Review in Fire Safety Strategies in Electric Vehicle

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Abstract

Electric vehicles, or EVs, are becoming a more cost-effective, emission-free mode of transportation. The primary source of power for these electric vehicles is the battery. Faulty battery management systems, cell thermal management, and thermal runaway can cause batteries to catch fire. Safety is a crucial factor that prevents catastrophic fire hazards and the loss of human life and precious property. Many fire detection and handling systems have been created that include a variety of sensors that measure different parameters, research at the battery pack level, and external cooling methods to control cell temperature and minimize thermal runaway. This study employs a unique method for detecting and analysing fire behaviour by combining Internet of Things (IoT) sensors with artificial intelligence (AI) and machine learning (ML) frameworks. Fire has a nonlinear character. In a conventional fire system, a single passive sensor system can falsely indicate a fire. The primary goal is to outline a neural network-based intelligent fire detection system. Based on trained data, the system gathers real-time data from several sensors and tracks the impact of these parameters' values. Achieving efficient battery management allows the system to notify the user in the event of danger. Energy storage systems and electric vehicles are better designed and function effectively using artificial neural networks. Performance metrics like State of Charge (SOC), State of Health (SOH), and State of Power are tracked to ensure the battery system operates safely. For early fire detection, various algorithms are discussed for their efficacy, future selection, and enhanced accuracy and efficiency.

Keywords: Intelligent fire alarm, Fire detection, Artificial neural network, State of charge and state of health for battery system.

1. Introduction

Because EVs are more convenient to drive, environmentally friendly, and a viable alternative to traditional energy sources, their use has grown in recent years. Batteries can catch fire, which is a drawback when using them as a power source. Both property and human life have been lost because of the fire disaster [10]. In Karnataka, there have been 83 instances of electric vehicles catching fire in the last years. These incidents were documented by the Karnataka State Fire and Emergency Services Department from January 2020 to November 2024. The research states that with 36 instances, 2024 had the most causes, followed by 2023 with 28, 2022 with 9, 2020 with 7, and 2021 with 3. The data shows a worrying rising trend in the last few years. According to the causes of EV fires, out of 83 cases, 65 occurred due to power leaks, 13 to battery explosions, and five to accidental fires. It is evident from these statistics that battery is the primary cause of the events. Therefore, using a battery at a safe and appropriate temperature is crucial. Among the numerous possible causes of fire are short circuits, gas leaks, battery aging, maintenance, cell quality, series cell voltage imbalance, state of charge while charging and discharging, and overheating [11]. We refer to an extended rise in cell temperature as a "thermal runaway." The primary causes include short circuits, overcharging, and overheating. This internal heating causes the battery to break, catch fire, and explode when it reaches its maximum temperature because it produces gases that raise internal pressure. Temperature and fire are crucial considerations when creating a battery management system (BMS) to reduce the possibility of battery flaws [8]. As a result, fire safety is more crucial when using batteries. Fire incidents are common in today’s world. To save lives and property, it is more crucial to contain a fire before it starts because there is an urgent need for an early fire detection system that can sound sirens or send alerts. For fire alarm systems to be more accurate, researchers must concentrate on creating effective algorithms and machine learning strategies.

Conventional fire detection techniques frequently depend on simple sensors and a monitoring system that might not deliver precise and timely alerts. In recent years, machine learning (ML) algorithms and Internet of Things devices have become widely used, enhancing the security and effectiveness of numerous systems [1],[3]. This novel approach and machine learning techniques for predictive analysis enable the efficient identification and mitigation of fire hazards in the batteries of electric vehicles. Protecting people in situations is the primary objective of this innovation. In the past, various approaches have been discovered. Several methods, such as Random Forest (RF), Logistic Regression (LR), K-Nearest Neighbour (KNN), and Support Vector Machine (SVM), are used to anticipate and identify fires beforehand [15].

