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Comparison between Permanent Magnet Synchronous Motor and Three Phase Induction Motor for Electric Vehicle Applications

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ABSTRACT

In this Paper the comparison between two traction motors i.e. Permanent magnet synchronous motor and three phase Induction motor has been done to find out the best traction motor suitable for electric vehicle application. First the sizing of vehicle parameters is done to find the rated torque, speed and power suitable to design a three phase induction motor. In Matlab simulation, the Simulink model of Fuel cell Electric vehicle using New York city drive cycle is run with two different motors .The simulation result is obtained with two types of controllers i.e. PID and Fuzzy controller and the simulation results show that Fuzzy controller gives better control characteristics.

Introduction

Electric vehicles are environment friendly vehicles that cause no tail pipe emissions and can surely reduce the major problem of air pollution in this century. Fuel cell electric Vehicle has long term potential to be the vehicle of future [1].

A design methodology is presented based on vehicle dynamics and is aimed at finding the optimal torque-speed profile to meet the operational constraints with minimum power requirement. The more the motor can operate in constant power, the less the acceleration power requirement will be [2].

Electric Vehicle Structure

An Electric Vehicle contains 3 main parts [3].

(1) Energy Source.

(2) Power Converter.

(3) Traction Motor.

Vehicle Dynamics

Tractive force required for propelling the vehicle is given by:

$$f_t = fmg + (0.5\rho c_x s v^2) + (mg\sin(\alpha)) + m(dv/dt) \quad (1).$$

The motor torque is given by:

$$T = f_t \times r / G \quad (2).$$

The motor Angular speed is given by:

$$w = G \times v / r \quad (3).$$

In above table, the parameters of a source vehicle (City bus) are chosen. The mass of the vehicle is taken as 5123Kg with inclination of 0 degree angle.

The parameters of city bus shown in above table are put in all above three equations and the following plots are obtained.

In the above plot of Power versus speed, at speed of 3000Rpm the power is becoming constant. So, at rated speed of 3000 Rpm, the rated power will be 60Kw and maximum motor power will be 80Kw respectively.

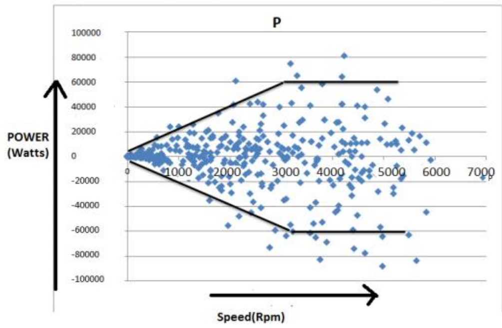

Figure 1. Power versus Speed

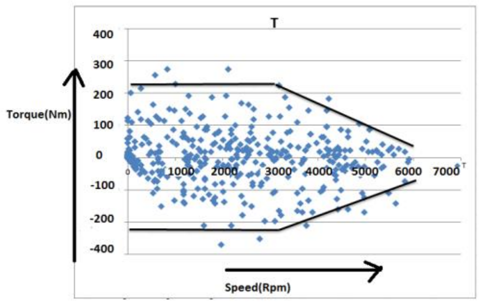

Figure2. Torque versus Speed

Similarly, In Torque versus Speed plot, at rated speed of 3000 Rpm the rated torque will be 220 Nm.

From the vehicle dynamics, the following above plots are done and the rated values of Power, Torque and speed is obtained whose values are used as an input for traction motor sizing. Rated speed, Rated motor Power and Rated motor torque will be used as an input for designing the parameters of Induction motor. Based on the certain equations of Electrical Machine Design, the following optimal designing of Induction Motor done is shown below.[4]

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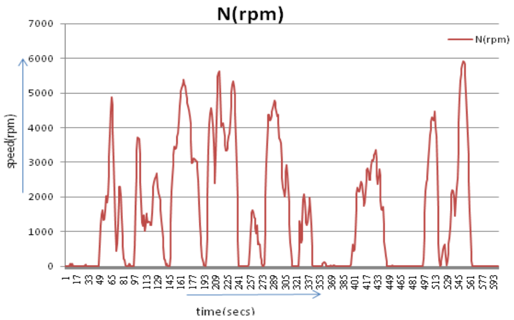

Figure.3. Speed (rpm) versus time (seconds)

The stator and Rotor designing of Induction motor is done in C++ language using the rated values of motor obtained in Table II and using the designing procedure of Electrical machine designing, the stator and rotor parameters are obtained.
The equivalent circuit parameters obtained is thus adjusted to increase the range of constant power region.

