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Design & Simulation of Motor Drive for an Electric Vehicle by Using MATLAB Simulink

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Abstract

Many companies are developing electric vehicles by fulfilling the requirements of less emission, increasing fuel economy etc. In this paper study of different types of resistances acting on vehicles are calculated. Design of Permanent Magnet Synchronous Motor (PMSM) is done. Speed control of Permanent Magnet Synchronous Motor is achieved by using closed loop system by PWM inverter technique. MATLAB simulation for the same is done by using MATLAB version R2018a.

***Keywords*— EV (Electric Vehicle), HEV (Hybrid Electric Vehicle) IM (Induction Motor), PWM (Pulse width modulation), Permanent Magnet Synchronous Motor (PMSM)**

I.INTRODUCTION

A very basic construction of Electric vehicle consist of motors either AC or DC, converter batteries and some control systems. Now another option for this is hybrid Electric vehicle because it gives more efficiency than conventional vehicle &less than purely electric vehicle. The pure electric car having highest efficiency and also known as Plug in type electric vehicle.[2] There are two types of electric vehicle

1. Plug in Electric Vehicle [2]
2. Hybrid Electric Vehicle [2]

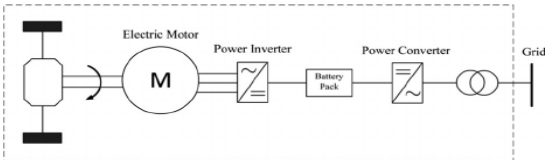

Fig.1 The Plug in type Electric Vehicle

A. Total Power Requires for Electric Vehicle

For calculating the total Power, Calculations of various types of resistances are considered. For that purpose some assumptions are made [3]

Assumptions

1. Frontal Area of Electric Car= (A) =2.450m^2
2. Angle of Inclination (θ) =20^0
3. Radius of Wheel ($R_{w)}$ = 0.3550mm other accessories + battery=350kg
4. Total Weight of Vehicle (W) =1500kg
5. Maximum speed of Electric Car (v) =100km/hr.
6. Mass of Electric Car=700kg
7. Peoples of 90kg each=450kg

There are some opposing forces that will be added on weight of electric Car i.e. Rolling Resistance, Aerodynamic Resistance & Gradient Resistance [3]

A. Rolling Resistance (W_R)

Rolling resistance is resistance that offered due to friction of tire and road.

$$(W_R) = K_r \times W \quad \ldots. (1)$$

Here, K_r is rolling resistance constant and is lies between 0.0095-0.18.

B. Wind Resistance (W_A)

Wind resistance is the resistance offered due to air pressure acting on a car.

It depends on velocity of wind, Speed & Mass

$$W_A = K_A \times A \times V^2 \quad \ldots. (2)$$

Here,

K_A=coefficient of air resistance ranges between 0.00235

A=Frontal area of car in m^2

V=speed of vehicle in Km/ hr.

Gradient Resistance=Gradient resistance is the resistance that offered due to steepness of road. It depends on speed of vehicle & mass.

$$W_g = \sin\theta \times W \quad \ldots\ldots..(3)$$

Here θ = angle of inclination of road

W=mass of vehicle

Total weight of car becomes W_T& this total weight is, weight of car plus summation of all forces i.e. resistances acting on the car. Figure 2 shows the different types of forces acting on vehicle [5]

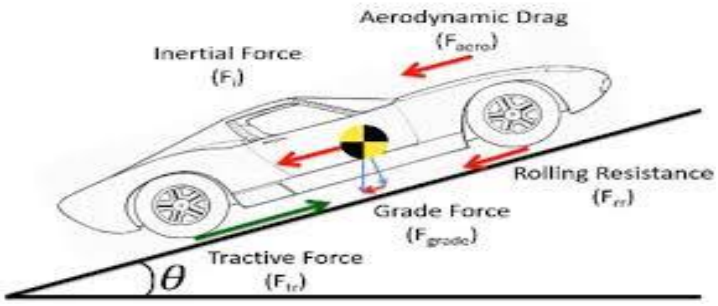

Fig.2 Forces acting on the vehicle

$$W_T = W_R + W_A + W_g + \text{Weight of vehicle} \quad \ldots. (4)$$

$$W_T = 120 + 57.57 + 704.20 = 2381.77 \quad \ldots. (5)$$

Now Total propulsion force F required for the moving of the vehicle is,

F= W_T (Mass of Vehicle) ×α (Acceleration)

