PLL Based Slip Frequency Control System for Improving Stability of an Induction Motor

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ABSTRACT

An induction motor slip frequency control can be controlled by different techniques. This work presenting the control of induction motor by the Phase Locked Loop (PLL).The different pulses can be generated by the PLL to fire the inverter circuit by means of which an induction motor can be controlled The control mechanism has been built by the MATLAB tool boxses.The proposed PLL along with the inverter circuit has been developed to generate the different frequencies .This method not only control the frequency but also increases the stability of an induction motor**.**

Index Terms— Direct torque control (DTC), Induction motor drive, Space vector modulation (SVM), Stator flux estimation**.**

1 INTRODUCTION

The induction motors plays an important role in many types of domestic and industrial machinery. The popularity of the induction motors due to its ruggedness and operational reliability. Several methodologies have been proposed to control the induction motor varying in complexity, performance and cost. The weakness of mechanical speed sensors, the maintenance of all kinds of sensors, the complexity of the induction motor, varies the resistance of rotor and stator because of heating which is the practical problems which limit the implementation of most control strategies when low speed controls are required. Several methodologies have been proposed to control the induction motor varying in complexity, performance and cost. So many techniques such as slip-frequency control, flux control, vector control can be used to control the induction motor. In steady-state characteristics of a torque and speed Control system of an induction motor utilizing rotor slot harmonics for slip frequency sensing. In this method to detect the slip frequency of a three phase squirrel-cage induction motor from rotor slot harmonics. A method of torque and speed control of the induction motor using the proposed slip frequency detector **.**The torque and speed control system is realized considering characteristics of the slip frequency detector. Experimental results can be proposed slip frequency detector realizes precise control of the rotor speed and torque except for a frequency of rotating flux over a wide range of the rotor speed (250 to 2500 rpm) except for a low-speed region. In one of a simple and effective algorithm for direct torque and flux control three phase induction motor drive is control **.**In this method, control technique is based on decouple between amplitude and angle of reference stator flux for determining required stator voltage vector. This proposed method eliminates the estimation of stator flux angle to generate stator voltage vector with constant switching frequency. Within given sampling time, flux as well as torque errors are controlled by stator voltage vector which is evaluated from reference stator flux. The direct torque control is achieved by reference stator flux angle which is generated from instantaneous rotor angle and slip angle. The amplitude of the reference stator flux is kept constant at rated value. Simulation results for 3 hp induction motor drive for both the proposed

algorithm and conventional techniques are presented and compared. The simulation results show that the proposed strategy has many advantages such as reduced torque ripple, nearly sinusoidal stator current.

2 Phase Lock Loop:

The study PLL has been heavily treated in literature and most of the theoretical and the analytical results of such are verified using simulations. Here we provide a real-time implementation of a PLL and analyze and verify the theoretical results associated with it on the implemented system. Such work takes us one step above from the traditional simulation and analysis of PLL to real-time implementation and analysis. The steady state and the acquisition of the PLL are analyses. The PLL is a useful control systems tool used heavily in communications engineering, radar, sonar, control engineering and many other applications [1]. In communications PLLs are used for carrier tracking, frequency synchronization, phase synchronization and symbol timing synchronization. Generally, with the trade-off between the acquisition and the tracking performance of PLL, such signal processing elements may be used to improve either the acquisition or the tracking performance depending on the application. In many cases researchers use simulations to analyze the performances of PLLs, but we go further a step up and use real-time implementation of PLL to analyze the performance [2]. The PLL can be implemented using MATLAB tool boxes consist phase frequency detector (PFD), charge pump (CP), loop filter, voltage controlled oscillator (VCO) and divider chip. According to the difference in between two signals applied to the PFD mainly reference signal and VCO- divider output signal, voltage pulse obtained at the VCO to control input signal after processed by the CP and the loop filter used to form the different and desired frequency signal to drive the inverter so that induction motor slip frequency can be stabilized. The phase frequency detector is a multiplier based detector, which also has a tendency of producing 2nd harmonic frequency components at the output. An alternative approach to design the phase detector is to use the four quadrant arctan function. The loop filter plays a major role on the performance of the loop; a single pole loop filter gives a second order loop, which is capable of tracking frequency offsets present in the received signal.

3 List of symbols

K_{pd}, K_a, K_{vco}, K_I, K_M, K_{pg}, K_{f} = gain constant associated with phase detector, slip-frequency limit amplifier, voltage-controlled oscillator, inverter, motor, speed transducer and pulse/voltage convertor, respectively

$K = K_{vco}K_IK_MK_{pg}K_f$

T_a, T_M, T_f, T_c, T_1, T_2 = time constants associated with the slip-frequency limit circuit, motor, pulse/voltage convertor, phase advance network and phase detector filter, respectively

$T_x = T_a\, T_M\, T_f$

$T_y = T_aT_M + T_MT_f + T_fT_a$

$T_z = T_a + T_M + T_f$

Ef =maximum output from phase-detector limiter

α = phase advance network constant
ω r, Ω (S) = speed and transformed speed of rotor
ωs = **equivalent synchronous speed o**f stator
ω f= equivalent slip-frequency speed

$$\frac{\Omega r(s)}{Ef(s)} = \frac{K_{VCO}.K_I.K_M\left(1 + ST_f\right)}{\left(T_a T_M T_f\right)S^3 + \left(T_a T_M + T_M T_f + T_f T_a\right)S^2 + \left(T_a + T_M + T_f\right)S + \left(1 - K_{VCO} K_I K_M K_{pg} K_f\right)} \qquad ----(1)$$

