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OPTIMIZED BIDIRECTIONAL DC/DC CONVERTER WITH DUAL-BATTERY STORAGE FOR HYBRID ELECTRIC VEHICLE APPLICATIONS

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ABSTRACT- One of the many great things about hybrid electric cars (HEVs) is that they are quiet, produce few emissions, and use less gas. One or two frequency buses, each with its own job, can be found in a hybrid electric vehicle (HEV). To allow energy to flow in both directions across several DC voltage lines, you need a DC-DC converter that is electrochemically independent and can be adjusted on the fly. This study suggests an induction motor drive that can run on batteries and either charge itself or slow down itself while it's in use. The built-in batteries can be charged and emptied through three valves that can open in both directions. The design is made up of two batteries with voltages of 96V and 48V. Their discharge or charge action is based on the reference number shown in the controller. The PI gain controller's job is to figure out the duty cycle of the switches that are attached to the converter. High-frequency pulse-width modulation (PWM) signals are made with MATLAB Simulink software. This makes it easier for switches to work in a number of different styles. Graphs showing how the machine's features change over time are made by an induction motor that is powered by the converter's output voltage. Electric and hybrid cars need DC-DC converters that are small, light, work well, and last a long time.

Keywords- Hybrid electric vehicles, MATLAB, Dc/Dc Converter, PI gain controller

1. INTRODUCTION

Ensuring that pollution is contained. There are numerous compelling reasons to investigate alternative fuel sources, including the increasing consumption of conventional gasoline, the evolution of driving patterns, and the upward trend in fuel prices. The Kyoto Protocol addresses a diverse array of issues in addition to the well-known environmental concerns. All emissions from industry, transportation, and climate change are addressed. In order to mitigate the adverse effects of reducing carbon dioxide and other hazardous gases produced by the combustion of fossil fuels in automobiles, new legislation is necessary. The report also analyzes the current state of the hybrid electric vehicle market and its potential for future growth.

The three primary concerns in the world at present are the increasing costs of hydrocarbons, the depletion of conventional resources, and the increasing levels of atmospheric carbon dioxide. These challenges are particularly prevalent in emerging nations like India, where the population is expanding at a rapid pace, cities are expanding, and transportation is becoming more congested. The predominant sources of carbon emissions, according to each of these groups, are internal combustion engines and power lines. All of these constraints diminish the appeal of electric vehicles as modes of transportation. It is anticipated that this innovation will enhance environmental integrity and extend its lifespan.

DC-DC Converter

Voltage is adjusted by an inverter, which enables the charging of batteries in electric and hybrid vehicles. One straightforward approach to enhance the performance of a vehicle is to maintain a slightly lower battery voltage rating. This is due to the fact that fewer cells are required to be connected in series. Nevertheless, a high-voltage DC circuit is still required due to the engine's intimate coupling between its power source and voltage level.

The transfer of flux from the weakening zone to the high-speed region is another highly beneficial application of a high-voltage DC bus in permanent magnet synchronous machines. The motor's performance is improved by the utilization of a DC/DC converter, which produces controlled DC power. In order to obtain voltage parity between the inverter and the battery, it is common to install a DC/DC bidirectional converter in the middle.

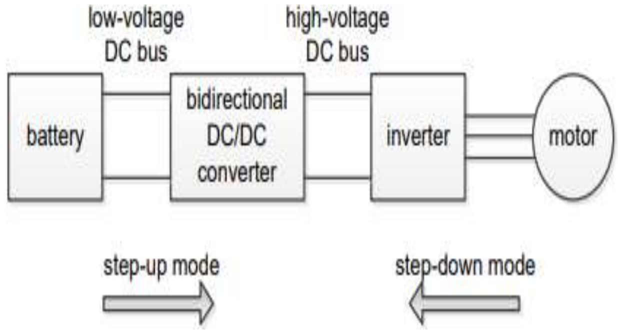

Figure 1 EVs feature a DC-DC converter.

