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Performance of induction motor at low and high speed using model predictive control method.

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***Abstract*—This anticipate proposes the mpc to check the execution of rate of prompting engine at high and low speed The proposed control technique repays the postponement time to enhance the execution of the framework, and subsequently keep up the exact following of the references at various rate areas. It utilizes the conceivable exchanging vectors of the converter Therefore, in light of least quality capacity the ideal exchanging vector is chosen for the following examining time incitation of the force converter. The complete plan is reproduced in matlab .**

Keywords—Predictive Control; Power Converter; Delay Time Compensation; Induction Motor; Torque & Flux.

I. INTRODUCTION

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Air conditioning machine drives are for the most part imperative in the mechanical applications. To control the electrical drives, two sorts of control techniques were generally utilized amid the most recent two decades in the businesses, for example, direct torque control (DTC) [1], [2] and field situated control (FOC). The misfortunes connected with the DTC can be controlled with appropriate use of space vector modulation, and forcing the prescient torque control (PTC) calculation [3]. As the prescient control strategy is basic and simple to execute because of the extraordinary advancement of the computerized signal processor, this control technique has been earned an incredible worry to research group. Be that as it may, this prescient control can be connected to control electronic converter, since this control can use the discrete way of force converter to foresee the future conduct of the system.Recently, numerous works have been researched effectively with the prescient control calculation which have been demonstrated the heartiness and practicality of the prescient control technique for force converter [4].

In this way, a prescient current control sustained by voltage source inverter [5]; prescient torque and flux control of IM encouraged by backhanded lattice converter (IMC) with solidarity power variable control at the information side [3]; solidarity power component control at the network side of a dynamic front end rectifier [6], [7]; multilevel inverter nourished prompting engine prescient control [8]; direct framework converter (DMC) bolstered prescient torque control of IM with receptive force pay [9]; prescient current control of a three-stage four-leg inverter [10]; prescient control of bidirectional AC-DC converter [11]; torque swell lessening of IM with prescient direct torque control strategy [12], and a weighting element improvement technique in the prescient control calculation for decrease of torque swell [13], [14] have been explored in the late decades. A complete audit for the change of info current and also add up to symphonious twisting (THD) examination at the information and yield side of the IMC with prescient control calculation was researched in [15]. Additionally, a thorough audit has been exhibited to outline the model prescient control (MPC) strategy connected to power hardware application in [16], and depicted the uses of MPC technique on four distinctive force gadgets converters and drives.

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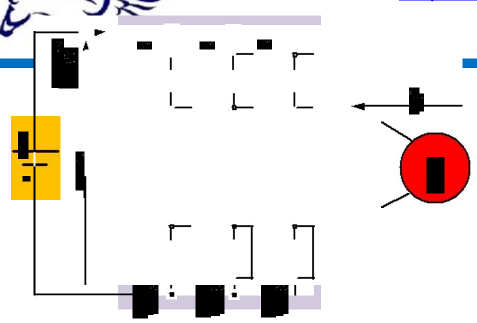


Fig. 1. Power converter topology

Overall quality functions of the MPC method, and a comprehensive predictive control scheme. In the fourth section, the simulation and experimental results are discussed to prove the feasibility of the proposed method. The last section is concluded with a comprehensive conclusion.

II. MODELING OF INDUCTION MOTOR

The power converter topology fed by induction motor (IM) is presented in Fig. 1. The three-phase system (y_a , y_b and y_c) can be represented as a two dimensional complex space vector (SV) as below:

$$y = y_\alpha + j y_\beta \quad (1)$$

where,

$$y_\alpha = \frac{1}{3}(2y_a - y_b - y_c), \quad y_\beta = \frac{1}{\sqrt{3}}(y_b - y_c) \quad (2)$$

In Eq. 2, $\alpha\beta$- reference frame is considered as the Stationary reference frame for expected space vector. The model of the IM referred to stator is obtained as described in [17]. The fixed coordinate stator and rotor voltage equations are presented as,

$$v_s = R_s i + L_s \dot{\psi}_s \quad (3)$$

$$v_r = R_r i_r + L_r \dot{\psi}_r - jp\omega\psi_s \quad (4)$$

where i, stator current; i_r, rotor current; R_s, stator resistance; R_r, rotor resistance; p, number of pole pairs, and ω, rotor angular frequency.
The stator flux and rotor flux can be presented as below:

$$\psi_s = L_s i + L_m i_r, \quad \psi_r = L_r i_r + L_m i \quad (5)$$

where, (L_s , L_r), self-inductances; L_m , mutual inductance.
The developed electrical torque in the IM can be represented by stator current and stator flux as the following equation:

