PERFORMANCE OF INDUCTION MOTOR AND BLDC MOTOR WITH FUZZY LOGIC CONTROLLER FOR EV APPLICATIONS

R Lakshmi[1], N Ramesh Raju[2], S Ramesh[3], K Murali Kumar[4], V Mamatha

[1]*Associate Professor, Department of EEE, Siddharth Institute of Engineering and Technology, Puttur, Andhra Pradesh, India.*
[2]*Professor & Head, Department of EEE, Siddharth Institute of Engineering and Technology, Puttur, Andhra Pradesh, India.*
[3]*Associate Professor, Department of EEE, Siddhartha Institute of Science & Technology, Puttur, Andhra Pradesh, India.*
[4]*Associate Professor, Department of EEE, Siddhartha Institute of Science & Technology, Puttur, Andhra Pradesh, India.*
[5]*Assistant Professor, Department of EEE, Siddharth Institute of Engineering and Technology, Puttur, Andhra Pradesh, India.*

ABSTRACT

In this paper, the performance evaluation of the Induction motor and BLDC motor with fuzzy logic Controller is simulated which can be used for Electric Vehicle related Applications to control the speed. Among electric motor Brushless DC motor (BLDC) is widely used, especially in automotive systems. This motor is widely used as a driving force in electric vehicles. BLDC motor is chosen because it has the characteristics of wide speed range, high efficiency, and reliability. Besides, BLDC motors require less maintenance and can operate quieter than DC motors. Even though it has many advantages, in its application the use of BLDC motors in electric vehicles is often less than optimal. There are still several flaws in using traditional control systems like PI, PD, and PID, especially when it comes to adapting to changes in load and track conditions. In this work, a control system was created using fuzzy logic to control the speed of the BLDC motor. The Fuzzy-PID control can offer better and more stable performance than utilizing the standard PI control, according to the findings of the tests that have been conducted. Both an induction motor and a BLDC motor with a fuzzy logic controller can be used to assess the performance of the EV in terms of speed regulation. The performance of the motor which regulates the better speed can be evaluated by using Matlab/Simulink 2018a Software.

Keywords: *BLDC Motor, Induction Motor, Electric Vehicle, Fuzzy Logic Controller and Hall Sensor.*

---

1. INTRODUCTION

Over brushed DC motors and induction motors, BLDC motors have a number of benefits, including improved speed-to-torque characteristics, high dynamic response, high efficiency and reliability, long operating life (no brush erosion), silent operation, wider speed ranges, and a decrease in electromagnetic interference (EMI).

The proper commutation of currents in its stator windings necessitates rotor position information because BLDC motors are electronically controlled by design. However, because a sensor failure could result in control system instability, it is not desirable to use Hall sensors in high temperature applications where reliability is of the utmost importance. Conventional controllers, which have a straightforward control structure and are simple to implement, pose yet another significant issue.

But the electric motors controllers pose difficulties under the conditions of nonlinearity, load disturbances and parametric variations. Traditional control systems are based on mathematical models in which the control system described using one or more differential equations that define the system response to its inputs. In many cases, the mathematical model of the control process may not exist or may be too expensive in terms of computer processing power and memory and a system based on empirical rules may be more effective for closed loop speed control.

The tendency to propose novel control strategies to boost the motor's performance has persisted due to the exaggerated benefits of the motor. In high-performance motion control applications, torque smoothness is essential, and BLDC motors must provide instantaneous torque that is precise and free of ripples. Trapezoidal voltage strokes and the rotor position govern the brushless DC motor. To keep the angle between the stator flux and the rotor flux at 120 degree, the voltage strokes between the phases need to be precisely synchronized in order to produce the most torque. We can potentially achieve excellent performance and controllability by adjusting the speed of a DC motor. BLDC engines are presently utilized in electric automobiles, moving factories, electric cranes, electric trains, and mechanical technology.

The proposed system has good tracking capabilities and fast response times when compared to conventional schemes. Then the resulting steady-state error is very low compared to the PI and FLC methods.

2. RELATED WORK

Nobuyuki Matsui, proposes the speed and position sensorless control of PM brushless DC motors with a sinusoidal flux distribution. Two approaches are presented and compared with each other; one is based on the voltage model of the motor and another is based on the current model. The starting procedure is also a very difficult problem under sensorless drives, because the sensorless drive algorithm uses voltage and current for estimation of rotor position, but no information is available before starting. A novel starting method is presented by using a salient-pole machine. Experimental results based on DSP-TMS320C25 controller are shown for comparisons, which demonstrate desired characteristics both in steady-state and starting conditions.