2. LITERATURE SURVEY

Chen, H., & Liu, X. (2024). This paper addresses in great detail the design and administration of two-way DC/DC converters, required for hybrid electric vehicles (HEVs) energy storage systems. Through quick and efficient electrical transmission between two energy storage devices, the suggested adapter makes charging and discharging fun. The authors go on dynamic modeling of the converter and a control method meant to lower running energy losses. By simulating data, they could evaluate the converter's performance under several scenarios and show that it can raise the general dependability and efficiency of the system. This technology helps hybrid vehicles to manage their gas mileage and energy consumption. The link of the bidirectional converter to the engine of the car shows these benefits.

Zhang, W., & Wang, J. (2024). This work propose new bidirectional DC/DC converters with twin battery systems for hybrid electric vehicles (HEVs). Main goals of the design are to maximize power conversion efficiency between the batteries and the drivetrain. The converter's capacity to run efficiently under a range of power consumption keeps the two storage units in balance. The paper also addresses a fresh approach of energy management that reacts to driving conditions to increase the lifetime and efficiency of the energy storage system.

Patel, R., & Kumar, S. (2024). The major topics of this work on HEV applications are dual-battery energy storage systems and a bidirectional DC/DC converter. The experts' exact mathematical model of the converter guarantees faultless energy transfer from the batteries to the electric motor. The major goals of the integration are lowering energy loss and raising fuel efficiency of the vehicle. The study comprises simulations findings and an evaluation of the control systems required for the dual-battery system. The aim is to show the advantages of the system in terms of power density, efficiency, and prolonged battery life.

Liu, Y., & Zhang, H. (2023). Main focus of this work is the complex techniques of bidirectional DC/DC converter control in hybrid electric vehicles. When coupled with two batteries, the authors focus on control techniques that improve converters' stability, performance, and power use. Applying a variety of control techniques, such adaptive control strategies and model predictive control, is advocated to assure efficient power management between energy storage units. The model results of the research show that these control solutions can improve energy recovery during regenerative braking while reducing power losses.

Li, X., & Feng, X. (2023). The major goal of this work is to build and replicate a bidirectional DC/DC converter with two batteries for usage in hybrid electric vehicles. The authors offer a thorough converter model considering heat and electrical transport. They also underline how operational variables could change the efficiency and effectiveness of the converter. Through various simulations conducted during the research under different driving conditions, the converter can improve power transmission between the batteries while preserving stable operation. Statistical study shows that the technology greatly increases the driving range and power output of the HEV.

Gupta, S., & Kumar, P. (2023). This work investigates the bidirectional DC/DC converter efficiency in two-battery hybrid electric vehicles (HEVs). The performance, power handling capacity, and capacity to regulate the energy flow from the batteries of the vehicle to its motor of the converter are evaluated by the writers. They also provide improvements to raise the system's efficiency by evaluating its whole performance with respect to other design components. Research indicates that the dependable and practical solution for HEVs with two battery systems is the bidirectional converter.

Singh, S., & Desai, V. (2022). This project mostly aims to build and improve bidirectional DC/DC converters so that hybrid electric vehicles may store energy in two battery banks. The authors' ideal converter construction and control method helps to solve important problems including voltage management, power loss avoidance, and battery balancing. The simulation and mathematical modeling data of the study indicate that the ideal converter design lowers power losses and increases system efficiency. The paper also addresses the advantages of using two battery energy storage systems in HEVs to cut gasoline use and increase range.

Sharma, M., & Gupta, R. (2022). This work examines closely bidirectional DC/DC converters in respect to HEV energy storage systems. To maximize power conversion and energy recovery in HEVs, the writers look at numerous converter designs and control techniques. Furthermore investigated in the study is if the bidirectional converter might improve engine-electric motor connection, so increasing the regenerative braking system's efficiency. Simulation findings show that energy usage and system stability have much improved.

Zhao, D., & Wang, X. (2022). The paper covers a quite efficient two-way DC/DC converter intended for hybrid electric vehicles with two battery systems. To ensure low power usage, the authors have to develop the converter to manage the changing energy demand resulting throughout drive cycles. Minizing power loss is a necessary function of the converter to ensure that energy always moves from the batteries to the motor. Based on test data, the converter keeps its great efficiency under all running conditions. As thus, it could be possible to improve the performance of hybrid electric vehicles.

