a short circuit. Furthermore, due to the absence of an appropriate cooling system or ventilation, it can be the reason for battery temperatures to upward thrust as the flammable electrolyte warms up. If the heat which is produced is out of control it can result in a cell explosion which can cause a chain reaction of fire in the whole battery pack, which needs to be avoided at all costs.

3. Methods to save batteries from firing (prevention strategies)

There is a system called battery thermal management system. which comes into action as the temperatures in the battery pack goes up mostly out of control the temperature rise is due to the continuous charge supply. There are several methods included in BTMS and with their help we can save the batteries from firing. They include air cooling, water cooling, phase change material cooling, direct refrigerant cooling, heat pipe cooling, thermoelectric cooling [5].

3.1 Air cooling

In air cooling the cells are placed in a way that there will be space between them so that the hot air can pass away. Air cooling makes use of the precept of convection to switch hot air away from the battery pack. As air runs over the surface, the inlet air which is cool because it enters from the atmosphere carries the hot air produced out in the battery pack. Air cooling is easy to accomplish. However now it is not very environmentally friendly and highly crude in contrast to liquid cooling. Air cooling is used in the past variations of electric powered cars [5].

3.2 Liquid cooling

Liquid cooling working mechanism is similar to what can be found in a conventional IC engine vehicle. But here water is used as a coolant. Liquid coolants have greater warmness conductivity and warmth potential (ability to shop warmth in the shape of electricity in its bonds) than air, and consequently performs very efficaciously and personal benefits like compact shape and ease of arrangement. Out of these options, liquid coolants will supply the fantastic overall performance for preserving a battery pack in the right temperature vary and uniformity. By treating liquid cooling system improperly there are some disadvantages too which include disposal of glycol it is harmful to the environment. Some of the biggest car manufacturers like Tesla, Jaguar and BMW follow liquid cooling in their designs.

There are two more subdivisions in liquid cooling system named direct and indirect cooling. In a direct cooling system, the cells stay in contact with the coolant but in indirect they won't, and direct cooling system is more complicated to achieve than indirect cooling system [6].

3.3 Direct refrigerant system

A direct refrigerant system (DRS) consists of an Air Conditioning loop; however Direct Refrigerant System makes use of refrigerant at once as heat switch fluid circulating in the course of the battery. The DRC device eliminates the secondary fluid (or water) pumps required in the system, which may additionally simplify operation and maintenance. A direct refrigerant cooling machine can result in a large vary of parasitic power, from as little as 4% to 5% to 30% of the turbine generator capacity. The DRC machine can additionally supply cooling in the course of all of the 24-hour day, as can a partial thermal storage system.

3.4 Phase exchange membrane

Phase exchange membrane absorbs warmth for the duration of the melting technique and saves it as latent heat until it reaches a maximum value. For a period, the temperature is saved at a melting factor and then the temperature expand is delayed. The PCM is used as buffer and also a conductor too in the battery thermal management system. Also, the PCM is constantly blended with any other battery thermal management system device such as liquid cooling or air-cooling machine to manipulate the battery core temperature.

3.5 Thermoelectric cooling

The thermoelectric cooling device has the adjustments which are electric powered voltage into temperature distinction and vice-versa. It gets rid of heat via the factors through hard electrical energy directly. It works on the concept called Peltier effect. It works by consuming electricity and sending heat from one side of the device to the other. It can work in the opposite direction too, but mainly used for cooling process. This technique really helps in cooling the overheating of battery in electric vehicles. [5]

3.6 Fans





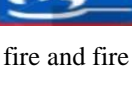
Fans are outfitted to improve warmth switch with the aid of compelled convection. Mixing a passive air machine with the thermoelectric machine and the related machine cools down the battery temperature even much less than the enter air temperature, and the power is constrained to much less than one kW. Heat pipe cooling is used as a passive cooling system.

A tiny water leak in a misguided hydro dam can increase into a torrent and take a shape down, so too much heat can build up damage to the insulation layer of the battery pack which results in an electrical shortage. The temperature can reach up to 500°C (932°F), which will allow the battery to explode. Which again causes the thermal runaway. This thermal runaway that takes place is regarded as “venting with flame.”