Champa.P. et al. suggest a technique for figuring out a brushless DC machine's initial rotor position when it is at rest without the use of a position sensor. The main idea behind rotor position estimation is based on the identification and evaluation of phase voltage and current responses linked to stator inductance variations with rotor magnet location. Only three voltage-pulse injections are used in the suggested approach, and a 30deg resolution is possible.

According to Ramesh.M.V. et al., BLDC motors have a very wide speed range, making speed control a crucial concern. When discussing the performance of a speed controller, a number of factors, including starting current, starting torque, rise time, etc., must be kept in mind. PID controllers and fuzzy PI controllers are the two basic techniques for managing speed. Both differ in terms of complexity and effectiveness. The PI and Fuzzy PI speed controllers for BLDC motors will be shown in this study. In order to assess the effectiveness of the suggested speed controllers, a simulation study is carried out. Additionally, a comparative research is conducted to confirm the system's efficacy.

Somanatham.R et al proposes modeling and simulation of sensorless control of permanent magnet brushless DC (PMBLDC) motor is carried out using zero-crossing back e.m.f technique. Since the neutral point of star connected machine is floating and not accessible to detect zero-crossing points, line back e.m.f information is considered. The motor is commutated at zero-crossing point of back e.m.f at 0deg delay (no delay), 18.5deg delay and 28deg delay instants of commutation from zero-crossing point of line back e.m.f signals. The various waveforms like line back e.m.f, phase currents, rotor position, speed, and torque with respect to time at no-load, half-load and full-load are obtained. From the results it is observed that the torque developed by the motor at larger delay angles is more pulsating due to more peak to peak currents.

Yan Wei-Sheng et al a sensorless fuzzy direct torque control (DTC) which drives brushless DC motors (BLDC). It is deduced that the amplitude of stator flux linkage cannot been controlled in BLDC-DTC since it is automatically determined by every 60 electrical degrees commutation. Then, the control of the flux linkage is unused in the proposed system. For the sake of improving the static and dynamic performance of the system, fuzzy logic is introduced into the system, which the torque error and flux linkage angle of BLDC were all properly fuzzified into several subsets to accurately select the voltage space vector in order to smooth the torque and quicken the torque response. A state observer is designed to estimate the back-EMF, the torque and rotor speed can be derived from the estimated back-EMF. Simulations illustrate the operation and performance of the proposed scheme.

Taeyeon Kim et al proposes a new sensorless drive scheme for a brushless DC (BLDC) motor based on the terminal voltage difference. Unlike the zero crossing point (ZCP) of the phase back electro-motive force (BEMF) which has been used in the conventional sensorless drive schemes, the ZCP of the BEMF difference between two phases corresponds to the commutation point of a BLDC motor accurately. So as to detect the ZCP and adopt it to the BLDC motor commutation, a circuit which constitutes of a differential amplifier and a comparator is designed. Some experimental results show that the output of the suggested circuit is analogous to the hall sensor signal and it can be used for BLDC motor sensorless drive.

3. PROPOSED SYSTEM

The block diagram of proposed system is shown in Fig 1. The power converter circuit converts unregulated power to Power. The Electric motor may be Induction motor or BLDC Motor. The fuzzy logic controller is used to control the speed of motors by producing controlling signal. This trigger signals control the power switches leads to controlled output to the motor. The components for the proposed system are as follows,