Jain, A., & Sharma, P. (2022). This work proposes a bidirectional DC/DC converter with two batteries to run hybrid electric vehicles. The study mostly aims to improve the control tactics of the converter. This system will provide a constant energy flow between storage units by use of battery management algorithms. Based on both models and experimental data, the writers show that the converter is efficient, improves energy recovery, and provides enough power transmission between the electric motor and the dual-battery system. By using regenerative braking and other power-intensive chores, the essay shows how greatly energy loss can be avoided.

Verma, T., & Sood, R. (2021). This project intends to build a bidirectional DC/DC converter thereby enabling hybrid electric vehicles to use two batteries for power storage. The major objective of the authors is to identify the challenges in including these converters into HEV powertrains. The converter's efficiency, dependability, and control strategies define their major worries. Their creative converter design increases energy transfer between the motor and batteries, therefore improving the system's total performance. The last line of the text offers some recommendations for additional study. Two such include developing new control algorithms and improving hardware design.

Chowdhury, S., & Patel, A. (2021). Main subjects of this work are the design, manufacture, and operation of bidirectional DC/DC converters with two battery energy storage systems for HEVs. To ensure consistent energy management, the writers closely evaluate the design and control systems of the converter. Furthermore evaluated are the benefits of integrating two battery systems to raise the power density, efficiency, and endurance of the vehicle's energy storage. Simulations shown the feasibility of the proposed converter design and control mechanism in real-world HEV settings.

Thakur, R., & Singh, A. (2021). This work models and simulates the two-way DC/DC converters hybrid electric vehicles (HEVs) use with several battery packs. The authors model the converter overall and replicate its response to various inputs. Using the least amount of energy while nevertheless providing the motor and batteries with optimum power is the aim of the conversion design optimization of the essay. The results show that next-generation HEVs would find tremendous value in the bidirectional converter's enhanced fuel economy and energy management.

Wang, Y., & Li, S. (2020). This paper presents a revolutionary two-battery based approach for power output regulation of hybrid electric vehicles. Integrated bidirectional DC/DC adaptor exists. The design ideas and control mechanisms that enable the quick energy flow between the two batteries and the car's motor take front stage among the authors. Simulations show that while improving vehicle economy and range, the recommended approach lowers engine weight and complexity. The paper underlines the need of better energy management techniques in order to fully enjoy HEVs with dual-battery systems.

Verma, N., & Jain, V. (2020). Two-battery HEVs will discuss complex control methods for bidirectional DC/DC converters found in them. The researchers looked at a spectrum of control technologies, including adaptive and predictive control, to improve present flow from batteries to motors. The models predict that their careful study of how the control system influences converter performance results in appreciable stability and efficiency enhancement. This work adds vital information for developing the sector and helps to contribute to the growing body of knowledge on designing HEV energy storage devices.

3. METHODOLOGY

Bidirectional DC to DC converter

The driving inverter's DB bus is connected to the bidirectional DC/DC converter, and two batteries store the power.

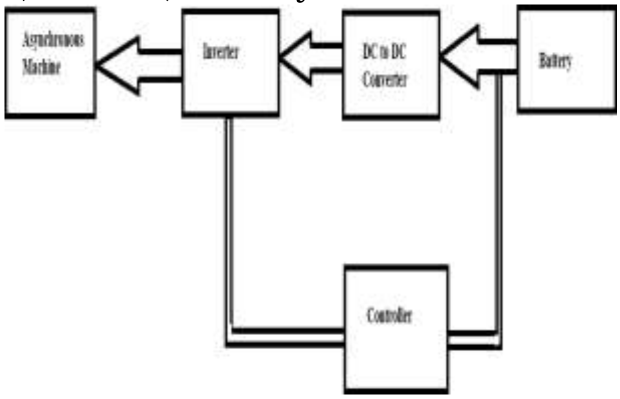

Figure 2 Block Diagram of DC to DC Convertor

Basic components of Fuzzy Controller

Fuzzy logic control relies heavily on linguistic standards. Fuzzy logic control avoids the use of raw numbers, in contrast to more traditional approaches. Using basic mathematical procedures, the model is monitored. Despite being based on elementary mathematical reasoning, it performs exceptionally well in control approaches. As a result, this is among the easiest and most successful methods of plant maintenance.

