



MODELLING AND SIMULATION OF ELECTRIC VEHICLE USING MATLAB

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ABSTRACT

In this project we discuss about the modelling and simulation is held between the two different types of electric motors that are used in electric vehicles. By this project we will compare the performance of different types of motors. The power consumption of motors and heat generated by the motor. These comparison between motor helps us to know the which motor has best performance and which motor is more power efficient and which motor is suitable for use in electric vehicles. Because, as we all know that in these upgrading world we are searching alternative for the fuel based vehicles. The usage of fuel is increasing and the production of fuel is decreasing these leads to the increases the cost of fuel. In this situation we have only choice that is electric vehicles. With the electric vehicles we have both advantages and disadvantages. So we need to calculate lot of mathematical calculations. The electric vehicles runs on the batteries so we need to charge the vehicle frequently. To charge the vehicle we need charging stations. To overcome from these types of problems we need to improve the range of electric vehicle by using better performance motor which runs on low power and which gives maximum performance. So in this project we compare the different motors to analyses the performance of motors. MATLAB-SIMULINK is used to create and simulate a mathematical model of a fieldoriented controlled Permanent Magnet motor driving system. Today, the use of Permanent Magnet Synchronous Motors (PMSM) is expanding in various sectors (particularly in the machine tool industry) due to their smaller size, lighter weight, and lower rotor loss when compared to induction motors of same capacity.

PERMANENT MAGNET SYNCHRONOUS MOTOR:

Permanent Magnet Synchronous Motors (PMSM) are commonly utilized in low and mid-power applications such as computer peripherals, robotics, variable-speed motors, and electric vehicles. The demand for simulation systems capable of handling motor drive simulations has increased as the market for Permanent Magnet motor drives has grown. By decreasing cost and time, simulations have aided the development of innovative technologies.

T. Sebastian [1] examined improvements in Permanent Magnet Synchronous Motors and developed analogous electric circuit models for such motors and measured parameters and calculated parameters the results of experiments on laboratory motors were also presented. Permanent Magnet motor drives were presented by P. Pillay in [2], and they were divided into two types: Permanent Magnet Synchronous Motor (PMSM) and Brushless DC Motor (BDCM) drives. To produce constant torque, the PMSM has a sinusoidal back emf and requires sinusoidal stator currents, whereas the BDCM has a trapezoidal back emf and requires rectangular stator currents. B. Cui [3] uses the state space method to model and simulate a permanent magnet synchronous motor powered by a sixstep continuous inverter.

Basic Model of the System:

The motor drive consists of four main components, the PM motor, inverter, control unit and the position sensor. The components are connected as shown

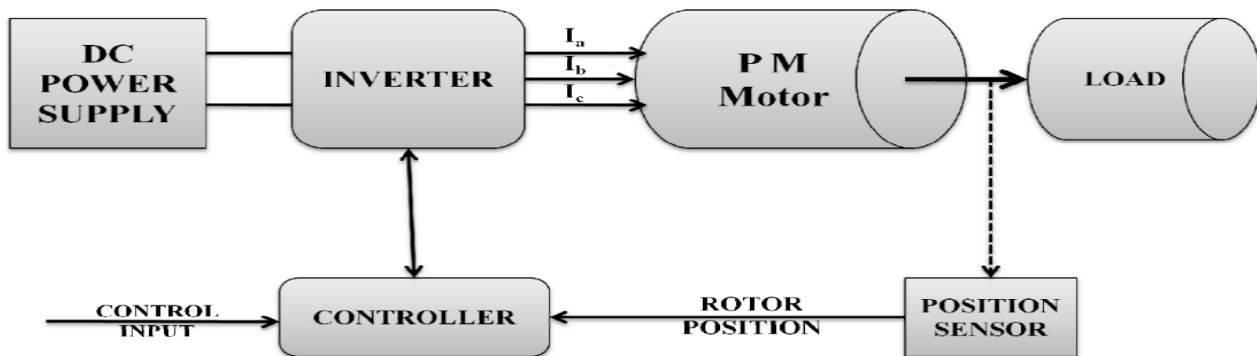


Fig.1. Schematic of the Drive System

The main components of the system are:

1. Permanent Magnet Synchronous Motor
2. Various Position Sensors

Incremental Encoders

Incremental encoders provide excellent precision and are simple to construct, but they lack information when the motor is at rest, and the motor must be stopped at the beginning point for accurate position.

Optical Encoders

Optical encoders are the most common form of encoder used in industry. A revolving disc, a light source, and a photo detector make up this system. The disc has coded patterns of opaque and transparent sectors and is positioned on the spinning shaft. These patterns interrupt the light emitted onto the photo detector as the disc spins, resulting in a digital pulse or output signal.

Absolute Encoders

The rotor's precise location is determined by the absolute encoder's accuracy, which is proportional to the encoder's bit count. It can spin endlessly, and the location can be monitored or acquired even if the engine stops.

Position Revolver

Rotating transformers are another name for position revolvers. The primary winding is situated on the rotor, similar to how a transformer works. The induced voltage at the transformer's two secondary windings is altered by 90 degrees depending on the rotor shaft angle. Two voltages can be used to compute the location.

Inverter

Devices that convert a DC voltage to an AC voltage with a changeable frequency and magnitude are known as voltage source inverters. They're often employed in variable-speed drives, and they have a well-defined switching voltage waveform in the terminals.

Controller :

The controller will use the inverter to create the reference currents within a range determined by the band gap width. The intended current of a certain phase is added to the negative of the observed current in this controller. The error is delivered into a hysteresis band comparator. The upper switch of the inverter leg is switched on when the error passes the lower limit of the hysteresis band. When the current tries to fall below the upper reference band, the bottom switch is activated.

