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An Integrated Control of PMSM Drive for Plug-in Electric Vehicle (PEV)

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ABSTRACT - The electric vehicle is a key new transportation technology to reduce the pollution and to reduce the use of fossil fuel. As the era of cheap fuel is coming to end, the focus on the electric vehicle (EV) is increasing. This Paper proposes a new and simple while cost effective method for plug in electric vehicle with permanent magnet synchronous motor drive (PMSM). An improved method is adopted for controlling the dc link voltage controller. And by designing a vector control mode the dc voltage is used for driving the PMSM which leads the generation of the required torque for the four-wheel drive system. The influence of PWM switching sequences on torque ripple is studied in terms of stator and rotor flux ripples. The influences of proposed system on On-board charging are studied in this paper. Further improving the studies, a system of an integrated charger circuit is designed and tested using vehicle-dynamics. The simulation was carried out in matlab-simulnik

Key Words: Fuel cell, boost converter, dc link voltage controller, PMSM drive, PHEV, Vehicle dynamics.

I. INTRODUCTION

In the modern era of transportation, electric vehicles have attracted the attention of the automotive industry because of the high-efficiency operation. The number of Electric Vehicles is growing dramatically in the last decade because of their low cost and convenience. The basic structure of an electric vehicle is a battery set, power converter, and an AC or DC motor. Now a concept of a hybrid electric vehicle also emerges which gives more efficiency. The fuel cell is the energy source for the traction motors [1]. When considering the performance of different batteries available, the Li-ion battery has more efficiency when compared to other batteries like Ni-cd battery, lead-acid battery, etc [2]. The energy stored in the battery is limited. It can be used only for a duration of time hence it requires an energy management strategy for achieving high efficiency. By considering the dynamic model of the battery the efficiency can be calculated [3]. The pure electric car has the highest efficiency and is also called a Plug-in Electric vehicle. The electrical vehicle classified into two major types plug-in electric vehicle EV[I] and hybrid electric HEV. For achieving energy efficiency and less compatible size the voltage of the battery is amplified for the required level. Why because if we use a battery of 24 V and if the requirement is 600 V, then we have to use 3 by 4 cell to achieve the voltage. it will cause more cost, space conception, and weight. So, DC-DC converters are used for achieving the required voltage which will amplify the cell voltage [4]. The amplified voltage level will be considered as the driving force for the traction motor. The boost converter also controls the power in both directions i.e., the bi-directional power flow. Both in discharging and regenerative braking. By considering a bi-directional boost converter will solve this issue in a better way [5]. Traditional plug-in electric vehicles are used Brushless DC (BLDC) motor. But BLDC motor has some shortcomings comes such as harmonic content in the back EMF. This results in some torque ripple at the motor torque. By comparing the performances of traction motor, the PMSM motors come in the first.it can be used to control the voltage level and torque ripple [6]. The main context in controlling a PEV is the control of torque for the traction. The control should be more robust and reliable [7]. Control techniques are used for torque control because the torque of a motor can't be controlled directly so there has to be some. There are many techniques for controlling the torque in which direct torque control techniques are more reliable [8]. By considering a PMSM motor for the traction purpose there will be fault situations and other failure chances. By designing a PMSM motor these constraints should be kept in mind [9]. The torque can be controlled by controlling the field, voltage, and current to the stator [10]. The dynamic response of the PMSM motor has much importance in vehicle dynamics, the process of testing efficiency of the proposed system with real scenario [11]. Hence Permanent Magnet Synchronous Motor (PMSM) can be used as a replacement for BLDC. An onboard battery pack is used to power the

PMSM motor. The vehicle dynamics, the process of testing the design values with real case environment. There have to be some constraints that should satisfy the process [12]. The constraints considered should be the real environment [13]. The parameters of the vehicle like mass, inertia, wheel dynamics should be in real case [14]. This paper is organized as follows Section II discuss the design specification of the proposed method, Section III variable speed PMSM drive with dc link voltage controller, Section IV design of motor dimension along with the calculation, Section V implementation of the proposed system, Section VI simulation results.

II. TOPOLOGY OF PROPOSED CONVERTER

The battery is the energy source for the vehicle. The introduction of the electric vehicle decreases the usage of petroleum powered vehicle and hence the environmental pollution decreases in a greater extend. Fig-1 represents the block diagram of the proposed method.

