Enhanced Modeling of Field-Oriented Control based inverter for Electric Vehicle

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Abstract. The paper mainly focuses on speed control mechanism of electric vehicle and the most affordable approach. As the awareness of environment grows among people, the usage of electric vehicles has significantly increased. This paper includes various techniques used in speed control of electric vehicles in present marker and proposes an alternate solution for the same. This paper also focuses on the various flaws that are encountered in the electric vehicles in market. This proposal of alternate solution mainly aims to reduce the cost usage in the manufacturing of electric vehicles at the same time maintaining the efficiency in speed control. The field-oriented control method is implemented along with dsPIC controller. The dsPIC controller offers increased efficiency, integrated peripherals and reduced system cost. The field-oriented control is a better approach to control the Permanent Magnet Synchronous Machine (PMSM). The PMSM offers smooth operation, better durability and regenerative braking and hence stands as a better option than (BLDC) Brushless Direct Current motors. Hence making a significant progress towards attracting more consumers towards electric vehicles.

INTRODUCTION

The petrol vehicles are most popularly used locomotives due to its availability and long life. These vehicles have been used by people since 19th century and they are more trusted by people across the world. Still these vehicles cause a significant amount of damage to the environment by releasing toxic gases. Though there are various manufacturing standards implied to manufacture them environment friendly, the damage is not fully eradicated rather reduced. In this scenario, the advent of electric vehicle makes a noticeable approach of locomotives that are environment friendly.

As the awareness of environmental pollution spreads among the people, the usage of electric vehicles has considerably increased. The electric vehicle manufacturers are trying to fuel up people's interest towards electric vehicles by increasing the mileage, electronic integrations, etc. The government also gives various aids to support the people's movement towards a pollution free environment.

This research paper concentrates on modification of speed control technique in electric vehicle that could considerably reduce the cost. This could make the electric vehicles more affordable for people from all walks of life.

TECHNIQUES OF CONTROL

Motors for Electric vehicles

The most dominant motors in the electric vehicle field are Permanent Magnet Synchronous Motors (PMSM) and Brushless Direct Current (BLDC) motors. These motors are guaranteed for higher performance, longer life duration and lower maintenance. Though the motors use similar working principle, they have some significant difference which makes the one takes upper hand. [1] The permanent magnet synchronous machines have a sinusoidal back emf which comparatively reduces the torque ripple and thereby maintaining a constant torque. The permanent magnet synchronous motor also gives higher torque efficiency even at lower speeds. Contrary to BLDC motors the PMSM has less core loss and noise dissipation. Hence the permanent magnet synchronous motors stand out as a best choice of the better motors for electric vehicles.

The Speed Control

[3] The speed controlling techniques of permanent magnet synchronous motors include: a) Scalar Control: The scalar control uses v/f method to control the speed of the motor but this provides a poor performance and efficiency. b) Direct Torque Control (DTC): The direct torque control directly controls the torque and flux thereby increasing the torque ripple. c)Field Oriented Control (FOC): [2] The field-oriented control makes an efficient, accurate speed control by modifying the magnetic flux of the motor. The Filed Oriented Control also has the additional advantages of reduced size, stable torque response and smooth operation making it most suitable for speed control of electric motor in vehicle.

WORKING AND OUTPUT

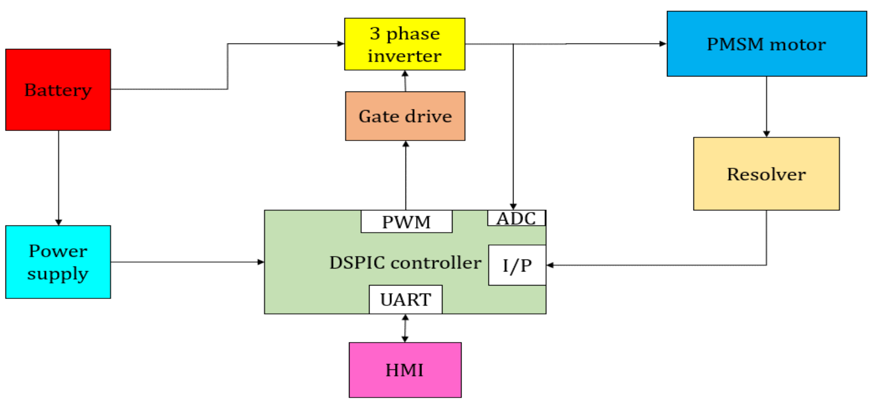
This project focuses on using the field-oriented control on permanent magnet synchronous motor to efficiently control the speed and reduce the torque ripple for smooth operation.