Load :

Switches are utilised in inverter power electronics. The switch is chosen based on its power and switching capabilities. The power devices and their switching capabilities are listed in Table 1 below. Because an AC current regulator must manage both the amplitude and phase of the stator current, current regulators for AC drives are complicated. The AC drive current regulator is part of the overall motion controller's inner loop. As a result, it must have the highest bandwidth in the system and a steady-state error of zero or nearly zero. Controlled current modes are available for both current source inverters (CSI) and voltage source inverters (VSI). The current source inverter is a natural current supply that may easily be modified to operate with regulated current. When compared to the CSI, the voltage source inverter needs more complexity in the current regulator but provides significantly better bandwidth and eliminates current harmonics, and is virtually solely utilised for motion control applications.

Equivalent Circuit of Permanent Magnet Synchronous Motor:

Motor equivalent circuits are utilised in the research and modelling of motors. The equivalent circuit of the motor may be determined from the d-q modelling of the motor using the stator voltage equations. Assume that the flux from the permanent magnets in the rotor d axis is represented by a constant current source, as shown in the equation below.

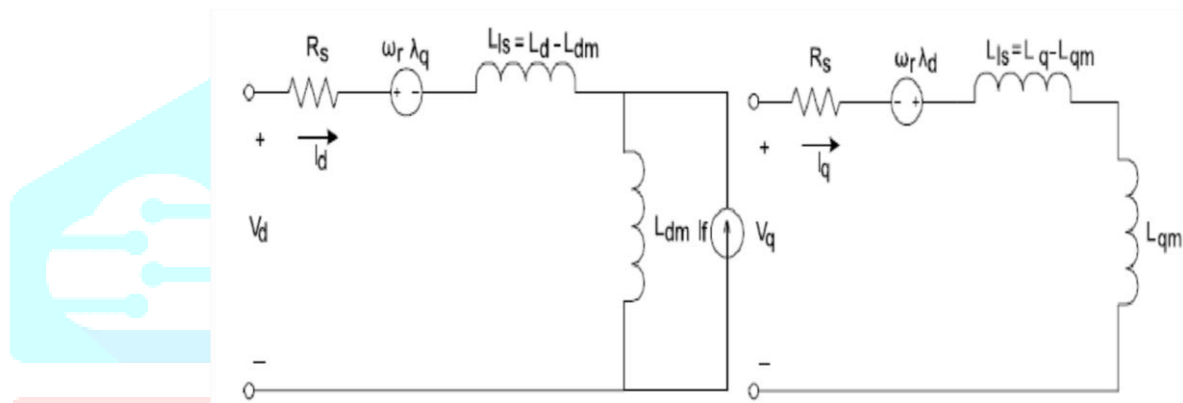


Fig .2. PMSM Electric circuit

Mathematical Equations of PMSM:

Stator voltage in the q axis:

$$V_q = r_s i_q + p(\lambda_q) + \omega_r \lambda_d \quad \rightarrow (1)$$

Stator voltage in the d axis:

$$V_d = r_s i_d + p(\lambda_d) - \omega_r \lambda_q \quad \rightarrow (2)$$

Stator flux in the q axis:

$$\lambda_q = L_q i_q \quad \rightarrow (3)$$

Stator flux in the d axis:

$$\lambda_d = L_d i_d + \lambda_{af} \quad \rightarrow (4)$$

Electrical speed:

$$\omega_r = P/2 \omega_m \quad \rightarrow (5)$$

Electromagnetic torque:

$$\begin{aligned} T_e &= 3/2 P/2 (\lambda_d i_q - \lambda_q i_d) \\ &= 3/2 P/2 (\lambda_m i_q + (L_d - L_q) i_d i_q) \quad \rightarrow (6) \end{aligned}$$

Mechanical equation:

$$T_e = T_L + T_d + B\omega_{rm} + Jp(\omega_{rm}) \quad \rightarrow (7)$$

Drive System in MATLAB / SIMULINK :

PMSM mechanical model, step load, relay, sub-system blocks, Multiplexers (MUX), De-multiplexers (DEMUX), and several Scopes for screening the results are all included in this Simulink model of the PMSM drive system.

The Constant block creates a constant value that might be real or complicated. In addition, depending on the Sampling mode selection, the block can generate either a sample-based or frame-based signal. The output of the speed reference block is compared to the current reference. The input from the speed reference is processed by the PI controller, which is a Subsystem block that represents a subsystem of the system it is part of. A virtual or non-virtual subsystem can be represented via the Subsystem block. Permanent magnets are at the heart of the system. The d-axis and q-axis voltages are provided to the Synchronous Motor model block. After converting to an ABC model, which shows input signals with regard to simulation time, the output of the PMSM Mechanical model, which is d-axis and q-axis current as well as torque created, is connected to the different Scopes. The role of a relay is to switch output between two constants, whereas a step load is used to generate a step function and also to offer a step between two definable levels at a predetermined period.

