SPEED ESTIMATION AND CONTROL OF INDUCTION MOTOR USING MODERN PREDICTIVE CONTROL

Nallamilli.P.G.Bhavani[1], R.Vani[2]

[1]*Assistant Professor, Department of Electrical and Electronics Engineering,*

Meenakshi College of Engineering, West KK Nagar, Chennai, India

[1]*E-mail: sbreddy9999@gmail.com*

[2]*Professor, Department of Electronics and Communication Engineering,*

SRM Institute of Science and Technology, Ramapuram, Chennai, India

[2]*E-mail: vanir@srmist.edu.in*

Abstract

This paper uses model predictive control that is Superior to traditional drive transmission to handle sensorless speed control of induction motor driven by a single stage sun. The proposed system, solar Photovoltaic (PV) array connected with Voltage Source Inverter (VSI) and predictive control system, MRAS. A MPPT algorithm based on perturbation and observation is used for harnessing the full power from a PV series. System predictive control strategy is a predictive control approach to standard optimisation. For less dependency on model parameters, MPC can achieve sufficient control efficiency and has been widely used in process control systems. MRAS speed estimation method was implemented to achieve sensorless operation to boost the device reliability and cost reduction of Hardware. In MATLAB / Simulink environment the desired configuration is modelled and simulated.

***Keywords**: Speed sensor less control, Model predictive control (MPC), Photo voltaic (PV), Perturb and Observe algorithm (PO), Model Reference Adaptive System (MRAS), Induction motor (IM)*

1. INTRODUCTION

In the present development, because of the fast exhaustion of non-renewable resources, many countries are promoting renewable energy resources to meet the growing demand for electric power[18,23,26]. The age of sunlight based PV-based vitality has come up as a significant option for a few purposes. The acceptance engine has supplanted DC drives in light of its mechanical straightforwardness, strength, dependability, minimal effort, better and less maintenance. A solar PV system is used here to feed induction motor drive using predictive control model. Single power peak is a main feature in photovoltaic and maximum power attainment is an important feature of PV system. A perception dependent on the Maximum Power Point Tracking (MPPT) calculation is utilized to control and watch the greatest force and power. P&O algorithm improves monitoring time and produces increased energy when the irradiation varies greatly, which is operationally simple and requires less hardware and easy implementation[25].

To achieve maximum motor output, induction motors (IM) permits one DC - DC converter and one VSI (voltage source inverter). Therefore, VSI performs regulation of the DC link voltage itself. The system however needs at least seven switches from the power converter and thus increases the switch losses. This also includes a DC-AC conversion performed in three-phase IM. Therefore it is important to use single stage control drive which in turn reduces the quantity of switches and misfortunes[10,11]. A VSI must keep up the MPP in a solitary stage design, and it likewise controls the voltage of the DC connect[13]. Field Oriented Control (FOC) and Direct Torque Control (DTC) are two particular drive control frameworks for their enlistment. These two plans are basic, and it is simple to execute and have a quick powerful reaction[9,12,14,15]. Yet, they are model based, and furthermore delicate to evolving boundaries. Main design of control rises under this kind of interest[16]. MPC has gotten the third decision of an elite drive framework notwithstanding the FOC and DTC speed control frameworks, creating considerable interest in research. Model Reference Adaptive System (MRAS) is one of the speed observator regularly utilized for acceptance engine drives[17,19,20,21]. MRAS speed eyewitness depicts two models, reference model and a movable model which yields and looks at two related signals, for example, motion, back emf or stator current[1]. A rule which is sensitive to speed moves the output error to null[22,24]. It is shown that, according to the simulation results[3], the combined MPC, MRAS framework shows better speed control execution and state estimation execution over a wide speed range and torque.

2. METHODOLOGY

The design of sun powered PV exhibit took care of sensorless engine acceptance drive with prescient control of the System[2] is appeared beneath in Fig.1.The proposed framework is a PV cluster followed by a VSI-controlled three-stage enlistment engine drive[4]. MRAS figures the engine speed, which is determined by the voltage of the DC connection and the motor currents. For MPPT a Perturb and Observe algorithm is used to produce VSI switching pulses, maintaining specification accuracy.

Figure 1 shows a straightforward schematic of a 3-stage enlistment engine, 415V, used to drive the framework controlled by a sun based PV cluster of maximum 8.7 kW.

