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DsPIC Based Power Assisted Steering Using Brushless Direct Current Motor

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ABSTRACT

This study illustrates the Electrically Assisted power Steering (EAS) using BLDC motor for a vehicle. Earlier the Electrically Assisted power Steering (EAS) was implemented with DSP. This study shows the usage of a dsPIC to control the BLDC motor with an encoder. The BLDC motor here is driven by dsPIC through a three phase inverter system. IRAMS type of inverter is used which is cost efficient and space efficient. The dsPIC supplied with the input of the steering. In its higher capacity the vehicles speed controller acts as the assistance level controller for steering effort. At the lower capacity, the torque controller gives the effort level control. In reality this can be realized as torque sensor and vehicle sensor interfaced in the dsPIC. For actual implementation in the system, a dsPIC-based BLDC motor controller with three-phase inverter module is used with Hall-effect sensor feedback. It is designed in such a way that the driver assistance can be varied at any time without any difficulty.

Keywords: Power Assisted Steering, dsPIC Control of BLDC, Incremental Rotary Encoder

1. INTRODUCTION

In order to avoid the disadvantages of earlier power steering (hydraulic) systems such as space efficiency, engine efficiency and compatibility with environment, the Electric Power Steering (EPS) system has come into existence. In Electric Power Steering (EPS) system the BLDC Motor is suitable because of the advantages compared to other types of motors.

The research taken place on BLDC motors conclude that the best suited motor for the automotive applications is the Brushless Direct Current (BLDC) motors (Lee *et al*., 2012; Guobiao *et al*., 2012) which are used for continuous rotation applications like electric power steering. BLDC motors are equipped with highly reliable positioning systems with start and stop functions.

Further, the BLDC motors offer a good control which is very much required for the vehicles and they are suitable for variable-speed applications. They can be used where space is less, because of its compact size. The modeling and simulation of BLDC Motor is done in matlab simulink for the power steering application and control (Nehaoua *et al*., 2013; Marouf *et al*., 2012).

As today drivers have to meet the increasing needs and demands the auto motive designers have to use the critical tool like the embedded processor. The automotive system designers to meet their needs they have to use sophisticated electronic control solutions, such as low-cost, low-noise, high-accuracy systems.

1.1. Conventional Method

In recent years the demand for Electrically Assisted power Steering (EAS) has rapidly increased, because of energy savings compared to Hydraulic Power Steering (HPS). Alternating current (ac) motors are highly efficient and easily controlled with modern power circuitry. Because of the recent developments in switching techniques, it is quite feasible to use ac motors with a battery supply. The traditional worm gear driven system uses DC Motor which is constrained by the limitations of the dc motors. In such case BLDC motor is

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used as an actuator in the application for electric power steering. The basic mechanical properties of the vehicle are essentially invariant among all of the available brands. The electrically assisted power steering system consists of BLDC motor mounted to the frame of the steering column and coupled to the wheels through a worm speed reducer.

Figure 1 shows the comparison of EAS and the ordinary steering systems. Electrically assisted power steering eliminates all the drawbacks of the hydraulic system and consumes energy only when it is in use. The effective torque and velocity control of a BLDC motor is based on relatively simple torque and Back EMF equations.

The conventional method of electrically assisted power steering is as shown in **Fig. 2**. As the technology develops, the DSP is made used for control and computation in special motors (Jancsurak, 2000) where the output of the driver is directly given to the inverter. The current sensing is done by the low cost shunt resistor. The voltage drop is processed with analog amplifier and connected to ADC module and used for current feedback and over current protection. Later the usage of the DsPIC was popular for low cost applications (ADC, 2011). DsPIC was used to control the PMSM (Zambada, 2011). An arm controller is used to controller for running the motor in both the directions (Ramesh and Amarnath, 2011). Dsp controller is sophisticated compared to arm controller which was used in power steering (Murugan *et al*., 2008; Prasad *et al*., 2012).

1.2. Proposed Method

The DsPIC is used to control the BLDC motor for low cost applications (D'Souza, 2005). In the proposed method, Implementation of Electrical Assisted Power Steering with dsPIC is done, in order to make the system with fast Analog to Digital Conversion, to reduce the complexity, to reduce the Overall size and to reduce the system cost by eliminating external components. The circuit diagram of the proposed method is as shown in **Fig. 3**.