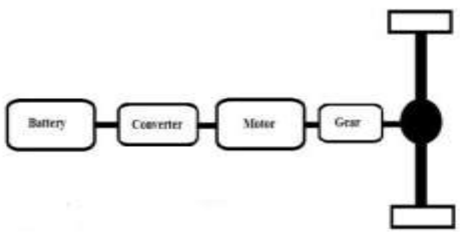

Fig -1: Proposed system

The performance of the electric vehicle is relied on the battery performance. The better choice is the Li- ion battery, which generates DC voltage which is then amplified by a bi directional DC-Dc converter. The amplified voltage is the driving force for the traction motor. Most likely the PMSM motor. The DC-AC inverter is controlled by the torque controller. The torque is generated in such a way that the mechanical torque developed is a constant over variable constraint. By controlling the PMSM motor the torque developed can be controlled and which helps to control the torque. Fig.-2 represents the proposed system.

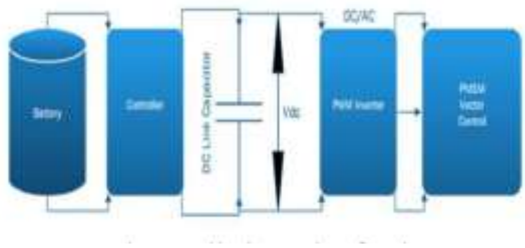

Fig -2: Proposed converter

III. OPERATING PRINCIPLES OF THE PROPOSED CONVERTER

The proposed design is used to control the PMSM motor by using the energy stored in the battery. The mechanical torque developed is the driving force for the proposed system. The voltage potential of the battery is amplified to desired voltage level. The dc link voltage is kept constant through out the operation, for getting higher efficiency. The control is done by implementing a PI controller with bi directional DC-DC converter. The constant dc voltage then inverted into AC voltage which is the driving force for the PMSM motor. The control scheme for the PMSM is done by implementing vector mode control. The ABC-DQ0 transformation is carried out by sensing the stator current and rotor speed. By controlling the both constraints the torque of the PMSM motor is controlled. The designed data are verified by vehicle dynamics with real case values. The constraints are inclination of the road, wind resistance and throttle condition. Fig-3 shows the control of the proposed converter.

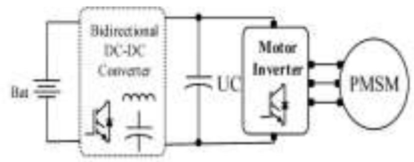

Fig-3: Control of the proposed system

IV. DESIGN OF THE PROPOSED SYSTEM

A battery, bi directional boost converter, PMSM torque controller and vehicle dynamics are the components of the proposed drive line.

4.1 Design of DC link voltage controller

Design of an electric drive for light weight electric vehicle involves the proper selection of motor and battery pack. A 500V PMSM motor with 1000 rpm base speed and 33.9 Nm highest output torque performance will be adequate for a typical PEV. A Li-

Ion battery has used as the power source for the proposed System which has rated capacity of 135Ah and nominal voltage is 365 V. To achieve the goals of the research a DC link voltage controller is used which keeps the voltage constant for PWM inverter.
Vdc can be found by,

V cell = (1 - D) V dclink …………………………………. (1)
V0/V cell = 1/ (1 - Duty cycle) ……………………..……. (2)
Duty cycle = (V cell-V dclink)/V cell…………………..………(3)

A DC link capacitor is used at the input side and a bidirectional boost converter is used to keep provision of recovering energy during regenerative braking. A three phase PWM inverter is used to convert the DC voltage into AC which is fed to the PMSM drive. The required duty cycle for a DC link voltage controller is incorporated in the converter which can keep the output voltage constant by varying the duty cycle of a bi-direction boost converter as per the required input voltage. The desired duty cycle has to operate the bi-directional boost converter which has further been used as the DC link voltage controller. The desired duty cycle is fed to two IGBTs as gate pulse. Fig-4 shows the bi directional DC-DC converter. Lower IGBT will receive duty cycle D and the upper IGBT receive duty cycle (1-D).