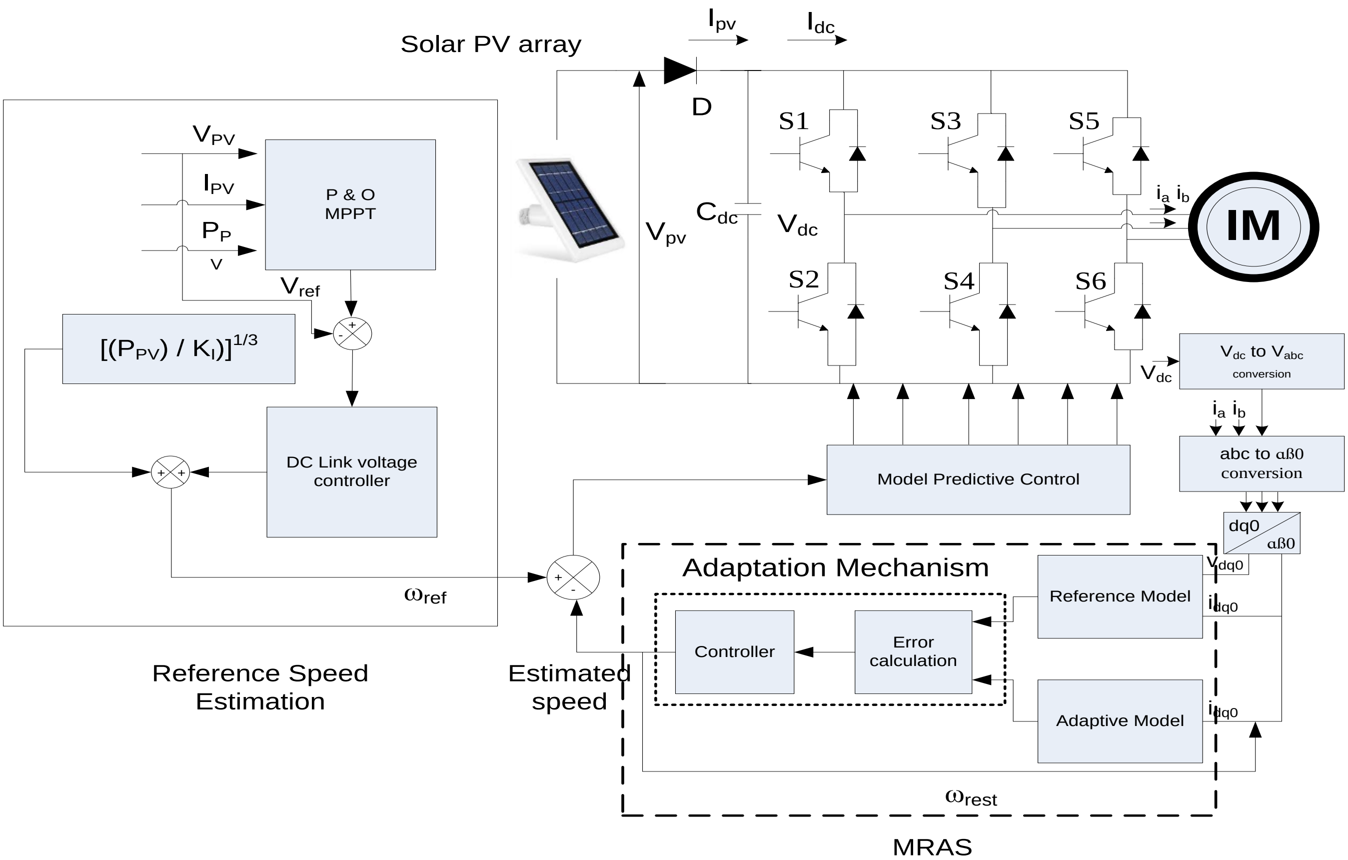


Figure 1: PV fed induction motor drive using Model predictive control

2.1. Solar PV generator configuration

A 8700 W PV exhibit is intended to drive a 7.5kW acceptance engine. A PV exhibit is introduced by associating 34 PV modules in open circuit voltage (Voc) arrangement equivalent to 734V and 25 modules corresponding to the short circuit current (Isc) identical to 15.5 A. The voltage of DC connection ought to be more noteworthy than the pinnacle abundancy of the line voltage gave to the engine to

$$V_{dc} = \sqrt{2}\, x\, V_L = \sqrt{2}\ x\ 415 = 587V \tag{1}$$

DC link voltage = 600V.

$$\frac{1}{2} x C_{dc} x (V_{dc}^2 - V_{dc1}^2) = 3aV_p I_t \tag{2}$$

DC link Capacitor is 2.5nF where V_{dc} is the voltage of the DC connection and V_{dc} is the minimum permissible voltage of the DC connection during the transient state, t is the time needed to recover the minimum permissible voltage of the DC-link, Current of the motor phase is I and voltage of operation is V_p. Hence the condenser value is selected as 2.5nF.

2.2. Design of Inverter

The inverter comprises of three modules with half extension; at moments of a given time the upper and lower power switches of every unit join turning on and off[5]. Contingent upon the condition of the switches in the individual half extension, every one of the three yield terminals can either be wired to the positive dc-interface voltage potential or to the negative potential.
Such switching states are

$$S_a = \begin{cases} 1, & \text{if } S_1 \text{ on and } S_2 \text{ off} \\ 0, & \text{if } S_1 \text{ on and } S_2 \text{ off} \end{cases}$$
$$S_b = \begin{cases} 1, & \text{if } S_3 \text{ on and } S_4 \text{ off} \\ 0, & \text{if } S_3 \text{ on and } S_4 \text{ off} \end{cases}$$
$$S_c = \begin{cases} 1, & \text{if } S_5 \text{ on and } S_6 \text{ off} \\ 0, & \text{if } S_5 \text{ on and } S_6 \text{ off} \end{cases} \tag{3}$$

In vector form, this can be expressed as:

$$S = \tfrac{2}{3}\left(S_a + aS_b + a^2 S_c\right) \tag{4}$$

3. PERTURB AND OBSERVE ALGORITHM

The single stage system that includes MPPT to extract maximum power through inverter. Here P&O algorithms shown in figure 2 for maximum power point tracking (MPPT) are implemented. VSI switching using Model predictive control and speed estimation with MRAS[6]. Consideration is given to the direction of perturbation according to the power transition[8]. If there is a positive power change then the voltage increases in the direction of the right side and in the event that it is negative or diminishes, at that point the voltage unsettling influence increments in course of the contrary left , and the aggravation way is resolved if the voltage at present is higher than the voltage at the past one, which would then be able to be estimated as a result of this adjustment in the PWM[7]. At starting, overshoot shows up as indicated by this condition and bit by bit diminishes until it arrives at a steady state, and when the yield power surpasses its full qualities, the control activity stop.

