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# Simulation and Implementation of Predictive Direct Torque and Flux Control of Induction Motor

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***Abstract*** **:- The project shows a prescient direct flux and torque control of an enlistment machine in view of limited states space display. The proposed control calculation chooses the exchanging condition of the inverter that minimizes the quadratic mistake amongst torque and flux forecasts to their figured qualities for all unique voltage vectors. The ideal voltage vector that minimizes a cost capacity is then connected to the terminal of the acceptance machine. The proposed prescient control utilizes just a single specimen time and it is related at first to a two-level voltage inverter then stretched out to a three-level converter. The system is extremely natural since it is exceptionally basic and gives best exhibitions contrasted with other control laws.**

***Keywords: Induction motor, predictive control, finite states-space model, cost function, multilevel converter.***

## I. INTRODUCTION

Enlistment engines are generally utilized as a part of mechanical applications because of their low support, straightforwardness and moderately minimal effort contrasted with different machines. In any case, their dynamical model is multivariable, very coupled, non-direct and the states are not all quantifiable for criticism control purposes. In this way, they are more hard to control than DC engines. The ordinary hysteresis current controllers are for the most part utilized for their quick element reaction, power and straightforwardness execution by contrasting measured load streams and references utilizing hysteresis comparators and each comparator decides the switching state of the relating leg of the converter to such an extent that the heap ebbs and flows are compelled to stay with the hysteresis band. Truth be told, these controllers guarantee a decent control of the current without need of having any learning of the framework transmission capacity are utilized yet this arrangement needs the learning of the framework parameters and it is hard to implement.PWM current control techniques are extremely prominent and are talked about widely in the writing, their essential rule is to contrast an isosceles triangle bearer wave and the key recurrence sinusoidal adjusting wave produced by a modulator, and the purposes of crossing point decide the exchanging purposes of force gadgets. The blunder between the reference and measured current is prepared by a relative basic PI controller which guarantees zero enduring state mistake for ceaseless reference however may fall flat for sinusoidal references bringing on undesired outcomes where superior exhibitions are required. Show Predictive Control (MPC) is a capable control methodology that uses the model of the framework to pre compute the conduct of the framework for a predefined skyline later on [6],[7]. A cost work assesses the pre ascertained outcomes and decides the ideal future control activities. Summed up Predictive Control (GPC) is the most well known technique frameworks where dead circumstances can be effectively adjusted, the idea is exceptionally instinctive and straightforward, the multivariable case can be effortlessly viewed as, simple consideration of non linearities in the model. The principle hindrances of the GPC control is the vast measure of counts.

Appeared differently in relation to excellent controllers and the quick effect of the model on the way of the ensuing controller. Starting late, Finite States Model Predictive Control (FS-MPC) appears as an engaging choice and offers an absolutely exceptional and able approach to manage control converters as a result of its brisk element response, no prerequisite for direct controllers, no necessity for modulator (PWM or SVM), absolutely phenomenal approach stood out from PWM, incredibly essential, extraordinary execution and can be realized with standard business chip. The procedure relies on upon the way that a predetermined number of possible trading states can be created by power converter ( 7 states for a two levels three-organize inverter,27 states for a three levels, 64 states for a four levels,… ) and that the model of the system can be used to anticipate the lead of the elements for each trading state. For the assurance of the best possible changing state to be associated with the structure a quality limit must be described. The cost limit is then surveyed for the expected values on each testing between time and the perfect trading state that minimizes the quality limit is connected in the midst of the accompanying reviewing break. The present paper inquires about the accommodating of a constrained states space indicate based farsighted control of an acknowledgment machine in term of straightforwardness hardware, dynamic response and over energy security. The perfect voltage vector of the inverter that minimizes the oversight between the torque and flux gauges to their prepared qualities is associated with the terminal machine at the accompanying looking at time, consequently including the nonlinear traits of the power collide with the control computation.

## 2. MODELLING OF TWO LEVEL VOLTAGE *SOURCE INVERTER*

Describe the inverter output voltages and to analyze the motor current control method, the concept of complex space vector is applied.