On increasing the value of Rotor resistance, the range of constant power region increases.[5]

Table 1. Vehicle Parameter Dynamics

Parameter	Symbol	Value
Coefficient of rolling friction	*f*	0.01
Vehicle mass	m	5123 Kg
Air density	ρ	1.3 Kg/m3
Grade angle	α	0
Frontal area	*s*	5.65m2
Aerodynamic drag coefficient	*Cx*	0.5
Gear ratio	*G*	20
Tyre radius	*r*	0.4m
Gravitational acceleration	*g*	9.81m/s2

Matlab Simulink Model

After the analytical approach, the final results are obtained from Matlab Simulink modeling to assess the performance and range of the proposed Electric Vehicle design.
The simulation model consists of the following blocks:
(1) Electrical Subsystem.
(2) Vehicle Dynamics.
(3) Energy management System.

The traction motor used is the Permanent Magnet Synchronous motor (PMSM) and three phase Induction motor (IM). The power converter used is the DC-DC bidirectional class C chopper. The battery used is Li-ion. The gain is changed for Different values and the output is recorded.[6]
The model used for simulation is a fuel cell electric vehicle which is shown below.

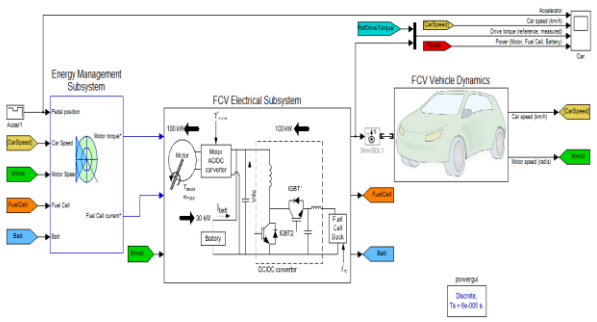

Figure 4. Fuel Cell Electric Vehicle Model

Table 2. Optimal design of induction motor

Parameter	Value
Output Power	60KW
No. of Poles	2
Stator Diameter(Minimum cost)	0.196 m
Stator length (Minimum cost)	0.221 m
Flux per pole	0.0238 Weber
Total conductors	300.49 2
Stator current per phase	79.456 Ampere
Stator area	22.70 mm 2
Stator diameter(good power factor)	0.165 m
Stator Length(good power factor)	0.124 m
Flux per pole	0.0383 Weber
Total Conductors	186.72
Stator diameter(Good efficiency)	0.153 m
Stator length(Good efficiency)	0.36 m
Flux per pole	0.0346 Weber
Total conductors.	206.7
Stator diameter(good overall design)	0.385 m
Stator length(good overall design)	0.604 m
Flux per pole	0.146 Weber
Total conductors	48.98
No. of Rotor slots	61
Rotor bar current	54.21 A
Total rotor copper loss	232.68 W
Slip	0.00 6 5
Stator Leakage Reactance	1.0812 Ω
Magnetizing current	6.085 A
Magnetizing reactance	41.72 Ω
Stator resistance per phase	0.048 Ω
Total resistance per phase	0.0043 Ω

Drive Cycle:

A drive cycle is a standardized driving pattern. This pattern is described by means of a velocity –time table.
Now putting the New York City drive cycle as an input and using PID controller the Simulink model is run and output is shown in figure 7.

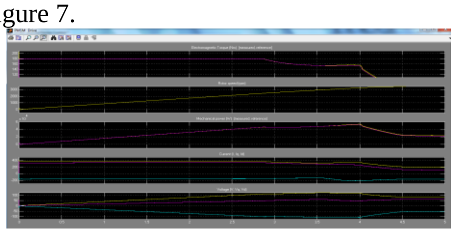

Figure5. Simulation Output Graph for PMSM electric vehicle using PID controller

Now ,we will replace PID controller by an Intelligent Fuzzy controller whose mamdani membership plot is shown in figure below.