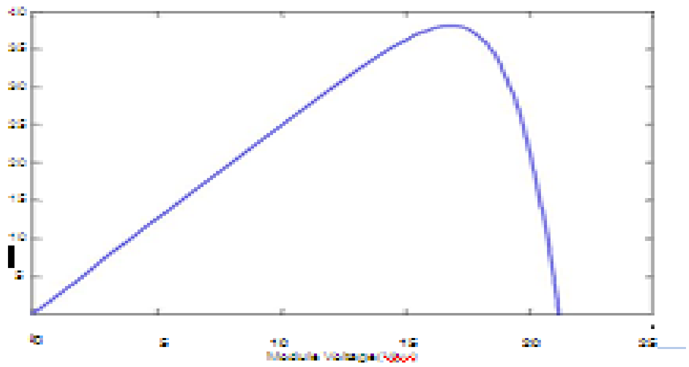


Figure 2: Power-Voltage Curve of the solar

From the flowchart shown in figure 3, it is observed that: On the off chance that force is on the left half of the most extreme force point, at that point the voltage increments ,and in like manner when force is on the correct side of the greatest force point, at that point the voltage diminishes[9].

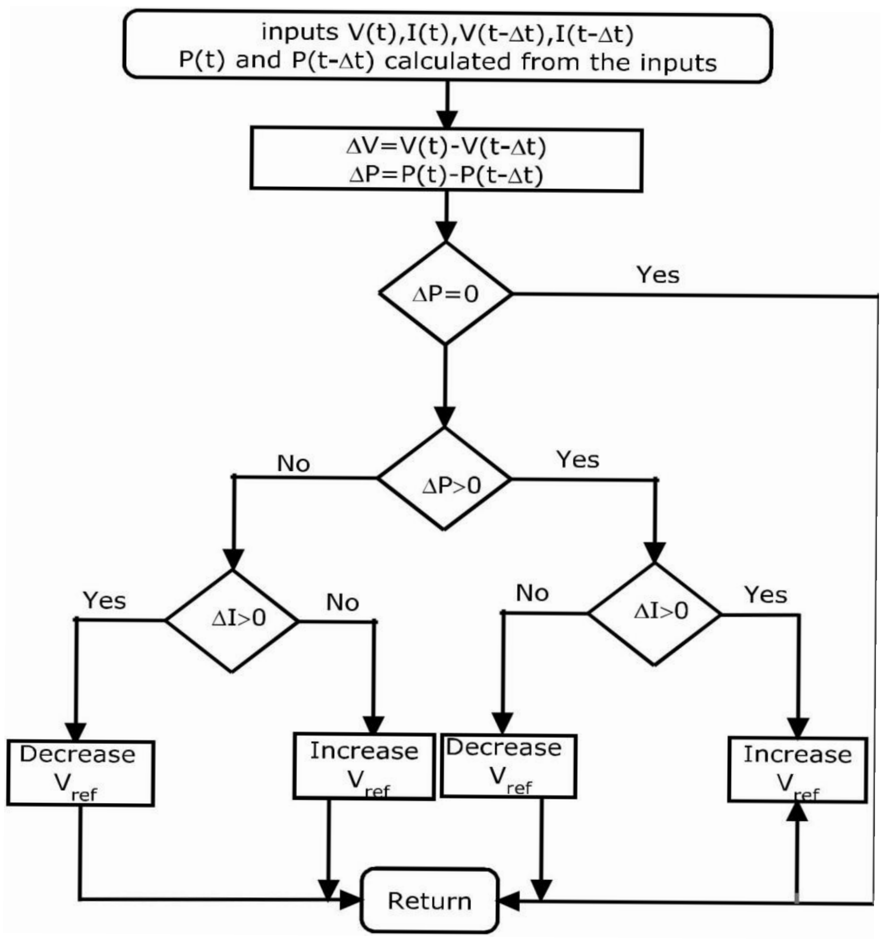
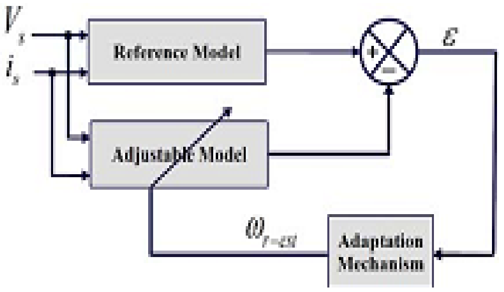


Figure 3: Perturb and Observe Algorithm Flow Chart

4. MRAS SPEED ESTIMATOR

The MRAS velocity estimation structure essentially consists of a reference model, unique model and a versatile system as shown in Figure 4a,4b. Independent of rotor speed, measures the state variable, X, against the voltage and current of the terminals[8]. The adjustable model which depends on the speed of the rotor estimates the variable of state, i[7]. The error between the measured and assessed state factors is then utilized by tf to drive the flexible model's adjustment component which produces the evaluated speed, tV. It should be noted that methods of speed estimation using MRAS can be divided according to the state variable into different forms[6] shown in figure 5. The most widely used are MRAS based on the rotor flux, back emf and stator current.