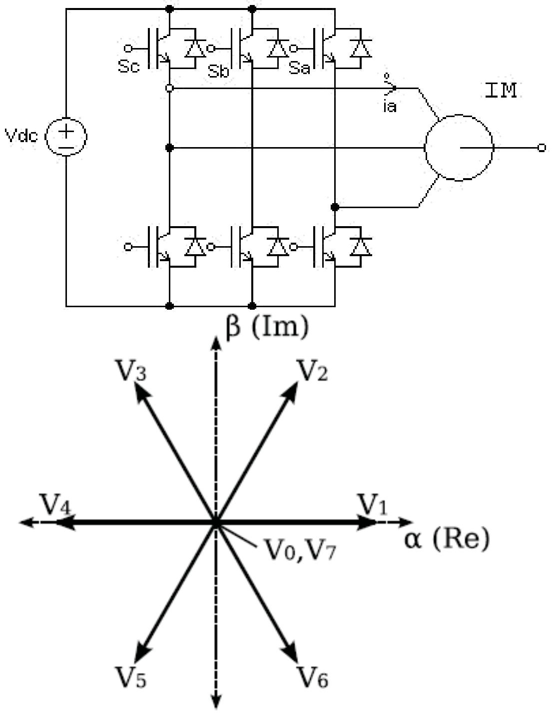

Fig.1: Two level voltage source inverter with seven possible voltage vectors

For a two level voltage source inverter feeding a symmetrical three-phase induction motor given in fig.1, each leg is composed of two by-directional switches (*Si1, Si2 i=a,b,c*) where a,b,c the three phases. The switching states *S* determined by gating signals are givenin a vectorial form as follows:

$$S=\frac{2}{3}(S_a+aS_b+a^2S_c)$$

The output voltage space vectors of the inverter are:

$$V=\tfrac{2}{3}(V_{aN}+aV_{bN}+a^2V_{cN})$$

Where ( $v_{aN}$ , $v_{bN}$ , $v_{cN}$ ) are the phase to neutral (*N*) voltages

As it is well known, there are eight possible voltage vectors that the inverter can apply on machine terminals. By using these switching functions the stator space voltage vector can be expressed as:

$$V(S_a,S_b,S_c)=\sqrt{\frac{2}{3}}V_{dc}(S_a+S_b e^{j2\pi/3}+S_c e^{j4\pi/3})$$

wheare $V_{dc}$ is the dc link voltage.

According to the combinations of switching modes, the space vectors $V_7(0, 0, 0)$ and $V_8(1, 1, 1)$ are the space zero voltage vectors and the others are the space nonzero active voltage vectors as shown in Fig. 1Also, the inverter output voltage is related to DC link voltage by:

$$V = V_{dc}\ S \qquad (4)$$

The inverter output voltage vector is kept constant during the switching period, so the inverter current and, hence, the motor currents can be controlled by choosing the appropriate voltage vector.

## 3. INDUCTION MOTORMODEL

A squirrel confine enlistment engine demonstrate sustained by voltage source inverter is utilized under improved suspicions where press immersion, skin impact, warming varieties of stator and rotor resistances are ignored. The model is communicated in the (α-β) reference outline where yields are stator streams and fluxes [7], the state factors are rotor fluxes and stator ebbs and flows as follows:where ($R_s$, $R_r$) are individually stator and rotor resistance per stage, ($i_s$, $i_r$) are stator and rotor current vectors, ($\psi_s$ ,$\psi_r$ ) are stator and flux vectors separately, ($L_s$ , $L_r$ , $L_m$ )are stator, rotor and shared inductances rotor ,$\omega_m$ is the rotor speed, Te is the electromagnetic torque of the machine and p is the quantity of match posts. In light of conditions one can speak to the dynamical model as:

## 4. PREDICTIVE CONTROL

Based on a given stator component voltage vector $V_{si}\,(k)$ , measured current $i_s\,(k)$ and estimated rotor flux $\psi_r\,(k)$ at current sampling instant, it is possible to *The* anticipated estimations of torque and stator flux are utilized to assess a cost work F that minimizes the blunder between anticipated qualities and their references and the exchanging state (compares to an ideal voltage vector) acquire one stage ahead expectation of stator current $i_s$ (k + 1) and rotor flux $\psi_r$ (k + 1) . Likewise, utilizing ,that produces the base estimation of this cost capacity is chosen to connected on machine terminals in the following testing time as per retreating skyline control. With the suspicion that it is conceivable to characterize a first request estimate (Euler joining guideline) for the subsidiaries because of the main request nature of the state conditions of acceptance engine show, we can compose that:

$$x(k+1)=x(k)+T\frac{dx}{dt}/_{x=x(k)}$$

$$=(1+T(x)x(k)+TBU(k))$$

where *T* is the sampling period.