F=1100.37Nm

C. Total power required

P=F× d/t

P=29.7KW

D. Wheel Torque (T_w)

=F×r_w=0.3906Nm

Here, r_w =radius of Wheel=0.355mm

F =Propulsion Force

E. Motor Torque (T_m) =Wheel Torque/Gear Ratio=0.1953

Gear Ratio =2

Table I gives the force and total Power required for Vehicle & calculated by above equations. [3][4]

TABLE I

FORCE AND TOTAL POWER REQUIRED FOR VEHICLE

Sr.No	Parameters	Symbols	Calculated Value
1	Weight of vehicle T	W	1500Kg
2	Maximum Speed	V	100KM/Hr
3	Rolling Resistance	W_R	120Kg
4	Wind Resistance	W_A	57.57kg
5	Gradient Resistance of vehicle	W_g	704.20kg
6	Total weight of the vehicle	WT	2381.77
7	Acceleration of the vehicle	α	0.462m/s2
8	Propulsion Force required for the vehicle	F	1100.37Nm
9	Power Required for the vehicle	P	29.7kw

II MOTOR DIMENSIONS

As per the power requirement, design of PMSM motor is done. Some assumptions are made to get the optimum size of PMSM motor [12]. Current density and flux density are assumed in such way that motor gives maximum efficiency at the time of running conditions.[3,6]

Now,

Efficiency of motor Ƞ=90%

Stator slots per pole per phase =3

Winding Factor K_w =0.955

Ratio of length to pole pitch=L/Ƭ=2

Electric loading (ac) =22000A/M

Magnetic Flux Density (B_{av}) =0.50 wb/m^2

Power Factor=0.9

Input Power=200V

Speed (Synchronous) (Ns) =1500rpm=2f/p=2*50/4=25rps

A. Calculations and Result

Sr. No.	Parameters	Values
01	Total no. of Rotor slot	38
02	Rotor slot pitch	17.60mm
03	Rotor Diameter	211.78mm
04	Length of Air gap between stator and motor	0.66mm
05	Total no. of conductors	510
06	No. of stator slot	36
07	Stator slot pitch	18.5mm
08	Turns per phase	42
09	flux per pole	0.020wb
10	Total stator current	95.147A

1. Motor dimensions Design

Q=KVA rating of Induction Motor

Q= P_m/ Ƞ× P.F

C_0 =output coefficient of induction motor

C_0=11 × B_{av} × ac × kW × 10^{-3}

Input Equation of Induction Motor,

$Q = C_0 \times D^2 \times L \times N_s$

Here, D=Diameter of motor=

L=length of motor=

All above values are taken [7]

2. Main Dimensions of PMSM

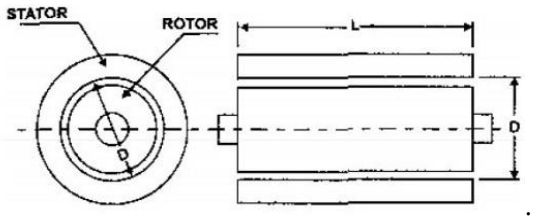

Fig.3 Main dimensions D and L

KVA rating (Q) =32.96 KVA

Output coefficient (C_0) = 115.555

Diameter of motor (D) = 0.2131m

Length of Motor (L) = 0.2510m

III. DESIGN OF STATOR AND ROTOR PARAMETERS

With consideration of some assumptions following parameters are calculated [9, 7]

Stator inductanceof motor =0.00041H

Rotor Resistanceof motor =0.0360ohm

Rotor Inductanceof motor =0.00041H

Mutual Inductanceof motor =0.0175

Inertia=0.37.9Kg/m^2

Force=0.0279Nm

No. of pole pairs=2

Parameters required for simulation is as above. These values are calculated from table no. II and motor size parameters

