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Research Article

Fabrication of Test Setup for Speed Control of Three Phase Induction Motor

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Abstract

The speed control system for three phase induction motor has variable frequency drive to change the frequency of supply, the rope brake dynamometer to load the motor and proximity sensor for measurement of angular velocity. The Arduino AT Mega Microcontroller is used to control the angular velocity. The set point is set through a potentiometer voltage, which is compared with feedback voltage of frequency to voltage converter interfaced with proximity sensor. Depending on mode of controller set, microcontroller outputs 0-10 VDC, which is interfaced with VFD. The trials are conducted by varying the load through rope pulley break dynamometer. The response of the system for proportional and proportional plus integral controller mode is obtained. The trials are conducted for load ranging from 0.7 kg to 1.4 kg load with set speed of 700 rpm. This paper briefly demonstrates the design and implementation of speed control system for the induction motor for proportional offset and integral mode to reset the offset.

Keywords: *Variable frequency drive, Arduino AT mega microcontroller, Speed Control, Induction Motor*

1. Introduction

The paper is about speed control of induction motor using Arduino AT mega microcontroller with proportional algorithm. Mathematical model of induction motor is necessary to configure proportional controller and can be achieved through simulation software. The paper highlights the mathematical model of induction motor using actual system. The trials are taken on the system and using non-linear characteristics of motor, proportional gain is configured. Speed control of induction motor is achieved at 700 rpm with change in load. The designed test setup of induction motor can be used as training equipment for technical institutes to learn the speed control of induction motor.

2. Organization of paper

The paper is organized as follows: Section I contains the description of the system with component specifications. Section II contains the mathematical model of the induction motor used to design proportional controller. Section III describes results and observations, conclusions and mentions the references used.

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3. Literature Review

The consolidated simulink model is constructed by creating simulink sub systems constructed using basic simulink blocks like integrator, gain, sum, etc., to solve one of the model equations, governing it. The entire analysis and simulation in this paper is based on the d-q circuit of the steady-state., while all the quantities referred to stator are studied. [Aleck W. Leedy, (2013)]

The objective of modelling and analysis of the PWM drive system of an induction motor is to ensure the stability of the controller when subjected to the variations in a load torque and reference speed with PI-controller in steady state operation. The simulation, the performance of the controller has been investigated both in open loop and closed loop using MATLAB/Simulink. The IFOC (Indirect Field Oriented Control) algorithm is discussed with detail Block diagram, with vector control on the basis of space angle (position) and modulus of the rotor flux space vector. [M.H Moradi, P.G Khorasani, (2008)]

Three phase induction motors have well known advantages of simple construction, reliability, ruggedness, low maintenance and low cost. The multi-phase drives leads over conventional three-phase ones as of lower torque pulsation, reduction in harmonic currents, reduced current per phase without the need to increase the phase voltage, greater reliability and fault tolerant features. The significant applications of n-phase induction machines include ship propulsion, electric aircraft, and electric/hybrid electric vehicles etc. The mathematical representation of n phase machines with an arbitrary number of phases on both stator and rotor, with unsymmetrical phase displacement and derivation of voltage equations and transformation to the d-q-o from of reference is main focus of research. [Lakhya Jyoti Phukon, Neelanjana Baruah,(2015)]

In the field oriented control strategy, nearly instantaneous torque control can be obtained allowing the drive to act as a torque transducer. The sensing of air-gap flux linkage is somewhat problematic and expensive in direct field-oriented control in which fairly robust with respect to variation of machine parameters is implemented. The model has two parts: the first, develop a current source inverter (CSI) with open-loop, and the second, a closed-loop control using PI controller. With a constant DC voltage source and the AC input stator currents for three phases, the Hysteresis Modulation Technique a current source inverter (CSI) is developed, where in the rotor angle, is derived from the electrical torque and the d-axis rotor flux linkages.[Rana A. Jabbar, Muhammad Junaid, M. Ali Masood (2009)]

Dynamic modelling and simulation of induction motor drives is significant in the validation of design process of the motor-drive systems, to bypass time consuming prototype constructions and testing. The dynamic model of the induction motor is derived by transferring the three-phase quantities into two phase direct and quadrature axes quantities. The MATLAB/Simulink modular model 3 - phase induction motor with a generic reference frame rotating with an angular speed, with several sub system calculating the stator flux linkage Q axis, stator flux linkage D axis, rotor flux linkage Q axis and rotor flux linkage D axis. The torque and angular speed equation is implemented using these d-q rotating flux [G. Renukadevi, K. Rajambal, (2012)].

