International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Design of Motion Uniformity of Electric Vehicle through PWM Drive

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DOI: https://doi.org/10.55248/gengpi.5.0224.0537

A B S T R A C T

The different kind of electric motor drive are used in electric vehicle technology. Each motor shows diversity in numerous features like power density, efficiency, speed, cost factor reliability and so on. One of the most popular electric motor drive is using Pulse Wide Modulation (PWM). The method can handle conventional strategy weakness such as switching tasks. The presence of switching losses in controlling BLDC motor to drive electrical vehicle (EV) is very common. The switching losses and back emf influenced the rotation of electric motor. They generate voltage ripple, current ripple, torque ripple, speed response, efficiency and so on. The ripples influence the smoothness of the electric vehicle drive performance. This research proposes the influence of PWM control to drive electric vehicle with monitoring the speed characteristic of electric motor. This research is simulated with Matlab and Simulink to obtained suitable frequency in triggering PWM module. The use of various voltage level at input gives varied speed response. The suitable range of speed response is able to drive the electric vehicle with high performance and smoothly. The research reaches a speed response is 4000 rpm it 4 second. This achievement is obtained with the input voltage 5 Volt. Due to smooth operation the use of PWM drive to electric vehicle, the stability and reliability of the motor rotation and electric vehicle operation could be fulfilled.

Keywords: electric motor drive, PWM, decrease torque ripple, optimization

1. Introduction

The electric vehicle is promising solution to curb the air pollution that caused by fossil fuel engines. The electric vehicle uses battery power with free pollution to drive with clean energy[1]. That they can replace 15% of all conventional engine car in 2040. Electric vehicle used various electric motor drive such as DC motor (shunt and series), induction motor, permanent magnet synchronous motor (PMSM), brushless DC motor (BLDC) and switch reluctance motor (SRM) for driving force. The selection of suitable drive method based on some parameters such as efficiency, reliability, cost, power density and torque to weight ratio. Power density is ratio of capacity to weight of any electric motor. The measurement of power density is using motor apex power. It is computed by apex power yield in (kW) by mass in (kg). The most effective power density is shown by permanent magnet motor. It offers highest power thickness which allowing a powerful and smaller machine frame. The second is induction motor and switched reluctance motor. Further, DC motors have poor power density.

The following requirement of modern electric vehicle can be formulated based on some parameters. They have minimum dimension of motor frame but has high torque, high maximum speed, ability to drive in overload mode, and high stability of each features and so on. The one of the most important feature is high uniformity in motion at different load for all speed. This feature creates a stability and convenient performance of electric vehicle while driving. Besides it also low consumption of energy since the frequency of charging and discharging of battery influence the livelong of battery itself[2]. Therefore, it impossible to reconcile all requirements in one device. In designing and operating such as electric drive in a particular case should meet the one of the requirement. Further, the proper electric vehicle selection of traction motor is related not only to the price/quality criterion. The motor must have satisfactory electromagnetic and mechanical performance. In electric vehicle, technical means are used to control the start and operation of the electric motor. The various control technology offer flow of high current to the load of control system. The starting and adjustment of electric motor become a crucial strategy to obtain satisfied electric vehicle. The control method is design based on technical point of view and economical perspective. When operation of an electric motor uses semiconductor device, due to the fast transistors, a large number of high frequency sinusoidal pulses of the same amplitude and different width are often obtained. The high frequency oscillation can damage insulation of motor winding and lead to premature aging. The use of semiconductor device in operation electric motor need to manage input frequency. The popular method to restrict the frequency is through PWM (manage Pulse Width Modulation) strategy. There are some scheme on PWM strategy implementation. They are High PWM-Low On, High On low-PWM, PWM-On and On-PWM[3]. The detail of the scheme is as shown in Fig. 1 below.