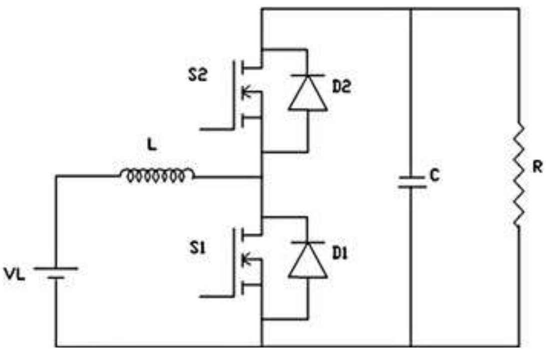

Fig -4: Bi- directional dc-dc converter

A PI controller controls the out put voltage at the desired voltage level. Fig-5 shows the feed forward control of the bi directional DC-DC converter.

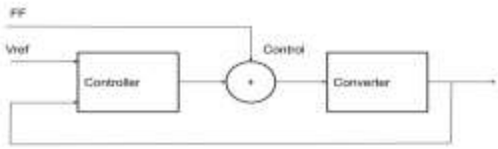

Fig-5: DC link voltage controller

4.2 PMSM drive

To control the speed of a PMSM motor vector control is widely used. It requires axis transformation hence the rotor angle information is provided by using a speed sensor. To regulate the direct axis (d-axis) and quadrature axis (q-axis) current two PI controllers are used. Similarly, a speed controller is needed to translate the speed command into d-axis current. Field weakening technique is not used in the proposed design hence the d-axis current command is kept as zero. By using current regulator required current for a commanded speed can be regulated for the PMSM drive. Here the three-phase current taken from the three-phase inverter is converted into two orthogonal d and q axis component. Fig-6 shows the torque controller.

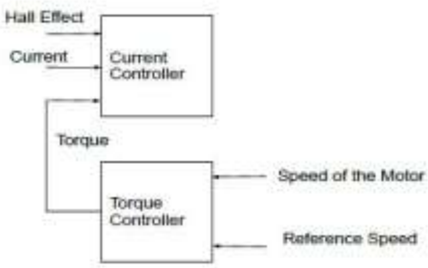

Fig-6: Torque controller

These two components of current are then tuned by using two PI controllers. For variable speed operation, the injected current to the motor must be varies according to speed command. A speed regulator will translate the desired speed command to torque command.

With permanent magnets on the on the rotor, losses from the field winding are minimised, Parameters which are for the better efficiency of PMSM motor are, PMSM motors have high power to weight ratio, large speed range, high power density, etc. Table-1 gives the PMSM parameter

Table -1: PMSM

Sl. No	Parameters	Value
1	Nominal power	3.5 KW
2	Voltage	415 V
3	Frequency	50 Hz
4	Synchronous speed	1500 rpm
5	power factor	.9
6	magnetic flux density	Wb=mA2
7	pole	2

4.3 Vehicle Dynamics

The vehicle dynamics is the model which consider longitudinal dynamics. The mechanical torque developed by the PMSM motor is the input to the system. The vehicle velocity is the output. The constraints used are inclination of the road, wind resistance, throttle of the vehicle. For the smooth operation the driving force should be equal to resistance force. Fig-7 shows the forces acting on the vehicle.

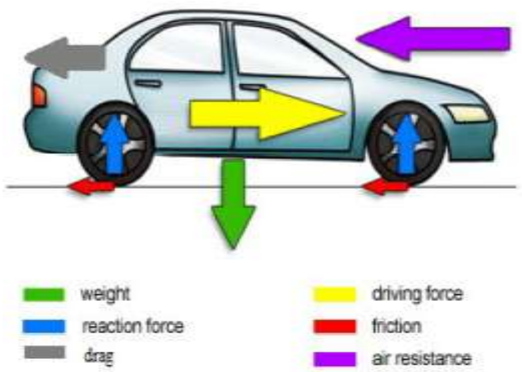

Fig-7: Forces acting on the vehicle

The vehicle dynamics helps to get reference from the real case environment and values. It includes library of modeling propulsion, steering, suspension, etc. Table 2 shows the parameters used for the vehicle dynamics.

