Design and Implementation of Powertrain for Electric Vehicle

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***Abstract* – The expansion of technology is increasing the number of Internal Combustion Engine(ICE) vehicles on road. As an effect, pollution and global warming are becoming serious problems. One way to avoid these problems is to switch to Electric Vehicles (EV) instead of ICE vehicles that emit harmful gases to the environment. Brushless DC (BLDC) motors that have high torque-weight ratio are used in electric vehicle for the vehicle propulsion. The automotive grade microcontroller of ASIL-D (Automotive Safety Integrity Level) is used. This paper explains about controlling the BLDC motor in EV through TC233LP-32F200 microcontroller.**

Keywords:* *EV(Electric Vehicle), BLDC(Brushless DC Motor), ASIL-D, Automotive, Capture/compare unit, Hall sensors, Six step commutation

1. INTRODUCTION

Transportation is becoming an inseparable part of human life. As technology continues to improve, global warming and unpredictable changes in climate are the serious issues faced by the world's population. One solution to these problems is to reduce the CO2 emission and other pollutants. ICE (Internal Combustion Engine) vehicles that are ubiquitous are the main cause of environmental pollution. Thus, these vehicles are being replaced by Electric vehicles. Electric vehicles are cheaper to run and eco-friendly as the price of electricity is lesser than the petroleum products i.e. petrol and diesel. Electric vehicles produce lesser noise compared to the internal combustion engine vehicles.

Electric vehicles do not produce any harmful emissions such as carbon monoxide(CO) that interferes the blood flow and oxygen supply to heart in human beings, nitrogen oxide(NOx) is another pollutant emitted by the ICE vehicles that causes toxic acid rainfalls. Electric vehicles also do not emit the greenhouse gases that deplete the ozone layer, assuring a greener environment. The drive motors of electric vehicles are robust and requires lesser maintenance compared to ICE vehicles that requires frequent engine oil change causing the maintenance costlier. The efficiency of internal combustion engine ranges from 35-40% whereas the electric drive motors have an efficiency of 96%. Electric vehicles are easily powered from local and renewable energy sources. Thus, reducing our dependency on the foreign countries for oil.

In general, electric vehicles are categorized into

Battery Electric Vehicles(BEV)

Hybrid Electric Vehicle(HEV)

Plugin Hybrid Electric Vehicle(PHEV).

These vehicles contribute to very less emission and zero oil consumption or very less oil consumption.

BEVs are completely electric vehicles. They are powered only by electricity from the vehicle's battery. BEVs do not possess any petrol/diesel engine, exhaust valves and fuel tank.

BEVs are often called 'plug-in' electric vehicles since they use a charger that is external charge the vehicle's battery [2]. Regenerative braking is the other process that charge the BEV's battery.

HEVs use two sources to power the vehicle. One source is petrol and the other is electricity supplied by the battery. The kinetic energy of the electric motor is converted to electric energy to recharge its own battery. This process is called 'regenerative braking'. HEVs start with the help of electric motor, then uses petrol engine as load or speed increases. These two sources are managed by a controller that assures best economy and driving experience.

PHEVs have an electric motor as well as a battery. The battery in a PHEV are charged by plugging it into the power grid. In PHEV, the battery is recharged during the vehicle transmission with the help of internal combustion engine. ICE is also used to propel the vehicle when the battery charge is below SOC (State of Charge). As Plug-in Hybrid Vehicles use electricity from grid, they help in saving the fuel costs.

2. RELATED WORK

Different controllers are used to control the speed of the BLDC motor in electric vehicle depending upon the requirements like ASIL level, cost, processing power, power consumption, reliability, life time, register size and memory. The control techniques that are usually used are as

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 05, May-2019

- Fuzzy Logic Controller
- Maximum Transmissible Torque Estimation controller
- Sliding mode controller

2.1. Fuzzy Logic Controller

The fuzzy logic controller is used to control the speed of the motor. This requires the fuzzy speed controller and fuzzy decision maker for the control of speed of the motor. The decision maker consists of variables like SOC (State of Charge) of battery, drive cycle, Vehicle speed, require acceleration, brake and reference speed. The error from the fuzzy logic controller is less than that of the PI controller.