Expectation of stator flux, stator current and torque can be made in light of past standard estimation before isolating genuine and fanciful segments as:

$$\Psi_{s\alpha}(k+1)=\Psi_{s\alpha}(k)+T_s V_{s\alpha}(k+1)-R_s T_s i_{s\alpha}(k)$$
$$\Psi_{s\beta}(k+1)=\Psi_{s\beta}(k)+T_s V_{s\beta}(k+1)-R_s T_s i_{s\beta}(k)$$
$$i_{s\alpha}(k+1)=(1-\gamma T_S)i_{s\alpha}(k)+T_s\left(\frac{k}{T_r}\psi_{r\alpha}(k)+\omega k\psi_{r\beta}(k)+\frac{V_{S\alpha}(K+1)}{\sigma L_S}\right)$$
$$i_{s\beta}(k+1)=(1-\gamma T_S)i_{s\beta}(k)+T_s\left(\frac{k}{T_r}\psi_{r\beta}(k)-\omega k\psi_{r\alpha}(k)+\frac{V_{S\beta}(K+1)}{\sigma L_S}\right)$$

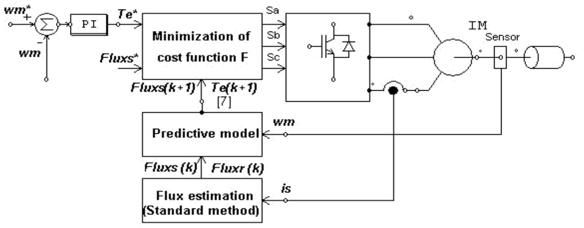

Fig2: scheme of predictive torque and flux control

The predicted electromagnetic torque is given by

$$T(k+1)=p(\Psi_{s\alpha}(k+1)i_{s\beta}(k+1)-\Psi_{s\beta}(k+1)i_{s\alpha}(k+1))$$

## 5. COST FUNCTION

The past gauges of (11) and (12) can then be used to evaluate the impact of every voltage vector on engine torque and stator flux. The cost work F packs the looked for lead of the inverter: minimize the accompanying oversight among reference and expected measured torque and stator flux by:

$$F=\frac{(T_e^*(k+1)-T_e(k+1))^2}{T_n^{\,2}}+\frac{(\Psi_s^*(k+1)-\Psi_s(k+1))^2}{\Psi_{sn}^{\,2}}$$

The farsighted controller is given by fig.3 and can be sketched out in the accompanying steps:

1)- Measure of mechanical speed and stator streams $\omega_m$ ( k ), is ( k)

2)- These estimations are used to envision torque and stator flux values $T_e$( k +1),$\psi_s$( k+1)

for each of the seven different voltage vectors by using as

above conditions

3)- The seven desire are evaluated using the cost work F

4)- The perfect trading state that analyzes to the perfect voltage vector that minimizes the cost limit is been associated on terminal machine in the accompanying testing time as it is spoken to by fig. 4.

5)Each one of the methods referred to above are reiterated each inspecting time speaking to the new references and estimations according to the withdrawing horizon control

## 6. OVERCURRENT PROTECTION

snappy torque or stator flux reference signal changes can convey incredibly high stator streams with risky zeniths realizing the pounding of either the motor or the power drive. To ensure that the stator current remains inside commendable breaking points, it is possible to make use of the flexibility of the figure system changing the cost work above. A third term that considers the stator current vector degree compel $i_{\max}$ is incorporated with a high weight pick up λ, The cost work including the over current security is given by:

$$F=\frac{(T_e^*(k+1)-T_e(k+1))^2}{T_n^{\,2}}+\frac{(\Psi_s^*(k+1)-\Psi_s(k+1))^2}{\Psi_{sn}^{\,2}}+\lambda(|i_s(k+1)|\rangle i_{\max})$$

By then, if a given stator voltage vector makes an over current, the third term will be equal to λ and will deliver a high estimation of limit F. Thusly, this stator voltage vector won't be been associated in the midst of the accompanying testing between time. If the voltage vector under appraisal does not make an over current express, the weighted variable will be proportionate to zero, and the cost limit is equal to above equation.