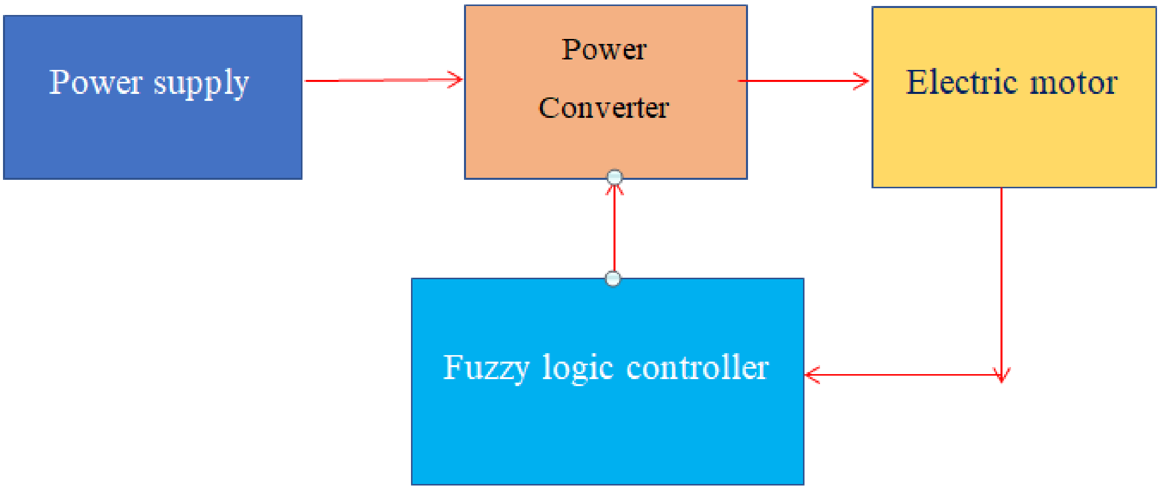

Fig -1 Block diagram of proposed method

3.1.1 BLDC Motor

Brushless DC motors differ from regular DC motors in that the armature current is electronically commutated rather than mechanically. A permanent magnet synchronous motor and a BLDC motor have comparable architectures. The polyphaser winding is housed in the stator, whereas permanent magnets are used in the rotor. A rotor position sensor and an electronic drive circuit are both included in a BLDC motor. The stator winding is fed by an electrical drive that is based on electrical switches.

3.1.2 Induction Motor

The induction motor's fundamental working principle is that the opposite current in the rotor bars is created by the stator's magnetic field. A magnetic field is then created in the rotor laminations by the induced rotor current. The rotor is always lagging, resulting in the rotor rotating due to the opposing field and the switching of the stator current.

3.1.3 Triggering Signal

To drive BLDC motors, voltage strokes are coupled with rotor position.

3.1.4 Fuzzy logic control

In crisp logic, the truth value acquired by propositions or predicates are 2 valued, namely True, False which may be treated numerically equivalent to (0, 1). However, in fuzzy logic, truth values are multivalued such as absolutely true, partly true, absolutely false, very true and so on and are numerically equivalent to (0,1). A false proposition is a statement which acquires a fuzzy truth value. Thus, given P to be a fuzzy proposition. T (P) represents the truth value (0-1) attached to P. In its simplest form, fuzzy propositions are associated with fuzzy sets. The fuzzy membership value associated with the fuzzy set A for P is treated as the fuzzy truth value T (P).

$$\mathbf{T(P) = \mu_A(x) \ \ where\ 0 \leq \mu_A(x) \leq 1}$$

Just as in crisp logic where predicates are quantified by quantifiers, fuzzy logic propositions are also quantified by fuzzy quantifiers. There are two classes of fuzzy quantifiers such as Absolute quantifiers and Relative quantifiers. While absolute quantifiers are defined over R, relative quantifiers are defined over [0-1].

Fuzzy inference also referred to as approximate reasoning refers to computational procedures used for evaluating linguistic descriptions.

4. SIMULATIN RESULTS OF INDUCTION MOTOR BY USING FLC

Fig -2 shows the simulink Model of Induction Motor with Fuzzy Logic Controller. Fig -3 shows the performance of the suggested fuzzy logic controller for an induction motor at 1500 rpm. The induction motor's time (sec) and speed (rpm) were shown on the X and Y axes, respectively. As indicated in the Fig -3, the controller's settling time is 0.9 seconds. After 0.9 seconds, the motor operates at a speed of 1000 rpm but the set speed is 1500 Rpm. Fig -4 shows the output torque response of the induction motor. The duration in seconds (sec) and electromagnetic torque value 9.5N-M.