[4] The project proposes a solution of utilizing the dsPIC micro controller to control the speed and torque of the synchronous machine as it is reliable for faster processing and lower in cost on contrary to other controllers used in market like infineon, reneasas, etc. The controller generates the PWM output based on the input from the accelerator and the current rotor position of the motor monitored by a resolver as depicted in figure (a). This pulse is fed to the 3-phase inverter through gate driver to isolate the high voltage signal and low voltage signal.

This DC signal is fed to the 3-phase inverter to generate the corresponding AC signal for the synchronous machine to operate with.

Finally, Hence, the varying acceleration produces varying pulse from the controller which is in turn used to produce the AC voltage for speed control of motor.

The torque is maintained at higher level by adjusting the rotor and stator vector positions as orthogonal as possible to achieve the maximum torque at any speed.



(a) Block Diagram

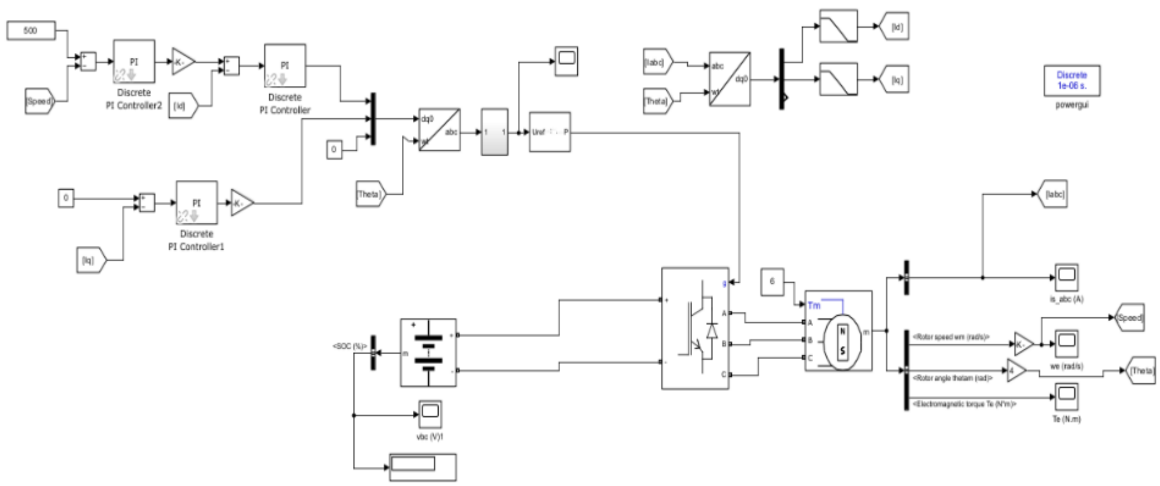
Proof Of Concept

The simulation has been worked on MATLAB Simulink is depicted in figure (b) and the speed and torque control is achieved successfully.

[6] The speed of the motor is continuously measured using a speed sensor which is compared with the desired speed. The speed difference between the actual and the desired value are compared this speed difference is processed and then the output is used to adjust the I_d (direct current) which affects the magnetic field strength in motor.

[7] The torque is aimed to achieve the maximum and hence the I_q (quadrature current) is compared to zero as this makes the rotor and stator vectors almost orthogonal contributing to higher torque. The current supplied from inverter to motor is converted to dq0 reference frames in order to get the I_q and I_d components of current in the 3- phase supply.

