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Artificial Neural Networks Based Energy Management System for Electric Vehicles.

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Abstract: Optimizing Electric Vehicle Energy Management for Enhanced Performance and Electric vehicles (EVs) have emerged as a promising solution to address environmental concerns and reduce dependence on fossil fuels. However, the widespread adoption of EVs faces several challenges, including limited battery capacity, range anxiety, and a lack of robust charging infrastructure. Addressing these challenges is crucial for the successful integration of EVs into the transportation ecosystem. This research paper presents a comprehensive study of the Energy Management System (EMS) for electric vehicles, a critical component that plays a pivotal role in optimizing energy usage and improving overall efficiency. The EMS is responsible for monitoring and controlling various systems within the EV, ensuring the reliable and efficient operation of the powertrain. The proposed EMS controller and energy management strategy (EMS) demonstrate improved time response to sudden and slowly varying load demands, resulting in reduced battery stress and an enhanced battery life span. The study also explores the development of systems capable of accurately predicting energy usage, minimizing losses, and enhancing the efficiency of the battery, while also improving the overall system cost. By effectively managing the power flow between different energy sources in the electrified powertrain, the EMS directly impacts the vehicle's performance, reliability, and user experience. This research provides valuable insights into the design and implementation of advanced EMS solutions, paving the way for the widespread adoption of electric vehicles and the realization of a sustainable transportation future.

Keywords: Energy management system, Electric vehicles

1. Introduction

The electric vehicles (EV) are used in Battery Power storage -based power facilities to great potential in reducing the impact of the transport sector on global warming by decreasing greenhouse gas emissions. Both the high purchase cost and limited range are a result of the current development state of the battery technology. Limited by the specific energy and cost of the battery A electric vehicles is a system made up of dispersed generators, various loads, Battery, and a control unit. To address the problem of range anxiety, this paper presents an energy consumption prediction method for EVs, designed for energy-efficient routing. By using a communication system with a Battery management system can work in tandem with the Auxiliary load [1]. This data-driven Vehicles methodology combines real-world measured driving data with geographical and weather data to predict the

consumption over any given road in a road network. The driving data are linked to the road network using geographic information system software that allows to separate trips into segments with similar road characteristics. The energy consumption over road segments is estimated using a multiple linear regression (MLR) model that links the energy consumption with microscopic driving parameters (such as speed and acceleration) and external parameters (such as temperature). A neural network (NN) is used to predict the unknown microscopic driving parameters over a segment prior to departure, given the road segment characteristics and weather conditions. [1].

Electric vehicles (EVs) often need to quickly discharge a lot of power, especially when driving in stop-and-go traffic. This can drain the battery quickly and cause fluctuations in power. To address this, researchers have developed a power management strategy that combines a lithium-ion battery and a supercapacitor (SC) as the EV's

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energy sources. This is called a hybrid energy storage system (HESS). The key to effectively managing the HESS is being able to predict future power demands. Researchers propose using an Internet of Things (IoT) vehicular network to collect data about the surrounding environment However, this raw data cannot be directly used to improve the HESS. So a two-level control structure was developed:

Level 1 uses a fuzzy logic controller (FLC) to manage the HESS power split based on future power demand information.

Level 2 uses an artificial neural network (ANN) to predict the future power demand from the IoT data.

Simulation results show that this power management strategy reduced: Average battery discharge power by 46.1% Power variation by 52.3% Compared to using a battery-only system. [2].

The battery management system (BMS) for electric vehicles that utilizes an artificial neural network (ANN) and fuzzy logic-based adaptive droop control theory. This approach offers several advantages over traditional BMS systems:

1. Decentralized Control Architecture: The proposed BMS has a decentralized control structure, which improves reliability.

2. Communication-Free Capability: The BMS can operate without the need for communication between battery cells.

3. Improved Reliability: The decentralized and communication-free design enhances the overall reliability of the system.

The key feature of the proposed BMS is the incorporation of an adaptive virtual admittance. This adjusts the value of the virtual admittance based on the current state of charge (SOC) of each battery cell. This allows the connected battery cells to share the load evenly during charging and discharging, improving the overall performance and efficiency of the electric vehicle.

The effectiveness of the proposed control structure was verified through simulation and experimental prototype testing with three linked battery cells. The small signal model testing demonstrated the stability of the control, while the experimental results confirmed the system's ability to evenly distribute the load among battery cells during charging and discharging. Compared to typical BMS systems,

The results show:

1. 15% increase in overall energy efficiency

2. 20% boost in battery life

These large gains in energy efficiency and battery longevity demonstrate the efficacy and superiority of the proposed BMS over competing systems. Overall, this combination of ANN and adaptive droop control theory based on fuzzy logic provides a highly efficient, reliable, and economical solution for EV battery cell management. [3].