With respect to referred publications, mathematical modeling of the system can be implemented using simulation. It generates required P, I D values as per the system model and that can be used to control the speed of induction motor. But in this dissertation, we implemented the system model approach in which characterization of the induction motor is studied on actual motor with load conditions. Using non linear characterization methods proportional gain is calculated and used to control the speed of induction motor.

Section I

4. System Description

Fig 4.1 shows the experimental set-up consists of an induction motor, VFD, Arduino AT mega microcontroller, frequency to voltage converter, and inductive proximity sensor for measurement of angular velocity of motor and rope pulley brake dynamometer for loading.

Fig. 4.1 Experimental Setup

4.1 Frequency to Voltage Converter (F-V Converter)

The F-V converter works on 230 V AC supply. The output is 0-10 V DC corresponding to 0 – 83.5 Hz input frequency. 83.5 Hz corresponds to 5010 rpm. The frequency to voltage converter is used to convert the angular velocity to voltage as microcontroller requires 0-10 V DC as feedback signal. The inductive proximity NPN type sensor is interfaced with F-V converter. The induction motor maximum speed is 1440 rpm, so F-V converter output is 0 – 2.88 V DC.

4.2 Arduino AT mega controller

The Arduino AT Mega 2560 microcontroller board is used in the project. It operates on 7-12 V power supply. It has 54 digital input/output pins of which 15 can be used as PWM outputs, 16 analog inputs, 4 UARTs - hardware serial ports, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Arduino AT mega produces 0-5 VDC output voltage which is not enough to control the VFD output of 0-10 V. Hence externally RC integrator circuit is interfaced to microcontroller to amplify output voltage up to 10v for microcontroller.

4.3 Variable Frequency Drive (VFD)

The VFD has single phase supply o – 230 V AC, control voltage 0-10 V DC, and the output is 3 phase AC supply for induction motor with frequency as per the control voltage. VFD is selected of Delta brand. The various parameters are required to be set before the VFD is put to operation. In the present work, the VFD is used as final control to the induction motor.

Section II

5. Mathematical Modeling of Plant

The mathematical model of the plant that is induction motor with rope brake dynamometer is developed as below.

$N = N(U, M)$

Linearization results,

$n = \frac{\partial N}{\partial F}\Big|_T f + \frac{\partial N}{\partial T}\Big|_F t$

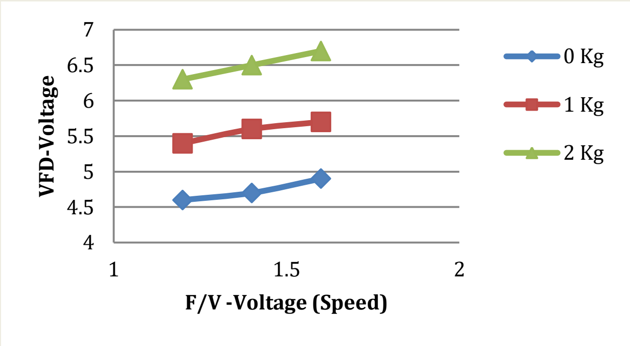

Fig 5.1 Speed Voltage Characteristics of IM

Since the exact mathematical relation is not known, the partial derivatives are evaluated from the physical interpretation of the speed torque characteristics of the induction motor as shown in Fig

$c_1 = \frac{\partial N}{\partial M}\Big|_U = 0.667$

$\frac{\partial U}{\partial N}\Big|_M = -7.49$

hence
$c_2 = -0.1335$

for plant modeling,
$n = JDn + U$
And
$$n = \frac{0.667}{1 + 0.1335JD}\,[m - 0.2\,u_L]$$