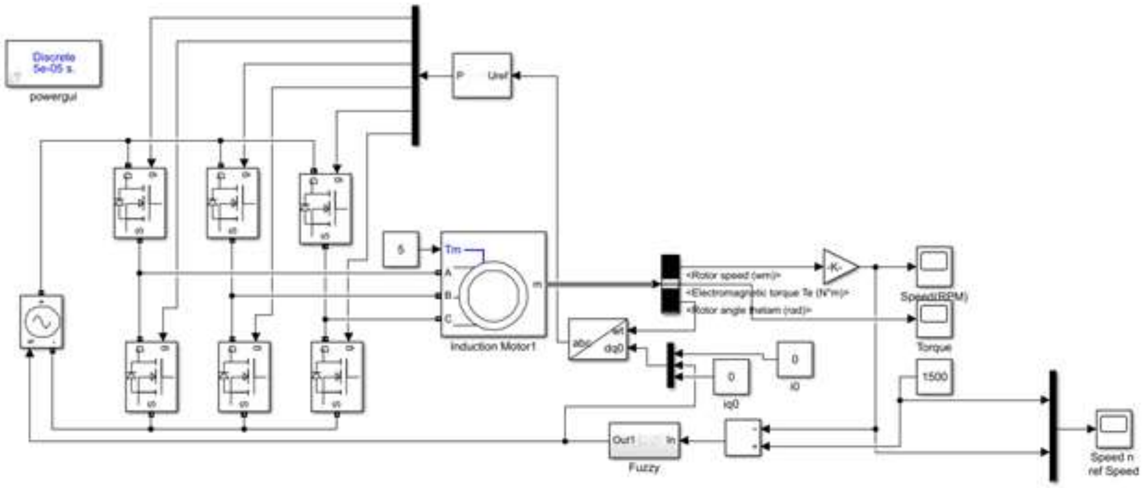

Fig -2 Simulink Model of IM with Fuzzy Logic Controller

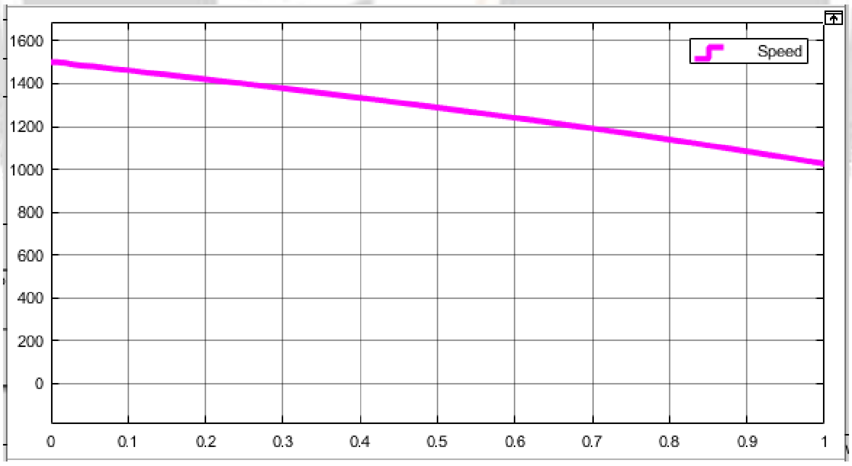

Fig -3 Speed of IM

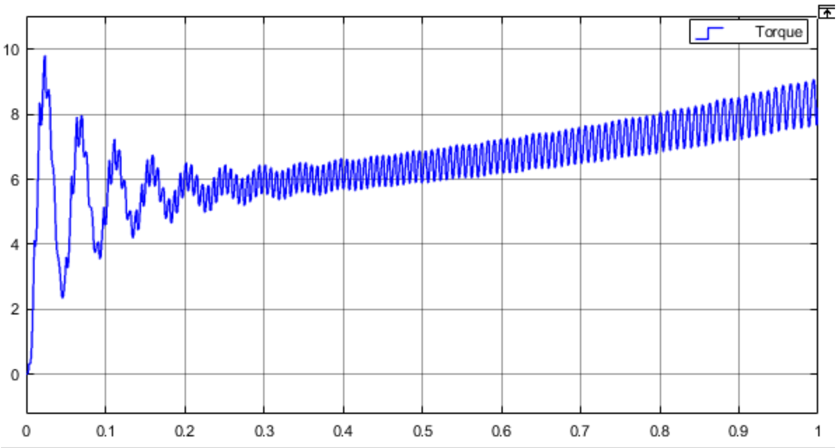

Fig -4 Torque of IM

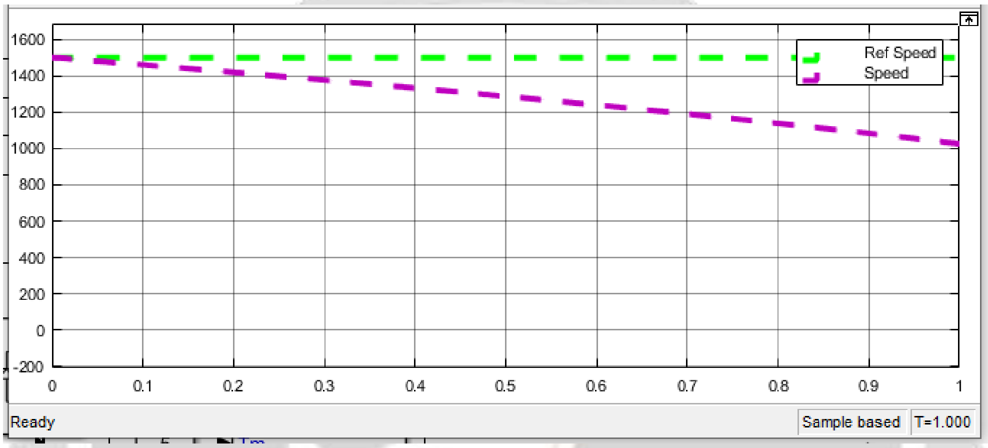

Fig -5 Speed Vs Reference Speed

5. SIMULATIN RESULTS OF BLDC MOTOR BY USING FLC

Fig -6 shows the simulink Model of BLDC Motor with Fuzzy Logic Controller Fig -7 shows the performance of the suggested fuzzy logic controller for a brushless DC motor at 1500 rpm. The BLDC motor's time (sec) and speed (rpm) were shown on the X and Y axes, respectively. As indicated in the Fig -7, the controller's settling time is roughly 0.018 seconds, with very little overshoot and undershoot. After 0.018 seconds, the motor operates at a constant speed of 1500 rpm, depending on the user's choices. Fig -8 shows the output torque response of the BLDC motor. The duration in seconds (sec) and electromagnetic torque value 5N-M. Performance Analysis of BLDC Motor Using Fuzzy Logic Controllers in Newton-meters (Nm) of the BLDC motor was shown on the X and Y axes, respectively.

The reference speed and actual speed of the motors are represented by the green and pink colour lines in this figure. Among these two Motors, BLDC motor has evaluated the better performance.