III. PROPOSED PREDICTIVE CONTROL

A. Discrete-time model predictive torque and flux control

The first order Euler's approximations can be represented as below:

$$y' = \frac{y(k+1) - y(k)}{T_s} \quad (7)$$

The predictive variables (stator flux and rotor flux) of the induction motor can be determined by applying the first order Euler's approximations as following:

$$\psi_s(k) = \psi_s(k-1) + v_s(k)T_s - R_s i(k) T_s \quad (8)$$

$$\psi_r(k) = i(k)\left(L_m - \frac{L_s L_r}{L_m}\right) + \frac{L_r}{L_m}\psi_s(k) \quad (9)$$

Predictive stator flux, stator current and torque in the next (k+1)th sampling time instant become,

$$\psi_s(k+1) = \psi_s(k) + v_s(k)T_s - R_s i(k) T_s \quad (10)$$

$$i(k+1) = \left(1 + \frac{T_s}{\tau_\sigma}\right) i(k) + \frac{T_s}{\tau_\sigma + T_s}\left[\frac{1}{r_\sigma}\left\{\left(\frac{k_r}{\tau_r} - k_r j\omega\right)\psi_r(k) + v(k)\right\}\right] \quad (11)$$

$$T_e(k+1) = \frac{3}{2} p\{\psi_s(k+1) \times i(k+1)\} \quad (12)$$

where, $r_\sigma = R_s + R_r k_r^2$, $\tau_r = \frac{L_r}{R_r}$, $k_s = \frac{L_m}{L_s}$, $k_r = \frac{L_m}{L_r}$, $\sigma = 1 - k_s k_r$ and $\tau_\sigma = \sigma L_s / r_\sigma$.

B. Delay time compensation

The computational time required in the predictive control calculation to foresee the variables, and processors delay break down the execution of the predictive control at the trial examination. To take care of this postponement issue, it can be viewed as the expectation skyline at (k+2)th inspecting time to anticipate the variables which are contrasted and the references, and decide the quality capacities. The ideal exchanging vector is chosen comparing to the base quality capacity, and connected it in the following (k+1)th testing time incitation. Accordingly, one examining time is accessible to repay the time delay created by the processor.

C. Determination of the predictive model for (k+2)th *sampling time instant*

Applying the Euler's Approximation, similarly, for the second next (k+2)th sampling time instant, the predictive stator flux, stator current, and torque become as follows:

$$\psi_s(k+2) = \psi_s(k+1) + v_o(k)T_s - R_s i(k+1)T_s \quad (13)$$

$$i(k+2) = \left(1 - \frac{T_s}{\tau_\sigma}\right) i(k+1) + \frac{T_s}{\tau_\sigma + T_s}\left[\frac{1}{R_\sigma}\left\{\left(\frac{k_r}{\tau_r} - k_r j\omega_m\right)\psi_r(k+1) + v_o(k)\right\}\right] \quad (14)$$

$$T_e(k+2) = \frac{3}{2} p\{\psi_s(k+2) \cdot i(k+2)\} \quad (15)$$

D. Quality function

The quality function in the predictive control of IM with delay compensation is presented as below,

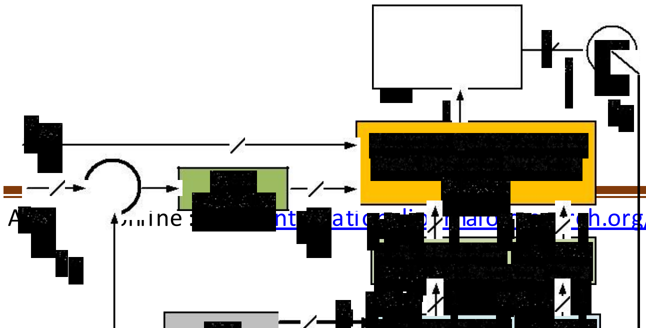
$$g_{IM}(k+2) = \left|T_e(k+2) - T_{ref}\right| + \lambda \left|\psi_s(k+2) - \psi_{ref}\right| \quad (16)$$

where, T_{ref}, ψ_{ref} are the reference torque and reference flux, respectively. λ, is the weighting factor, and represent the flux control has a priority control rather than the torque control.