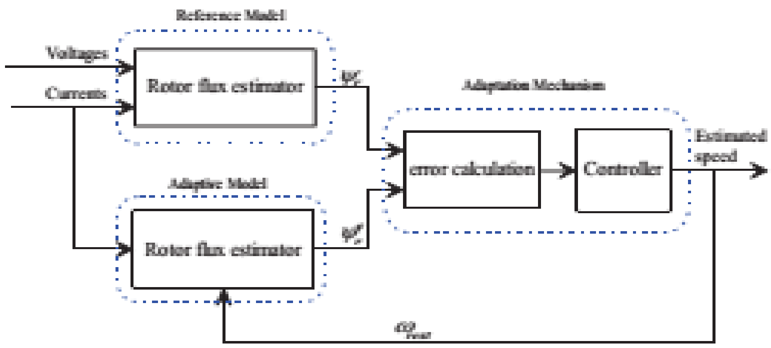


Figure 4a: MRAS estimation structure **Figure 4b: Rotor Flux based MRAS**

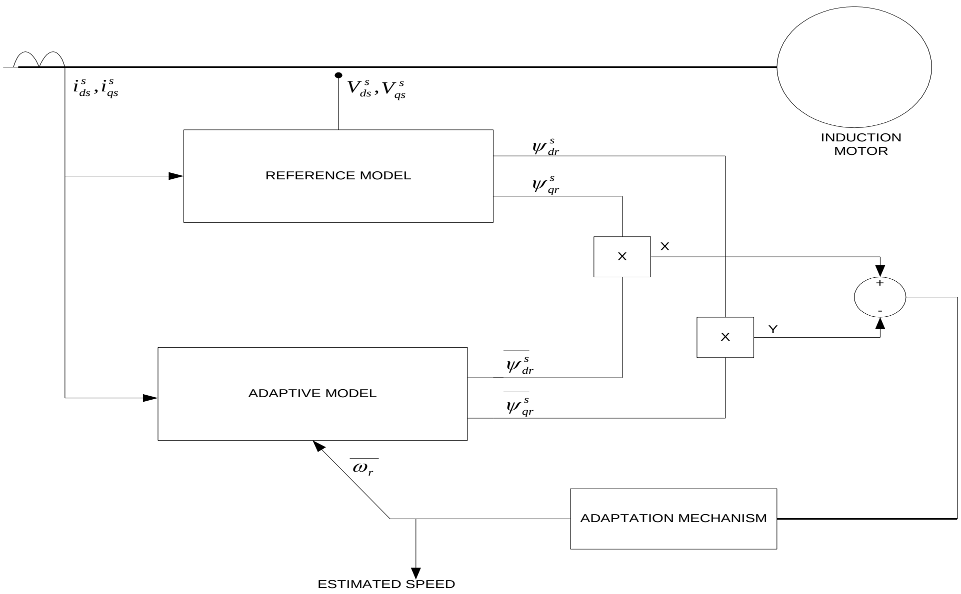


Figure 5: Block diagram of MRAS model for Induction Motor

As approximate amounts, the basic structure of the traditional style rotor flux dependent MRAS is identical to the one with rotor transition. In this plan, the enlistment engine stator circuit conditions are utilized by the speed-free reference model normally communicated as voltage model to extract the rotor flux value. Usually expressed as the current model, the adaptive model relies on rpm, and uses rotor circuit equations of the induction motor. In the adjustment procedure a Proportional-Integral (PI) controller is utilized to gauge rotor speed.

5. MODEL PREDICTIVE CONTROL

MPC principles, we present a control technique, which thinks about all exchanging successions over a short exchanging horizon N, referred to as the control horizon in the MPC. The sequence of semi-conductor switch positions S is defined as a switching sequence, from time stage 0 to time step N-1 after some time span N. The MPC plot figures the drive reaction for each exchanging succession in a subsequent stage, for example the advancement of yield factors over the exchanging horizon N, in view of the nonlinear, discrete-time forecast model. To reproduce a since a long time ago yield horizon, the "promising" yield directions are extrapolated, and the quantity of time-steps are resolved when the primary yield variable hits a hysteresis limit. The expenses related with each exchanging arrangement are determined by partitioning the complete number of exchanging changes in the arrangement by the length of the extrapolated direction. The model prescient plan can be worked in two different ways, with $N > 1$ and $N = 1$, frequently varying in the level of opportunity for the exchanging successions, consequently the computational weight and the productivity.

6. RESULTS AND DISCUSSION

Simulations of the model predictive control scheme were performed with Matlab-Simulink to determine its effectiveness. MPC has given better response than Vector control shown in table 1.

