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Hybrid Electric Vehicle Integrating Battery and Flywheel with CAN Protocol

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Abstract: *The way Hybrid Electric Vehicles talk to each other is very important for how they work. This paper looks at a Hybrid Electric Vehicle that uses a battery and a flywheel together with a Controller Area Network protocol to help them work together. The flywheel is very good at giving and taking back energy quickly which helps the battery longer. This is especially useful for Hybrid Electric Vehicles that start and stop a lot because the flywheel can catch the energy that would be wasted when the Hybrid Electric Vehicle is stopping and use it to help the Hybrid Electric Vehicle move. We used a kind of motor a flywheel and a master control unit to make this work. We looked at how the flywheel could make energy and compared it to other ways of making energy.*

Keywords: Controller Area Network(CAN), Hybrid Electric Vehicle (HEV), Flywheel Energy Storage System (FESS), Hybridisation, Battery Management System (BMS)

I. INTRODUCTION

Growing demand for environmentally friendly transportation alternatives have inspired research in hybridization, where different power sources are combined to provide an economic and performance driven electric vehicle [1]. Battery and flywheel systems, which combine high energy density storage in batteries and high power density storage in flywheels, possess advantages over other hybrid systems because they allow for extended vehicle range through energy stored in the battery and rapid power buffering through the use of flywheels during acceleration and braking [2]. In order for these various components to be controlled effectively, efficient communication protocols between the devices are necessary. The Controller Area Network (CAN) bus has emerged as a preferred standard in electric vehicle architectures because it allows for reliable, high data rate communication [3]. A battery and flywheel combined system, in which different power sources are combined to deliver greater economic and performance characteristics, has been a primary focus of research due to the need for economical and environment friendly transportation [1]. Systems can take advantage of the high power density of flywheels during times of acceleration and regenerative braking and high energy density of batteries for sustained propulsion. The Controller Area Network (CAN) bus is often used for communication and control within an electric vehicle due to its high data transfer rate and its reliability [3].

One aspect that makes the CAN appropriate for integration with the universal controller unit for the electric vehicle application is that it is well-suited for real-time control [4]. Particularly, CANopen allows for the implementation of modular communication and a robust data exchange protocol between sub-systems (e.g., Battery Management System, power converters) by specifying standardized message formats and services [5], [6].

The standardized communication approach allows for seamless integration of components, which allows testing and validation of control strategies from hardware-in-the-loop systems to virtual simulations [7]. Comprehensive prediction of EV performance and design parameters, including motor and battery power characteristics, driving range and overall performance, is possible through model based systems design methods including simulated and real hardware components [8]. Development and iteration are greatly accelerated through the integration of a virtual EV model, system, and actual ECUs via the CAN bus for an EV conversion process [9]. One of the drawbacks of integrating

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existing battery management systems with multiple manufacturer CAN implementations is that it requires the development of a CAN matrix to successfully decode signal information and messages [10].

Accurate decoding is essential to ensure that vital operating parameters (e.g., motor speed, battery charge state and operation mode) are accurately communicated to the cluster display [11]. In addition, the interaction of signals allow for a greater detail of battery parameters, such as state of health, which is essential in predicting battery life and determining overall performance [12]. The universal control unit enhances the interaction by providing one point of control for multiple critical sub-systems (e.g., Battery Management System, motor control) using the CAN protocol for enhanced performance and optimized thermal management and efficiency [4].

In a hybrid system where machine learning models or Kalman filtering are employed within the BMS for estimation of charge and state of health under dynamic operation, thorough integration of the system components is needed to facilitate sophisticated coordination of each component [13], [14]. Multidomain complexities of this problem coupled with the need for a system that is to be extensively developed and iterated necessitates a model-based design methodology [15], [16].

In this paper we propose a comprehensive framework for a hybrid electric vehicle system incorporating a battery and flywheel system controlled by the CAN protocol for improved dynamic performance and energy efficiency through optimized power flow and communication [17]. Flywheels provide efficient power buffering for transient loads while the battery system handles sustained power demand. The system is coordinated through the CAN bus for real-time data transfer and control. In this hybrid configuration, energy storage devices benefit from one another's intrinsic characteristics to enhance the overall performance and longevity of the hybrid electric vehicle [18]. Specifically, the flywheel system provides for rapid energy charging and discharging, allowing for increased efficiency, and the battery offers sufficient energy density to allow for extended vehicle operation [19].