The fundamentals of fire detection techniques include:

1.1. IoT Sensor Detectors

1.1.1. Temperature Spot Detectors: Localized temperature detection is accomplished with temperature spot detectors, which consist of a thermocouple and a bimetallic strip. Temperature variations are detected by a thermocouple, which then transforms them into electrical voltages. The vehicle's engine and several battery modules are covered with thermocouples. These aid in identifying various hot temperature spots. Bimetallic strips are made of two distinct materials that are joined together and have different temperature coefficients at temperatures. This strip functions similarly to a switch, sending out a fire signal by closing its contacts [7][12].

1.1.2. Smoke Detector: In short, fire events in batteries occur when cell components rapidly oxidize through an extreme chemical procedure of combustion, generating heat, light, and a variety of reaction products that may be solid or gaseous. These detectors can identify one or more of these fire occurrences [7][12].

1.1.3. Off Gas Detector: Failure of a cell or battery results in off-gassing. To identify the initial indications of off-gas before they become too diluted, off-gas sensors must be placed strategically and have a high enough sensitivity. Off-gas sensors and referenced sensors are frequently employed for controlling the ambient air conditioning. Situational awareness of a facility's state can be obtained by off-gas detection [12].

1.1.4. Heat Detector: The heat detector emits heat when the battery dies. Because of their sensitivity to the heat that batteries release, these detectors can be connected to fire safety and battery management systems and may issue warnings [12].

1.2. Fire Detector System

An approach to creating a BMS for EV battery fire detection that integrates an IoT sensors and artificial neural network-based fire detection system is described in this article. Utilizing sensory data including temperature, smoke density, and CO concentrations, a neural network approach to fire detection has been developed that assesses the probability of a realistic fire state. This technique uses data from individual sensors to address the drawbacks of domestic fire alarm systems. By comparing the expected and measured values in the momentary sliding window, the alert system adjusts to shifting environmental conditions. Burning flames were separated from non-burning fires using the rates of growth in CO2 and CO concentration. It shortens response times and lowers the frequency of annoying alerts. The BMS is an electric vehicle's brain, regulating and coordinating the energy flow into and out of the system. BMS ensures that batteries operate within acceptable temperature ranges. To track and modify cell temperature, it employs complex techniques. When the batteries are in safety mode, they are charged and discharged, overheated, and alerts are sent to take corrective action if something goes wrong [8],[13]. Through the maintenance of the safety temperature, the BMS hinders safety operation, prevents overheating, and improves battery performance overall. An accurate estimation of the battery's charge level (SOC), state of health (SOH), state of power (SOP), remaining usable life (RUL), cell voltage balancing, and heat management are all necessary for a proper BMS design [6],[15],[16],[19]. Fire is a physical and chemical procedure that produces heat, light, and smoke. Heat, CO/combustion products, and smoke detectors are all part of the multi-sensor system, which is designed to obtain fire data [5],[12]. The primary goal of using machine learning techniques to fire detection is to improve the sensitivity of identifying actual flames rather than setting off false alarms. Neural networks, convolutional networks (CNNs), several kinds of recurrent neural networks, long-term memory (LSTM), and gate recurrent units (GRU) are all very useful deep learning approaches [18],[20]. radial basis function (RBF), Fuzzy logic can make powerful, complex decisions and is appropriate for alarm and fire detection systems [17]. A convolutional neural network (CNN) is another deep learning-based method for detecting fires. Among the deep neural network classes, CNNs are especially well-suited for image processing tasks. The Smart Fire Detection System (SFDS) is an enhanced method of fire detection for smart cities based on YOLOv8 that employs deep learning to instantly identify fire characteristics. The most recent development to enhance machine learning-based fire detection models is transformer-based methods [18]. The method captures the dependencies between the various patches by processing the fire image as a collection of patches. There are different methods which may be used to detect fires. This study focuses on artificial neural networks (ANN) as a method of machine learning. This fire detection system obtains fire data and converts it into electrical signal processing. This data is processed by an artificial neural network (ANN), a framework for information processing. Furthermore, because of their intelligent qualities, neural networks have been effectively used to the resolution of numerous challenging real-world issues in pattern recognition, identification, signal processing, and forecasting. To minimize mistakes, the ANN model employs a Back Propagation Neural Network (BPNN) [7]. Temperature, smoke density, and CO content are examples of input signals that these networks receive from input layer neurons. T1, T2, and T3 are the three output terminals where data information is received after being recorded into the hidden layer. These fire statistics can be divided into three categories: no fire, smoldering fire, and fire. Fire detection requires the identification of smoke and flame. The presence of smoke prior to ignition aids early fire detection and risk mitigation. Therefore, an intelligent automatic fire system may efficiently detect fires by combining sensor data input to an ANN with learning algorithms and learned data [7]. Multi-parameter fire detectors, a BMS unit, and an ML framework make up the fire alarm system. By keeping an eye on several variables, this system helps detect fires early and operates safely. It is not possible to detect fires accurately using traditional individual fire detection [12]. Incorrect operations are interpreted when a problem arises. The intelligent and powerful multi-parameter fire alarm system can identify fires more accurately and quickly. It comprises variables like temperature, flammable gas, vibration sensors, flame detectors, smoke, battery voltage, and current. Several detection techniques must be used to identify fire incidents, depending on their size, configuration, and placement of the cells inside the application [6].