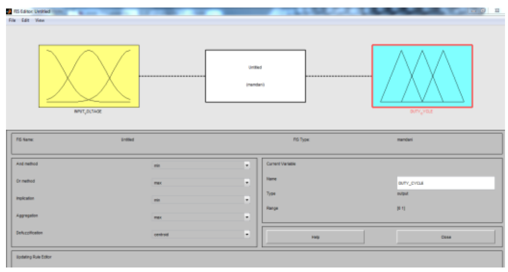

Fig.6 Mamdani Input output membership plot

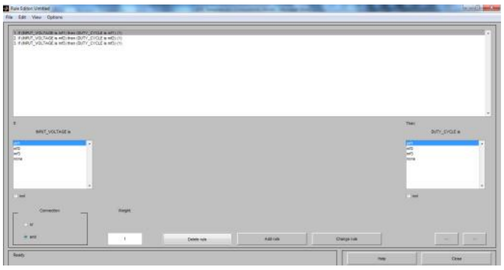

Fig.7.Fuzzy rules

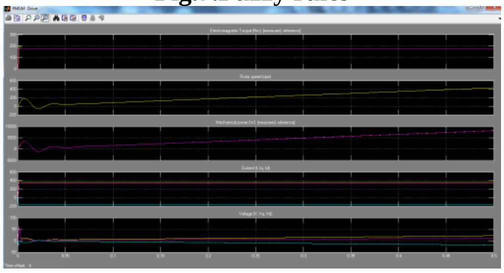

Fig.8.Simulation output for PMSM drive using fuzzy controller

In the above figure it is clear that using fuzzy logic controller, the steady state error has been reduced i.e. better stability has been achieved.

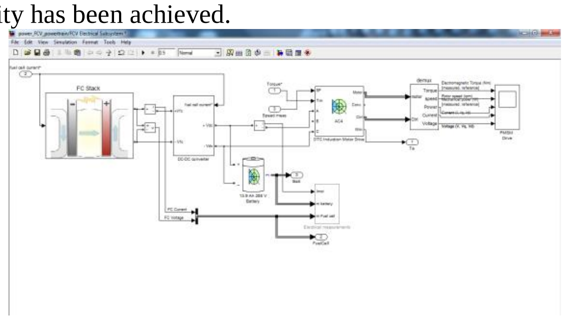

Fig 9. Simulink model using Induction motor drive.

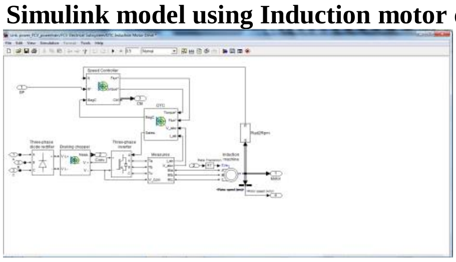

Fig.10.AC4 induction motor drive

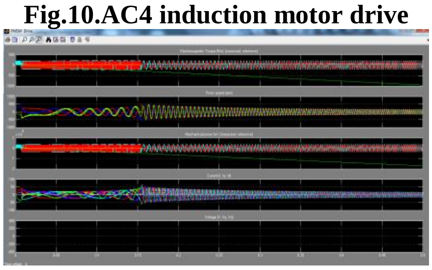

Fig.11.Induction motor drive output using PID controller

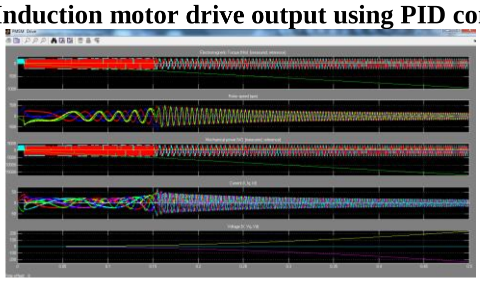

Fig.12.Induction motor drive output using Fuzzy logic controller

In fig.11 and 12.it is again clear that better plots are obtained with fuzzy logic controller.

Now, the plot for Li-ion battery is shown below using both PID and fuzzy logic controller to show the usefulness of Fuzzy logic controller and its robustness over PID controller.

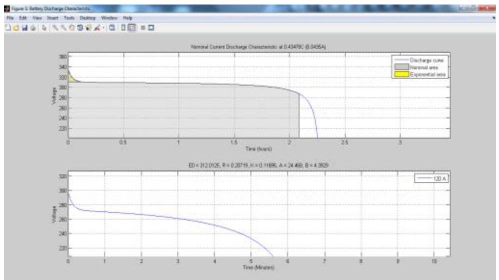

Fig.13.Battery discharge characteristics.