Controller Design

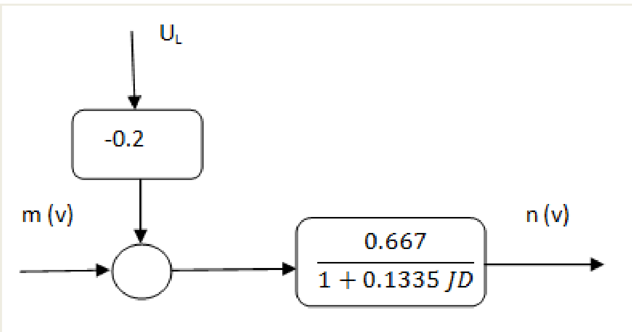

Fig 5.2 Plant Model

From the plant model, the controller can be modeled in the following manner

$$n = -0.2u_L + \frac{0.667}{1 + 0.1335JD}m$$

Now for infinite time system is in stable state. Therefore D=0 and equation changed to

$n = 0.667m - 0.2u_L$

Assuming no external disturbance present,

$u_L = 0$

Therefore

$$\frac{m}{n}\Big|_{u_L} = 1.49 = \frac{1}{K_{G2}}$$
$M_2 = 5.6745$
Now,

$$\frac{u_L}{n} = -\frac{1}{BK_{G2}} = -7.45$$
$U_2 = 0.6275$

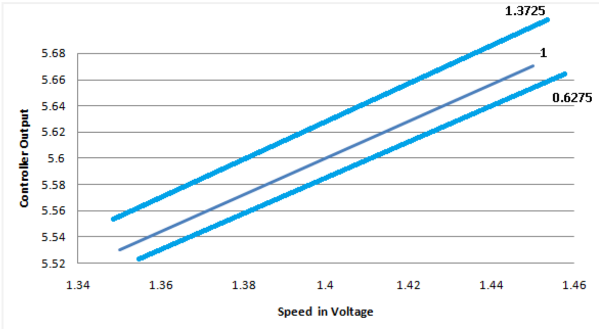

Fig 5.3 Controller output vs Speed in Voltage

For the controller, Proportional band with respect to chart is

$P_b = \frac{5.67-5.53}{1.45-1.35} = 1.4$

Proportional gain is

$K_p = \frac{1}{1.4}.100 = 71.4$

Obtained proportional controller gain is 0.714 for this system to get the desired speed of against variable load. The proportional band of the P controller would be 0.2668

Program

Program is created in Arduino AT mega icrocontroller using variables and the proportional gain with error and output equation.

```
pinMode(A0,INPUT);
pinMode(9,OUTPUT);
kp = 0.741
error = Pot_read - setSpeed;
output = -(kp * error)+127;
```

Required part of program is mentioned here. Initialization of input and output and pin configuration is done. The proportional gain of 0.741 is used in the Arduino program. Change in speed is represented by pot_read variable. It is compared with set speed and microcontroller generates required voltage to maintain the speed at set point.

Section III

6. Result and Observations

Table 1: Observation Table

Sr. No	Actual Speed (RPM)	Load (Kg)
1	341.3	0.5
2	697.8	0.7
3	697.9	1
4	697.1	1.3
5	297.8	1.5

The speed of the motor is seen constant within the range of 0.7 to 1.3 kg while it abruptly decreases when the applied load exceeds the range of 0.7 at its lower level and 1.3 at its upper level. This shows the proportional band which is present in the P controller. It can be observed that the actual speed does not match with desired speed very accurately. Always an offset is present of minimum 2.1 RPM. This is the effect of the proportional controller which can be neglected by adding integrating controller at the cost of rise in the instability present in the system.

Conclusion

The mathematical model of induction motor is developed by taking the trials on setup. Proportional controller is configured to 0.741 for set point speed of 700 rpm (1.4V). The test setup for induction motor is giving constant speed against variable load. Speed control is achieved at set point of 700 rpm for load range of 0.7 kg to 1.4 kg.

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