IV MODEL DESIGNED IN MATLAB SIMULINK

Model designed in MATLAB version R2018a is as follows

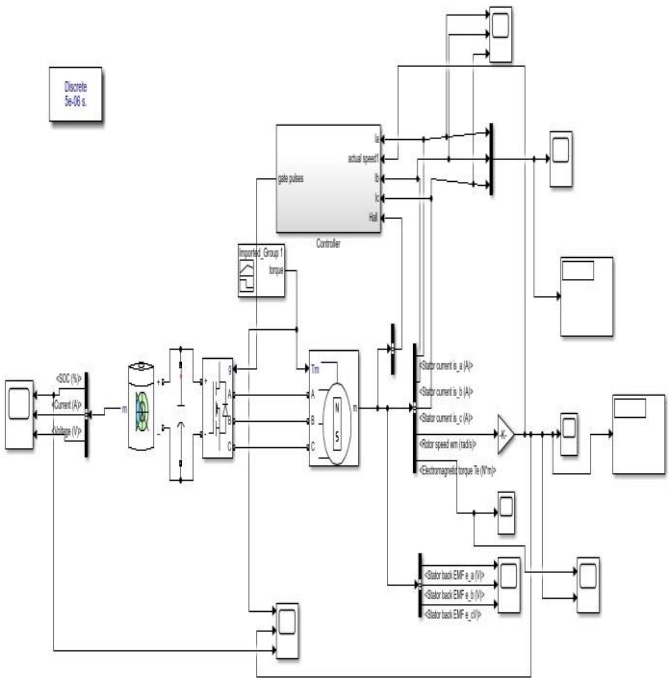

Fig. 4 Model Designed in MATLAB Simulink version R2018a

V. RESULT AND DISCUSSION

A. Stator EMF

Figure shows result of stator emf of PMSM motor in which three results of back emf produce is occurs.

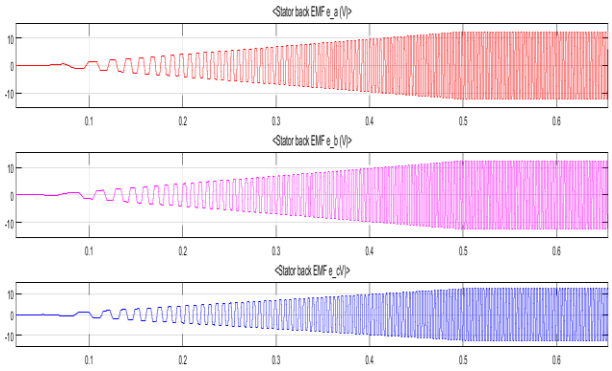

Fig. 5 Stator EMF

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B. Stator Current

Figure shows result of stator current of three signals that is stator current A, stator current B, stator current C

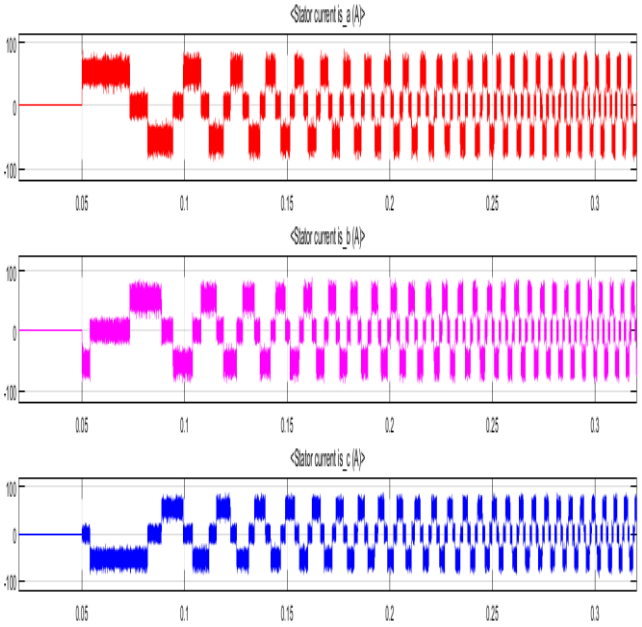

Fig. 6 Stator Current

C. Reference Speed and Actual Speed

Figure shows result of reference speed and Actual speed of motor.

Reference speed is set to 1500rpm.Depends on reference speed actual speed also changes to set speed of motor.

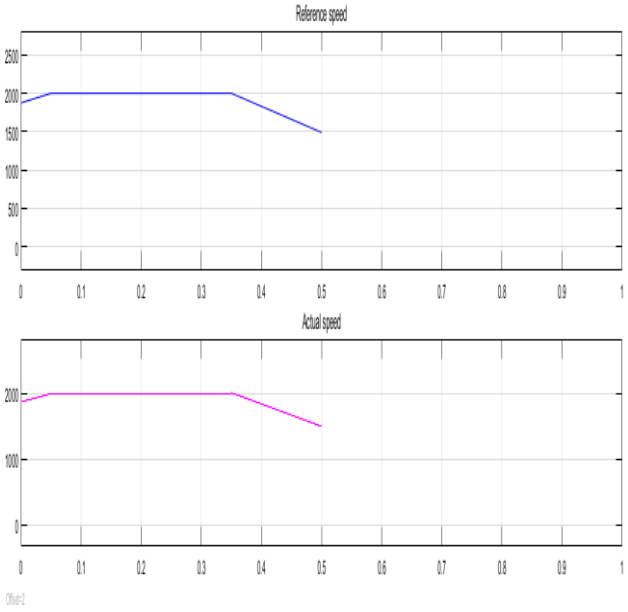

Fig. 7 Reference Speed and Actual Speed

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D. Gate Pulse

Figure shows result of gate pulse provided to the controller block of model.