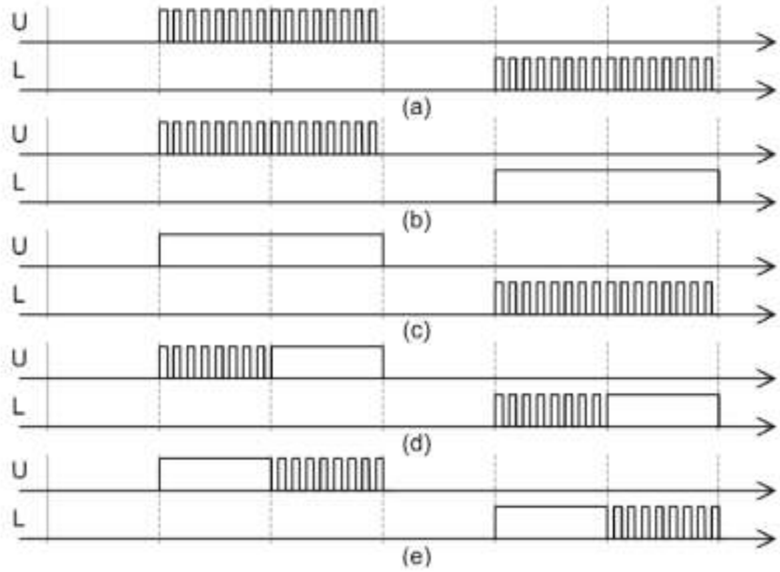


Fig. 1 PWM strategies: (a) bipolar PWM; (b) H-PWM-L-On;(c) H-On-L-PWM; (d) PWM-On and (d) On-PWM[3]

The Fig.1 shows how PWM and its varied used to control driving electric motor, especially BLDC motor. In order to implementation the PWM strategy, the need of switching task is customized with the PWM method requirement. The supporting switching architecture is as shown in Fig.2 below.

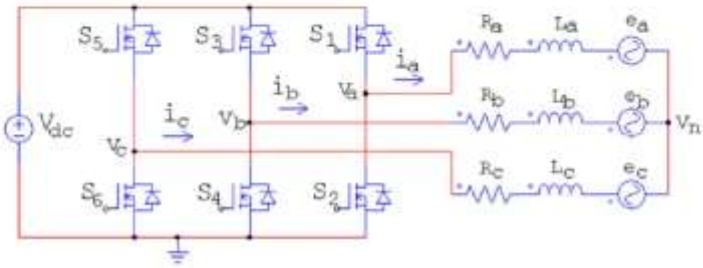


Fig. 2 Basic equivalent switching circuit of 3-phase of BLDC[3]

The Fig.2 shows the combination switches circuit to create various scheme on using PWM strategies to control and drive BDLC motor. The switches contain 6 units of semiconductor devices (S1 – S6). Thus, the BLDC motor contains resistances (Ra,Rb,Rc)and inductances (La,Lb,Lc) load types. Then, emf (ea,eb,ec) is generated by motor coils while rotating.

The equivalent of various scheme of PWM–On, where S3 and S6 the switches are closed. It is as shown in Fig. 3 below.

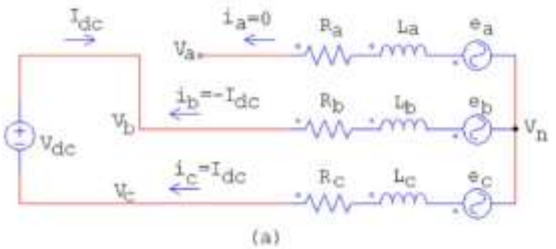


Fig.3 The Equivalent circuit of PWM-On state

Further, other type of switch combination is as shown in Fig. 4 below.

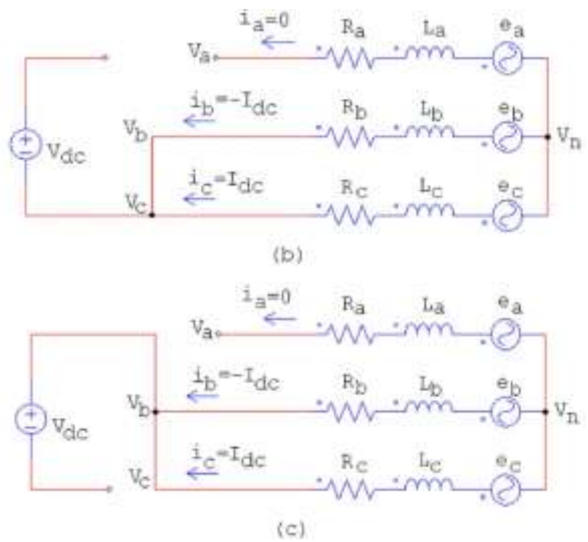


Fig. 4 The Equivalent circuit in (b) Upper switch PWM-Off state; and (c) Lower switch PWM Off state.