Table 1. Comparison Result of MPC and Vector control

CONTROL METHOD	SPEED (RPM)	SETTLING TIME(ms)
MPC	305	2.25
VECTOR CONTROL	305	3.5

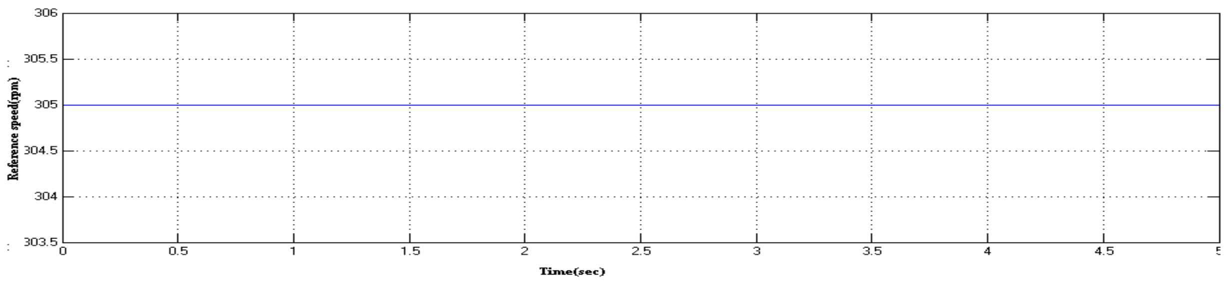


Figure 6: Rotor Reference speed at 305 RPM

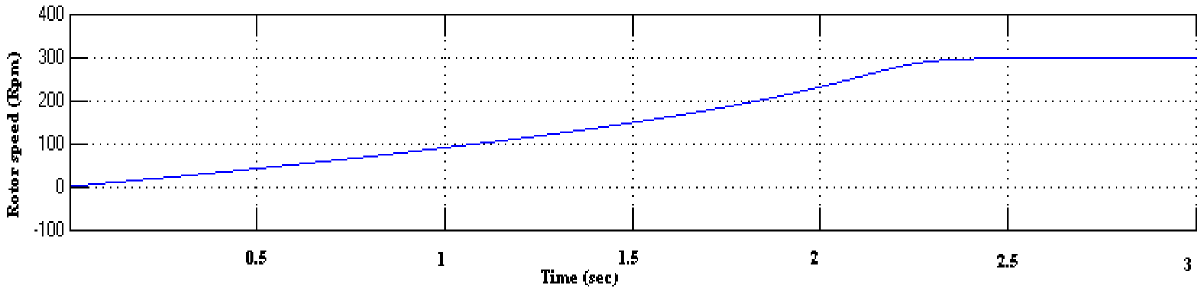


Figure 7: Rotor speed by using MRAS at 305 RPM

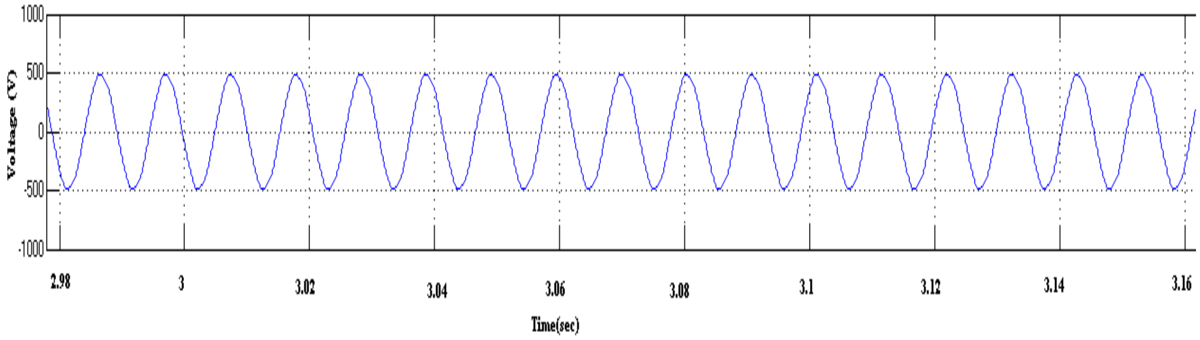


Figure 8: Stator Voltage

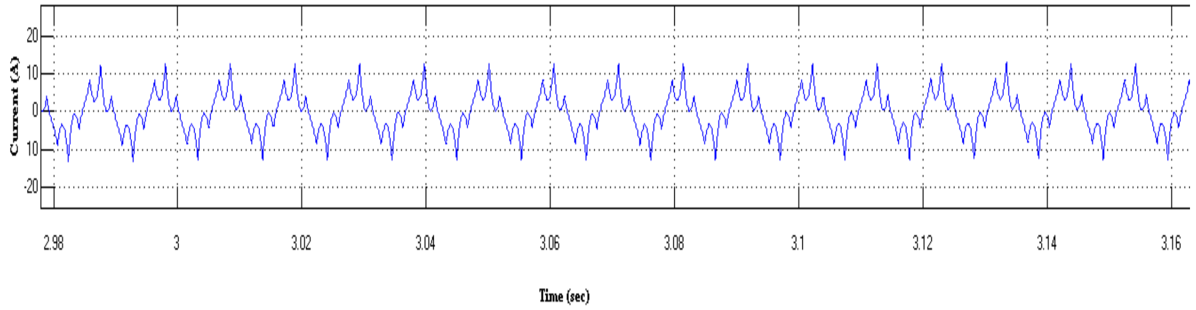


Figure 9: Stator current

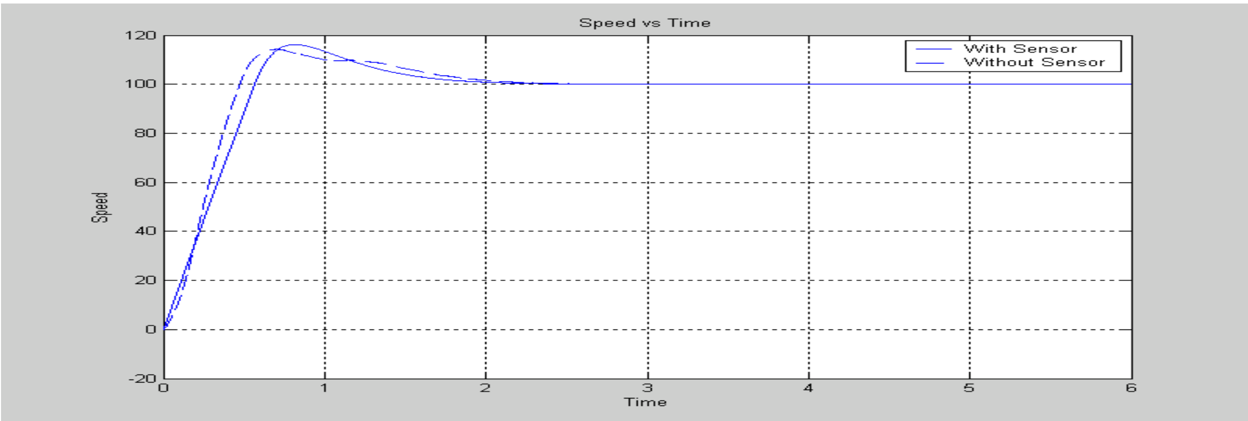


Figure 10: Rotor speed by using MRAS 100 RPM

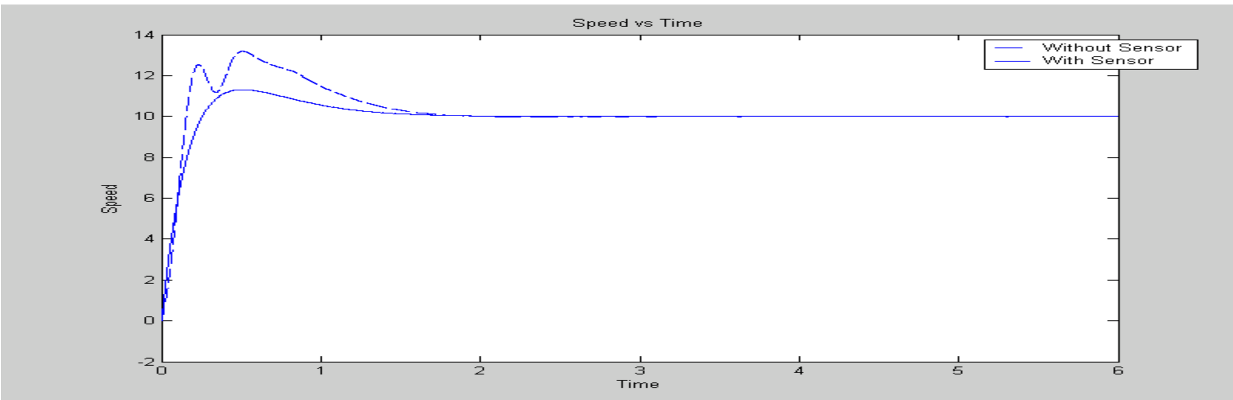


Figure 11: Rotor speed by using MRAS at 10 RPM

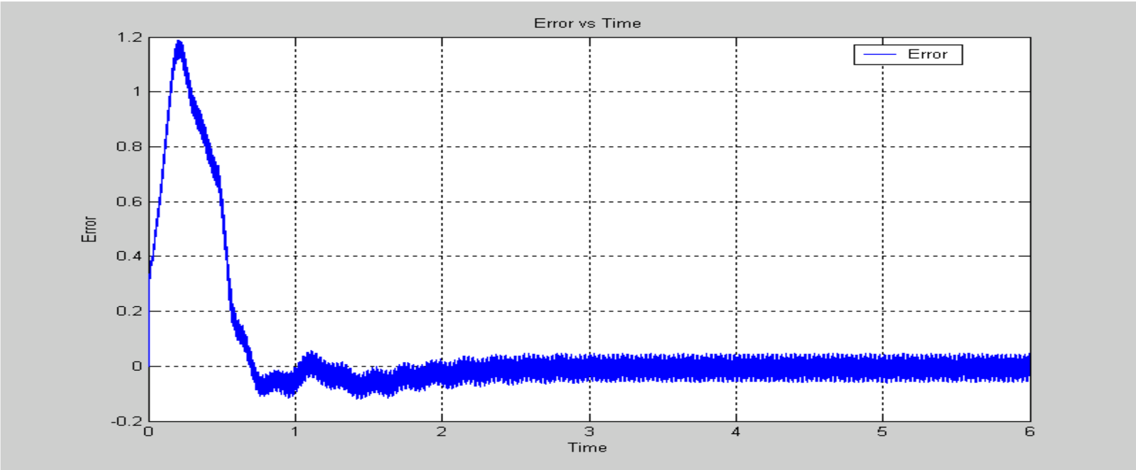


Figure 12: Flux Error between the Adjustable and Reference Model