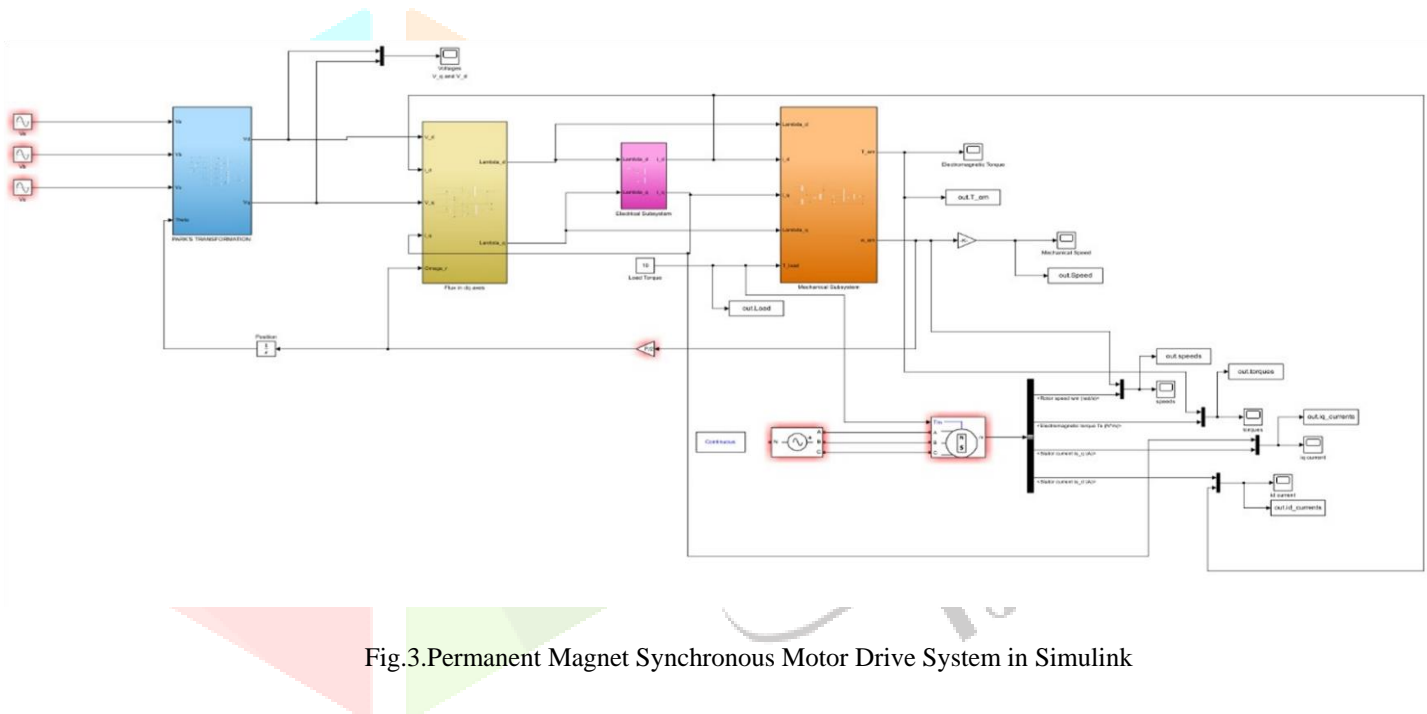


Fig.3. Permanent Magnet Synchronous Motor Drive System in Simulink

DC MOTOR:

INTRODUCTION:

Any rotary electrical motor that transforms direct current electrical energy into mechanical energy is referred to as a DC motor. The most popular varieties rely on magnetic fields to create forces. Almost all DC motors contain an internal mechanism, either electromechanical or electronic, that changes the direction of current in a section of the motor on a regular basis.

Because they could be supplied by existing direct-current lighting power distribution networks, DC motors were the first type of motor to become extensively employed. The speed of a DC motor may be varied across a Tools, toys, and appliances all employ small DC motors. The universal motor is a lightweight brushed motor that can run on direct current and is used in portable power tools and appliances. Larger DC motors are being employed in electric vehicle propulsion, elevator and hoist drives, and steel rolling mill drives. With the introduction of power electronics, it is now possible to replace DC motors with AC motors in a variety of applications. Large range by varying the supply voltage or adjusting the current intensity in the field windings. Automobile manufacturers collaborate with scientific research organizations and technical colleges to produce a variety of electric motors that are specifically designed for use in automotive applications. As a consequence, numerous types of electric motors, such as DC motors, induction motors, and variable magnetic resistance motors, were chosen for usage in

automobiles. The three-phase inductive motor is the most often used and now the most ubiquitous, followed by the series DC motor. A series DC motor will be investigated in this study, which is employed in electric propulsion in general and electric automobiles in particular. MATLAB/SIMULINK will be used to model and simulate the operating equations of such motors and their equivalent electric circuits. To drive and regulate the speed of this motor, an appropriate switching electronic controller based on PWM method is utilised; this controller was also created in the same comprehensive computer model. This entire model was used to simulate the motor and inverter. The results are analyzed and discussed in order to use this series DC motor to convert a small truck automobile into an electric vehicle at Damascus University's Faculty of Mechanical and Electrical Engineering. The investigation of motor performance was done under the assumptions of changing car load from one passenger (the driver) to six passengers, as well as motor performance while an electric car is driven with various load torques on varying road slopes and on country roads.

Mathematical Model of Series DC Motor:

In terms of speed control and regulation with great precision and tiny increments, DC motors are regarded the best type of motor. The following electrical specifications were used in a practical case study on the management of a series DC motor built for traction applications. The ability to change the direction of rotation by switching the polarity of the input Voltage is a benefit of employing this type of motor. This motor provides a high torque that is proportional to the load current's square value. The similar circuit for a series DC motor is shown

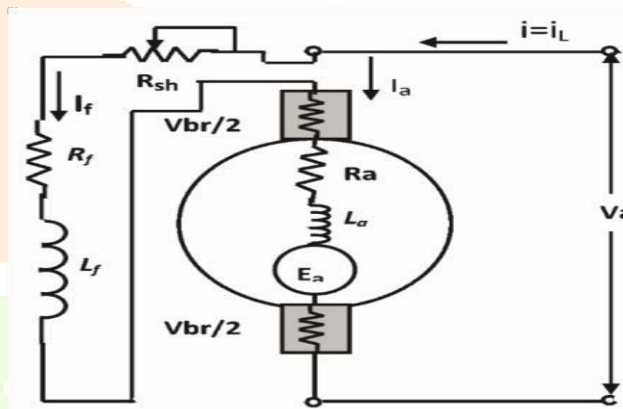


Fig.4. Armature controlled SEDC motor

Mathematical Equations of DC Motor:

Field volt is maintained constant. Hence field will remain constant.

$$k_e \Phi = \text{constant}$$

$$v_a = i_a R_a + L_a \frac{di_a}{dt} + E_b \quad \rightarrow (1)$$

$$E_b = (k_e \Phi) \omega_m \quad \rightarrow (2)$$

$$T_m = (k_e \Phi) I_a = I_L + J \frac{d\omega_m}{dt} + B \omega_m \quad \rightarrow (3)$$