2.2. Maximum Transmissible Torque Estimation controller

MTTE eliminates the problem of estimating vehicle velocity that is important to four-wheel-drive vehicles, in spite of installing longitudinal acceleration sensor. For single axle vehicles, speed is estimated for torque control from the speed information of the undriven wheels.

3. METHODOLOGY

Design and development of Powertrain for electric vehicle is carried out in five stages. The five stages are Design and simulation, Software implementation, Hardware implementation, Integration of software with hardware, Testing. The power train of the electric vehicle consists of an AC to DC converter, 24V, 3.5 A, 53W BLDC motor and Powertrain controller. The battery output is DC and cannot be given directly to the motor so to convert the DC power from the battery to AC power and feed it to the BLDC motor, AC-DC converter (Inverter) is used. The inverter is pulse width modulated in order to vary the voltage applied to the motor. By varying the supply voltage, the speed of the BLDC motor is varied. The hall sensors give information about the position of the rotor and help in calculation of speed. The hall signals are given to the microcontroller as feedback. The information about the required speed is sent to the microcontroller through CAN (Controller Area Network) protocol for communication between the microcontroller and the accelerator pedal. CAN sends the required duty cycle to achieve the desired speed. According to the required duty cycle and the hall sensor output, the next switching pattern for the inverter switches is provided. The inverter phase current and dc link voltage, motor phase current and voltage are sensed continuously and fed back to the microcontroller. Also, the temperature of the inverter and motor are continuously monitored.

The electric vehicle incorporates Regenerative Braking. Regenerative braking is method of capturing the motors energy during braking to charge the battery. During this process, motor acts as a generator. The kinetic energy of the motor is converted into electricity to charge the battery.

Generation of PWM for Inverter

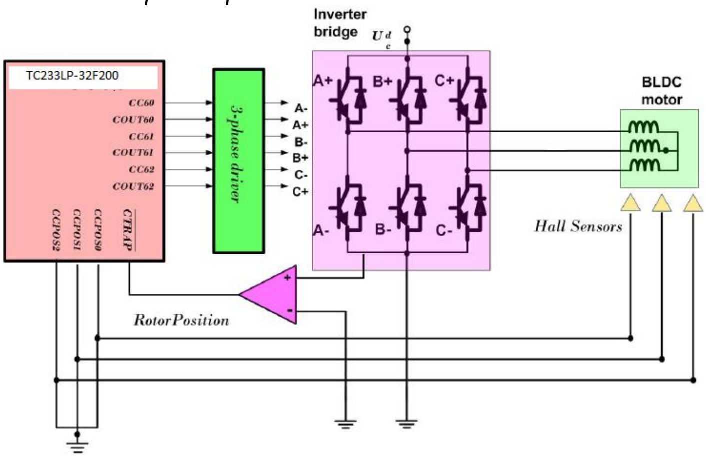

Fig 1: Circuit diagram of Powertrain

From, Fig 1 it is observed that the hall sensor output is given to the microcontroller as feedback signals. The microcontroller TC233LP-32F200 has Capture/compare Unit 6 (CCU6) that generates PWM pulses and switching patterns to the inverter switches based on the rotor position captured from hall sensors. The input to the microcontroller is hall sensor output. The driver circuit takes switching patterns as input from the microcontroller and gives required signals to inverter. CTRAP will make outputs of the CCU6 to enter passive state and there will be no modulation, stops the motor operation.

Six IGBTs make up the inverter. A pair switches controls one phase of the motor. The high side switch is connected to positive DC rail voltage and the low side switch is connected to ground. The current flows in positive direction in one coil and in negative direction to GND in another coil. This type of commutation is called block commutation where always one phase is inactive. If high side and low side switches turn on simultaneously, there will be a short circuit. To avoid this, dead time is inserted using timer 12 in CCU6.