Hence, for the system to be stable
$$K_{VCO}\, K_I K_M\, K_{pg}\, K_f \qquad \leq 1 \qquad ----------(2)$$

The steady-state speed at this point is given by
$$\omega\ r = \frac{K_{VCO}\, K_I K_M}{1-K} \qquad ----------(3)$$

$$\omega\ r = \omega\ s\ -\ \omega\ f = \omega\ s-\ K_{VCO}\, K_I K_M \qquad ----------(4)$$
Substituting this equation in (3) we get

$$1-K = \frac{\omega_f}{\omega_s - \omega_f}\, E_f \qquad ----------(5)$$

Fig. 1 The block diagram for complete system [3]

The slip-frequency limit loop consists of one zero and three poles, two of which may be complex to the overall transfer function. Filter will provide further two poles due to that there is possibility of system unstable. To avoid this phase-advance network as shown in Fig.1

The time response of the system is given by the root locus in Fig2. The time can be reduced but result in instability, which pushes the root locus on the right-hand side of the s-plane ie. Root locus shift towards imaginary axis, decreases system stability, system becomes oscillatory in nature and as the constant k approaches towards '1' stability decreases.

Fig2 Time response

4 Stability of slip-frequency limit loop:

The overall transfer function of the block diagram can derived as follows

Since the slip frequency is fixed, the value of k must be selected for the maximum speed.

5 **Experimental Drive:**

The experimental drive was built in laboratory of the University of Manchester Institute of Science and technology[3]. It consists of 3-phase, 1380r/min, 0.37 kw, 50Hz induction motor coupled via a toothed belt to a separately excited d.c. machine which could be used as brake. The a.c. motor was fed from a well tried industrial, transistorised inverter employing a d.c. link with a pulse modulation. [13]
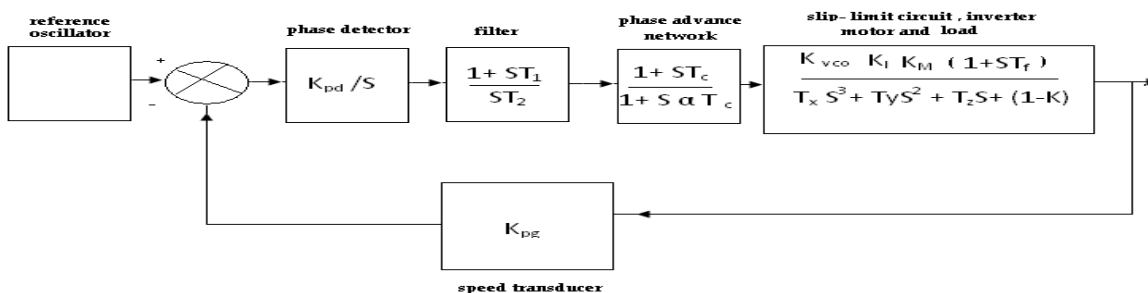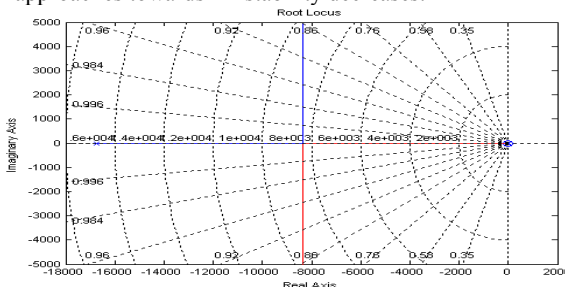
Transfer functions individual items
Control circuit of slip-frequency
Feedback loop with pure integrator as the stator frequency signal is fed back, the best form for the slip-frequency amplifier is a pure integrator.
$G_a (s) = (K_a /S)/ (1+ K/S) = (1/ 1+S / K_a) = 1/ 1+ ST_a$
Inverter
The output frequency need not be the same as that of the voltage-controlled oscillator. D.C. link inverter is assumed producing quasisquare voltage waves, the amplitudes of which are automatically adjusted with negligible time delay, to a value which will ensure substantially constant airgap flux.
$G_I (S) = K_I$
Induction motor with inertial load
The torque is assumed to be proportional to the difference between the stator frequency and rotor frequency as fed back from the output. If the load is pure inertia, the overall transfer function can be manipulated to be
$G_M(S) = K_M/ 1+ST_M$
Frequency/voltage convertor
As the filter time constant cannot be ignored, the transfer function is
$G_f (s) = K_f / 1+ ST_M$
Phase-detector
Although the inputs are analogous to speed, the comparison is made on the basis of phase which is analogous to position. Hence, the transfer function will contain a pure integrator to give
$G_{pd} (s) = K_{pd} /S$

Phase-detector filter

For good tracking with reasonable bandwidth a filter with the following type of transfer function was employed

$G_c(s) = 1 + ST_1 / ST_2$

Phase-advance network

The standard phase-advance network with matching amplifier was used to give

$G_{pa}(s) = 1 + ST_c / 1 + S \alpha T_c$

Voltage-controlled oscillator and speed transducer

As the lags in the voltage-controlled oscillator and speed transducer are negligible, their transfer functions are pure gains as

$G_{vco}(s) = K_{vco}$

$G_{pg}(s) = K_{pg}[3]$

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