Taking Laplace transforms for eq (1)

$$V_a(s) - E_b(s) = i_a(s) [R_a + sL_a] \quad \rightarrow (4)$$

$$I_a(s) = \frac{v_a(s) - E_b(s)}{R_a + sL_a}$$

$$= \frac{v_a(s) - E_b(s)}{R_a (1 + \frac{sL_a}{R_a})}$$

$$\frac{L_a}{R_a} = T_a \quad \square \text{ time constant of armature circuit}$$

Hence
$$I_a(s) = \frac{va(s) - Eb(s)}{Ra(1+sLa)}$$

$$\frac{va(s) - (ke \phi) \omega_m(s)}{Ra(1+sLa)} \rightarrow (5)$$

Laplace for eq (5)

$$T_m(s) - T_L(s) = \omega_m(s)[B + sJ] \rightarrow (6)$$

$$\omega_m(s) = \frac{Tm(s) - TL(s)}{B + sJ}$$

$$\omega_m(s) = \frac{Tm(s) - TL(s)}{B(1 + s\frac{J}{B})}$$

$\frac{J}{B} = T_m$, where T_m is mechanical time constant of motor

Hence, motor speed is

$$\omega_m(s) = \frac{Tm(s) - TL(s)}{B(1 + sTm)} = \frac{(ke \phi) Ia(s) - TL(s)}{B(1 + sTm)} \rightarrow (7)$$

Drive System in MATLAB / SIMULINK:

The following model was generated using MATLAB/SIMULINK tools and illustrated based on the mathematical model of dynamic state for the series DC motor indicated before. The control system in use is a closed loop system that maintains a constant output despite changes in the system's operational parameters. This is accomplished by sampling the system's output and comparing it to intended values on a regular basis, providing feedback on output value faults to the PID controller for processing. The control systems used in continuous PID controllers are commonly used to address the error signal based on the desired parameters such as speed, torque, current, and position, and to adjust the values of these parameters to achieve better transient response through several criteria, including relative deviation of the output such as speed, control the speed of response, static error, and the system oscillating.

The proportional part of the controller is commonly used to address problems with speed of response, while the integral amplifier part is used to process errors that occur in the steady-state, and the differential part plays a complementary role in damping oscillations that occur in a transient state while reaching the desired state. The pedal-based control used to drive a DC motor in an electric automobile is based on the PWM (Pulse Width Modulation) technology, which is one of the most recent ways for controlling motors and delivers lower power loss.

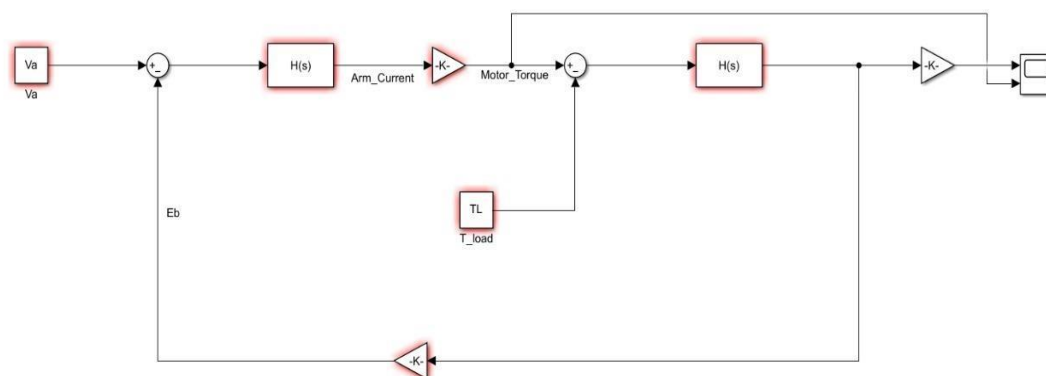


Fig.5. Simulation model of series DC motor

SIMULATION RESULT & DISCUSSION:

Permanent Magnet Synchronous Motor:

At the constant torque and flux-weakening areas of operation, the suggested approach designed in Simulink for a PMSM drive system was compared to the two current control methods, Hysteresis and PI controller. The motor is driven with constant torque until it reaches its rated speed, at which point it switches to flux-weakening mode. The three phase currents generated by the motor as a result of the hysteresis current control are shown in Figure 6. Park's reverse transformation is used to derive the currents. The current is clearly non-sinusoidal during start-up and becomes sinusoidal when the motor reaches the controller command speed at steady state.