Fig.4 (b) shows the equivalent of the circuit PWM –Off state where S3 is turn off. ib is equal to ic which different direction. Otherwise, Fig.4(c) shows the equivalent circuit if S3 and S6 are off condition.

The block diagram on using PWM to control BLDC motor is as shown in Fig. 5 below.

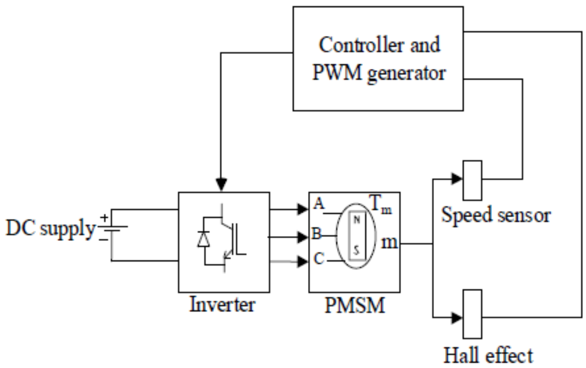


Fig. 5 The block diagram of BLDC motor driving[4]

Fig.5 shows the block diagram of drive BLDC motor. It contains a DC supply, DC-AC converter (inverter), BLDC motor, speed encoder, hall effect censor and a controller[4]. The construction of BLDC motor is as shown in Fig.6.

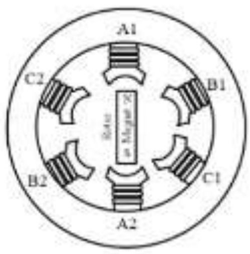


Fig. 6 The construction of BLDC motor[4]

There were many methods to drive BLDC motor in order to obtain smooth performance. This performance is needed in electric vehicle driving. Since the smooth performance was able to keep the motor from premature aging. The use of current control to adjust speed of BLDC motor is implemented in Fig.7[5]. The block diagram of current based on controlling BLDC motor is as shown in Fig. 7 below.

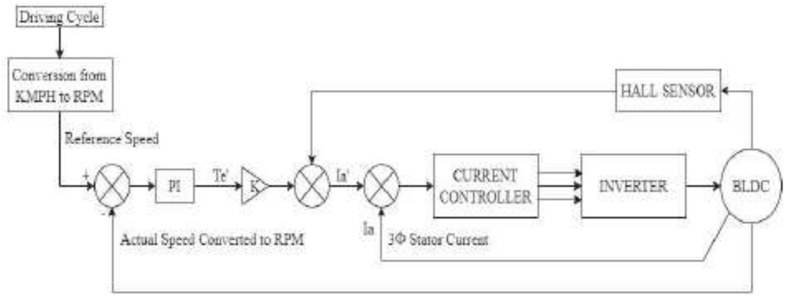


Fig. 7 The block diagram of current based controlling BLDC motor[5]

The Fig.7 shows the current based to control BLDC motor. This method is not able to predict the suitable voltage for magnetic field in BLDC motor. Since, the voltage input and output of controller was not calculated. The torque ripple can be generated in operation of the motor. The other used simple PWM method to handle torque ripple of the BLDC motor[6]. The block diagram of this method is as shown in Fig.8

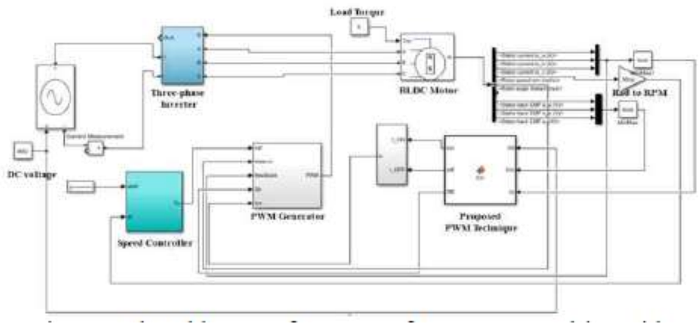


Fig. 8 shows a architecture of closed loop with PWM strategy[6]

In order to increase efficiency the other method used advanced estimator to control BLDC motor[7]. This architecture uses Sensorless to estimate rotor position detail. The block diagram of this method is as shown in Fig. 9.