The Hardware used here was selected to reduce the cost and space. The replacement of the DSP with dsPIC is always an added value. The inverter system used here is a compact module which produces a filtered output which results in a reduced cost and space with higher efficiency and an increased accurate output. A development board is used to program the dsPIC. The proposed system consists of digital signal controller and the BLDC Motor.

1.3. Digital Signal Controller

A Digital Signal Controller (DSC) is a single-chip, embedded controller that integrates the control attributes of a Microcontroller with the computation and throughput capabilities of a Digital Signal Processor in a single core. Digital Signal Controller is fast, sophisticated and flexible interrupt handling and has a wide array of digital and analog peripheral functions

1.4. BLDC Motor

The BLDC motor contains a rotor with permanent magnets and a stator with windings as shown in **Fig. 4**. Commutation is performed electronically in BLDC motors.

The BLDC motor used here has 8 magnetic pole pairs on the rotor and a three-phase star connected windings on stator. The motor is equipped with three Hall Effect sensors. The Hall sensors produce three 180° (electrical) overlapping signals as shown in the **Fig. 5**. Thus it is providing six mandatory commutation points. The Hall sensor outputs are directly connected to processor and it generate the necessary switching sequence as per commutation.

To rotate the BLDC motor, the stator windings should be energized in a sequence. Rotor position is sensed using Hall Effect sensors embedded into the stator. The equivalent circuit of a BLDC motor is shown in **Fig. 6**. The voltage equation of BLDC motor can be represented as:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L & 0 & 0 \\ 0 & L & 0 \\ 0 & 0 & L \end{bmatrix}\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

Where:

R	=	Phase resistance
L	=	Phase inductance
V_a, V_b, V_c	=	Phase voltages
i_a, i_b, i_c	=	Phase currents
e_a, e_b, e_c	=	Back EMFs:

$$T = \frac{e_a i_a + e_b i_b + e_c i_c}{\omega}$$

where, ω is motor angular velocity.

IRAMS10UP60B is an Integrated Power Module and an incremental rotary encoder is used to motion related information such as velocity. **Figure 7** indicates the encoder output.