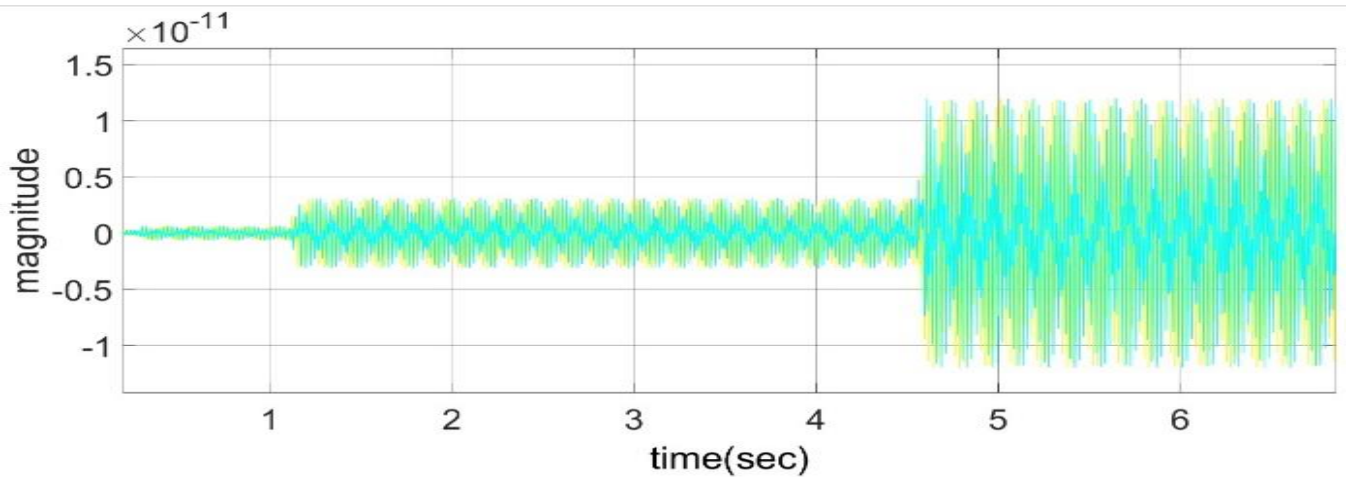


Fig.6. q-axis voltage (V_q) and d-axis voltage (V_d)

i_q and i_d components of current with respect to time, and it is noticed that the magnitude of the i_q component of the current is initially high, but after a specified time period, it achieves a stable state and remains steady with regard to time. The value of i_d is zero since field oriented control is employed.

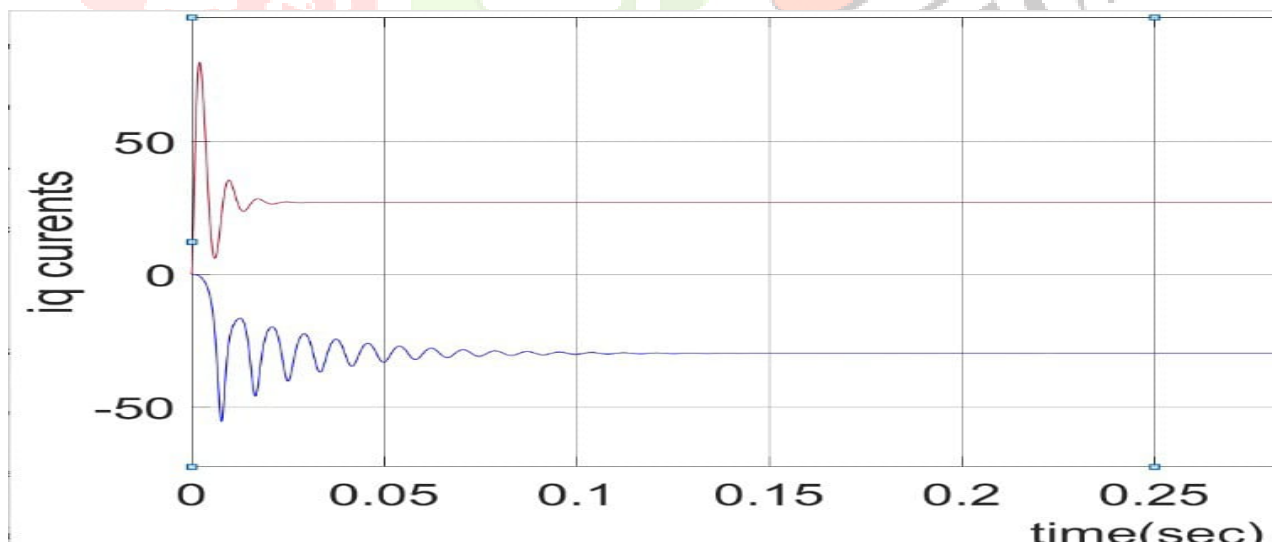


Fig.7. i_q current in PMSM

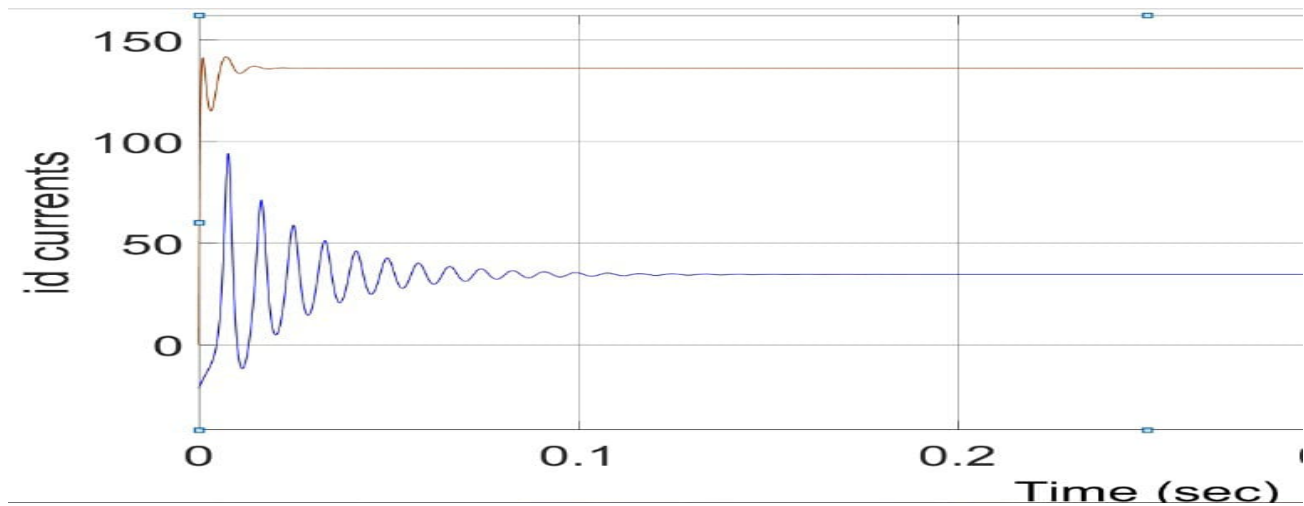


Fig.8.Id current in PMSM

Electro Magnetic Torque:

The motor's produced torque. Starting torque is double the steady state value for the beginning time, i.e. from 0 to 0.01 seconds. After 0.03 seconds, the torque will remain constant, and the value of this constant torque, as shown on the Torque Vs Speed graph, is 1.12 Nm. After 0.023 seconds, the actual torque is found to be following the reference torque. The torque density is also found to be satisfactory.