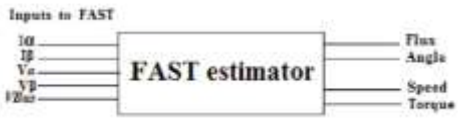


Fig. 9 shows the field oriented control (FOC) provides good torque, low torque ripple and improved efficiency. The programmed controlled measures current Iα, Iβ, voltage Vemf , Vg and Vbus to control flux, angle rotation, speed axis and torque. The method has fluctuated current at the starting phase. So, it need other method to keep the current and speed in good uniformity.

2. Method

In order to keep the speed of BLDC in low ripple, include current, and torque, the method uses PWM strategy and H bridge block to control BLDC motor. The motor has maximum speed at 4000 rpm. It has 12 V source. Otherwise, PWM reference voltage is max value 5 Volt. The detail of diagram block of proposed method is as shown in Fig. 10

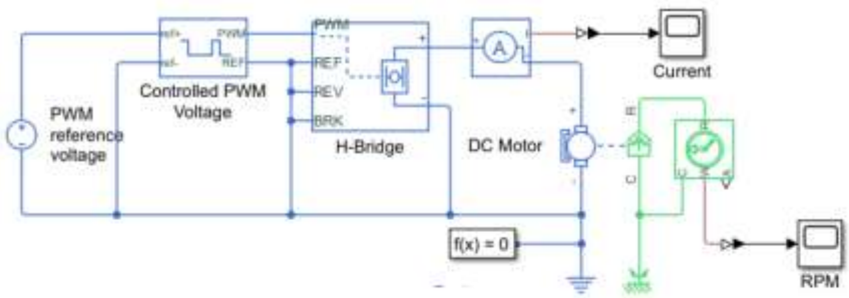


Fig. 10 The PWM strategy with H bridge architecture of proposed method

The method uses various voltage reference. It is from 1 – 5 volt. The method measures the maximum achievement of speed and the time needed to reach the speed stability. The method also measure DC current of the BLDC motor and shaft speed. The motor is simulated using Matlab and Simulink with no load installation.

3. Result

The result of the proposed method is starting with the use of reference voltage 1 Volt. The Motor speed and current is as shown in Fig. 11 below.

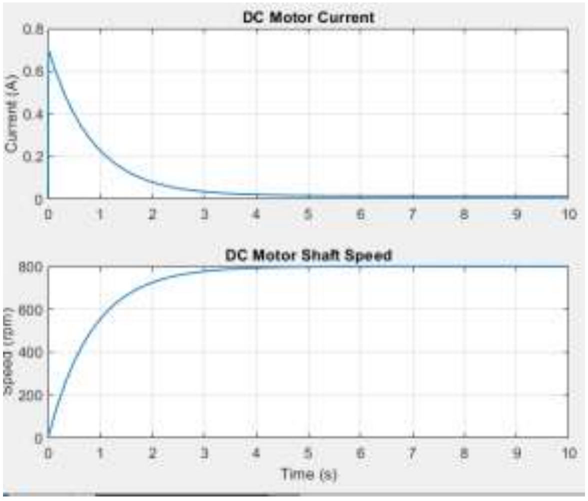


Fig. 11. The graph of using reference voltage 1 volt.

The max speed is obtain at 800 rpm in 4 second. The current also stable in 5 second. The increase of reference voltage is performed in voltage reference in 2 volt. The motor speed is obtained as shown in Fig. 12.

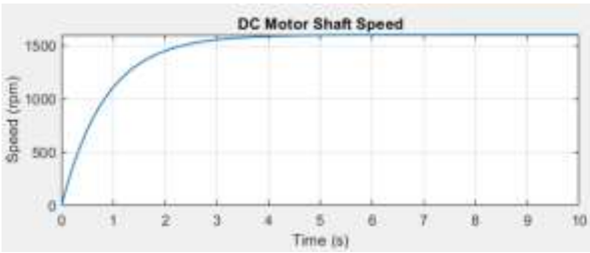
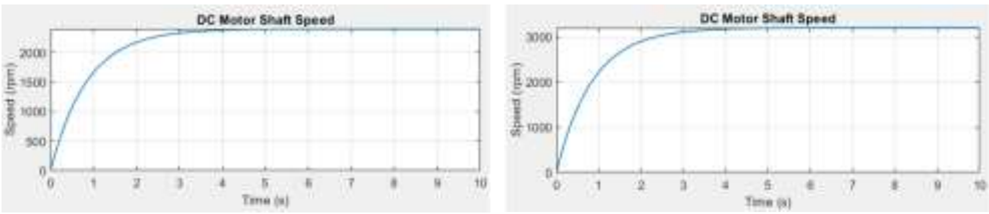


Fig.12 The motor speed at reference voltage 2 volt

Then, other varied reference voltage is 3 and 4 Volt is shown in Fig. 13 (a) and 13(b).



