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SMART EV BATTERY CONTROL FOR HILL CLIMB

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ABSTRACT - The hill starting control strategy was developed using the hill-start assist system to address the issue of easy slipping while starting an electric vehicle on a hill. The state equation of the slope recognition was achieved by simplifying the vehicle longitudinal dynamics equation and then a Luenberger observer was designed based on this state equation to recognize the road slope online. The problem of function trigger and the Hill Starting Aid valve control in the hill-start assist system had been solved by the slope recognition and starting resistance calculation. The simulation results show that the designed observer could recognize the road slope effectively and the system could meet the requirements of safety and driving comfort in hill starting process.

I. INTRODUCTION

Electric vehicles are gaining significant traction as a sustainable alternative to traditional gasoline-powered cars. However, their performance, particularly in challenging conditions like steep inclines, remains a critical area for improvement. When climbing hills, you need a lot more power, which can quickly drain the battery and put pressure on the motor. Simplified power management algorithms or driver intervention are common in current EV systems, which may not be suitable for varying slope conditions. This project introduces a sophisticated solution that integrates Artificial Intelligence (AI) and the Internet of Things (IoT) to intelligently manage battery power during hill climbs. By dynamically adjusting the motor's torque based on real-time slope detection, the system aims to optimize energy consumption, extend battery life, and enhance the vehicle's hill-climbing capabilities. The use of an ESP32 facilitates robust connectivity and data processing, while a gyroscope sensor provides the crucial input for incline detection.This paper firstly introduces the principle of hill climbing algorithm and the stator structure of SynRM, then designs the new energy vehicle power system, electric drive EMC with load test system, and pure power vehicle power battery model, then describes the experimental equipment and method of new energy vehicle optimization based on hill climbing algorithm, and finally analyzes the simulation results of new energy vehicle battery pack current optimization.

II. BASIC OVERVIEW

2.1. Principle of Hill-Climbing Algorithm

Parameter optimization in engineering has always been an important and tricky problem, and although many effective algorithms have emerged, each has insurmountable drawbacks. In most cases, a single optimization algorithm is not a good solution to the problem, and it is easy to fall into local convergence and poor local search ability is always a pressing problem to be solved. If we can appropriately use the advantages of other algorithms for local optimization search to make up for the shortcomings of a single optimization algorithm, it is undoubtedly an effective means to improve the operation efficiency and solution quality of the optimization algorithm [4-5]. The hill-climbing method is one of them, and it is widely used due to its straightforward operation and lack of parameter restrictions. The hill-climbing algorithm distinguishes between random solutions with fixed sequence numbers farther from the wave crest and random solutions with fixed sequence numbers closer to the wave crest with a smaller difference. This characteristic coincides with the trend of the optimal step size. Therefore, the variation of the difference accuracy of the random solutions separated by fixed serial numbers is used to adjust the variation of the step size adaptively so that it is larger at the beginning and smaller at the end to converge to the wave peak at the fastest speed. The specific operation consists of the following steps. Step 1: Determine the function value of an arbitrary initial solution vector K = [k1, k2, k3,...]. Step 2, the set of solutions to be selected is generated randomly with the solution K as the center, b (the size of the solution set is taken as 3), and the vectors in B are generated subject to the constraint step. ·σ] ∈ b k b k b b B , (1) The initial constraint step, b is the initial constraint step coefficient, which is taken as 0.01. Kinetic Mechanical Engineering 31 In step 3, the solution in B with a fitness higher than K and the largest distance from the current solution is used as the new solution to replace the original solution B. Meanwhile, the difference between the two solutions is calculated as the following equation. K Kold b b b B new ∈ =max − (2) Knew Kold L = − (3) Step 4, the next new solution is still generated around the center of C, but the resulting change is determined by the generation step L. K K b L new old = +1/ ∗ (4)