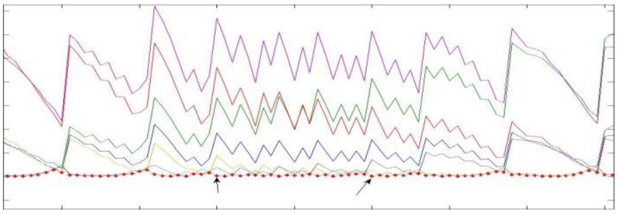

Fig 3: cost function optimization

## 7.MULTI LEVEL PREDICTIVE CONTROL

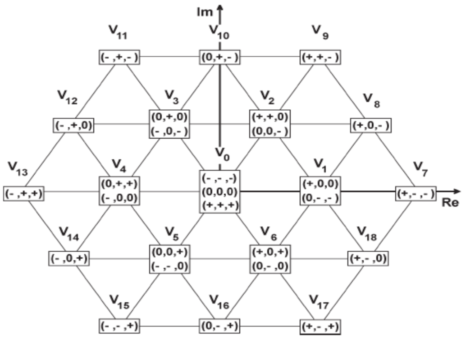

Fig.4:Three level voltage source inverter with twenty seven possible voltage vectors.

The quality function to be minimized for 27 voltage vectors now is given by:

$$F_{[27]}=|\Delta T_e(k+1)|+|\Delta\Psi_s(k+1)|+\lambda(|i_s(k+1)|\rangle i_{\max})$$

Where $\Delta T_e(k+1)$, $\Delta\Psi_s(k+1)$ are the standardized torque and flux errors. By analyzing the outcomes got with a three level voltage inverter setup, it is clear to see that the multilevel topology gives best exhibitions than the two-level one particularly in term of lessened torque swell and low flux swaying and low sounds on current waves since the quantity of recompense states is generally decreased with the three level topology as can be seen in fig 8 and fig 10.

## 7. SIMULATION RESULTS

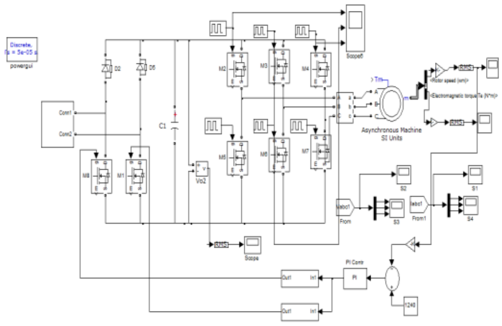

Fig5:Simulink model of the closed loop system with PI controller:

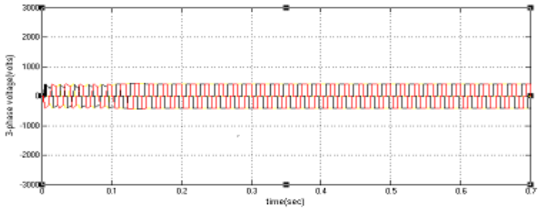

Fig.6:Input Voltage Waveform

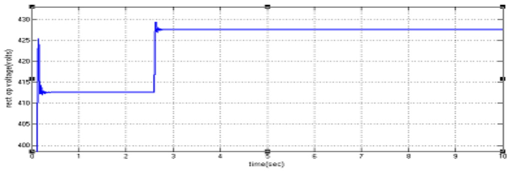

Fig.7:Outputvoltage of Rectifier

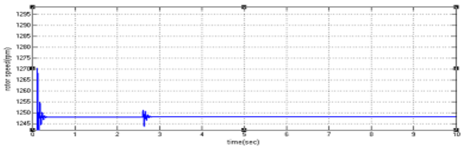

Fig.8:Motor speed

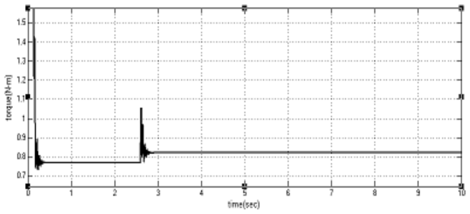

Fig.9:Torque

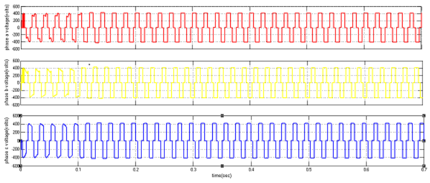

Fig.10:Output volatge

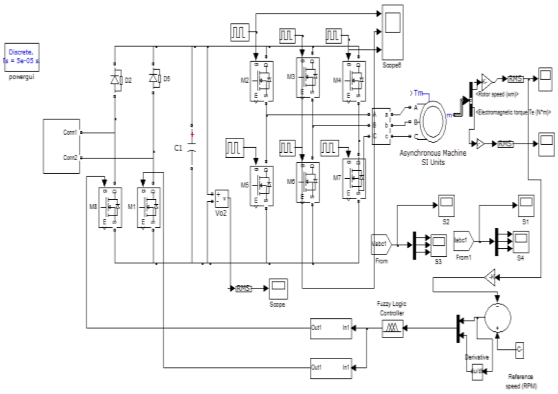

Fig.11 :Simulink model of the closed loop system with FLC controller:

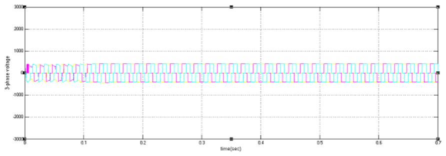

Fig.12:Input voltage

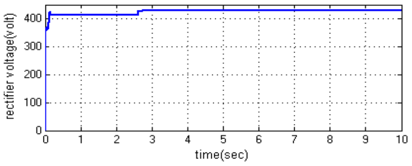

Fig.13:Output voltage of rectifier

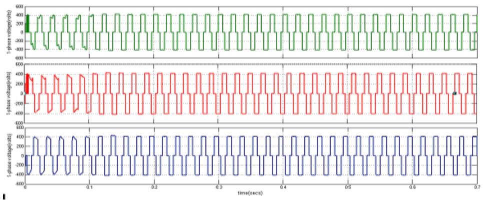

Fig.14:Output voltage of inverter

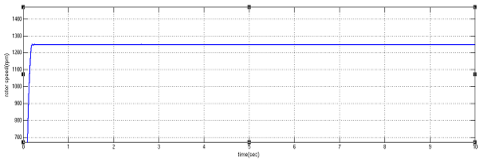

Fig.15:Motor speed

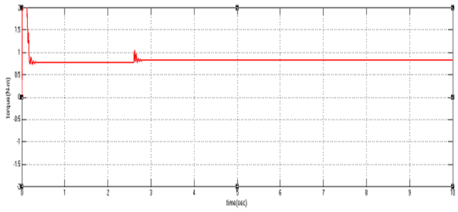

Fig.16:Torque

## COMPARISON TABLE

| Controller | Rise time (s) | Peak time (s) | Settling time (s) | Steady state error (RPM) |
|---|---|---|---|---|
| **PI** | **2.6** | **2.7** | **2.9** | **5.6** |
| **FLC** | **0.1** | **0** | **0.15** | **0.9** |

## CONCLUSION:

A Predictive Direct Torque and Flux control procedure (PDTC) utilizing a limited state-space model of an enlistment engine has been introduced. The control plan is extremely straightforward and utilizes discrete model of the converter to anticipate the conduct of torque and stator flux of the framework and to acquire the most appropriate converter exchanging state considering the torque and flux mistakes by assessing at initial 7 conceivable blends of the topology and afterward 27 voltage vectors are utilized for the advancement to improve the exhibitions. The prescient control does not requirement for modulators as in PWM or in SVM strategies, likewise there is no requirement for inward circles controllers.

To be sure, recreation comes about demonstrate an exact following of torque and flux modulus. Particular arrangements of recreation results have been done demonstrating the superior of the prescient control framework.

Speed response of PI controlled system has oscillations

Speed response with FLC controller is very smooth compared to PI controller

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