2. Model of battery management system (BMS) for electric vehicles

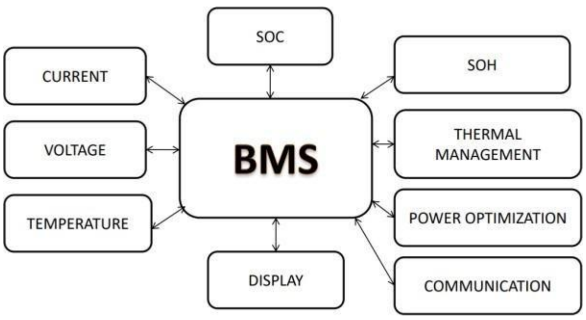

Fig. 1: Battery Management system model

BMS (Battery Management System) offers several important benefits for electric vehicles

Improved Performance

The BMS helps maximize the performance of the battery packs. This allows electric cars to travel farther on a single charge and extends the overall lifespan of the batteries. The BMS does this through automated mechanisms that identify and resolve any issues or malfunctions with the battery.

Enhanced Safety and Reliability

The BMS has comprehensive monitoring and safety features to prevent overcharging, over- discharging, and temperature problems. This ensures the batteries are safe and durable, reducing the risk of accidents or failures for electric vehicle owners.

Real-time Monitoring and Diagnostics

The BMS closely monitors the batteries in real- time, logging data on their health and detecting any malfunctions. This information helps the vehicle manufacturers schedule proactive maintenance to address issues, significantly improving customer satisfaction. [4].

The BMS is a critical component that monitors and manages the battery system in electric vehicles to ensure safe and efficient operation. Some key aspects of modeling a BMS for EVs include:,[16] a battery energy storage system (BESS), a super- capacitor (SC), and power electronic converters constitute a DC standalone. The primary energy resource in the system that is intended to fulfil the greatest load demand during the day is the photovoltaic system. To deliver net output power into the network and adjust the PV output power [5].

3. Artificial neural networks

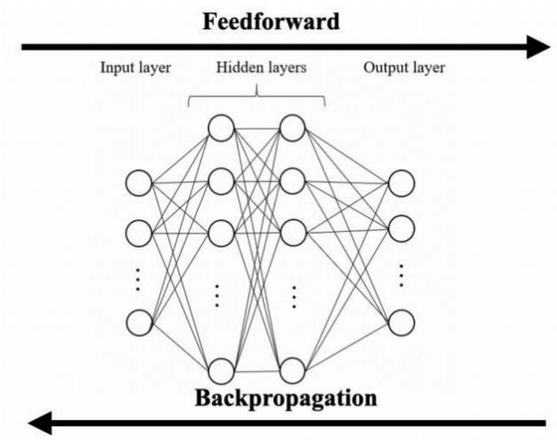

Fig. 2: The basic architecture of neural network

Artificial neural networks are composed of adaptable units known as artificial neurons, which possess modifiable parameters. These neurons are capable of performing simultaneous computations for the purpose of data processing.

Neurons in a neural network are divided into layers, and each layer performs a specific type of computation. The first layer receives input data, which is called the input layer. One or more hidden layers use the output of the input layer to run different calculations on the input data. The final result of the network is produced at the last layer, which is called the output layer.

In a neural network, the connections between the neurons are weighted, which means that the intensity of each connection is determined by a numerical value. To minimize the discrepancy between the network's output and the desired output for a particular input, the weights of the connections are modified during training.

Neural networks have two main processes in each iteration: feedforward and backpropagation. During feedforward, the input data is propagated through the network layers to produce an output. In backpropagation, the error between the actual output and the desired output is calculated and propagated back through the network to adjust the weights and minimize the error. [5],

Each edge between neurons in an artificial neural network has a specific weight. The output of each neuron in a layer is computed by taking a weighted sum of its inputs, applying an activation function to the result, and passing the output to the next layer. The activation function adds nonlinearity and aids in capturing intricate connections between the input and output variables.

The computing process can be represented by the following equations:

Let the input to a neuron be x1, x2, ..., xn and the corresponding weights be w1, w2, ..., wn. The weighted sum of the inputs is calculated as:

z = w1x1 + w2x2 + ... + wn*xn

An activation function f is then applied to the weighted sum to produce the output y:

y = f(z)

Common activation functions used in neural networks include the sigmoid function, hyperbolic tangent (tanh), and rectified linear unit (ReLU). These functions introduce nonlinearity and help the network learn complex patterns in the data.