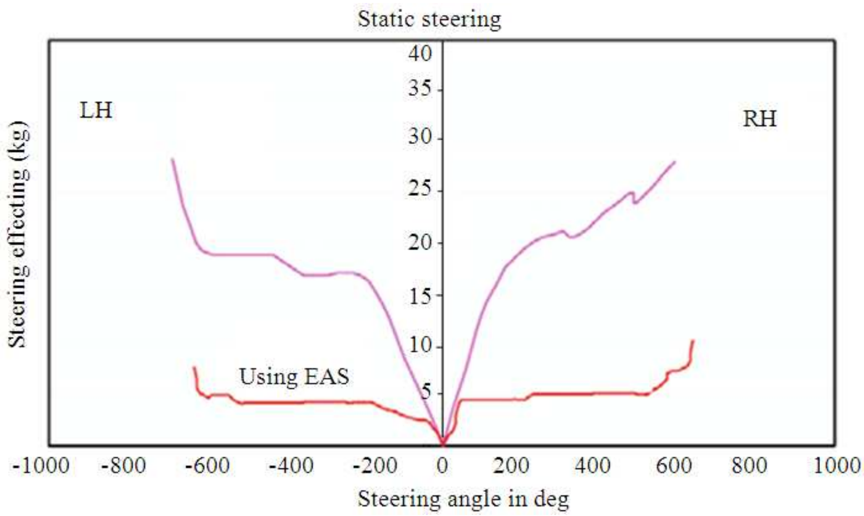

Fig. 1. Comparison of EAS and ordinary steering system

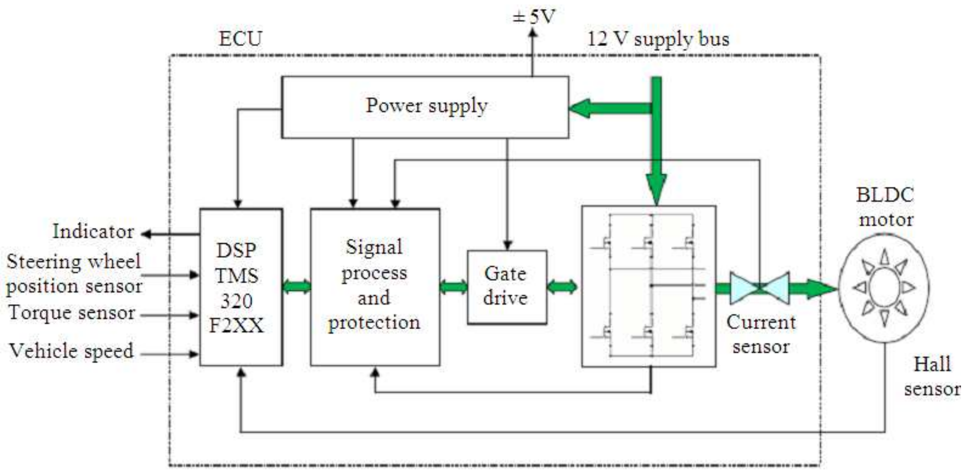

Fig. 2. Block diagram of the conventional method

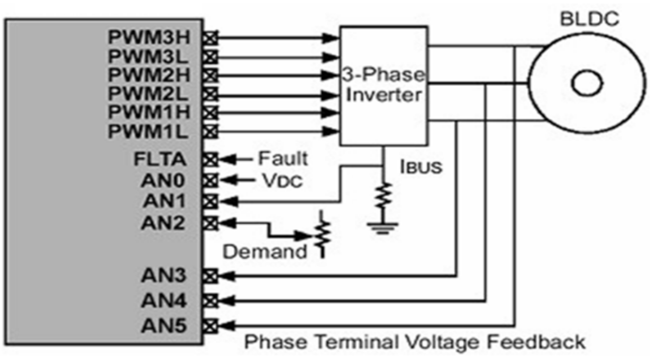

Fig. 3. Circuit diagram of proposed method

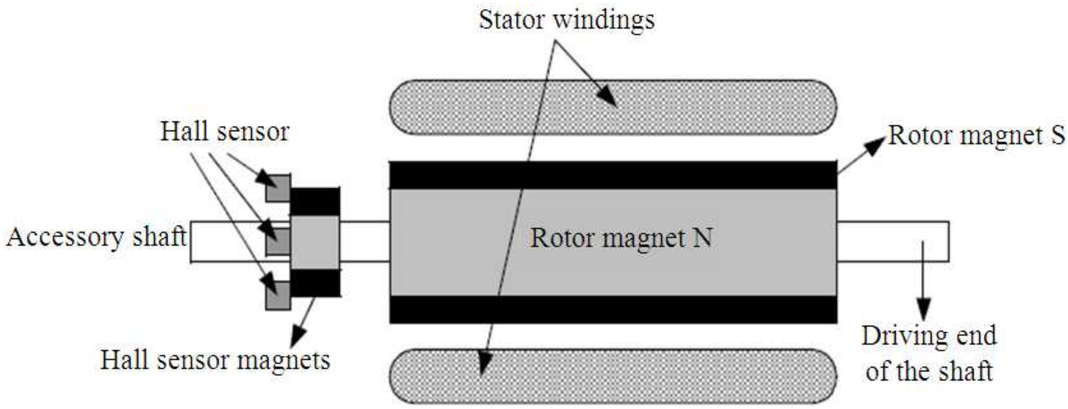

Fig. 4. BLDC motor

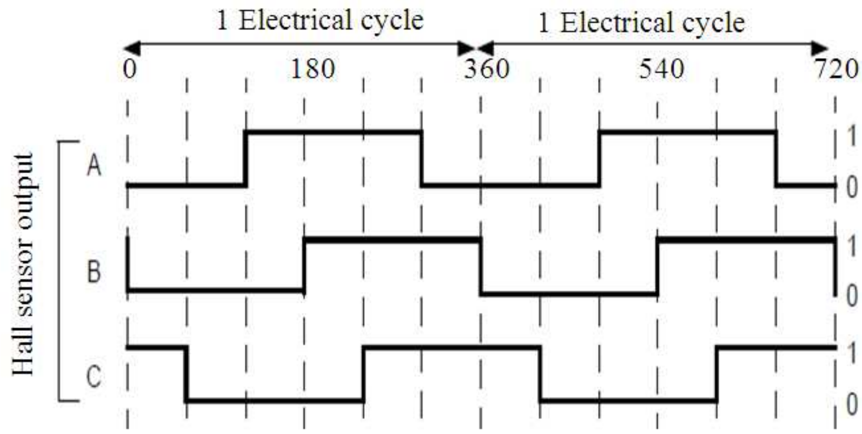

Fig. 5. Hall sensor output

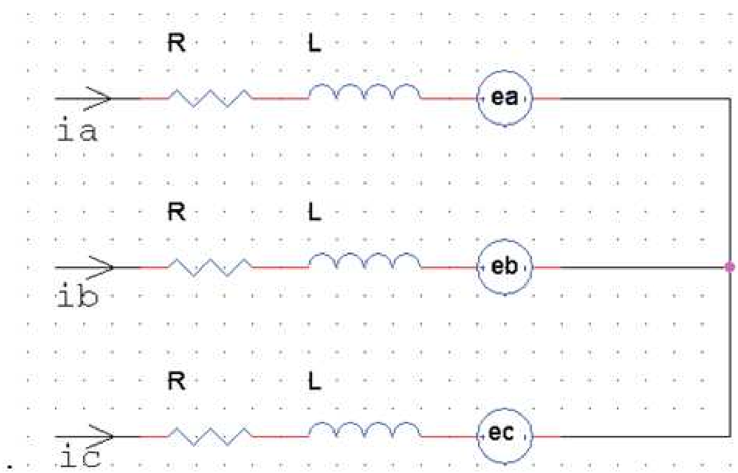

Fig. 6. Equivalent Circuit of BLDC

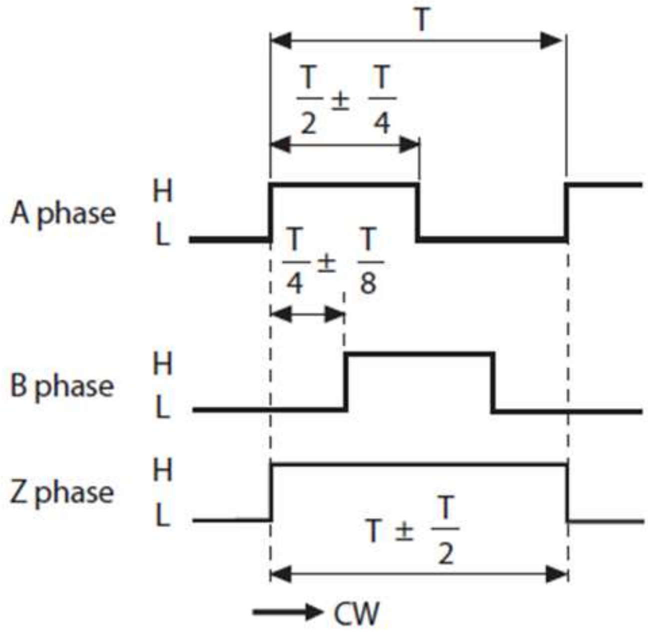

Fig. 7. Encoder output

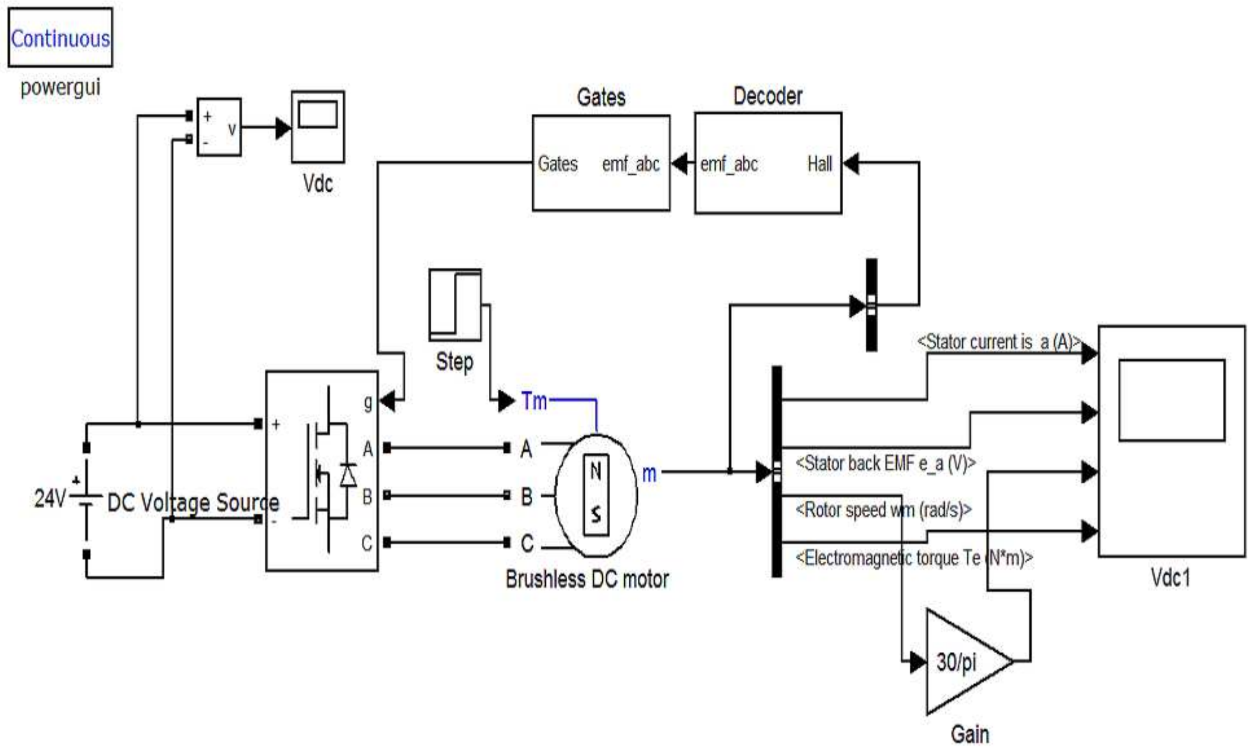