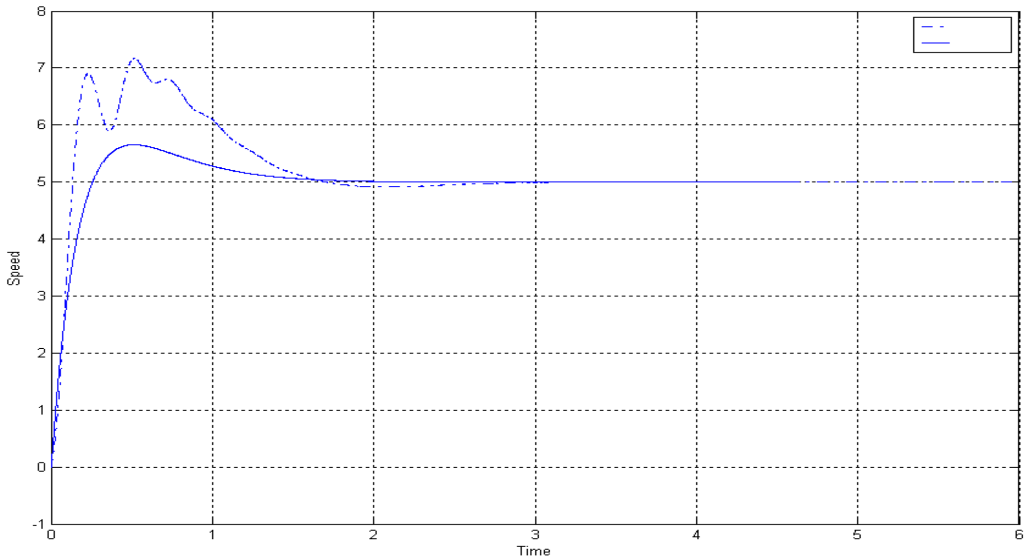


Figure 13: Rotor speed by using MRAS at 5 RPM

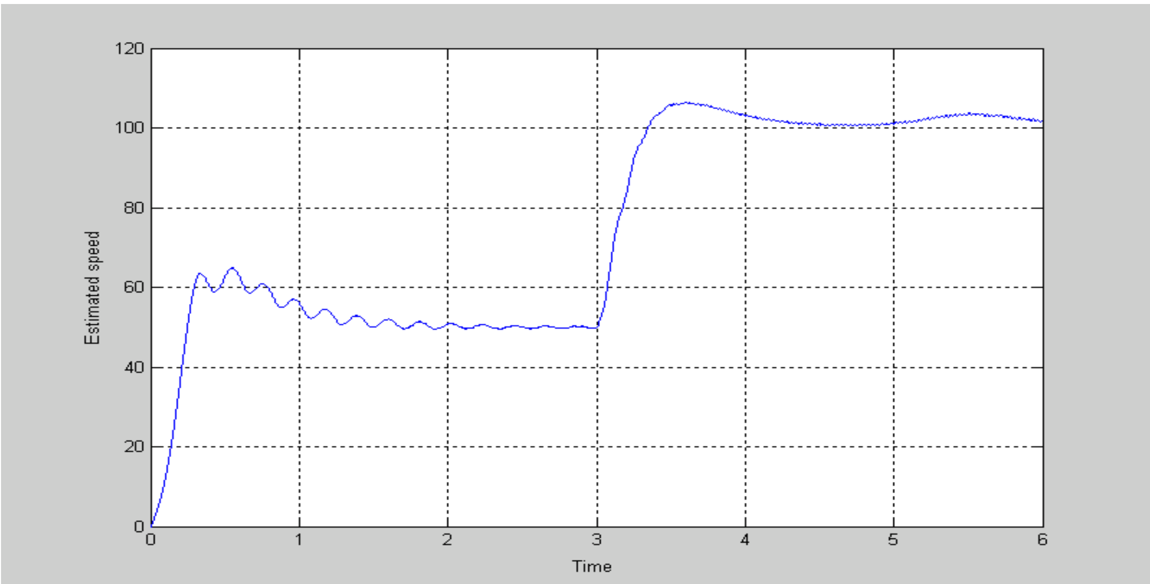


Figure 14: Step change in Reference speed from 50 rad/sec to 100 rad/sec

The performance of the MRAS has been observed at various speeds and results are compared with those of with sensor shown in Figures 6-14. Also efforts were made to implement a model of MRAS that incorporates low pass filters to avoid harmonics at low speeds.

7. CONCLUSION

Speed control using MPC fed sensorless IM was found to be very satisfactory, and it is suitable for electric vehicles. The engine takes off easily. The reference speed is produced by the DC interface voltage controller that manages the voltage at the DC association alongside the speed estimator. The intensity of the PV exhibit is held at full force point at the hour of progress in irradiance, which was possible through MPPT algorithm based on P &O. Combining the model predictive control with MRAS speed estimator for high-performance induction motors is feasible. The simulation results obtained affirm the positive properties of the sensorless enlistment engine drive conspire proposed for speed. Recreations have been tried utilizing the proposed sensorless speed control arrangement of enlistment engines that joins the MPC current controllers and the MRAS speed estimation. MRAS speed estimation at low speeds will give efficient and accurate results.