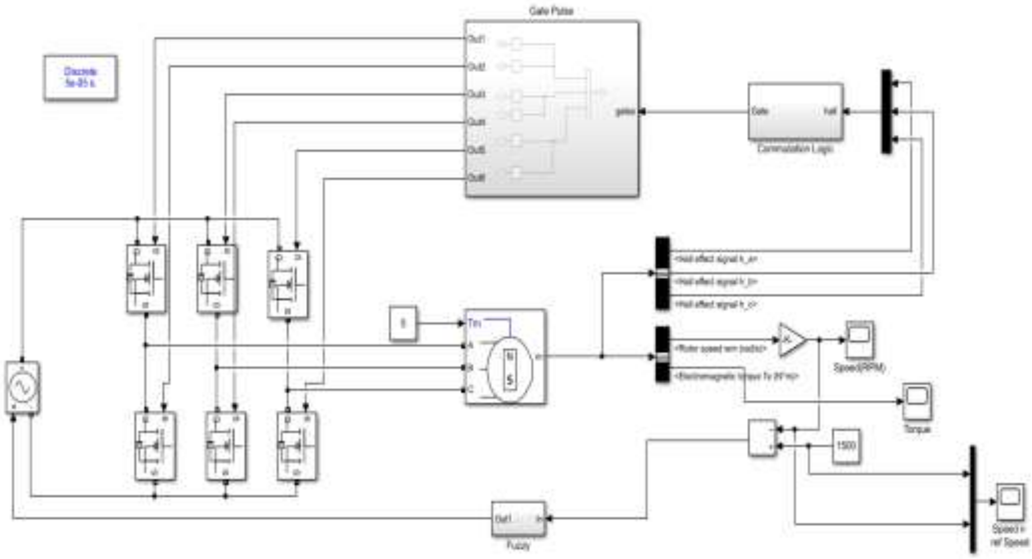

Fig -6 Simulink Model of BLDC Motor with Fuzzy Logic Controller

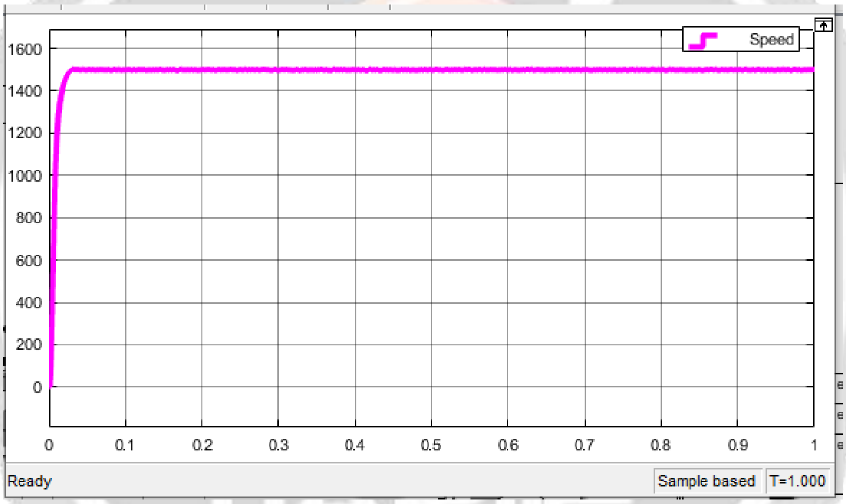

Fig -7 Speed of BLDC Motor

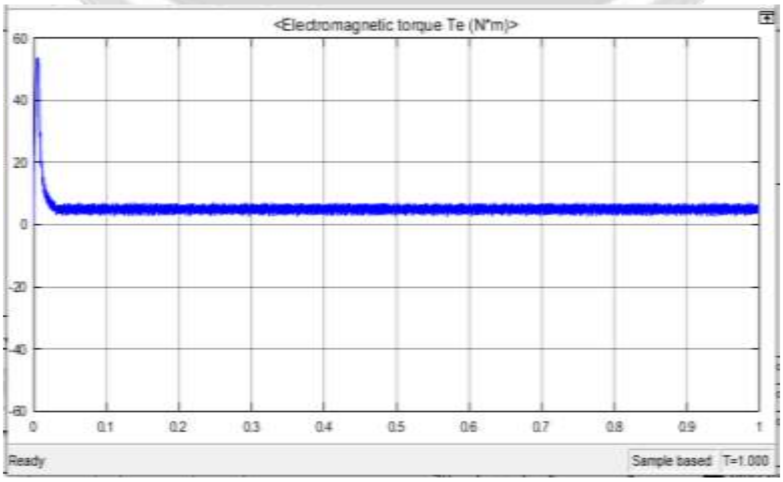

Fig -8 Torque of BLDC Motor

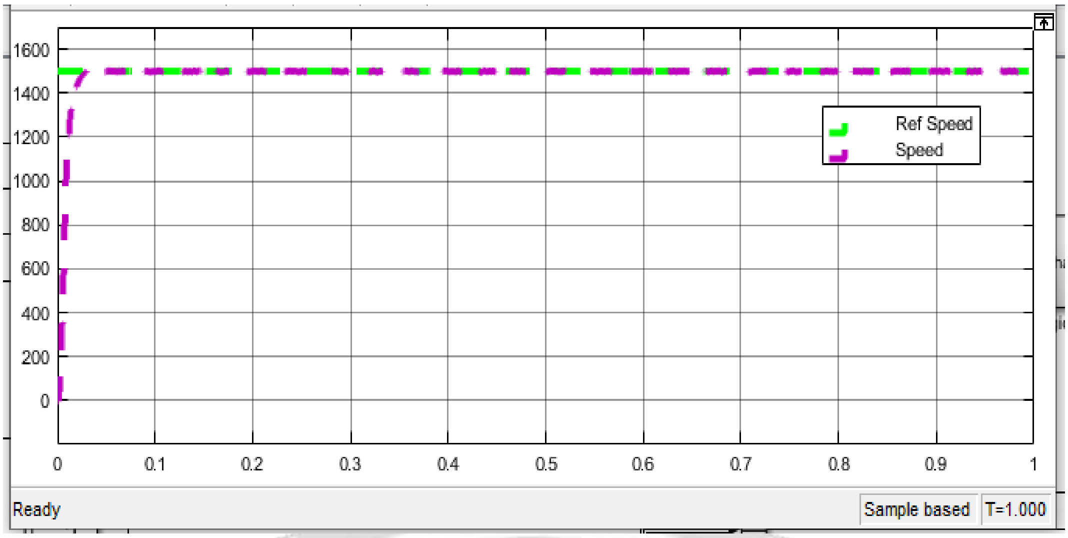

Fig -9 Speed Vs Ref Speed of BLDC Motor

6. CONCLUSION

The performance evaluation of Induction motor and BLDC motor with fuzzy logic Controller has been evaluated for Electric Vehicle related Applications to control the speed. The sensorless techniques based on the back EMF sensing and the rotor position detection with a high starting torque is suggested. The rotor position is aligned at standstill for without an additional sensor. Also, the stator current can be easily adjusted by modulating the pulse width of the switching devices during alignment which will be helpful to reduce cost and complexity of the drive system without compromising the performance. The performance of both Induction motor and BLDC Motor with Fuzzy Logic Controller is evaluated. Among these two Motors BLDC motor has results in the better performance. The performance of the motor which regulates the better speed can be evaluated by using Matlab/Simulink 2018a Software.

7. REFERENCES

1. Gopal et al Comparative analysis of Speed control of BLDC motor using PWM and Current Control Techniques, IEEE IAS Global Conference on Emerging Technologies (GlobConET) 2022.
2. R. Lakshmi et al, “Comparison of Transient Responses of Two Switch forward converter with sliding mode controller and HC-Fuzzy controller”, Journal of Emerging Technologies and Innovative Research pp 277-287, 2023.
3. Nobuyuki Matsui, “Sensorless PM Brushless DC Motor Drives”, IEEE Trans. on Industrial Electronics, Vol.43, No.2,pp.300-308, April 1996.
4. Champa.P, Somasiri.P, Wipauramonton.P and Nakmahachalasint.P, “Initial Rotor Position Estimation for Sensorless Brushless DC Drives”, IEEE Trans. on Ind. Applications, Vol.45,No.4, pp.1318-1324,July 2009.