Intelligent control algorithms are necessary to ensure proper power sharing and to prevent catastrophic system failure as it often depends on the availability of accurate sensor readings [20]. This system enhances the dynamic responsiveness of the vehicle and significantly reduces stress on the battery by optimizing the dispatch of power between the devices, which is extremely important for electric vehicles due to battery degradation and management issues [21], [22]. Sophisticated energy management strategies which often employ machine learning techniques such as K-nearest neighbor, Support Vector Machines, Naive Bayes, or Deep Q-Learning with Hierarchical Action Spaces are implemented to adapt the energy management algorithm to dynamic operation conditions [23]. Optimized energy management strategies in conjunction with intelligent machine learning are implemented to improve real time power distribution and reduce hydrogen consumption in fuel cell electric vehicles [24]. For light electric vehicles, particularly those with nonlinear and dynamic behavior, conventional control strategies often fail. These type of advanced strategies must be employed to achieve efficient real time power flow [25].

II. LITERATURE REVIEW

The following literature review summarizes current findings regarding hybrid energy storage systems especially the combinations of battery and flywheel integrated in electric vehicle. It examines a number of energy management strategies based on deep reinforcement learning and fuzzy logic control [27]. Communication protocols for integrated hybrid system communication will also be discussed. Comparing battery and flywheel, battery possesses high energy density which contributes high range of the electric vehicle while flywheel has high power density to facilitate fast charging and discharging needed for dynamic load variation [28]. These two types of energy storage systems have a high potential for Hybrid Electric Vehicle applications. Energy management using Hybrid Energy Storage System has been considered a good solution for overcome poor power density of battery, charging-discharging frequency and battery cooling issue for electric vehicle [29].

Electric vehicle (EV) and hybrid electric vehicle (HEV) use a variety of communication protocols due to varying required data rates, reliability and different real-time control requirements. The controller area network (CAN) is very commonly used for electronic control of systems. CAN is very cost-effective, efficient, and well-proved and also easy

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for different ECUs communication. Its broadcast nature and priority based arbitration make it perfect for transmitting the necessary information between the ECUs like the torque request and motor status. The type of communication protocol which is used in electric vehicles include CAN, LIN, FlexRay and automotive Ethernet which provides various kinds of characteristic depending on data rate, reliability and fault-tolerances for control and in vehicle networks [30, 31, 32]. CAN provide balance of data rate and reliability and fault-tolerance which is adequate for electric powertrain and chassis control, while FlexRay could deliver higher data rate for safety critical systems like steer-by-wire. Automotive Ethernet is developed for system that require high data rate and for communication between different domains and external systems.

Therefore, this communication standards used between various ECUs in the vehicles, including the CAN, LIN, Ethernet based communication provide a real-time data exchange between them in an electrical power system and a crucial communication mechanism within the complex vehicle systems and powertrains, allowing various ECU control data like the battery states of charge, flywheel speed and motor torque demand to be transmitted reliably. Robert Bosch Gmbh defined the CAN as the serial bus controller area network, which is suitable for in vehicle communication for their cost-effectiveness, error tolerant, low cost and also differential signal transmission [35, 36]. The CAN is work on layer of physical and Data Link layer according to OSI model and has used Carrier Sense Multiple Access with Collision Detection (CSMA/CD) for data arbitration. The message arbitration mechanism based on Arbitration Message Priority is shown in figure 2.3 [37].

III. METHODOLOGY

The CAN architecture in vehicles is really useful because it helps us get information in time from different parts like the battery and the inverter. We can see how everything is working and make changes as we go to get the results. The CAN protocol is good at dealing with messages and making sure important information gets through when a lot of different parts are trying to communicate at the same time. The information we get includes things like how power the vehicle needs and the status of the battery.

This helps the system work well and be reliable. The CAN architecture and its protocol are important for electric vehicles to run smoothly. The way the CAN protocol is designed and its rules help it manage information from a lot of parts. This means electric vehicles can work properly and get the most out of their performance. The battery and the inverter are two examples of parts that send information through the CAN architecture. The information they send helps us understand how the vehicle is doing. We can then use this information to make adjustments and get the performance possible.

This is all thanks to the CAN architecture and its ability to handle a lot of information on time. The CAN architecture is really important, for vehicles because it helps us get the information we need from the battery and the inverter and other parts and this helps us make sure the vehicle is working well.