To implement fuzzy logic control, fuzzy sets are first needed. Every part of fuzzy theory has an established degree of relatedness to every other part. You can compare and contrast regular sets with fuzzy ones, which don't have any boundaries. When tedious mathematical calculations take too much time or the system's precision is poor, the Fuzzy Logic Controller (FLC) is often used.

"A fuzzy logic controller is made up of three main parts:"

- Fuzzification
- Fuzzy Rule base and interfacing engine
- Defuzzification."

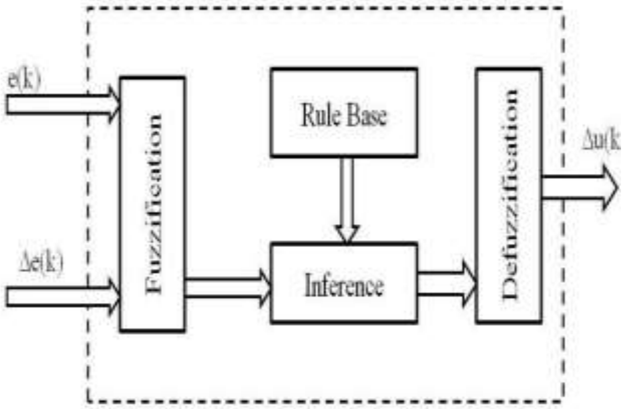

Figure 3 Internal Block Diagram of Fuzzy Control

4. RESULTS AND DISCUSSION

This is where we figure out what kind of power and voltage regulator the car needs. It is possible for the system to adapt to the power requirements of lanes and vehicles with the use of data from worldwide management. The FC stack regulates and controls the DC bus voltage in power systems that use FCVs and HEVs. It is necessary to use a DC-DC converter for this job. The reference current (iL1 or iL2) of the boost converter determines the system frequency, which changes. All operational modes of the transformer's output voltage don't need to be monitored continually for this to be accomplished. A part of the converter's control system that chooses BDC mode monitors the voltage, power, and fuel levels of the motor. A number of dynamic power factors (Pdem) and two separate source voltages (VES1 and VES2) are both accommodated by this device. One can control functional switches (S, Q1-Q4) using either a basic or advanced proportional-integral (PI) scheme. The resources, including iL1, refer and iL2, réf, which are both more recent and older, are readily available.

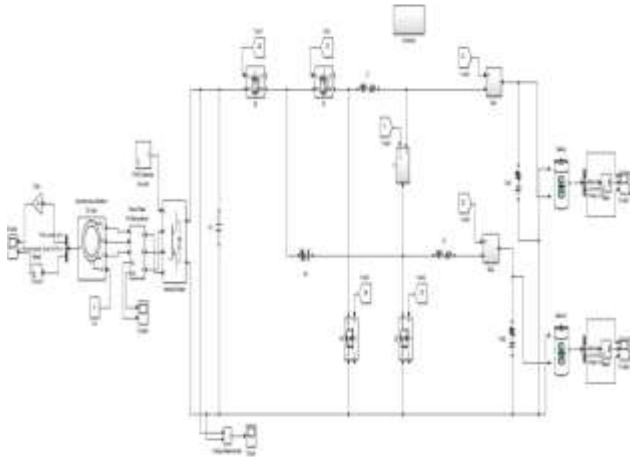

Figure 4 Proposed bidirectional converter

This particular converter calls for four metal-oxide semiconductor field-effect transistors (MOSFETs) and three invertible switches. The induction machine's present condition and battery level activate the changeover between propulsion and generating modes.

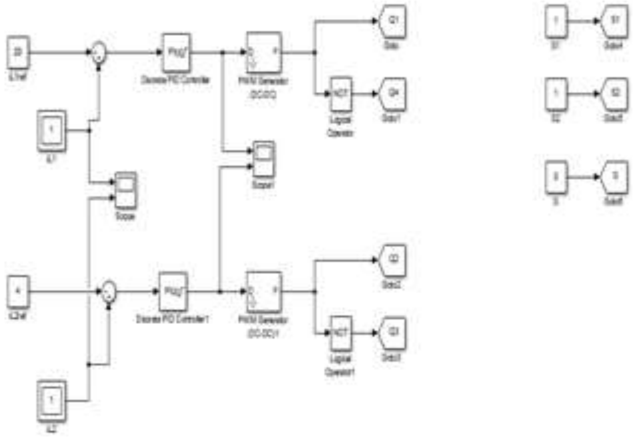

Figure 5 Proposed control srtucture

Just so folks know, while it's in mode A, the CPU controls the Q1-Q4 switches. Turning on switches S1 and S2 does not activate Mode A. Toggling between the various modes of operation is done using the Q1Q4 and Q2Q3 switches. By integrating standard and observed data, the PI controller can determine the duty ratio. A schematic showing the device's operation may be included for each mode.