5. Somanatham.R, Prasad.P.V.N, Rajkumar.A.D, “Modelling and Simulation of Sensorless Control of PMBLDC Motor Using ZeroCrossing Back EMF Detection” IEEE SPEEDAM 2006 International Symposium on Power Electronics, Drives, Automotive and Motion.
6. R. Lakshmi, (2014), “Closed Loop Control of the Two Switch Serial Input Interleaved Forward Converter Fed DC Drive”., The International Journal of Science & Technology, Vol. 2, Issue 3, pp. 45-48, 2014.
7. Bimal K Bose, “Modern Power Electronics and AC Drives”, Pearson Education Asia 2002.
8. Miller. T.J.E., “Brushless permanent magnet and reluctance motor drives ", Clarendon Press, Oxford, 1989.
9. Ramesh.M.V, Amarnath.J, Kamakshaiah.S and Rao.G.S, “Speed control of Brushless DC Motor by using Fuzzy Logic PI Controller”, ARPN Journal of Engineering and Applied Sciences, Vol.6, No.9, September 2011.
10. R. Lakshmi et al “Fuzzy logic control of two switch & three switch serial input interleaved forward converters”, Indonesian Journal of Electrical Engineering and Computer Science, Vol.16, No.1, pp. 147-155, 2019.
11. Yan Wei-Sheng, Lin Hai, Li Hong,Yan Wei, “Sensorless Direct Torque Controlled Drive of Brushless DC Motor based on Fuzzy Logic”, IEEE Trans. on Ind. Elec. and Appl., Vol.23, No.4. 2009.

12. Taeyeon Kim, Chungil Kim, Joon Lyou, "A New Sensorless Scheme for a BLDC Motor Based on the Terminal Voltage Difference" IEEE Trans. on Industrial Applications, Vol.6, No.7, pp.1710-1715, September 2011.
13. Anjali A.R, Calicut University, "Control of Three Phase BLDC Motor Using Fuzzy Logic Controller", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol.2, Issue 7, July 2013.
14. R. Lakshmi et al "Closed Loop Control of the Three Switch Serial Input Interleaved Forward Converter Fed Dc Drive"., IOSR Journal of Electrical and Electronics Engineering, Volume 12, Issue 6 Ver. III, Nov- Dec.2017.
15. Sheng, Y., Xingcheng, W., Longda, W. and Pengchao, H. Fuzzy-PID Control System Design of Brushless DC Motor Based on Vector Control. IEEE Journal 2017.