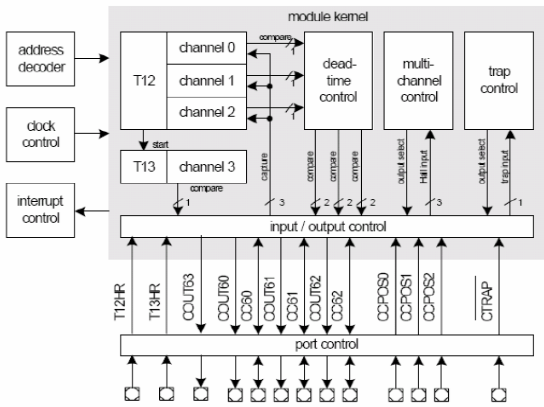

Fig 2 : Capture/Compare Unit 6 (CCU6)

The capture/compare unit 6 consists of two timers T12 and T13 as shown in Fig 2. It has two registers MCMOUTSH contains actual hall pattern (CURHS) and the expected hall pattern (EXPHS) and MCMOUTSL contains corresponding

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 05, May-2019

output pattern(MCMPS). Three basic steps followed Hall pattern sampling, output pattern and next hall pattern update in software, shadow transfer of updated pattern on the arrival of defined event.

1. Hall Pattern Sampling

The CCU6 is operated in 'Hall Sensor Mode' (MSEL6x = 1000B). Hall patterns are given to the CCU6 through CCPOSx (x=1,2,3) input pins. The hall patterns are sampled with module clock fCCU6. Any noise spikes in the input is suppressed by the noise filter in dead time counter (DTC0). If hall event occurs (change in hall inputs), DTC0 generates a delay between the occurred event and sampling point. As the counter value approaches 1, the hall patterns are sampled and compared with CURH (Current Hall Pattern) and EXPH (Expected Hall Pattern). If the sampled hall pattern matches CURH, its considered as noise and it is filtered and no other action is taken. If the sampled hall pattern matches the expected pattern, it is considered as correct hall event and the bit CHE is set high. This bit initiates an interrupt.

2. Hall pattern and output pattern software update

Once the hall patterns are sampled, respective output pattern must be obtained to control the BLDC motor speed. The output channels CC6x and COUT6x (x=1,2,3) generate the output pattern with the help of independent timer T12 and T13. T13 is used for PWM generation to modulate the DC bus voltage to control the speed of the BLDC motor. COUT6x gives the PWM output and controls the high side switches. CC6x give the output that is not modulated and it controls the low side switches.

Table 3.1: Commutation table for Forward motoring

Rotor Position [H2… H0]	Next Position	COUT 62 C+	CC 62 C-	COUT 61 B+	CC 61 B-	COUT 60 A+	CC 60 A-	Hexa Equivalent
1	3	0	1	0	0	1	0	12
3	2	0	1	1	0	0	0	18
2	6	0	0	1	0	0	1	09
6	4	1	0	0	0	0	1	21
4	5	1	0	0	1	0	0	24
5	1	0	0	0	1	1	0	06

Table 3.2: Commutation table for Reverse motoring

Rotor Position [H2…H0]	Next Position	COUT 62 C+	CC6 2 C-	COUT 61 B+	CC6 1 B-	COUT 60 A+	CC6 0 A-	Hexa
1	5	1	0	0	0	0	1	21
5	4	0	0	1	0	0	1	09
4	6	0	1	1	0	0	0	18
6	2	0	1	0	0	1	0	12
2	3	0	0	0	1	1	0	06
3	1	1	0	0	1	0	0	24

Table 3.1 and 3.2 shows the commutation table for forward and reverse motoring. Tables also indicate the rotor position and their respective CCU6 output channels and switching pattern for inverter switches.

3. Shadow transfer of updated patterns

PWM outputs are synchronized with hardware events through a mechanism called Shadow Transfer. This mechanism consists of two registers, one is a shadow register and the other is actual register. The contents of shadow register are transferred to actual register if a correct hall event occurs.

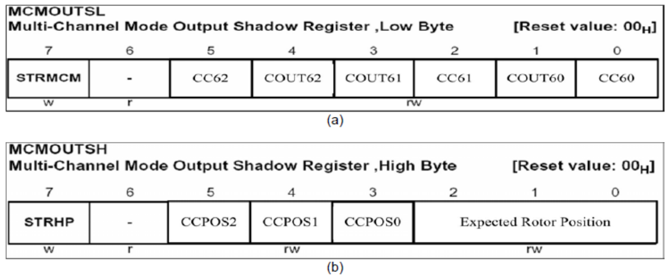

Fig 3: (a) MCMOUTSL register (b) MCMOUTSH register

Once shadow transfer happens, the next pair of rotor position and corresponding CCU6 outputs are pushed into MCMOUT registers. Next, MCMOUT register controls the output patterns and decides the switches to be turned on in the inverter

4. RESULTS AND DISCUSSIONS

This section tells about the hardware implementation of the EV prototype. It shows the required setup to make the observations. The variation of speed with respect to the duty cycle is shown in this section.