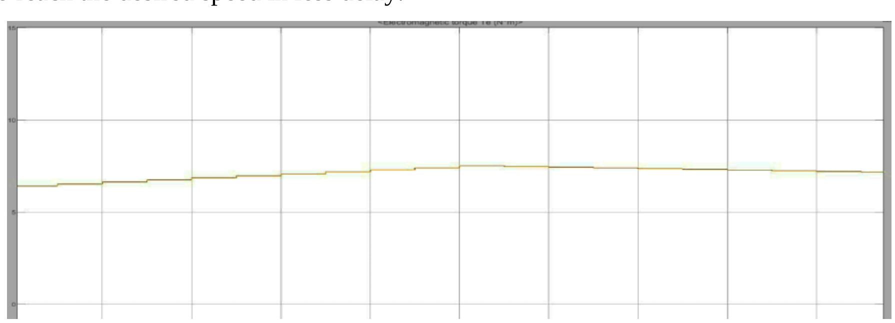
These components can used are used in controlling the speed and torque of the motor as discussed above. After making the necessary modifications in the rotating reference frames, these components are again then converted to the voltage reference frames. These transformations from rotating reference frames to voltage reference frames and vice versa are done using Clarke-Park.



(b) Matlab simulation diagram

(c) Speed of rotor (rad/s)

The figure (c) helps to understand that the motor is able to produce the desired speed i.e. up to 500 rpm and maintain the same when the desired output remains the same . This shows that the system is able to maintain the steady state and the motor is able to reach the desired speed in less delay.



(d) Electromagnetic torque – (Nm)

The figure (d) shows the output fetched from the MATLAB Simulink , where the torque has less ripples and the desired speed is achieved as expected. This also depicts that the system is able to respond to the torque demands quickly based on the change in speed. This stands as a proof that the above proposal can be used successfully for speed and torque control of motor in electric vehicles.

Real Time Implementation

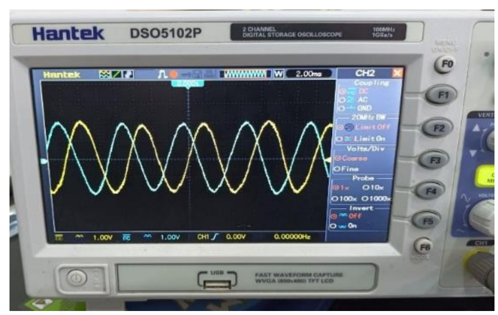
The real time implementation involves the permanent magnet synchronous machine controlled using the field-oriented control method. This includes the 3-phase inverter controlled by dsPIC controller. [5] The inverter has six MOSFETs – Metal-Oxide-Semiconductor Field-Effect Transistors connected which receives the input from the gate drivers. These gate drivers are fed by the controller's PWM – Pulse Width Modulation. These drivers are used to isolate the MOSFET operated in high voltage signal and the controller operated at low voltage signal. The driver also amplifies the signal before conveying it to the MOSFET as they operate on a relatively higher voltage.

The voltage is sensed when the accelerator is given and based on the corresponding input voltage received by the dsPIC controller, the corresponding PWM is given as output to the gate driver.

The gate driver pulse is fed to the three-phase inverter through MOSFET. The brake application is indicated based on the input to the digital pin in the controller. This signal helps in identifying the application of brake while controlling the motor for locomotion.

Using the dsPIC considerably reduces the cost compared to other controllers used on market. The motor used and the mechanism of control makes the product more efficient and reliable for usage. Hence, making a perfect combination of affordability and durability.

(e) Hardware



(f) DSO Output

The figures (e) and figure (f) depict the hardware implementation of the Simulink model and the corresponding DSO output that ensures that expected result of speed and torque efficiency is achieved.

CONCLUSION

Thus, the effective speed controlling mechanism has been built that is easy for maintenance, durable and affordable. This considerably decreases the manufacturing cost, making it reachable to more consumers of electric vehicle. The simulation output provided in Fig. 3 and Fig. 4 stands as a proof for the proposed system. The system has been built not only on the basis of cost reduction but also on the intension of providing a system with high accuracy and precision.

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