(a) 3 volt (b) 4 volt

Fig. 13 The characteristic of speed when use of reference voltage 3 and 4 volt

Based on Fig. 11 – Fig.13 the speed of motor increase from 800 rpm, 1600 rpm, 2400 rpm and 3200 rpm. The increase 1 volt of reference voltage increases the speed about 800 rpm. Furthermore, the time reaches the stability of speed is constant at 4 second. The speed graph shows the low ripple or it has uniformity in speed. That the electric vehicle can be suitable when using this architecture and setting.

4. Conclusion

The increase of development electric vehicle around the world. There are many methods available to drive the electric vehicle. The conventional techniques used to drive electric motor with various types. The use of DC motor has some drawback such as low on power density, inefficient and high cost. Otherwise, the use of AC motor has low cost in maintenance operation. Now, the highest power density machine is permanent magnetic motors. That the motor is very common used in electric vehicle. One of the permanent magnet motor is BLDC motor. This motor is designed to applied in this research. The drive BLDC motor is supported by PWM strategy. This method is able to decrease torque ripple of the motor. The assessment is done through evaluating shaft speed of the motor. It show that the speed is stable at maximum rate according to reference voltage. The 1 volt of reference voltage is able to produce speed at 800 rpm. Beside the low ripple of speed, the time to reach stability speed is in 4 second. In 4 second, the electric vehicle also reaches the uniformity of motion. That the electric vehicle can drive with low ripple torque and smooth operation. Finally, the proposed method can keep the electric vehicle run in uniformity motion.

References

[1] S. S.Babu andA.Sukesh, "Current Programmed Controlled DC-DC Converter for Emulating the Road Load in Six Phase Induction Motor Drive in Electric Vehicle," 2020 IEEE Int. Conf. Power Electron. Renew. Energy Appl. PEREA 2020, 2020.

[2] S.Rachev, D.Stefanov, L.Dimitrov, andD.Koeva, "Evaluation of Electric Power Losses of an Induction Motor Driving a Compact Electric Vehicle at Change of Parameters and Loads," 2019 Electr. Veh. Int. Conf. EV 2019, pp. 1–5, 2019.

[3] S.Bhogineni andK. R.Rajagopal, "PWM schemes for average line to line voltage based sensorless control of BLDC motor," India Int. Conf. Power Electron. IICPE, pp. 1–6, 2012.

[4] R.Bhosale, W.Warshe, M. P.Shreelakshmi, P.Arlikar, A. K.Prakash, andV.Agarwal, "Performance comparison of Two PWM techniques applied to BLDC motor control," Proc. 2018 IEEE Int. Conf. Power, Instrumentation, Control Comput. PICC 2018, pp. 1–6, 2018.

[5] G.Gupta andM.Sreejeth, "Comparative analysis of Speed control of BLDC motor using PWM and Current Control Techniques," 2022 IEEE IAS Glob. Conf. Emerg. Technol. GlobConET 2022, pp. 610–614, 2022.

[6] Y. K.Lee, "Commutation Torque Ripple Minimization for Three Phase BLDC Motor Drive using A Simple PWM Scheme Reliable to Motor Parameter Variation," Asia-Pacific Power Energy Eng. Conf. APPEEC, vol. 2019-December, no. 11, pp. 4–7, 2019.

[7] S.V.Girish, R. K.Sababathy, S.Vijayakumar, andB.Venkatalakshmi, "Advanced estimator based sensorless BLDC motor control," Proc. 2013 Int. Conf. Adv. Comput. Commun. Informatics, ICACCI 2013, pp. 1748–1752, 2013.

[8] M.Tadic andC.Cuspidi, "Left ventricular strain and arterial hypertension: Is longitudinal strain ready for primetime?," J. Clin. Hypertens., vol. 22, no. 4, pp. 683–685, 2020.

[9] R.Sarfika, Sulistiawati, E.Afriyanti, andI. M. M. Y.Saifudin, "Self-care behavior among adult patients with hypertension in Padang, West Sumatra, Indonesia: A cross-sectional study," Belitung Nurs. J., vol. 9, no. 6, pp. 595–602, 2023.