1.3. Continuous Thermal Management

This study looks at every feature and metric used to assess battery pack thermal runaway fires. By creating the causal structure model of thermal runaway in battery packs, their relationships would be thoroughly studied [2]. An accurate detection and early warning model for battery packs will be developed because of this investigation. Methods to reduce false alarms and missing reports and increase the accuracy of early warning data were proposed, including grading implementation, complete conditional decision-making, and sorting and screening based on distinctive factors. Several methods, including radioactive substances, recognizable smoke particles, concealed particulates, vapors, gaseous emissions and light, can identify the stages of cell breakdown. The key to stopping fire from starting is early recognition of a growing scenario [13].

1.4. Artificial Intelligence

This review paper discusses opinions and current studies on several fire detection algorithms. By utilizing the algorithmic solution, this system enhances its overall sensitivity. The main topic of discussion is performance metrics and data sets that are used to train machine learning models and create more precise models. The framework outlines the data processing, predictive models, and components required to implement an early fire detection system [6]. Overall, this research clarifies how IoT and machine learning can improve EV safety in the context of early battery fire detection using state-of-the-art technologies and a data-driven approach that increases productivity and accelerates the transition to a sustainable transportation future [3].

2. Literature Survey

Miao, H. (2024). In this study, a multi-sensor early warning detection model was developed. the significant thermal runaway caused by the internal short circuit. It is possible to identify accidents at least fifteen minutes beforehand. It is possible to raise the average accuracy rate to 98.24% and lower the system average missing alarm rate to 0.588% [2]. Kiruthiga, S., Baritha Begum, M., Selva Mariyappan, N. S., Prasanna Venkatesh, K., Srihari, P., & Vignesh Saran, T. (2024) Accordingly, the proposed work consists of two phases. The First phase performs exploratory data analysis on the dataset and diagnoses the fault. In the second stage, the fire is checked and detected beforehand using machine learning (ML) techniques [3]. Dr. V. Saminathan. (2024). The main goal is to create a reliable system that can track the condition and functionality of EV batteries over time. Keep an eye on crucial variables including temperature, voltage, and charge level. Describe how data is gathered from multiple sensors that track engine temperature, vibration, battery voltage, and battery temperature [9]. Use MATLAB and ThingSpeak software to create graphical representations of the data that was gathered. Emphasize any abnormalities, trends, or patterns found in the data [1]. Zhang, X., Chen, S., Zhu, J., & Gao, Y. (2023). To accurately identify defects in lithium-ion batteries, an observer based on an electrochemical model and fuzzy logic algorithm is employed. Lithium-ion battery internal problems, including overcharge, over-discharge, and battery aging, can be successfully detected using the observer's internal parameter residuals, which are computed using the electrochemical model and fuzzy logic algorithm [4]. Diaconu, B. M. (2023). Presenting the latest developments in machine learning methods for fire detection, prevention, and propagation modelling is the aim of this paper. Initially, a quantitative investigation was conducted to determine how an AI program enters a fire detection region [5]. Ghalkhani, M., & Habibi, S. (2022). To increase design, manufacturing, and operational efficiencies for use in electric vehicles and energy storage systems, the combining of simulation-based