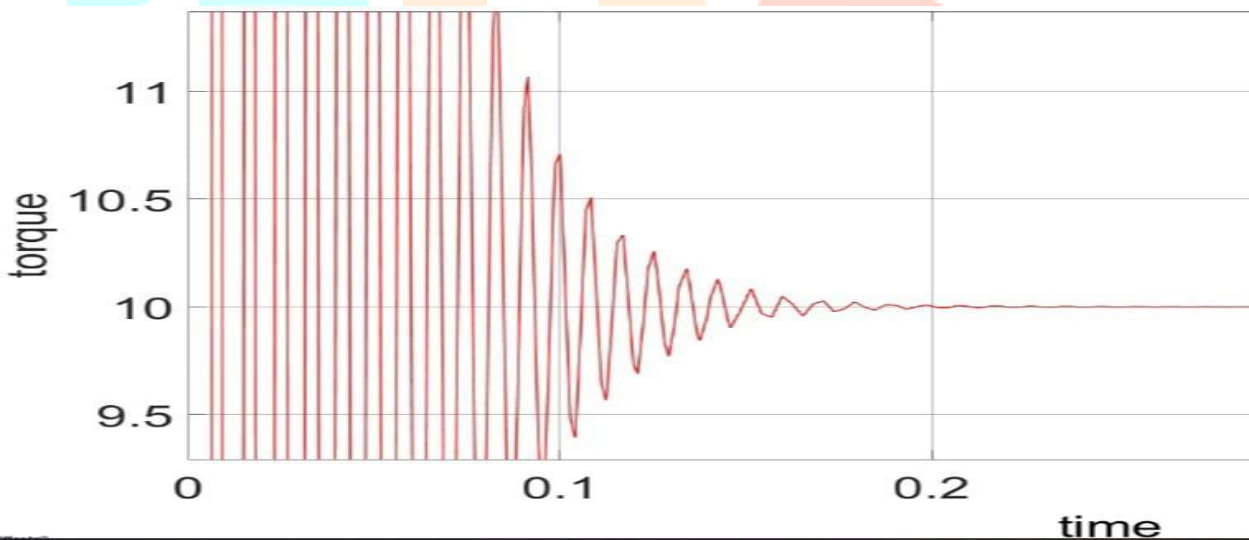


Fig.9.Electro Magnetic Torque

Mechanical Speed:

A fluctuation in pace across time From 0 to 200 rad/sec, the speed increases smoothly and then plateaus after 0.02 seconds. The simulation result is validated since steady state speed is the same as the requested reference speed.

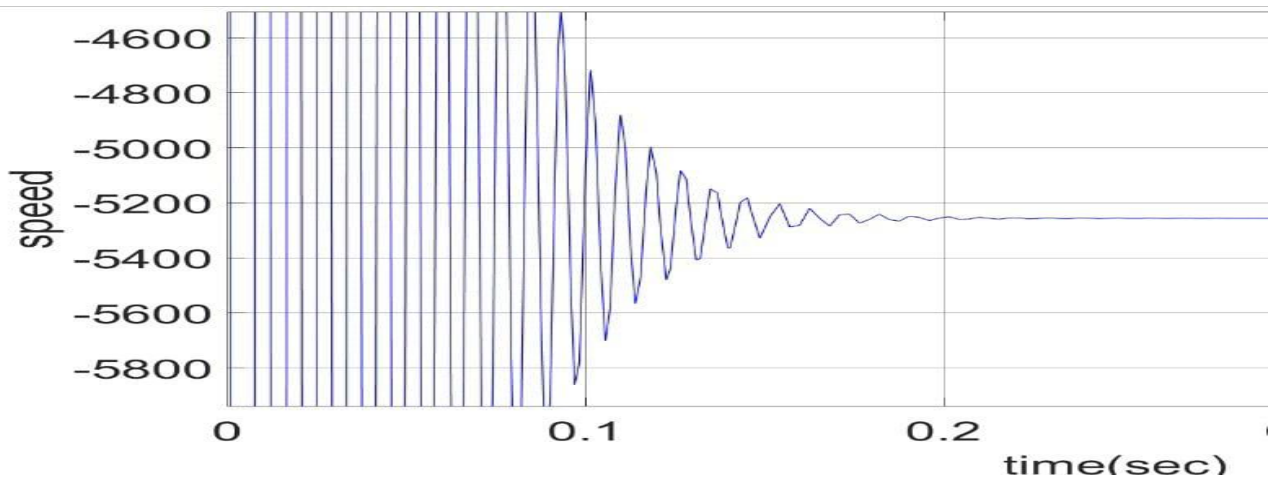


Fig.10.Mechanical speed of PMSM

Speeds:

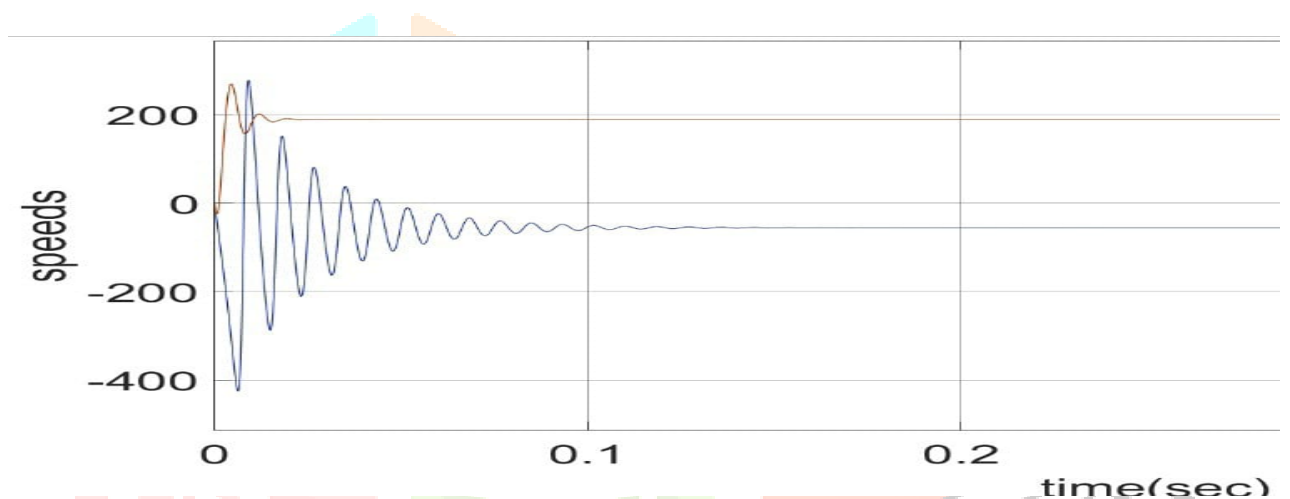


Fig.11. Speeds of PMSM

Torque:

The interplay of two magnetic fields (one on the stator and one on the rotor) produces a reactance torque in a PMSM. Except for the field weakening operation, the magnetic field of the rotor is represented by the constant magnetic flux of permanent magnets.

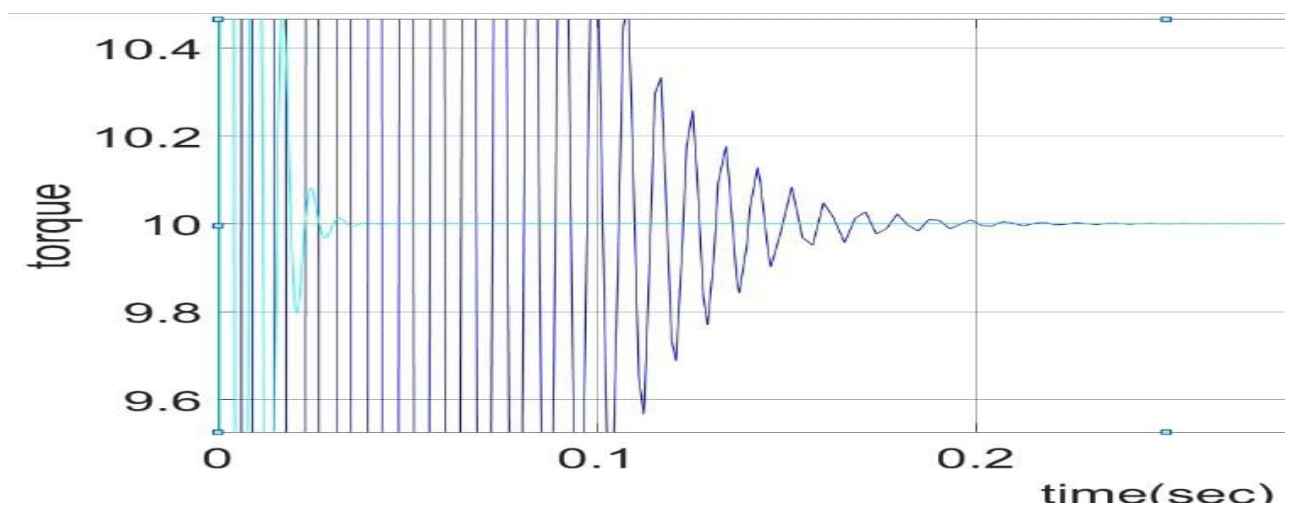


Fig.12.Torque of PMSM

Simulation Results of DC Motors:

To analyse the behavior of a series DC motor with an inverter, a simulation of the whole model constructed in MATLAB/SIMULINK was performed to evaluate it. The tests were carried out in a variety of scenarios in which the electric automobile was believed to be in operation. These cases can simulate running with various loads on the motor axis while the car accelerates from 0 rpm to a steady speed that is maintained for a period of time; running on streets with slopes that apply a smooth increase in speed; and running on rural roads with holes and small slopes that force the driver to break and change speed. A series DC motor with the specifications listed in table 1 was simulated, and the tests below were performed using the computer model of the series DC motor and its controller. This series DC motor was tested in the lab and then installed in a small truck to convert it to an electric vehicle. It should be noted that a series DC motor cannot run without a load, therefore when the automobile is stopped, the motor will be disconnected from the power source and its speed will be zero. Altering the rotation speed is accomplished by accelerating the pedal and changing the current of the motor. Simulation illustrates the operation of a Series DC Motor under various load torques, with the empty car weighing 550 kg and the driver and 5 passengers weighing 450 kg.

When a load torque equivalent to 100 percent of the nominal torque of the DC motor is applied, the change in time of torque, current, and rotation speed of the Series DC motor is shown.