Table -2: Vehicle dynamics

Sl. No	Parameters	Value
1	Mass of Car(W)	1500 Kg
2	Max Speed (v)	100 Km/hr
3	Rolling resistance (Wr)	120 Kg
4	Aerodynamic or Wind resistance (WA)	81.31 Kg
5	Gradient resistance (Wg)	704.20 Kg
6	Total weight (WT)	2405.54 Kg
7	Propulsion force	500 Nm

V. CONTROL SCHEME OF DRIVE LINE

5.1 DC link control

DC link control is the essential part of the on-board charge control. The factors considered when designing a DC link voltage controller are cost, environment, reliability and specifications. DC link capacitors are introduced in order to reduce the ripples and improves the overall efficiency. The DC-DC controller is implemented with feed forward voltage controller. Switching pulses are generated by optimizing the transient response of the reference.

The voltage controller works as below.

Gate pulse = (Kp + Ki*(TsZ/Z – 1))(vref ⎕ v) + FF ……….(4)

here:

Kp: proportional gain of PI controller.

Ki: integral gain of PI controller.

Ts: sample time of PI controller.

Vref: required voltage

5.2 PMSM control

PMSM control is the stager proceeding to dc link. For the smooth operation of the PEV requires a minimum torque. The torque is being controlled by control scheme. Fig-8 shows the proposed torque controller.

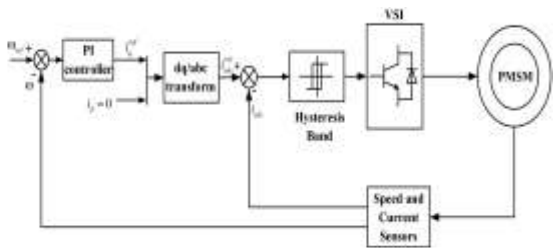

Fig-8: Torque controller

For controlling the torque, the speed of the rotor and stator current are sensed. The error signal is generated with the help of a PI controller. Thew error signal is then converted into ABC-DQ0 frame. In the proposed system the torque is controlled by measuring the speed of the rotor and the stator current. Fig -9 shows the torque reference control scheme for the proposed system.

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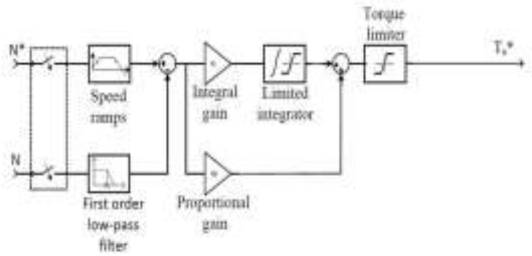

Fig-9: Torque reference measurement

In the proposed control hysteresis current controller is used for the generation of switching pulses. Reference torque and current gives required pulse for switching.

5.3 Vehicle Dynamics

Vehicle dynamics is the validation of the designed data with the help of real-life constraints. Fig -10 shows the control scheme for the vehicle dynamics. In the vehicle dynamics the mechanical torque is the input, the real case conditions are the constraints and the velocity of the vehicle is the output. The constraints are throttler, inclination and wind resistance. Fig-11 shows the torque distribution over the vehicle dynamics over front and rear tires.

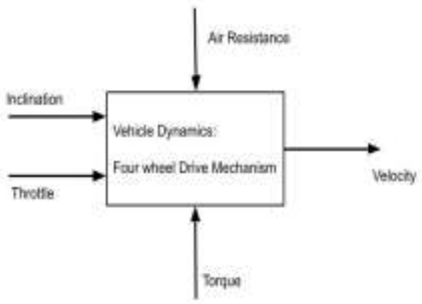

Fig-10: Vehicle Dynamics

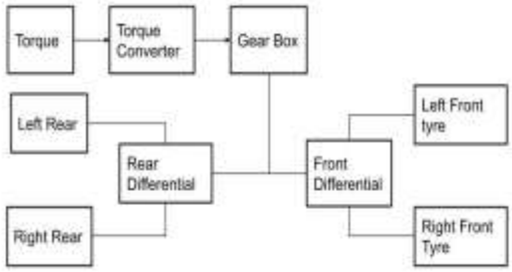

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Fig- 11: Torque distribution over the tier

In this proposed system a 2 axle 4-wheel drive car is considered.