design optimization of the battery pack and Battery Management System (BMS) continues to evolve and has broadened to incorporate innovations like artificial intelligence/machine learning (AI/ML). These sophisticated ideas, which are unique to BMS, allow for a more precise forecast of battery performance, including its State of Health (SOH), State of Charge (SOC), and State of Power (SOP). Focus on the challenges of onboard implementation and integrating sophisticated battery models and algorithms with the cloud-based BMS [6]. Sun, P., Bisschop, R., Niu, H., & Huang, X. (2020). Large-scale battery packs and massive EV fire testing are costly and hardly reported. Since the market for EVs is growing, more people are becoming EV owners. Even if there are still unresolved fire safety concerns, lithium-ion batteries (LIBs) energy density is still rising. The likelihood of EV fire incidents will rise as a result. This study examines these fire hazards in addition to incidents using battery-powered EVs, particularly the LIB. A thorough review is also given of the few extensive fire tests that EV has undergone, as well as the associated fire safety measures [10]. Ghalkhani, M., & Habibi, S. (2022) contribute significantly to the estimation of battery SOH. Future study should therefore concentrate on the difficulty of onboard implementation as well as the use of sophisticated battery models and algorithms [6]. Valizadeh, A., & Amirhosseini, M. H. (2024) looks at real-world uses, difficulties, and new developments in machine learning research on lithium-ion batteries. The significance of machine learning approaches is examined, along with their transformational potential. There is discussion of the use of machine learning in the development, production, maintenance, and disposal of lithium-ion batteries [20]. Talaat, F. M., & ZainEldin, H. (2023). The YOLO-V8 enhanced fire detection method, You Only Look Once (YOLO), is one such CNN-based object identification framework that is widely utilized in computer vision applications [18]. Madani, S. S., Ziebert, C., Vahdatkhah, P., & Sadrnezhaad, S. K. (2024). Computer vision (transmission of images or video) and CNNs' subsequent processing are the foundations of the most popular algorithms. Few research address how each metric relates to a specific problem type, even though most studies reporting computer vision and CNN algorithms report all conventional performance indicators. Models for fire detection and classification use F1 scores for accuracy, precision, recall, and recall as performance indicators. In the practice of fire detection systems, positive samples are far less frequent than negative samples [19]. Yang, F., Qu, N., & Li, C. (2017). A fuzzy neural network fire detection algorithm is investigated to improve the accuracy of fire detection. This approach provides some sort of countersignature and improves fire detection accuracy by combining neural nets and unique fuzzy logic. Fragmented logic is suitable for fire detection and alarm systems because it can make complex decisions. The fuzzy logic toolbox's commands and functions implement the fire detection method before creating a fuzzy controller [17]. Yadav, Amit. (2018). Real-time observation of deployed zones is provided by the ANN-based fire detection system. Using three detection parameters—heat (temperature), smoke density, and CO gas—an artificial neural network-based intelligent fire detection system is created. This data aids in calculating the likelihood of three fire condition representatives: smoke, fire, and no fire. Identification mistakes are extremely low, according to the simulated MATLAB findings. By integrating several sensor data sources, the neural network-based fire detection system enhances its capacity to accurately predict fires. It reduces false alarms and provides an early warning when any type of fire starts [7].