4. Role fire extinguishers in preventing EV fires

When an electric vehicle is caught on fire one of the major problems is the toxic gases that are released from the vehicle like hydrogen fluoride [7] For each type of fire there are certain type of fire extinguishers. Overall, there are 5 extraordinary fire extinguishers, which are: Water, water mist or water spray fire extinguishers, Foam fire extinguishers, Dry Powder fire extinguishers, Carbon Dioxide (“CO₂”) fire extinguishers and wet chemical. The following chart shows the fire category and the type of fire extinguisher to use [8].

classification of fire and type of fire extinguisher to use

fire extinguisher type	symbol	description use on
A		paper, wood, textile and rubbish
B		use on flammable liquids
C		use on electrical equipment
D		use on combustible metals
K		use on combustible cooking oils




Figure.2 Classification of types of fire and fire extinguisher to use

So as mentioned water type is used for A class fires, foam or spray type is used for both A and B class fires, ABC powder can be used for A, B and C class fires, wet chemical can be used for K class fire and CO₂ type can be used for C class fire. So, it is sensible to use either ABC powder or CO₂ type fire extinguisher for stopping a fire caused by an electric vehicle [8].

5. Automatic fire extinguishing system using fault secure multidetector.

In the mentioned paper a fire extinguisher is being used which can be used in an electric vehicle for the prevention of spreading of fire in case of firing. The system works through automation by installing a temperature sensor, smoke sensor placed near the battery pack to monitor the external temperature of the battery. A DC motor attached to a string which is connected to the lever of the used fire extinguisher. Here an ABC powder type fire extinguisher is used. The automation is achieved by setting up an Arduino which consists of a code written with the help of Embedded C [9].

5.1 Working and components used in automatic fire extinguishing system

There were sensors used in this project which include temperature sensor and smoke sensor. Those sensors are installed in desired locations around the battery pack of the EV which reads the temperature and sends the signals to Arduino to analyze if the received signals have crossed the certain limit which is 112-121 degrees centigrade at anode and 139-147 degrees centigrade at cathode on the first layers of cells [10]. It will lead to thermal runaway which results in electric fire. The system also consists of a hose pipe which runs throughout the battery pack which has nozzles at desired places. The system is also equipped with solenoids which will allow the flow of extinguisher when needed [11].



Figure.3 ESP2866 Lua NodeMCU

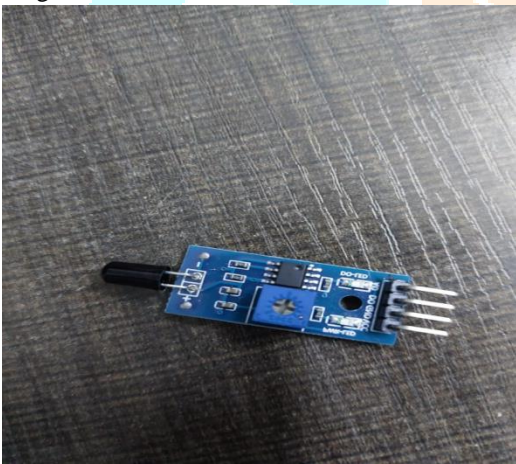


Figure.4 Temperature Sensor



Figure.5 Smoke Sensor

There are few drawbacks in this study because of the type of fire extinguisher used. In the mechanism of this setup a bomb is being used which might cause some problem for other parts of the vehicle while activating and the system takes up quite a space for installation and the string which is attached to the motor is unprotected. While releasing the powder the extinguisher can cause visibility problems and there is no protection against reignition which is a considerable matter in electric vehicle firing [12]. So instead of using ABC powder we can use a CO₂ type fire extinguisher which works specifically for electric fires and won't have to

worry about reignition problems. Instead of using a string mechanism we can use a gear setup where the cap of fire extinguisher and motor are meshed with two gears for the activation process.

6. Conclusion

As we have discussed above it is clear that there are several factors affecting the battery life of an electric vehicle which include charging, temperature, the way of charging and maintenance. The effects if the above-mentioned systems might lead to failure of the battery pack or even may damage the whole system sometimes it might lead to the firing which is a problem the electric vehicle industry is facing. There are several methods to save a battery pack from firing which comes under the prevention strategies they include Battery Management System (BMS), different types of cooling systems like air, liquid, refrigerant systems, thermoelectric cooling systems and by providing fans. One of the important things to consider in this whole field of battery management system is the passive safety in situations of firing. The thing that we have discussed in this paper is called automatic fire extinguishing systems which play a vital role in saving human lives and minimizing vehicle damage. This invention of Automatic Fire Extinguishing System is wonderful and it is properly inside the attain of each person.- If huge quantity of time is spent on its similarly lookup and development, it may want to without a doubt show to be an effective product in the fire security department.- This gadget is relevant to the one-of-a-kind sizes of fire extinguisher and excessive controlling functionality over them.- The easy format of it lets in minimal of preservation work.- After set up of this system, there will now not be any disturbance and uneasiness to the driver and additionally to the passengers. The consequences suggest that, after the utility of the machine the danger of furnace in Electric Vehicle is decreased through approximately 80%.

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