Fig. 8. Simulation circuit of open loop configuration

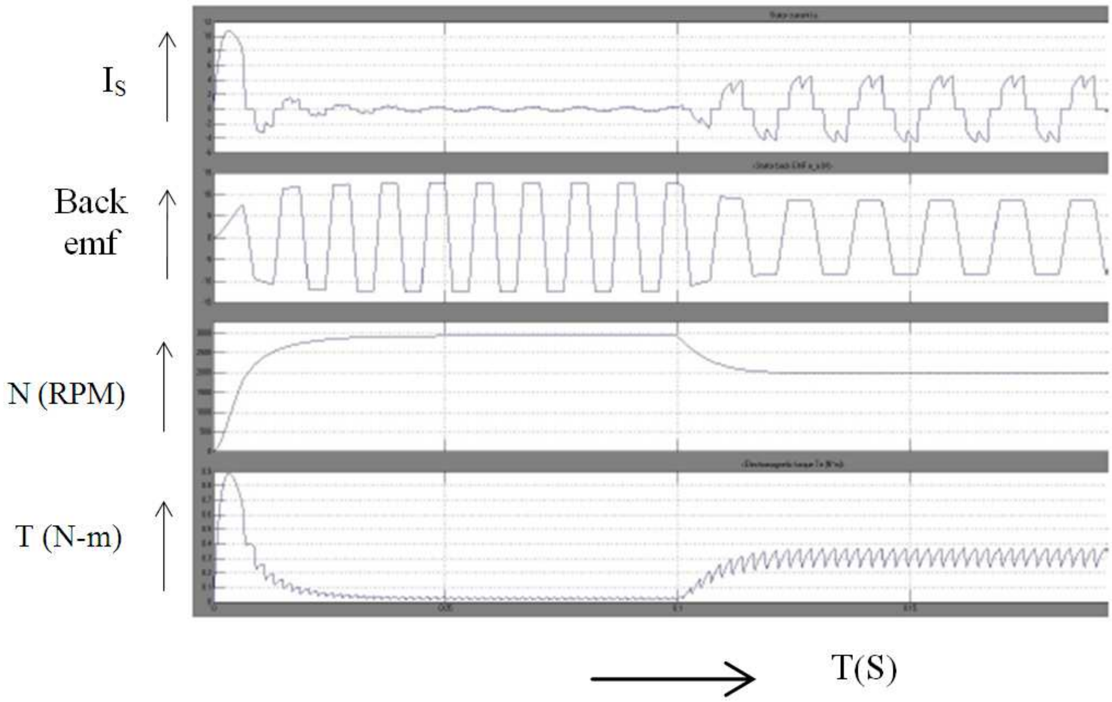

Fig. 9. Simulation results of open loop configuration

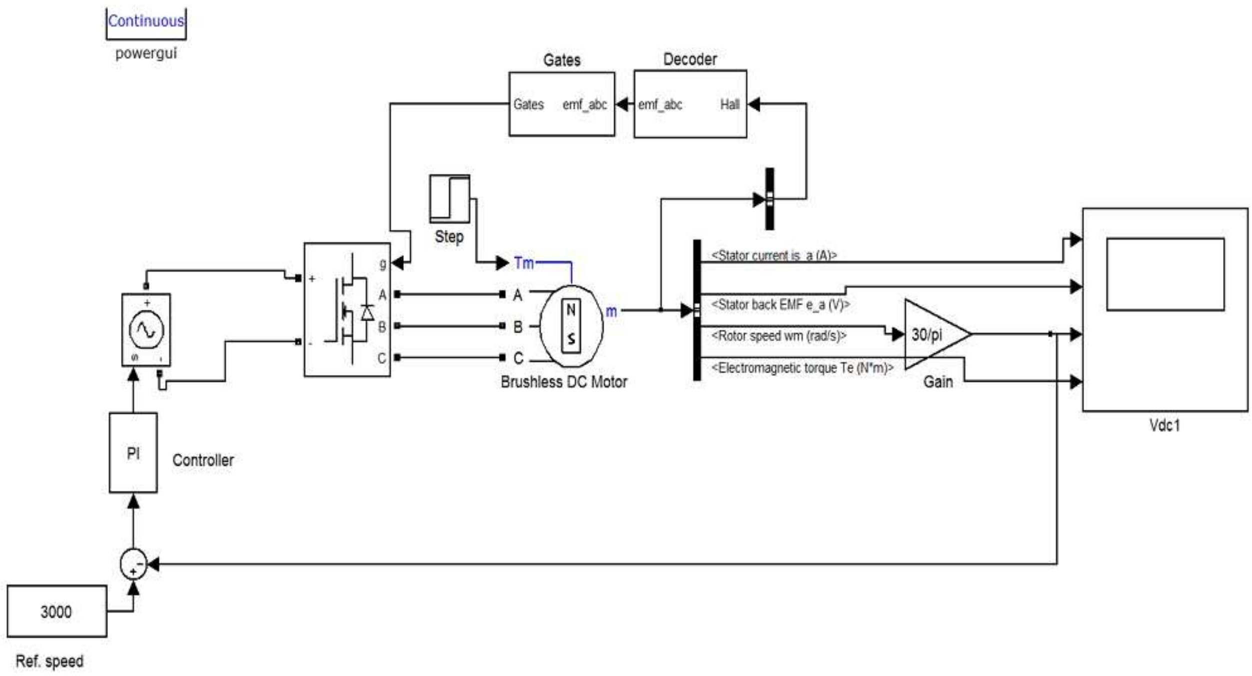

Fig. 10. Simulation circuit of closed loop configuration

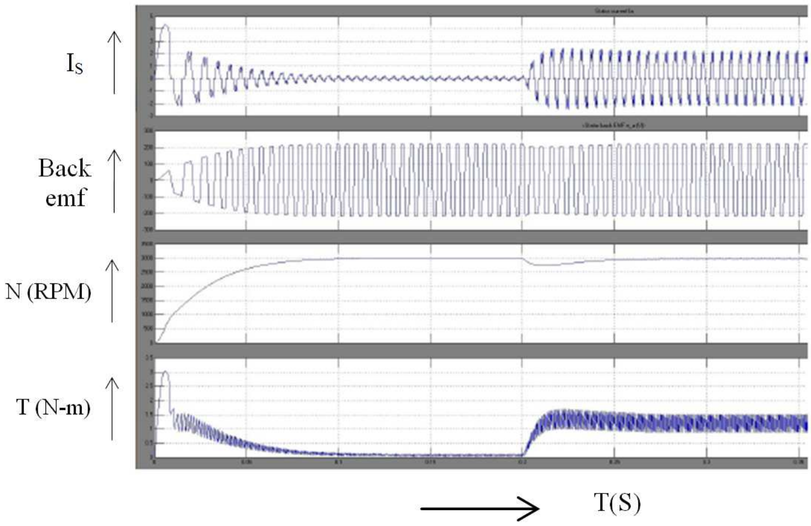

Fig. 11. Simulation results of closed loop configuration

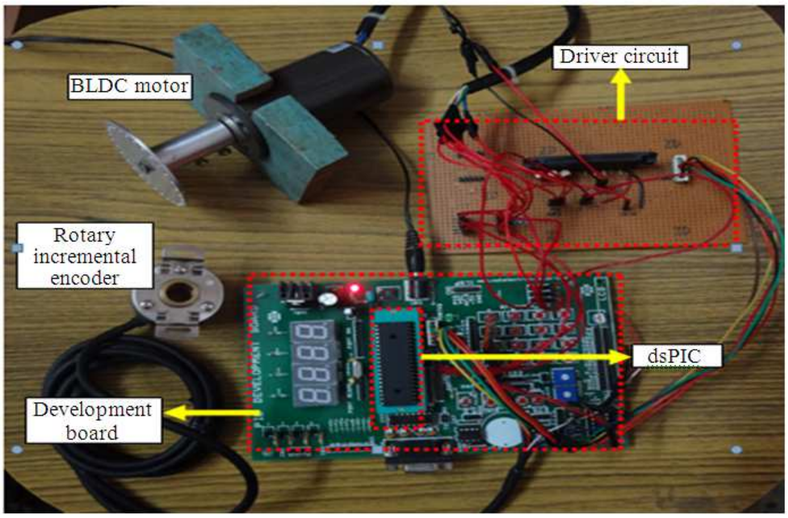

Fig. 12. Snapshot of the proposed method

Table 1. Specifications of the BLDC motor

Parameter	Value	Units
Voltage	12V	volts
Speed	3000	rpm
Torque	5.7	N-cm
Current	2.4	amps
Output power	30	watts