3. Methodology

One of the challenges in creating and guaranteeing the efficiency and safety of electric vehicles is managing battery systems. The battery system includes thermal runaway, charging and discharging, and the integration of parallel and serial cells. The safety and effective use of a battery in the optimal temperature range are more important. The battery management system's design heavily relies on the voltage, current, and temperature characteristics of the battery terminals [8]. The fundamental idea is to create an algorithm to determine the correlations between these characteristics. These characteristics are monitored continuously and stored based on observations. To identify the optimal solution, machine learning techniques are used to analyse these observed values and predetermined values. The required performance and security can be ascertained by utilizing the many machine learning methods that are available [1],[3],[5]. Using data-driven methods and cutting-edge technologies, early fire design detection can lower risks and enhance performance. A battery is a timely variant, nonlinear, and complex electrochemical system. Accurate estimation of temperature and charge level is a challenge. By integrating artificial intelligence using ML algorithms, you can design a solution for real applications. With the help of machine learning, it is simple to forecast several battery situations, including State of Charge (SOC), State of Health (SOH), and Remaining Useful Life (RUL) [6],[9],[16]. Artificial intelligence includes machine learning. It develops algorithms, makes judgments, learns from experience, and adjusts over time. It also uses statistical data to identify patterns. The four types of machine learning algorithms are reinforcement learning, supervised learning, unsupervised learning, and semi-supervised learning. These are methods of learning. Typical data-driven methods include artificial neural networks (ANN), support vector machines (SVM), and deep learning algorithms [6]. This paper focuses on an ANN framework for early fire detection.

4. Components of System

Major The system consists of IoT sensors such as temperature, smoke detector, engine vibration sensor, voltage, and current sensors. These sensors are continuously monitored to manage the performance level of the battery. BMS controls and coordinates the battery's charging and discharging, overheating, and safety operation. In case of any problematic condition, the system alerts the user, and ML algorithms take corrective measures. An artificial neural network is employed in the suggested system to investigate various parameters and their interdependence. LiFePO4 is a type of LIB used as a power source for vehicles. The vehicle's and the battery's temperatures are tracked via the DS18B20 temperature sensor. SW18020P is a vibration sensor that detects vibration of the engine. Engine vibration impacts battery pack structure. The thermal management block comprises components designed to regulate the temperature of critical systems, the battery pack, electric motor, power electronics, and other key components. It prolongs the battery's life, maximizes energy efficiency, and keeps the operating temperature within safe bounds. MQ2 smoke and gas detectors detect the presence of fire or temperature near the battery pack. The current sensor ACS712 is used to measure the voltage and current of a battery pack.

4. 1. ANN Model

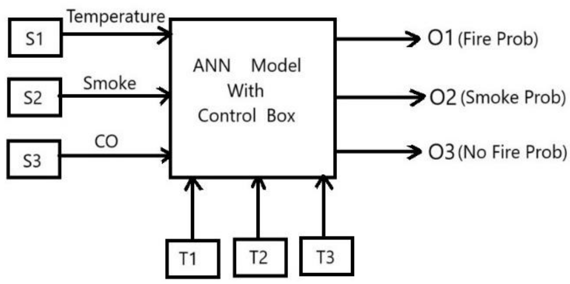

Figure 1. ANN Model block diagram.

The deployed zone's temperature, CO content, and smoke are measured by sensors 1, 2, and 3. The input variables that the ANN model uses to train the ANN are T1, T2, and T3. The artificial neural network is an intelligent information processing system that works like the human brain. It remembers trained selected data when given as input. Selected data is used to train the ANN. Once trained, the ANN remembers the law in their weights and intelligently determines the relationship between the fire data and patterns. O1, O2, and O3 are the system's outputs, and they are separated into fire probabilities like fire, smoldering, and no fire. Every neuron weighs a different amount.

Numerous neural network models can be modified for use in fire detection. To minimize errors when mapping two related spaces based on training data, back propagation (BP) has been employed. Each neuron in a layer is fully interconnected with all the neurons in the layer above it. Data information is stored in the hidden layers, and combination operations on the input, hidden, and output layers produce the result.