4.1 Hardware Implementation

Table 3 shows the specifications of the inverter, BLDC motor and MOSFETs used for the inverter.

Table 3: Specifications

BLDC motor	24V, 3.5A, 53W
Li-ion battery	3.2V, 2.6A
MOSFET	100V, 8A
Microcontroller	Aurix TC233 series

Fig 4 shows the hardware implementation of the powertrain that consists of the inverter, BLDC motor, powertrain controller.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 05, May-2019

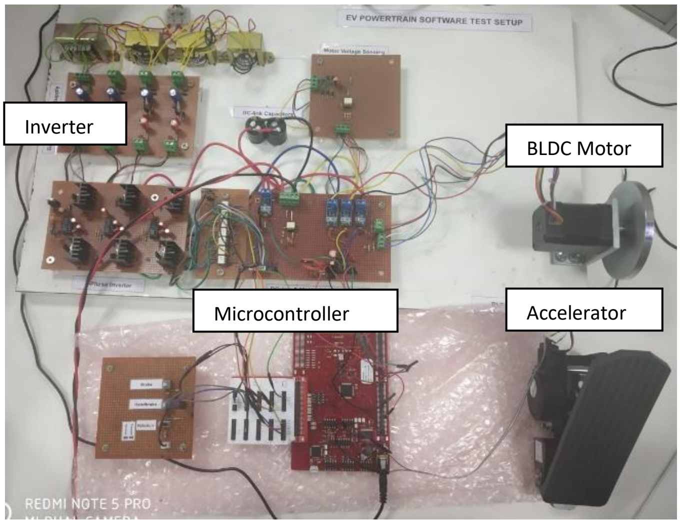

Fig 4: Powertrain setup

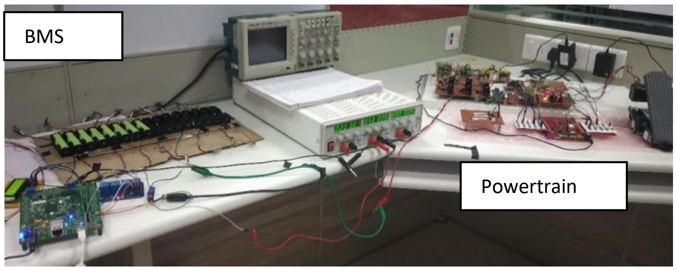

Fig 5: EV prototype

4.2 Result

The motor speed for different duty ratio are taken as results.

Table 2 Result

Duty Cycle%	Motor Speed (rpm)
0	0
20	412
40	926
60	1458
80	2156

5. CONCLUSION

There are many ways to control the BLDC motor of in an electric vehicle. One such methods using Aurix TC233 is discussed in this paper. Caputure/compare unit 6 is used to generate the pulses and switching sequence to the inverter. The prototype of Electric vehicle with 24V, 3.5A, 53W BLDC motor is tested. The speed variation due to change in duty cycle is tabulated. It is observed that the speed varies as the duty cycle increases.

REFERENCES

[1] S. Dang, J. Ju, D. Matthews, X. Feng, and C. Zuo, “Efficient solar power heating system based on lenticular condensation,” in Information Science, Electronics and Electrical Engineering (ISEEE), 2014 International Conference on, vol. 2. IEEE, 2014, pp. 736–739.

[2] S. Yang, Z. Hong, S. Wei, S. Dang, P. Kecerski, and A. Gholamzadeh, “Highly efficient solar energy vehicle design based on maximum power point tracking,” in Information Science, Electronics and Electrical Engineering (ISEEE), 2014 International Conference on, vol. 1, April 2014, pp. 390–394.

[3] S. Dang, A. Odonde, T. Mirza, C. Dissanayake, and R. Burns, “Sustainable energy management: An analysis report of the impacts of electric vehicles,” in Environment and Electrical Engineering (EEEIC), 2014 14th International Conference on. IEEE, 2014, pp. 318–322.

[4] K. Chau, C. Chan, and K. Chau, Modern electric vehicle technology. Oxford science publications, 2001.