VI. RESULT AND DISCUSSION

A 3.6-kw system is developed and verified using MATLAB/ Simulink. The Li-ion battery of 84 V is used as the source. The frequency selected for DC link controller is 10KHz and that of PMSM controller is 20 KHZ. Fig-12 shows the battery V-I characteristics. For the smooth operation the voltage is amplified to 600 V. Fig-13 shows the steady state performance of the vehicle. The DC link voltage is maintained at 600 V. The dc link current is varying with switching pulse. the average value of the current is zero over a cycle. The dc link current is also a constant over steady state performance. Fig -14 shows the dynamic response of the Dc link controller. Over the period the load condition is varied, rotor speed is varied. The dc link voltage retains its reference, which will not affect the stability of the system.

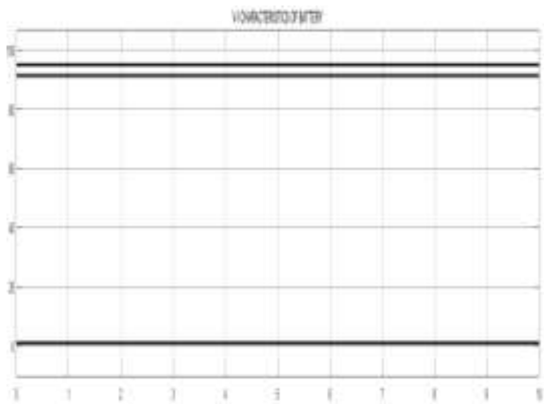

Fig-12: Battery characteristics

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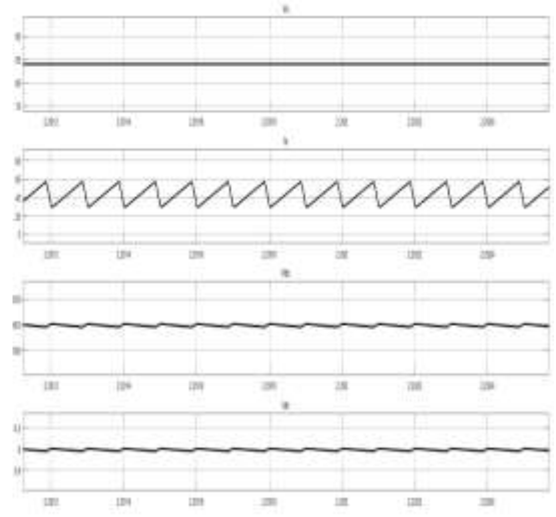

Fig-13: Steady state performance

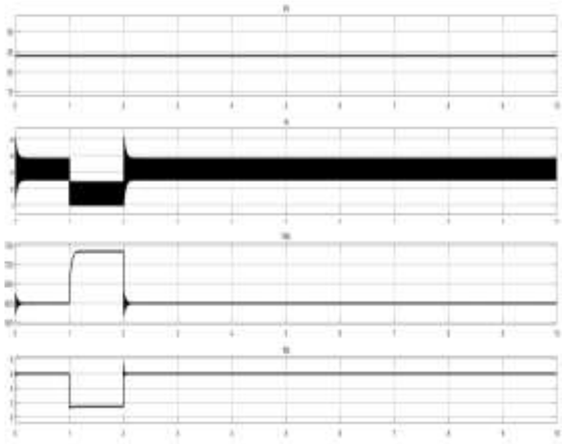

Fig-14: Dynamic performance

Fig-15 shows the steady state performance of the drive line. That is the rotor speed is kept constant the load variation is kept zero.

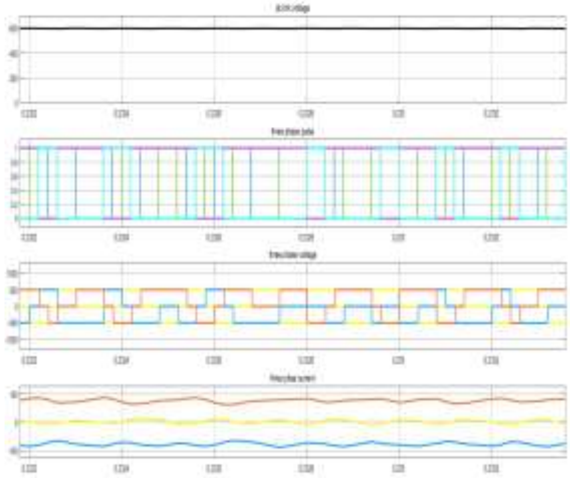

Fig-15: Steady state performance of PMSM

From the figure its clear that the pulse generated is accordance with the load change. The dc link voltage is inverted to required voltage level for the smooth operation of the PMSM. Fig-16 shows the rotor speed variation with torque development. the torque developed will be constant.