2.2. Structure of SynRM

The stator structure of SynRM can be generally classified into axially stacked and transversely stacked [6]. The axially stacked structure combines two insulating materials with different permeability characteristics, resulting in an increase in the magnetoresistance difference of the SynRM, which results in a higher torque density and lower losses in the SynRM, effectively improving the SynRM power factor. At the same time, the multi-stacked sheet processing can reduce the rotor hysteresis as well as eddy current losses, which are not present in SynRM compared to PMSM that focuses on rotor heating [7]. The advantage of multi-stacked sheet makes the rotor surface of the motor fine and not rough, the magnetic resistance can be smoother undulation changes, effectively improving the dynamic operation performance, which has a good application in the NVH of NEV and other important index performance. Of course, it also has a cumbersome rotor structure processing process, the rotor can not be installed start winding, there are certain restrictions in the high-power application scenario [8]. With the development of technology, these defects and limitations will also be further improved and applied. Transverse laminated rotor structure with air gap magnetic barrier layer. It also has the characteristics of high convex pole rate of axial laminated type, less pulsation, high temperature resistance, etc. The processing process is less difficult, and it is formed by punching laminated type, which has higher mechanical strength and is more suitable for engineering applications, and now most of such structures

III. NEW ENERGY VEHICLE SYSTEM DESIGN

3.1. New Energy Vehicle Power System Modeling The establishment of new energy vehicle power system includes three models, which are engine model, motor model and battery model, as shown in Figure 1. (1) Engine model There are two main methods to build the engine model: theoretical modeling and real-world modeling. But neither is the best choice, and both have certain advantages and disadvantages. Theoretical modeling first analyzes the engine to get a theoretical calculation formula, but the factors considered are less, and the application to practice may lead to deviation in the overall model computing speed due to its own poor operability, but it can accurately reflect the Kinetic Mechanical Engineering 32 instantaneous response characteristics of the engine [11]; practical modeling is to establish the working characteristics of the engine graph through a large amount of relevant experimental data to reflect its working process, and then use Numerical analysis method is used to derive a set of data from the established characteristic diagram, and finally the interpolation method is used to obtain the function equation of input and output [12]. The operation is relatively straightforward in comparison to theoretical modeling. Although its precision is not as high as theoretical modeling's, it is sufficient to meet the requirements of the study, which is why the experimental modeling approach was chosen to create the engine model. Power model of new energy vehicles Engine model Engine model Electric motor model Battery model Figure 1. Power model of new energy vehicle (2) Establishment of the motor model Since there is no motor in the power system of the transmission vehicle, for the new energy vehicle, the motor is mainly used as a backup power source. The modeling method is similar to the previous engine modeling method, which also needs to use the first-order inertia delay link to change the steady-state output torque into dynamic torque [13]. (3) Establishment of battery model In the power system of NEV, the battery and the motor together provide energy for the vehicle, which is the main source of vehicle power and more important part of the power section, so it is very meaningful to establish an accurate model for the whole vehicle. Since the battery is a complex process in which chemical reactions occur electrically, the model is also very complex, and the Rint model is chosen to model it, and the battery can be seen as a circuit composed of a power source and a resistor [14-15]

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IV. OBJECTIVE OF THE PROJECT

1. Develop an IoT-enabled control system using ESP32 for real-time monitoring and management of EV battery performance.

2. During hill-climbing conditions, incorporate a gyroscope sensor for precise slope and vehicle inclination detection.

3. Create and implement an artificial intelligence (AI) model that can intelligently identify driving situations involving uphill travel by processing sensor data.

4. Automatically adjust motor torque based on slope detection to ensure efficient climbing without excessive battery drain.

5. Enable real-time data transmission of battery status, slope angle, and motor performance to a mobile application for user monitoring.

6. Optimize energy consumption and battery life by delivering power only when required and in proportion to climbing demand.

7. Reduce the need for manual intervention and ensure smoother performance across a variety of terrains to enhance driving experience and safety.

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V. METHODOLOGY

The paper methodology combines hardware integration, sensor data acquisition, AI-based decision-making, Internet of Things (IoT) communication for real-time monitoring, and systematic approach. The entire procedure is outlined in the steps that follow:

1. System Design and Hardware Setup

Due to its Wi-Fi capability and efficiency, the ESP32 Microcontroller was chosen as the central processing and IoT gateway.