4. 2. Statistical Analysis of SOC and SOH

How long a battery can operate without needing to be recharged is indicated by its state of charge. Battery state of charge (SOC) can be used to evaluate a vehicle's performance and range. Appropriate SOC estimation is essential and can be impacted by a few variables. Calculations can be made more accurate and efficient with the use of cutting-edge technology. Data-driven SOC estimates include evaluation, method selection, and real-world applications for hardware along with software development. The selection of suitable machine learning models is another aspect of it, which involves evaluating the model's computing needs, memory limitations, and energy efficiency in addition to considering aspects like model complexity, interpretability, and performance [15]. The restricted availability of data is a major obstacle when utilizing data-driven strategies for SOC estimation. Conventional approaches depend on a limited collection of data gathered under circumstances. SOC estimations can be roughly categorized into five methods: hybrid, model-based, lookup table-based, coulomb counting, and data-driven. Data-driven methods fall into two categories: the Data-Driven SOC estimate method (DEM) and the Model-Based SOC estimation method (MEM). The accuracy and efficacy of SOC are evaluated using data-driven methodologies, numerous error rate terms, and computing complexity.

Accurate SOH measurements make it possible to avoid fire threats. Numerous battery metrics, including capacity, internal resistance, and charging and discharging cycles, can be measured to do this. Vehicle batteries continue to deteriorate with use, resulting in safety concerns and a reduction in useful battery capacity. Aspects including power, capacity, internal resistance, and the number of cycles of charging or discharging are all included in its evaluation index to guarantee the battery's steady and safe operation at run time. It represents the proportion of the battery's accessible capacity during the current cycle over the capacity from the first cycle. The battery's initial state of health must be 100%. The battery is at the end of its usable life if its state of health (SOH) falls to 70% or 80%. Direct techniques for measuring electrical quantities like voltages and currents make up the conventional method. Modelling and data-driven techniques are part of the new strategy. Model-based methods are difficult and inaccurate since they entail creating models and monitoring several factors. Without depending on models, the data-driven approach has the benefit of flexibility in the non-linear mapping connection between parameters and estimated values. The accuracy of the results is affected when machine learning techniques are used for estimate [14],[15]. The end-to-end SOH estimation is accomplished by a neural network that learns and extracts information automatically. ANN with BPNN is used to estimate SOC and SOH in combination with an artificial intelligence-based filter [19].

5. Schematic of System

The detection systems that are currently in use depend on conventional techniques like thermal sensors and monitoring systems. They are incapable of active risk mitigation, accuracy, or early detection. Figure 2 depicts the layout of the entire suggested system.

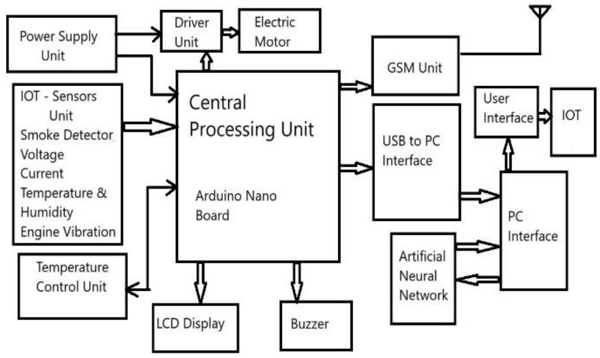

Figure 2. Layout of System.

The layout of the system comprises a main controller board as a control unit, a control algorithm, input IoT sensors, a power supply unit, a GSM unit, an interface for IoT, an ANN unit, a motor, motor drivers, a PC interface, and a temperature control unit.

5.1. Control Algorithm

The entire system's safe operation is managed by the control algorithm. Observing and managing every device that is connected. In addition to displaying the output values and sending the user alert messages, it functions as a battery management unit. The battery management system detects any situation and sends out control signals to modify the battery's temperature to regulate power flow in the system. It contributes significantly to effective and safe operation. The battery's charging and discharging, power consumption, temperature, and overall health are all under its control. When the battery is operating, the sensors and battery management unit cooperate to track the voltages and currents of the batteries. Any changes to the temperature and SOC values are updated and shown on the LCD. Notify the user with a buzzer sound when the battery's temperature reaches predetermined levels. The temperature is kept at 45°C to ensure normal, safe operation. It generates the required action and handles important data regarding the system's temperature, SOC, and battery health.