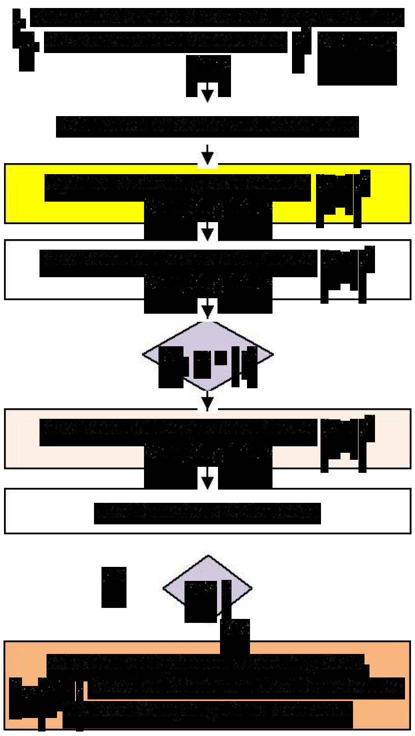
E. Delay time compensated predictive control scheme

The predictive control scheme and algorithm for induction motor control are presented in Figs. 2(a) and 2(b), respectively. The predictive controller satisfies the following steps:

- First: stator voltage, $v_o(k)$; stator current, $i(k)$; and speed, $\omega_m(k)$ of induction motor are measured in the k^{th} sampling time instant.



(a)



(b)

Fig. 2. (a) Predictive control scheme and (b) algorithm

- Second: stator reference flux (ψ_{ref}) and reference speed (ω_{ref}) are known values. Speed controller is used to set the reference

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torque (T_{ref}).

- Third: estimation of the stator and rotor flux.
- Fourth: predictive torque T_e (k 1) and predictive stator flux ψ_s (k 1) are predicted in the next sampling time period $(k+1)^{th}$ based on measured variables. And, this predictive torque and flux are used to predict the $(k+2)^{th}$ predictions of the same variables for all eight possible switching vectors.
- Fifth: the $(k+2)^{th}$ predictive values are compared with their respective references, and determine the quality functions for all the possible switching states.
- Lastly, the optimum switching vector corresponds to the minimum cost function is selected for the next sampling time actuation.

IV. SIMULATION RESULTS

The proposed control technique is confirmed in MATLAB Simulink and in addition test acceptance with DS1104 R&D Controller at various velocity locales to legitimize the execution of the proposed control plan. The parameters utilized as a part of the recreation and experimentation are given in Table I

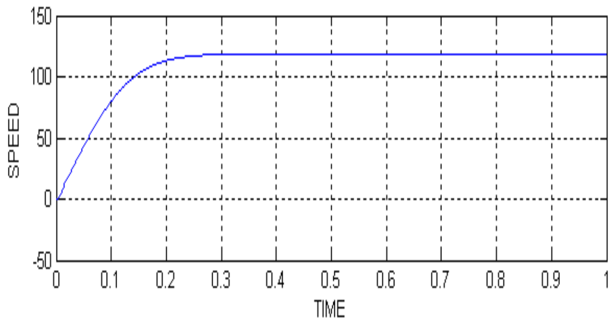
A. Simulation Results

The Figs. 3 and 4 speak to the aftereffects of IM control connected with model predictive control (MPC) technique at fast and low speed areas, separately. In both reenactments, the motor begin at 0.01s with the reference torque of 6 Nm in Figs. 3(a) and 4(a). The predictive torque takes after the reference torque with high following reaction in both checks. In Figs. 3(a) and 4(a), when the motor get its reference rapid of 125 rad/s, and 37.125 rad/s, individually, the predictive torque gets to be at least, and takes after the reference torque, precisely high torque of 6 Nm in both the examination.

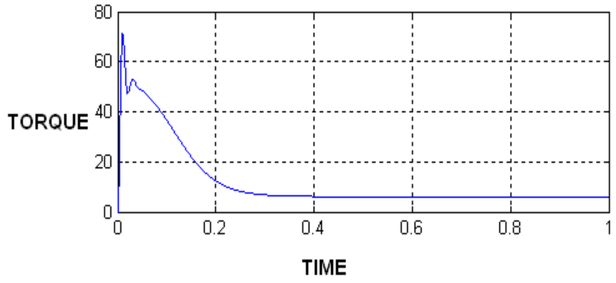
Additionally, the predictive stator flux tracks the reference flux extremely well, and keep up the size of 1.0 Wb all through the recreation time in Figs. 3(a) and 4(a). The Figs. 3(b) and 4(b) demonstrate the αβ − components of the stator current of IM comparing to reference changes in the reenactments which demonstrate an exceptionally reassuring conduct with the stage removal of 90o between the two components at forward and reverse speed areas.