- Gyroscope Sensor (e.g., MPU6050) is mounted on the EV to detect slope angles and orientation in real time.
- Motor Driver (e.g., L298N or brushless DC controller) is integrated to regulate motor torque and speed based on control signals from the ESP32.
- Battery Monitoring Circuit is included to track voltage and current, ensuring efficient power utilization.

2. Slope Detection and Data Collection

- The gyroscope continuously measures pitch angles of the EV.
- Sensor data is transmitted to the ESP32, which preprocesses the raw values.

To distinguish between flat, uphill, and downhill conditions, slope thresholds are established.

3. Putting AI Models into Action

- An AI algorithm (rule-based or lightweight neural network) is trained with slope data for classification of driving conditions.
- The model is deployed on the ESP32 to identify hill climbing conditions in real time.

The model determines the required torque adjustment based on slope steepness.

4. Automatic Power Alteration

- When an uphill condition is detected, the ESP32 sends control signals to the motor driver.
- Torque and power supply are increased proportionally to the slope gradient, ensuring smooth climbing.
- The system prevents unnecessary power usage on flat or downhill roads.

5. IoT Integration and Data Transmission

- The ESP32 transmits real-time vehicle data (battery level, slope angle, torque status, and motor performance) to a cloud server or mobile application.
- A **mobile app/dashboard** displays this information using graphical representations and alerts for critical conditions such as low battery or steep inclines.

6. Testing and Validation

- The prototype is tested under different terrains and slope conditions.

- System performance is evaluated in terms of torque response, battery consumption, and climbing efficiency.
- Results are compared with conventional EV hill-climbing approaches to demonstrate improvement.

System Block Diagram:

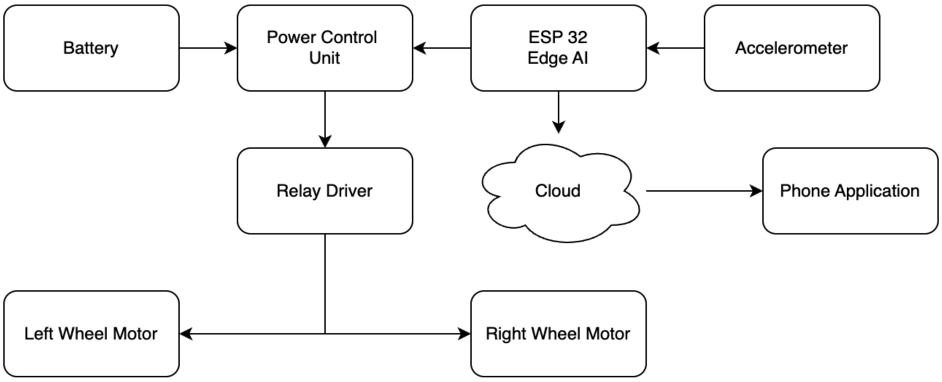

Fig 1.1 Block Diagram

VI. CONCLUSION

This paper proposes a "Smart Electric Vehicle Battery Power Alteration" system designed to optimize EV performance specifically during hill climbs. The system can automatically detect inclines and adjust motor torque in real time by utilizing an AI model, an ESP32 microcontroller, and a gyroscope sensor. This intelligent management aims to improve the vehicle's efficiency, extend battery life, and provide a smoother, safer driving experience on challenging terrains. A scalable solution for future enhancements is provided by the system's incorporation of Internet of Things (IoT) capabilities for real-time monitoring of the battery and vehicle status. The electric drive system is the power source of the new energy vehicle, and it is a serious threat to the safety and reliability of the vehicle due to its electromagnetic interference source alone. In this regard, this paper optimizes the new energy electric vehicle system, and in order to improve the performance of the electric drive system, the optimization results of the current optimization control strategy are analyzed, showing that the anti-interference of the electric drive products can be improved after using the optimization strategy.

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