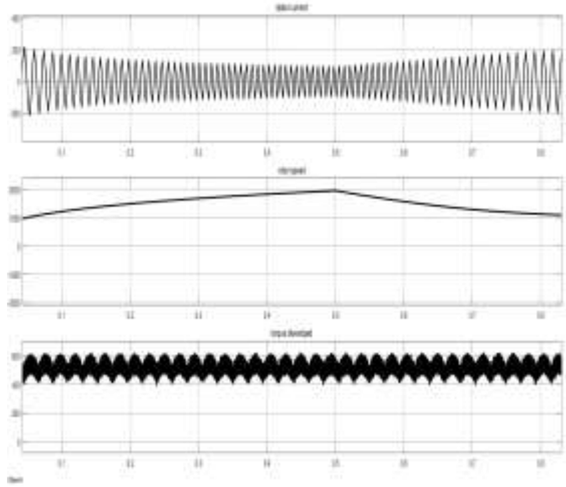

Fig-16: Torque-current characteristics

During the operation even if the rotor speed is varied the torque developed is kept constant by controlling the ABC-dq0 transformation of the stator current.

Now consider the vehicle dynamics, the testing of the given data with real time values. Fig-17 shows the performance of the vehicle. Fig-18 shows the vehicle under variable constraints. The constraints wind, throttle, inclination is varied during the simulation. Which leads to the variation in the speed but the performance of the doesn't decreases even if the velocity decreases. The response of the vehicle is high enough to keep the vehicle in high performance.

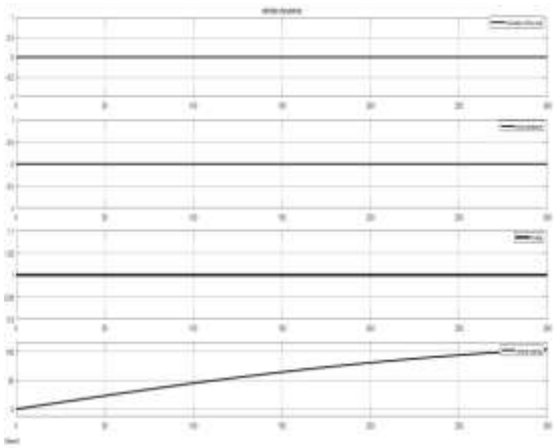

Fig-17 : Vehicle dynamics under steady state

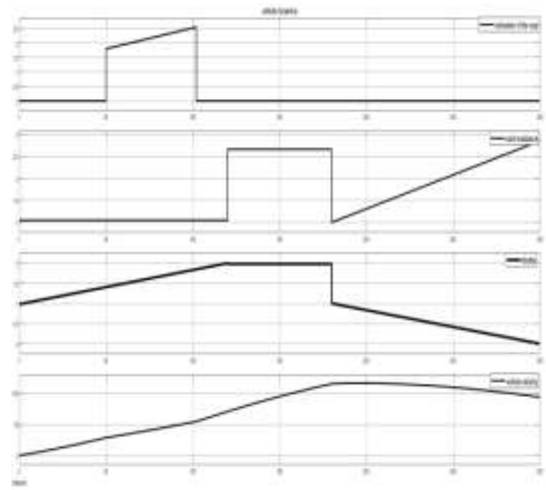

Fig-18: Vehicle dynamics under steady state

VII. SUMMARY

In this proposed paper, the performance of a plug-in electric car is analyzed and verified using vehicle dynamics with real case environment. Vehicle dynamics under steady state and dynamics conditions are evaluated. The results shows that the vehicle is high efficiency over the real case environment. The proposed design well a replacement for the conventional transportation vehicle. The power requirement for the drive line is designed and tested. New concept of torque control of PMSM motor is implemented. The analysis gives the idea about the new concept of drive line. The speed of the vehicle can be controlled by controlling the PMSM motor.