Simulation without controller:-

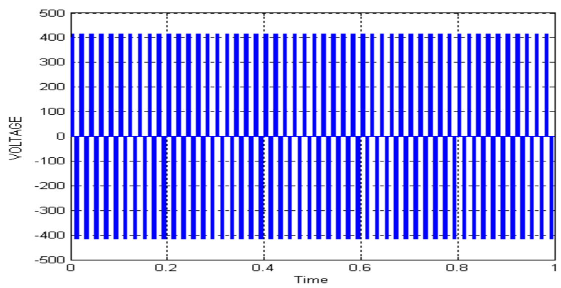
High speed



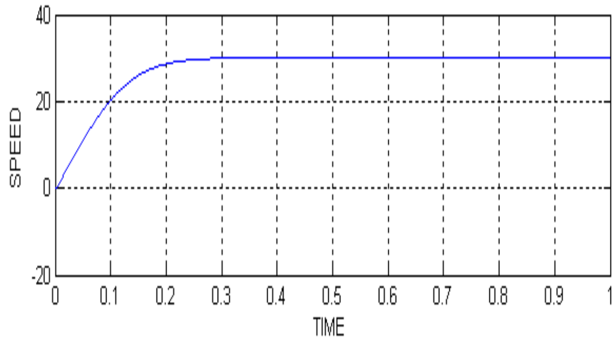
Torque :-



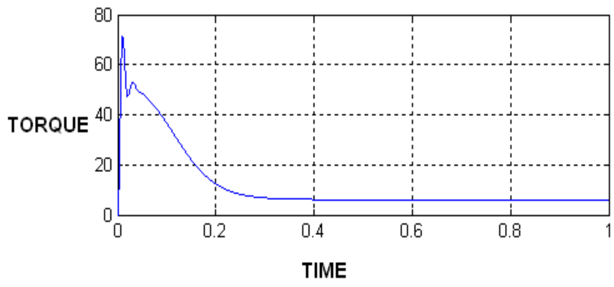
Inverter :-



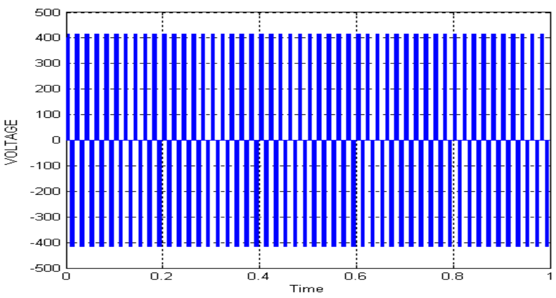
Low speed:-



Torque :-

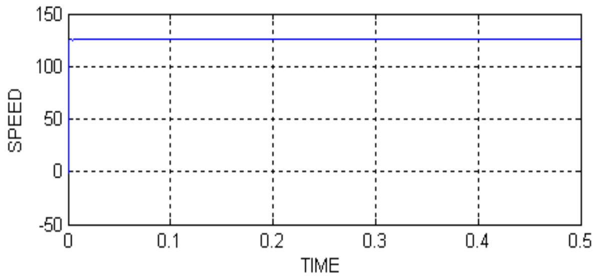


Inverter :-

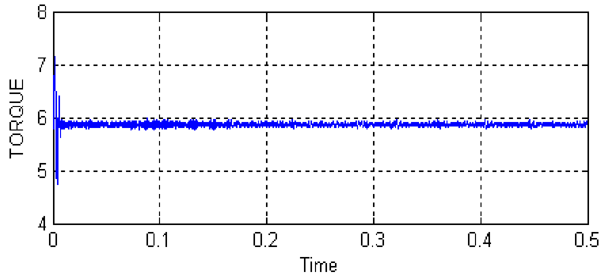


Simulation with controller: results

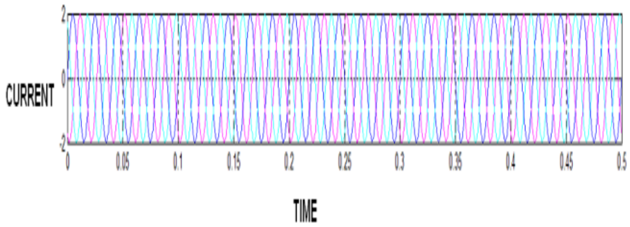
High speed:-



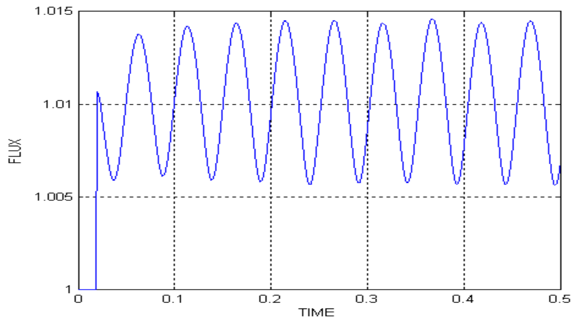
Torque:



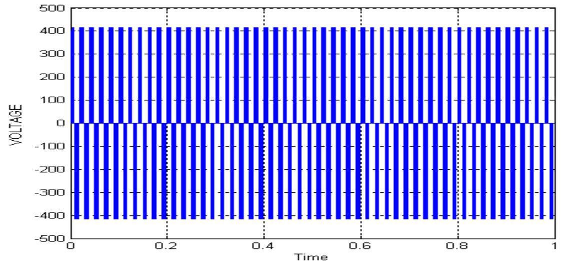
Current:



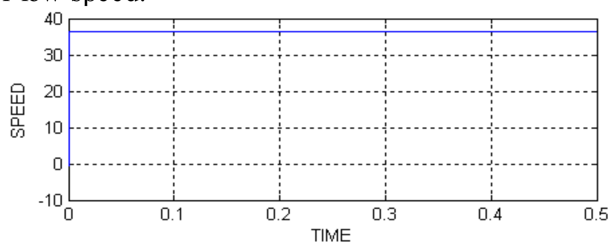
Flux:



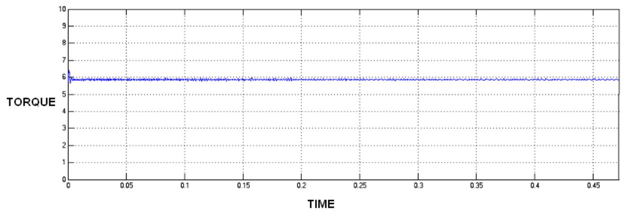
Inverter output:-



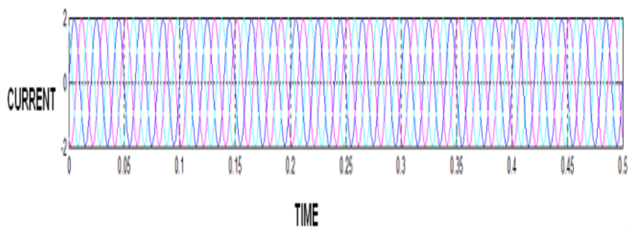
For low speed:-



Torque:-



Currents:-



Flux:-

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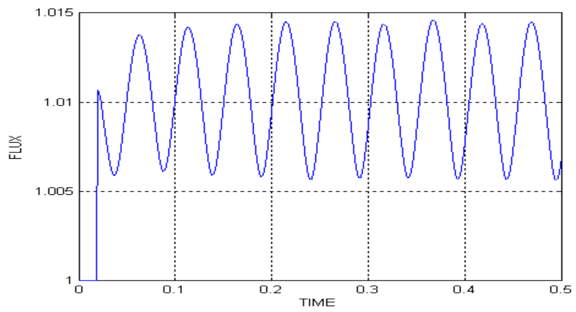

TABLE I: SIMULATION AND EXPERIMENTAL PARAMETERS

Description	Variables	Values
Sampling time	T_S	25 µs
DC voltage	V_{dc}	500 V
Supply frequency	f_S	50 Hz
Reference speed	ω_{ref}	125 rad/s and 37.175 rad/s
Nominal torque	T_{nom}	6 Nm
Reference Flux	ψ_{ref}	1.0 Wb
Stator resistance	R_s	21 Ω
Stator inductance	L_s	1.053 mH
Rotor resistance	R_r	22.63 Ω
Rotor inductance	L_r	1.081 mH
Mutual Inductance	L_m	0.9963 mH
Number of poles	p	2
Moment of inertia	J	0.04 Kg m^2
Weighting Factor	λ	T_{nom} / ψ_{ref}
Motor h.p		1.26 h.p
Current	i	2 amp

V. CONCLUSION

The reproduction demonstrate that the predictive control is a promising control instrument that is vigorous and effective to control the force converters and electrical machine drives. The proposed delay time repaid model predictive control technique uses the discrete and inductive nature of the force converter and impelling engine load. In this control, the long expectation skyline, i.e, the second next (k+2)th predictive variables are anticipated, and contrasted with the references with decide the quality capacities for all the conceivable eight exchanging vectors of the converter to beat the unavoidable control delay.

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