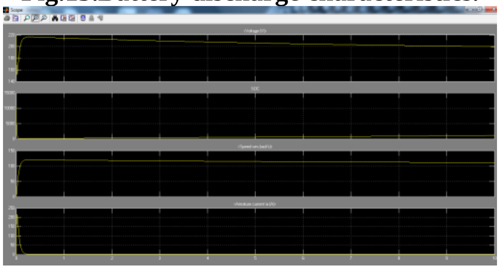

Fig14.Li ion simulation output using PID controller

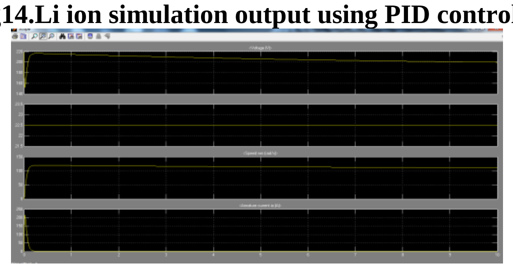

Fig.15.Li ion simulation output using Fuzzy controller.

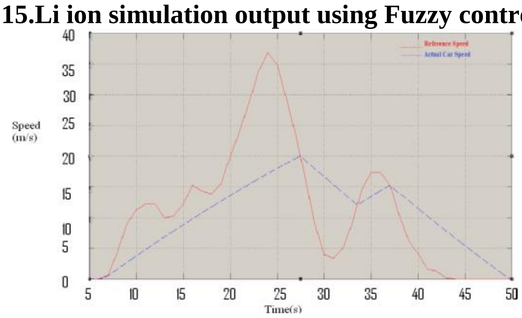

Fig.16.Induction motor drive output using PID controller

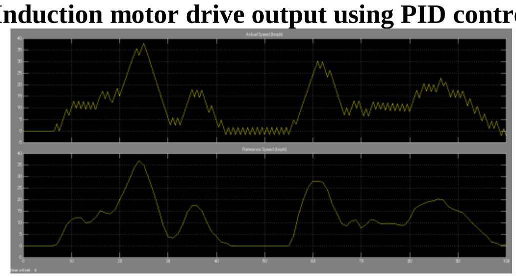

Fig.17.Induction motor drive output using Fuzzy logic controller.

From fig.16 and 17,it is clear that the reference and actual speed of induction motor have very less difference if fuzzy controller is employed. However ,PMSM gives better simulation results than Induction Motor. Their advantages are [6].Since, the magnetic field is excited by high energy of magnetic fields; it results in high efficiency and easy speed control.

(1) They have longer operating lives and an increased reliability and Brushless DC motor has been recommended for high performance electric vehicle [7].

Recent research has indicated that the permanent magnet synchronous motor and brushless dc motor (BLDC) can compete with Induction motor for electric vehicle propulsion [8], [9], [10].

Conclusion

Both PMSM and Induction motor shows good characteristics of traction motor for electric vehicle applications. But PMSM motors are better preferred as its efficiency is higher than Induction motor and can better serve as a electric vehicle motor. From all

Above plots, it is also clear that with the use of Intelligent controllers such as Fuzzy logic controller, the drive range and efficiency of electric vehicle can be improved as it is more robust compared to classical PID controllers and gives better control characteristics.

References

[1], [2] Mehrdadehsani, Khwaja M. Rahman and Hamid, A.Toliyat,"Propulsion system design of electric and hybrid vehicles", IEEE transactions on industrial electronics, Vol44, No.1, February, 1997, pp.19-27.

[3]. C.C Chan and Y.S Wong ,"Electric Vehicles charge forward", IEEE Power and Energy Magazine, November/December 2004, pp. 2-12.

[4], [5]. In Alcala, A. Claudio, G.V Guerrero,"Analysis of Propulsion system in Electric Vehicles", CIE 2005, September 7-9, 2005, PP 312-313.

[6]. Peter Lindahl, Eric Moog, Steven R. S haw, Montana State University, "Simulation ,design and validation of an uav sofc propulsion system", IEEE transactions on aerospace and electronic systems,Vol. 48,no.3,July 2012, pp 2583-2592.

[7]. A. Tashakori, M. Ektesabi," Direct torque controlled drive train for electric vehicle", IAENG, Proceedings of the world congress on engineering.

[8] K.Buhr and P.vozenilek,"Analysis of an electric vehicle with a BLDC pm motor in the wheel body", transactions on transport sciences volume 5, number 1, 2012,PP 1-10.

[9] Juan de Santiago Ochoa,"Fem analysis applied to electric machines for electric vehicles", digital comprehensive summaries of Uppsala dissertations from the faculty of science and technology 845.59 pp.

[9] Juan de Santiago Ochoa,"Fem analysis applied to electric machines for electric vehicles", digital comprehensive summaries of Uppsala dissertations from the faculty of science and technology 845.59 pp.

[10]. Rahul Singh, Vinit Chan dray Roy and C.K. Dwivedi, IJEEE, Vol I, Iss-3, 2012, PP. 2931-5284.