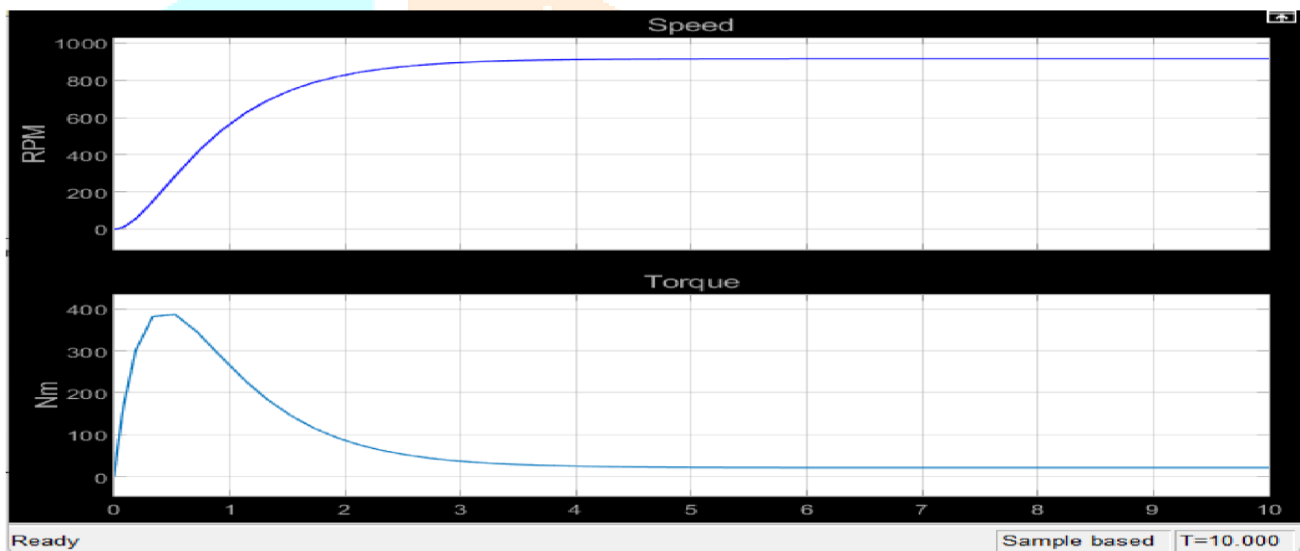


Fig.13.Speed and Torque of DC Motor

CONCLUSION:

In this study, we examine two distinct electric motors for use in electric vehicles based on several criteria such as power-to-weight ratio, torque-speed characteristics, and so on. Efficiency, controller cost, and motor cost Comparative. The following is a result of the evaluation. One of the major issues facing electric car makers is to offer consumers with an electric vehicle that performs as well as a gasoline vehicle while remaining inexpensive. As illustrated below, the costs of several electric motors with the same voltage and output power ratings are compared. A mathematical model for a Permanent Magnet motor drive system with field oriented control is created. The Speed Control of Permanent Magnet Synchronous Motor has been successfully designed using a speed controller for closed loop operation. Armature current control and field current control are the two main approaches for regulating motors. However, we can only modify the stator current with this sort of motor. Because this motor has just one source, the AC supply on the stator, the only method to regulate it is to manipulate the AC supply on the stator. A complicated control system including power electronics and microcontrollers is required. Such that the motor operates at the reference or required speed the quick reaction time. The benefits of a Permanent Magnet Synchronous Motor are demonstrated. The motor's real torque output.

1. DC brushed motors are simple to regulate and provide great torque at low speeds, but they have a high maintenance cost, are huge in size, and have a low efficiency.
2. Synchronous motors are more efficient at lower speeds, increasing battery usage and driving range. When a steady torque is required, a synchronous motor is chosen.

REFERENCES:

- [1] T. Sebastian, G. Slemon, and M. Rahman, "Modelling of permanent magnet synchronous motors", *IEEE Transactions on Magnetics*, vol. 22, pp. 1069-1071, 1986.
- [2] P. Pillay and R. Krishnan, "Modelling of permanent magnet motor drives", *IEEE Transactions on Industrial Electronics* vol. 35, pp. 537-541, 1988.
- [3] B. Cui, J. Zhou, and Z. Ren, "Modelling and simulation of permanent magnet synchronous motor drives," 2001.
- [4] J. R.R. Ruiz, J.A.Rosero, A. G. Espinosa, and L. Romeral, "Detection of demagnetization faults in permanent-magnet synchronous motors under nonstationary conditions," *IEEE Trans. Magn.*, vol. 45, no. 7, pp. 2961–2969, Jul. 2009.
- [5] M.D. Prieto, A.G. Espinosa, J. R. Ruiz, J.C. Urresty, and J. A. Ortega, "Feature extraction of demagnetization faults in permanent-magnet synchronous motors based on box-counting fractal dimension," *IEEE Trans. Ind. Electron.*, vol. 58, no. 5, pp. 1594–1605, May 2011.
- [6] X. Junfeng, W. Fengyan, F. Jianghua, and X. Jianping, "Flux-weakening control of permanent magnet synchronous motor with direct torque control consideration variation of parameters," 2004.
- [7] R. E. Araujo, A. V. Leite, and D. S. Freitas, "The Vector Control Signal Processing blockset for use with Matlab and Simulink", 1997.
- [8] C.-m. Ong, *Dynamic Simulation of Electric Machinery using Matlab /Simulink*: Prentice Hall, 1998.
- [9] H. Macbahi, A. Ba-razzouk, J. Xu, A. Cheriti, and V. Rajagopalan, "A unified method for modeling and simulation of three phase induction motor drives," 2000.
- [10] J. H. Reece, C. W. Bray, J. J. Van Tol, and P. K. Lim, "Simulation of power systems containing adjustable speed drives," 1997.
- [11] Bambang K, Soebagio M, Hery P. Design and Development of Small Electric Vehicle using MATLAB/SIMULINK. Institute of Technology, Indonesia; 2011.
- [12] Richard A. Mathematical Modelling and Simulation of a PWM Inverter Controlled Brushless Motor Drive System from Physical Principles for Electric Vehicle Propulsion Applications. Cork Institute of Technology, Ireland; 2011.
- [13] Cuenca R M, Gaines L L, Vyas A D. Evaluation of electric vehicle production and operating costs. Centre for transportation energy system division Argonne National Laboratory Illinois; 2011.
- [14] Mohan N, Undeland T M, Robbins W P. Power electronics: converters, applications, and design. 2nd Ed. New York: John Wiley & Sons; 1995.
- [15] Mulukutla S. Electrical Machines – Steady State Theory and Dynamic Performances. West Publisher; 2003.