Flux density	0.01875	Kg m sec
Inertia	0.052	Kgm^2
Phase resistance	2.256	ohms
Phase inductance	1.105	mh
Mutual inductance	6.8	mh

1.5. Simulation Results

The simulation circuit for the open loop configuration is as shown in **Fig. 8** and the simulation results are shown in **Fig. 9**. In the simulation results when the load is added the speed reduces to a greater extent and the torque increases.

Simulation circuit of the closed loop configuration is as shown in **Fig. 10** and the simulation results are shown in the **Fig. 11**. Here when the load is applied the dip in the speed is very less and it is recovered within a short period of time 0.05 sec which makes the smooth running of the vehicle.

The BLDC motor specifications are given in the **Table 1**. The actual setup of hardware circuit is as shown in **Fig. 12**.

The speed obtained in the simulation and in the hardware is same.

2. CONCLUSION

This study explains the controlling of the BLDC motor using dsPIC with the input given by an encoder which acts like a steering has been performed successfully. The prototype arrangement is shown in this study can be used in real time operations, by connecting the torque sensor which sense the torque applied on the steering wheel by the whole body weight and the speed sensor which is used to sense the vehicle speed to the dsPIC. This enables system developers to implement their designs in an efficient, timely manner. The motor starts smoothly and run even with load and load transients. The proposed method can be commercialized with dsPIC which is cost efficient and as effective as DSP along with the introduced Inverter system. Simulation and experimental results are shown which validate the suitability of the proposed method.

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