References

[1] *R. Kennel and A. Linder, "Predictive control of inverter supplied electrical drives," in Proc. IEEE Power Electronics Specialist Conference (PESC'00), Galway, Ireland, **(2000)**, (CD-ROM).*

[2] *Zhang Songbai, Zheng Xu, Youchun Li and Yixin Ni, "Optimization of MPPT step size in stand-alone solar pumping systems," IEEE Power Eng. Society Gen. Meeting,**(2006)**.*

[3] *S. K. Sahoo and T. Bhattacharya, "Field Weakening Strategy for a Vector-Controlled Induction Motor Drive Near the Six-Step Mode of Operation," IEEE Trans. Power Electron., vol. 31, no. 4, pp. 3043-3051, **(2016)**.*

[4] *M. A. Elgendy, D. J. Atkinson and B. Zahawi, "Experimental investigation of the incremental conductance maximum power point tracking algorithm at high perturbation rates," IET Renewable Power Generation, vol. 10, no. 2, **(2016)**, pp. 133-139.*

[5] *B. Singh, G.Bhuvaneswari and V.Garg, "A Novel polygon based 18-pulse AC–DC converter for vector controlled induction motor drives," IEEE Trans.Power Electron., vol.22, pp.488-497,**(2007)**.*

[6] *R. Kumar, S. Das, P.Syam and A.K. Chattopadhyay, "Review on model reference adaptive system for sensorless vector control of induction motor drives," IET Elec. Power Appl., vol.9, pp.496-511, **(2015)**.*

[7] *J. Holtz, "The induction motor – a dynamic system," in Proc. Annual Conference of the IEEE Industrial Electronics Society (IECON'94) vol. 1, Bologna, Italy, **(1994)**, pp. P1–P6.*

[8] *E. Camacho and C. Bordons, Model Predictive Control. London, UK: Springer-Verlag, **(1999)**.*

[9] *Zhang Yongchang, Yang Haitao, "Model Predictive Control for Speed Sensorless Induction Motor Drive," Proceedings of the CSEE, vol. 34, no. 15, pp. 2422-2429, May 25, **(2014)**.*

[10] *Jose Rodriguez, Patricio Cortes. Predictive Control of Power Converters and Electrical Drives. Wiley-IEEE Press, Chichester, United Kingdom, **(2012)**.*

[11] *"Sensorless Vector Control of 3-phase BLDC Motor Using a Novel Extended Kalman", A.Ejlali and J. Soleimani, Member, IEEE transactions,**(2012)**.*

[12] *"A Novel Space-Vector Current Regulation Scheme for a FOC Induction Motor Drive" Yi-Hwa,Liu,Chern-Lin Chen,Rong-JieTu,IEEETrans.on Industrial Electronics Vol.45,No.5, **(1998)**.*

[13] *"Field Oriented Control of a Five Phase Induction Motor fed by a Z-Source Inverter"Omar Ellabban,Haitham.,IEEE Trans. On Industrial Technology **(2013)**.*

[14] *"Performance of Induction Motor Drive by IVC method using PI and Fuzzy Controllers"Ch.Chengaiah and I.SivaPrasad.,International Journal of Science Environment and Technology .,**(2013)**.*
[15] *"Current Regulation Strategies for the Vector Controlled Induction Motordrives",DonaldHolmes,BrendanPeter,McGrath,StenartParker.,IEEE Trans on Industrial Electronics.,**(2012)**.*
[16] *"Indirect Vector Control of an Induction Motor with Fuzzy logic Based Speed Electrical and Computer Engineering,**(2010).***
[17] *"Simulation of Six-Switch Three Phase Inverter fed IM drive System",International Journal of Recent Trends in Engineering.,**(2009)**.*
[18] *"A Novel Space-Vector Current Regulation Scheme for a FOC Induction Motor Drive" Yi-Hwa,Liu,Chern-Lin Chen,Rong-JieTu,IEEETrans.on Industrial Electronics Vol.45,No.5, **(1998)**.*
[19] *"Field Oriented Control of a Five Phase Induction Motor fed by a Z-Source Inverter" Omar Ellabban,Haitham.,IEEE Trans. On Industrial Technology, **(2013)**.*
[20] *"Performance of Induction Motor Drive by IVC method using PI and Fuzzy Controllers"Ch.Chengaiah and I.SivaPrasad.,International Journal of Science Environment and Technology .,**(2013)**.*
[21] *"Current Regulation Strategies for the Vector Controlled Induction Motor drives",DonaldHolmes,BrendanPeter,McGrath,StenartParker.,IEEE Trans on Industrial Electronics.,**(2012)**.*
[22] *"Indirect Vector Control of an Induction Motor with Fuzzy logic Based Speed Electrical and Computer Engineering,**(2010)**.*
[23] *"Simulation of Six-Switch Three Phase Inverter fed IM drive System",International Journal of Recent Trends in Engineering.,**(2009)**.*
[24] *"A General PWM strategy for Four-Switch Three Phase Inverter",MauricioBeltraode, Rossiter Correa Cursino, Brando Jacobina, EdisonRoberto, IEEE Trans. On Power Electronics, **(2006)**.*
[25] *"Performance of a 4-Switch,3-Phase Inverter fed IM drive system",P.S.Phutane,Suraj R.Karpe.,International Journal of Advanced Research in Electrical,Electronics and Instrumentation Engineering, **(2013)**.*
[26] *"Microcontroller Based PWM Controlled Four-Switch Three Phase Fed Inverter Motor Drive",Nalin Kant Mohanty,RagunathMuthu.,Serbian Journal of Electrical Engineering, **(2010)**.*