Block diagram

The block diagram consists of three main components, which are a battery, a controller, and an electric motor. Other auxiliary components are connected through master and slave nodes, which communicate with each other via CAN bus. The master node has three sensors connected to it. The temperature sensor, which monitors battery temperature, turns on the cooling fan, and makes the buzzer beep when motor temperature exceeds 50°C. The ultrasonic sensor calculates the distance of the incoming object if it appears for more than 3 seconds, then it sends SMS alerts to the registered number, which contain location coordinates and motor temperature that incorporates the GSM and GPS module. Lastly, the LDR sensor is used to automatically turn ON the headlight in case of night conditions or low light intensity. Flywheel is used as a secondary energy storage system whose angular momentum is converted into electrical energy by the generator that produces AC voltage. As the system runs on DC voltage, the AC voltage is converted into DC voltage by rectification using two full-wave bridge rectifiers.

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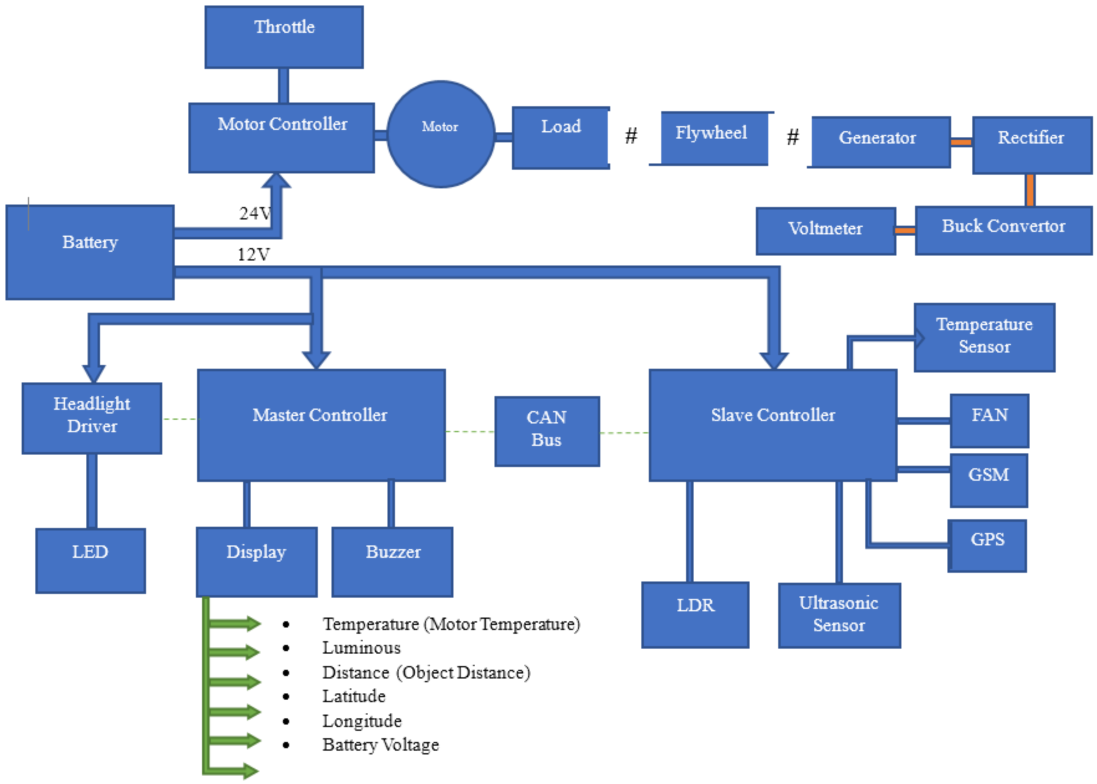

The generated voltage can sometimes be greater than the required voltage, so to step down the voltage, a buck converter is used. The generated voltage can be monitored by a DC voltmeter that can be used to supply power to other auxiliary sub-systems. The LCD display shows the following parameters: battery voltage, light intensity, distance, motor temperature, longitude, and latitude.