REFERENCES

[1] G. Tomazic, "Considerations regarding the comparison of traction batteries," Proceedings of 9th Annual Battery Conference on Applications and Advances, 1994, pp. 96-103, doi: 10.1109/BCAA.1994.283610.

[2] S. Podder and M. Z. R. Khan, "Comparison of lead acid and Li-ion battery in solar home system of Bangladesh," 2016 5th International Conference on Informatics, Electronics and Vision (ICIEV), 2016, pp. 434-438, doi: 10.1109/ICIEV.2016.7760041.

[3] N. Mars, F. Krouz, F. Louar and L. Sbita, "Comparison study of different dynamic battery model," 2017 International Conference on Green Energy Conversion Systems (GECS), 2017, pp. 1-6, doi: 10.1109/GECS.2017.8066241.

[4] T. W. Hariyadi and A. Adriansyah, "Comparison of DC-DC Converters Boost Type in Optimizing the Use of Solar Panels," 2020 2nd International Conference on Broadband Communications, Wireless Sensors and Powering (BCWSP), 2020, pp. 189-194, doi: 10.1109/BCWSP50066.2020.9249464.

[5] Z. Kan, P. Li, R. Yuan and C. Zhang, "Interleaved three-level bi-directional DC-DC converter and power flow control," 2018 3rd International Conference on Intelligent Green Building and Smart Grid (IGBSG), 2018, pp. 1-4, doi: 10.1109/IGBSG.2018.8393534.

[6] A. M. Saleque, A. M. A. Khan, S. H. Khan, E. Islam and M. N. Chowdhury, "Variable speed PMSM drive with DC link voltage controller for light weight electric vehicle," 2017 International Conference on Electrical, Computer and Communication Engineering (ECCE), 2017, pp. 145-151, doi: 10.1109/ECACE.2017.7912896.

[7] X. Ma, Y. Yu, H. Zhang, W. Wang and L. Liu, "Study on direct torque control of dual Y shift 30 degree six-phase PMSM," 2015 IEEE 10th Conference on Industrial Electronics and Applications (ICIEA), 2015, pp. 1964-1968, doi: 10.1109/ICIEA.2015.7334434.

[8] M. Abassi, A. Khlaief, O. Saadaoui, A. Chaari and M. Boussak, "Performance analysis of PMSM DTC drives under inverter fault," 2017 International Conference on Advanced Systems and Electric Technologies (IC_ASET), 2017, pp. 244-249, doi: 10.1109/ASET.2017.7983699.

[9] O. M. Abassi, I. Saadaoui, A. Tlili, A. C. Khlaief and M. Boussak, "PMSM DTC drive system fed by fault-tolerant inverter connected to a photovoltaic source," 2018 9th International Renewable Energy Congress

(IREC), 2018, pp. 1-5, doi: 10.1109/IREC.2018.8362559.

[10] R. Dou, F. Song, H. Liu and X. Men, "Demagnetization Quantification of PMSM Based on Support Vector Regression," 2018 Prognostics and System Health Management Conference (PHM-Chongqing), 2018, pp. 619-623, doi: 10.1109/PHM-Chongqing.2018.00111.

[11] Zhifu Wang, Ye Huiping, Yupu Wang and Shi Jianjun, "Dynamic control of motor torque during the shifting process in PMSM-AMT system," 2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific), 2014, pp. 1-5, doi: 10.1109/ITEC-AP.2014.6940893.

[12] Y. Boukadida, A. Masmoudi, G. M. Casolino and F. Marignetti, "A simple assessment of the dynamics of the road vehicles," 2018 Thirteenth International Conference on Ecological Vehicles and Renewable Energies (EVER), 2018, pp. 1-6, doi: 10.1109/EVER.2018.8362416.

[13] J. Zhang and X. Liu-Henke, "Model-based design of the vehicle dynamics control for an omnidirectional automated guided vehicle (AGV)," 2020 International Conference Mechatronic Systems and Materials (MSM), 2020, pp. 1-6, doi: 10.1109/MSM49833.2020.9202248.

[14] S. Kulothungan, R. V. Anirudh, K. Sivashankar and A. K. Dash, "Design and Development of a Vehicle Dynamics Model for a Drive Simulator," 2018 3rd International Conference on Communication and Electronics Systems (ICCES), 2018, pp. 153-156, doi: 10.1109/CESYS.2018.8723987.