5.2. Temperature Control Unit

At the predetermined set value, the temperature is maintained by the temperature control unit. The power supply of the motor is cut off, and the buzzer is activated if temperatures are increased above 40°C, and if a temperature drops below 40°C, it activates the motor supply [9].

5.3. ANN Learning Algorithm

Figure 1 illustrates how the artificial neural network is utilized as a fire detection model. This detector takes in trained data as input. Neural network technology is used by ANN, which increases accuracy and reliability. Neural networks with back propagation are used to minimize result errors. Its application improves precision. In figure 3, the Back Propagation Neural Network's structure is displayed. ANN is applicable to signal processing, forecasting, pattern recognition, and system identification.

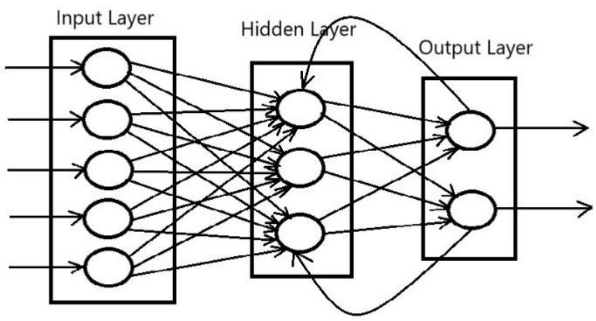

Figure 3. Structure of Back Propagation Neural Network.

Another name for learning algorithms is training algorithms. It is predicated on the MATLAB learning rules. Learning rules are used to carry out a predetermined task. Training sets are selected input data that serve as the foundation for the learning rule. Take the programming pattern below, for instance.

$$(\mathrm{m1}, \mathrm{n1}), (\mathrm{m2}, \mathrm{n2}) \ldots\ldots (\mathrm{mq}, \mathrm{nq}) \qquad (1)$$

Where nq is the matching target for the chosen network and mq is the network's chosen input. The simulated network's outputs are compared after the inputs have been applied to the network. Learning rules are modified in MATLAB ANN software to provide output that is closer to the target. Supervised learning types of learning rules were utilized in this work.

6. Results and Discussion

The current system uses artificial neural networks and back propagation neural networks as input layers. The output layer provides the likelihood of a fire. Back propagation neural networks are trained using 40 typical instances. To approximate a function that links input variables with predetermined output variables, a neural network is trained using the input variables and matching intended output. The well-trained BPNN responds to inputs logically. It is better for the fire detector system, as evidenced by the positive observed outcomes. This real-time fire simulation is produced using MATLAB's ANN model [7].

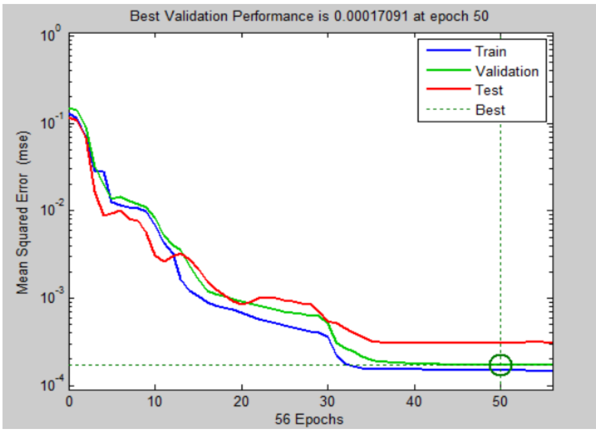

Figure 4. Validation performance test [7].