Sr. No.	Components	Specifications	Quantity
1	Brushless DC motor	250W,24V,10A ,1440rpm	1
2	Lead Acid Battery	12V,8A	2
3	Charger	12V	1
4	DC generator	24V	1
5	CAN module	MCP2515	2
6	Controller Arduino ATmega350	5V	1
7	Relay	12V	2
8	Buck Converter	12V – 24V	1
9	HC-SR04 Sensors	5V	1
10	LDR	3-5V	1

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11	NTC	5V	1
12	BLDC FAN	12V	1
13	Buzzer	3-5V	1
14	LED	12V	1
15	Motor Controller	24V	1
16	Voltage Regulator IC7805	12V	1
17	GPS	5V	1
18	SIM900A GSM Module	4V	1
19	LCD	5V	1
20	Flywheel	Iron ,D=120mm,T=12mm,M=1.180Kg	1

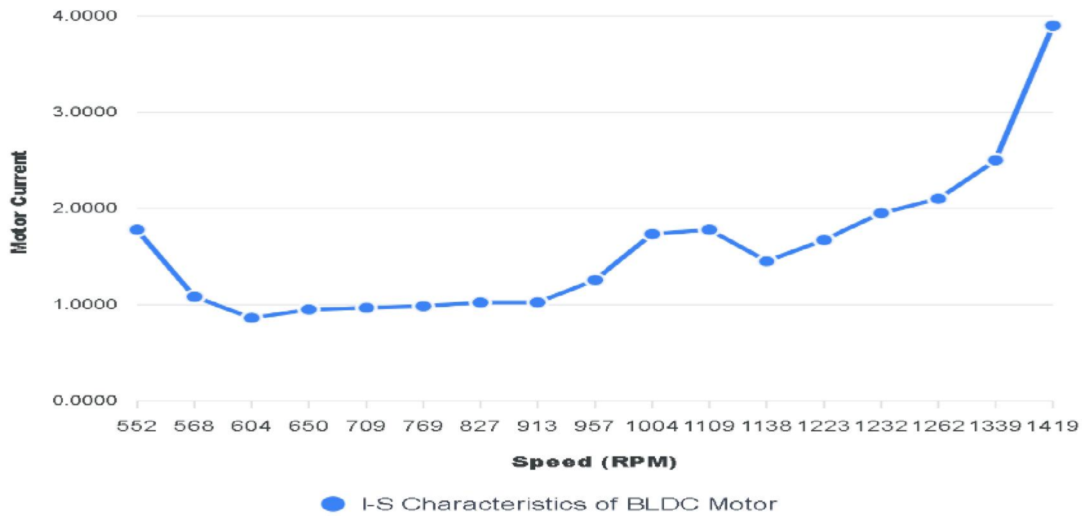
List of Components

Table 1. V-S Characteristics of BLDC Motor

Sr No.	Motor RPM	Motor Current (I_M)	Generated Voltage (V_G)
1.	552	1.072	5.5
2.	568	1.082	6
3.	604	0.862	6.5
4.	650	0.95	7.5
5.	709	0.967	8.5
6.	769	0.985	9.5
7.	827	1.022	11
8.	913	1.231	12.5
9.	957	1.255	13
10.	1004	1.734	14
11.	1109	1.779	15
12.	1138	1.45	16
13.	1223	1.672	17
14.	1232	1.952	18
15.	1262	2.1	19
16.	1339	2.5	20

17.	1419	3.9	21

Table 1. During regenerative operation time when the vehicle is moving faster it can produce more electrical energy via generator. The motor current stays much the same when the vehicle is going slow or medium speed, around 0.8A to 1.2A, which means it is working well within optimal range. When the vehicle is running really fast above 900 RPM the current consumed by motor goes up a lot all the way to 3.9A with approaching rated speed of motor i.e. 1440 RPM which means it needs more power. There are some changes in the current when the vehicle is going at medium speeds, which shows that the system is being controlled and operates within the rated conditions. BLDC motor systems, like this one can help make transportation safer, cleaner and more efficient. The above table also gives the relation between motor speed and the current consumed by motor which denotes that speed is directly proportional to the current as well as the generated voltage by the BLDC generator.



IV. CONCLUSION

This project shows how to design and build a hybrid electric vehicle prototype. It combines an electric motor with flywheel. The various ECUs work together by using the CAN protocol for communication and managing the ECUs and motor to make the vehicle reliable and efficient. The CAN protocol helps all components of the vehicle to communicate with each other, which includes the battery unit, motor controller and motor. The CAN protocol share information in real-time. So the vehicle can run smoothly without any delay and it can find problems or fault very early. If any minor issue occurs it fix the performance issues automatically. The model helps in monitoring parameters like voltage, current and speed. This makes it easier to see how the system works and fix any minor problem. The project also talks about the benefits of modern technology that can be used in traditional vehicles. Modern green technology makes vehicle more reliable and support more sustainable vehicles. This work is a starting point for research on hybrid and electric vehicles. It shows how better communication and control can make transportation safer, cleaner, reliable and more efficient.

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