[5] M. Zhang, Y. Sun, S. Dang, and K. Petrou, “Smart grid-oriented algorithm of data retrieval and processing based on crio,” in Information Science, Electronics and Electrical Engineering (ISEEE), 2014 International Conference on, vol. 2. IEEE, 2014, pp. 686–689.

[6] S. Dang, R. Kakimzhanov, M. Zhang, and A. Gholamzadeh, “Smart gridoriented graphical user interface design and data processing algorithm proposal based on labview,” in Environment and Electrical Engineering (EEEIC), 2014 14th International Conference on. IEEE, 2014, pp. 323–327.

[7] Z. X. Ma, M. Zhang, S. Shaham, S. P. Dang, and J. Hart, “Literature review of the communication technology and signal processing methodology based on the smart grid,” in Applied Mechanics and Materials, vol. 719. Trans Tech Publ, 2015, pp. 436–442.

[8] M. Ehsani, Y. Gao, and A. Emadi, Modern electric, hybrid electric, and fuel cell vehicles: fundamentals, theory, and design. CRC press, 2009.

[9] M. Etezadi-Amoli, K. Choma, and J. Stefani, “Rapid-charge electricvehicle stations,” Power Delivery, IEEE Transactions on, vol. 25, no. 3, pp. 1883–1887, 2010.

[10] R. J. Bessa and M. A. Matos, “Economic and technical management of an aggregation agent for electric vehicles: a literature survey,” European transactions on electrical power, vol. 22, no. 3, pp. 334–350, 2012.

[11] Y.-J. Lee, A. Khaligh, and A. Emadi, “Advanced integrated bidirectional ac/dc and dc/dc converter for plug-in hybrid electric vehicles,” Vehicular Technology, IEEE Transactions on, vol. 58, no. 8, pp. 3970–3980, 2009.

[12] C. Botsford and A. Szczepanek, “Fast charging vs. slow charging: Pros and cons for the new age of electric vehicles,” in International Battery Hybrid Fuel Cell Electric Vehicle Symposium, 2009.

[13] Z. Jiang, T. Xiao, V. a. Kuznetsov, and P. ´ a. Edwards, “Turning carbon ´ dioxide into fuel,” Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 368, no. 1923, pp. 3343–3364, 2010.

[14] W. Xiangqin, “Existing bottleneck problems and countermeasures in china’s electric vehicle development [j],” Energy Technology and Economics, vol. 3, 2011.

[15] K. Morrow, D. Karner, and J. Francfort, “Plug-in hybrid electric vehicle charging infrastructure review,” US Department of Energy-Vehicle Technologies Program, 2008.

[16] W. Kempton, J. Tomic, S. Letendre, A. Brooks, and T. Lipman, “Vehicleto-grid power: battery, hybrid, and fuel cell vehicles as resources for distributed electric power in california,” Institute of Transportation Studies, 2001.

[17] C. Goebel, “On the business value of ict-controlled plug-in electric vehicle charging in california,” Energy Policy, vol. 53, pp. 1–10, 2013.

[18] A. Ziegler, “Individual characteristics and stated preferences for alternative energy sources and propulsion technologies in vehicles: A discrete choice analysis for germany,” Transportation Research Part A: Policy and Practice, vol. 46, no. 8, pp. 1372–1385, 2012.

[19] S. Sadeghian, F. Leurent, and V. Boutueil, “Electric vehicle charging infrastructure forcasts in france,” in European Transport Conference, 2012.

[20] Schneider-electric.co.uk, “Ev link charging solutions — schneider electic uk,” 2015. [Online]. Available: http://www.schneider-electric.co.uk/sites/uk/en/productsservices/electrical-distribution/products-offer/ev-link-chargingsolutions/ev-link-charging-solutions.page

[21] J. Cao and A. Emadi, “A new battery/ultracapacitor hybrid energy storage system for electric, hybrid, and plug-in hybrid electric vehicles,” Power Electronics, IEEE Transactions on, vol. 27, no. 1, pp. 122–132, 2012.

[22] L. Lu, X. Han, J. Li, J. Hua, and M. Ouyang, “A review on the key issues for lithium-ion battery management in electric vehicles,” Journal of power sources, vol. 226, pp. 272–288, 2013.