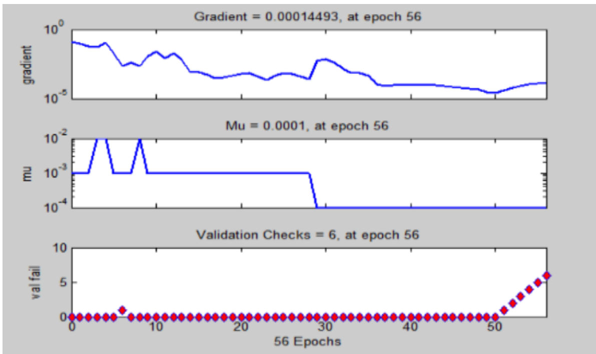

Figure 5. Simulated output [7].

Figure 4 displays the validation performance test, and Figure 5 clearly compares the simulated and expected outcomes. The simulated outcomes closely match the predicted values. Output clearly demonstrates that using ANN produces high-quality output. Using this technique, good fire detection and recognition are achieved. The difference between the model's observed values and the predicted value for inputs is known as the root mean square. The estimated value of the variable is obtained by the square root of the mean square error. The error is calculated using the formula below.

$$\mathrm{Err(e)} = \mathrm{Err(p)} - \mathrm{Err(a)} \quad (2)$$

Where Err(a) represents the error for the actual value and Err(p) represents the error value for the expected value.

7. Conclusion

In this paper, a novel approach that produces precise results for more precise early fire detection is covered. When compared to other approaches, ANN increases the accuracy and dependability of detection and alerts. The error in predicting fire warnings is decreased by using an ANN-based system. Safety could be significantly increased by cleverly integrating neural networks to detect fires. Determining the different voltage currents, controlling the cell temperature, minimizing heat escape, and measuring SOC and SOH all help to prevent fire threats. Additionally, it talks about BMS and how to minimize battery fire risks to maximize vehicle performance. This study offers an intelligent algorithms fusion technology based on a fire alarm, a typical fire, and a multi-data fusion technology method. The ANN is appropriate for fire detection and alarm systems and possesses a strong general judgement. The fire detection algorithm is implemented with the ANN toolbox's functions and instructions. This study examines a neural network model for intelligent system training and simulation, as well as neural network-based fire detection. Some conclusions reached are as follows:

- By analysing many kinds of data simultaneously, this study can enhance the system's capacity to adjust to its surroundings and identify fires with accuracy.
- The study also explains how neural networks are used to combine sensor data in an intelligent automatic fire alarm system to significantly improve safety by accurately identifying fires.
- The neural network's high recognition rate significantly lowers the possibility of false alarms and fire alarm leak checks. Compared to the conventional fire system, the results show more precision.
- There is minimal discrepancy between the simulated and expected outcomes, and the simulation results are satisfactory. Thus, it demonstrates the exceptional sensitivity of ANN fire alarms.
- Since artificial neural networks can execute in parallel, their numerical power allows for a very quick system construction with several benefits, including precise pattern identification, efficient learning, and the capacity to manage noise and incomplete input. This allows for quick designs without requiring in-depth understanding.
- Extends the battery's life and keeps it within safe bounds by managing and monitoring it to prevent harm.
- ML approaches can be used to evaluate battery health, SOC, and current voltage measurements.
- A temperature monitoring device helps prevent battery explosions caused by rises in temperature.

The use of artificial neural networks has other advantages, including:

- By using feedback, they might aim to increase the accuracy of their predictions.
- Intermediate outputs don't require a database to be stored.
- They can carry out several tasks at once without compromising system performance.
- These methods will reduce the probability of electric vehicle spontaneous combustion accidents, improve the market acceptance of electric vehicles, and promote the development of the electric vehicle industry.

In conclusion, the use of cutting-edge technologies can improve this system even more. Smart building fire accident problems can be successfully resolved with this approach. For future BMS, the ML algorithms that can be employed to estimate SOC and SOH exhibit tremendous promise. Cloud-based computing, multi-joint estimation, hybrid models, improved sensing, online retraining, and onboard implementation are some of the technologies. Future study is anticipated to focus heavily on these areas. EVs operating in harsh conditions can greatly increase performance, range, and mileage while quickening the transition to carbon peak carbon neutrality targets.

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