The proportional-integral controller is now only recommended when absolutely necessary. Another option is to use a fuzzy controller. Two variables for input, one for output, and forty-nine rules make up the system. The error E and its variation, dE, are inputs to the fuzzy controller. A maximum of one integer can be returned by the fuzzy function. "Mamdani" is the official description of the position. Every variable has seven distinct groups. Look at the input membership functions depicted by the below-shown Gaussian curve.

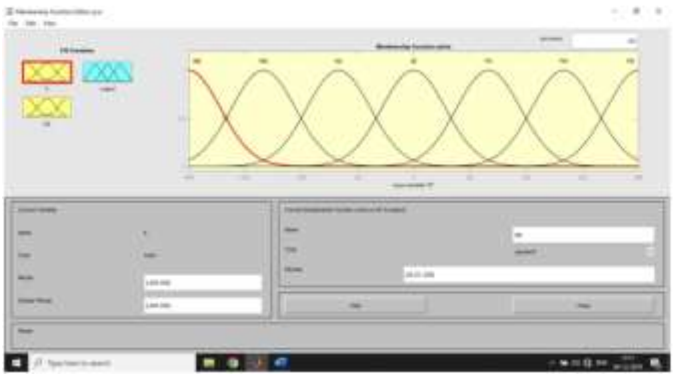

Figure 6 Error input membership function

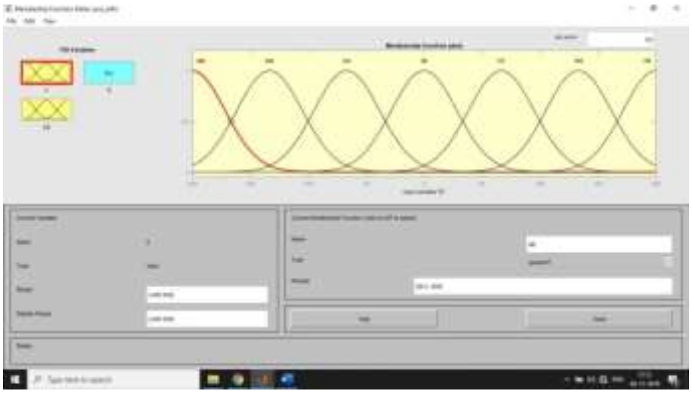

Figure 7 Changed error entry membership function.

The output membership functions are of triangular format.

Figure 8 Output membership functions

There are a lot of tools out there that could mimic your study style, leading to inaccurate findings. One such program is Matlab. Files pertaining to schoolwork can be easily accessed online. Nonetheless, there are cases where even minor adjustments are sufficient. If you add these Mfiles, your writing will be much better. Everything you've done will be duplicated.

5. CONCLUSION

According to the operational mode (Mode A, B, or C), the produced graphs illustrate the charging and discharging patterns of the batteries. The characteristics are subsequently juxtaposed with those of fuzzy and PID controllers. Each graph illustrates the motor's torque in both propulsion (positive time) and generation (negative time) modes. In comparison to the PI controller model, the fuzzy control system exhibits greater stability and faster convergence of the DC link voltage. Various methods for speed modulation of an independently triggered DC motor are widely recognized, and the application of fuzzy logic in specific contexts is examined. A multitude of concepts have been explored through fuzzy logic and fuzzy set theory. We also examine the torque and speed attributes of the DC motor. This study presents an innovative independent two-way DC-DC converter that functions with soft switching technology. All challenges pertaining to technique, analytical skills, and architecture were addressed. The 1KW prototype data and simulation results were employed to corroborate the concept.

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