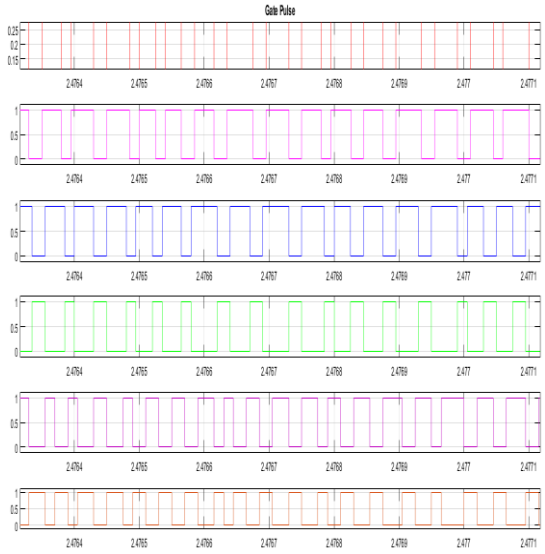

Fig. 8 Gate Pulse

E. Gate Pulse Comparison with Battery & Speed

Figure shows result of comparison of state of charging of battery and rotor speed of motor. As rotor speed of motor increases state of charging decreases.

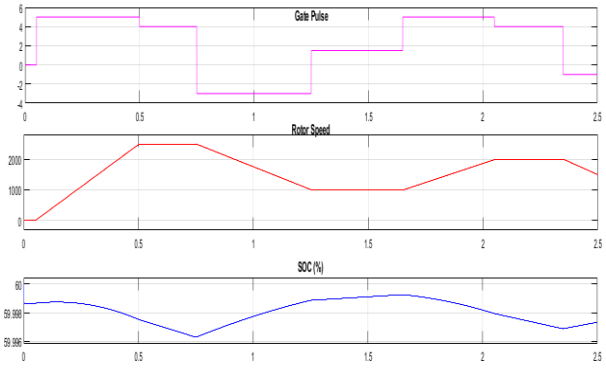

Fig. 9 Gate Pulse Comparison with Battery & Speed

F. Battery Wave forms

Figure shows result of battery current, voltage and state of charging with respect to time.

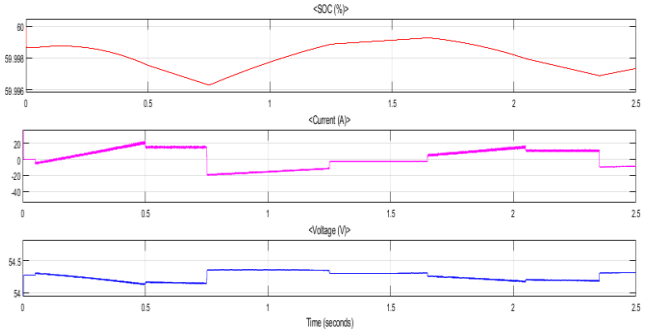

Fig. 10 Battery Waveforms

G. Torque and Speed

Figure shows result of torque and speed of motor with respect to time.

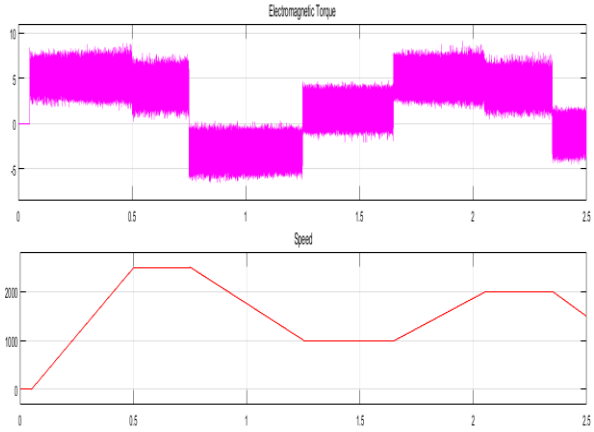

Fig. 11 Torque and Speed

VI. CONCLUSION

In this work design of permanent magnet synchronous motor is done. Speed control of PMSM motor is done by using MATLAB Simulink. This work provides smoother speed control of electric vehicles.

MATLAB models are also designed as per the process parameters calculated. The power requirement for Electric Vehicle was also calculated. The forces acting on the vehicle like Rolling Resistance, Aerodynamic or Wind Resistance, Gradient was calculated.

The motor dimension design by considering various parameters like KVA rating, Stator Current, Turns per Phase, Flux per Pole, Stator Slot Pitch, Rotor Diameter, Rotor Bar Current, Rotor Current for Motor was also done.

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