4. **Digital Twins: Revolutionizing Battery Management in Electric Vehicles**

Two major concerns for EV customers are the battery capacity and thermal safety. The State of Charge (SOC) is a crucial indicator of the available charge left in the EV battery at any given moment. While various existing approaches can estimate the SOC, the accuracy of these algorithms is a primary cause of "range anxiety" for EV users.

Similarly, safety-related issues like thermal runaway can be triggered by high temperatures arising from faulty cells in a battery pack. Early detection and prevention of thermal runaway are essential for ensuring the overall safety of the battery system.

Typically, SOC estimation and thermal monitoring are performed by the Battery Management System (BMS) of an EV. However, the BMS has computational limitations and may not be able to run complex algorithms that guarantee accurate results.

a digital twin-based solution to develop features that can accurately estimate the SOC and monitor the thermal variations between cells. By leveraging the capabilities of digital twin technology, the proposed approach can overcome the limitations of traditional BMS systems and provide a more robust and reliable battery management solution for electric vehicles.

Digital twins are enabled through advanced technologies such as the Internet of Things (IoT), big data analytics, cloud computing, Artificial Intelligence (AI), and Machine Learning (ML). Typically, digital twin models of physical objects are hosted on cloud platforms, where cloud computing handles real-time data storage and computational requirements. [8].

5. Improved State of Charge Estimation for Li-ion Batteries using Artificial Neural Networks

Electric vehicles (EVs) rely heavily on battery technology, which is often considered a bottleneck in their development. The state of charge (SOC) is a crucial parameter in lithium-ion batteries, as it directly impacts the vehicle's driving range and performance.

This research project presents an enhanced approach for estimating the SOC of Li-ion batteries using Artificial Neural Networks (ANNs). The accuracy of ANN-based SOC estimation depends on various factors, such as the input order, output order, and the number of hidden layer neurons. The key contributions of this work are:

1. The developed ANN-based SOC estimation model does not require a detailed battery model or specific parameters, but instead relies on readily available sensor data, including current, voltage, and temperature measurements.

2. The computational efficiency of the ANN model is improved through the use of a novel soft computing method, the RAO algorithm, which optimizes the ANN architecture and parameters.

3. The proposed ANN-based SOC estimation is implemented using a dsPIC30F4011 controller, demonstrating its practical applicability for real-world EV applications.

The performance of the developed ANN-based SOC estimation model is evaluated under diverse EV driving cycles. The results show that the proposed approach achieves higher accuracy and faster computational times compared to other state-of- the-art SOC estimation algorithms.

This research contributes to the advancement of battery management systems in electric vehicles, enabling more accurate and efficient SOC estimation, which is crucial for improving driving range, battery life, and overall EV performance. [7].

6. Future Trends of Intelligent EMS

Due to the sporadic nature of renewable energy sources, times when solar energy production is little or non-existent need the use of a battery storage system. To reduce the uncertainty around the nearby availability of renewable energy sources, battery storage systems are used combined with solar PV systems The energy that is stored in the battery system may be used to provide the necessary power during peak and non-peak hours. The microgrid power systems' dependability and stability will be improved by the battery storage system, which will also balance out the effects of power fluctuations from the available renewable energy sources. The battery's efficiency and performance are contingent upon several factors such as the surrounding temperature, charge level, voltage fluctuations, and charging and discharging rates. The battery's durability is also determined by these variables. On the other hand, the effect of these variables varies according to

7. Conclusion

Digital twin technology offers a promising approach for comprehensive battery health management in EVs. By creating a virtual representation of the physical battery system, digital twins enable real-time monitoring, accurate state estimation, and predictive maintenance throughout the battery's lifecycle. The integration of digital twin technology into vehicle battery health management can enhance battery safety, extend service life, and optimize performance, ultimately improving the overall value proposition of EVs. The proposed ANN-based SOC estimation model using the RAO algorithm provides a more advantageous solution for enhancing the overall performance of SOC estimation in Li-ion batteries. The optimization of ANN architecture parameters improves the model's capacity and efficiency.

The ANN-based RAO algorithm works effectively without considering the battery model, making it a versatile and practical approach for real-world EV applications. The superior performance of this method over other techniques demonstrates its potential for real-time implementation. The development of advanced BMS solutions, leveraging technologies like digital twins and intelligent algorithms, is crucial for addressing the key challenges faced by EVs, such as range anxiety and thermal safety. These innovations will drive the widespread adoption of electric vehicles and the realization of a sustainable transportation future. By addressing the limitations of traditional BMS systems and incorporating cutting-edge technologies, the research presented in this work paves the way for more reliable, efficient, and user- friendly battery management solutions in electric vehicles.

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