PID Speed Controlled Model of Induction Motor Using Simulink

Eko J. Akpama, Iwara E. Omini, Emmanuel E. Effiong, Raymond U. Ezenwosu

Abstract— **The PID controlled algorithm satisfies the control of an induction motor under speed response at constant load, electromagnetic torque response at constant load and three phase stator current at constant load. It demonstrates how to employ SIMULINK tool in MATLAB for effective simulation of a (PID) controller with a specified load. Parameters for the operation were carefully selected as the machine was tuned for optimal performance. The suggested approach has quality traits, including: easy implementation; stable convergence characteristics and accurate performance. Software PID was used to obtain both the initial PID parameters under normal operating conditions and the optimal parameters under specified load conditions. The proposed PID controlled model is tuned according to the ranges of the chosen parameters. In order to prove an outstanding execution of the method, a three phase asynchronous induction motor was modeled in MATLAB environment. The result show that with PID controller the machine has fast reference tracking, steady speed corresponding to the reference speed under load condition with a slight overshoot and low undershoot. The simulated results displayed the potential of the proposed PID controller to be very efficient**

Index Terms— **PID controller, modeling of induction machine, speed control, v/f control technique**

I. INTRODUCTION

Induction motors are commonly used in many applications due to its numerous merits like high efficiency, low maintenance cost, robust construction, efficient and simple in nature etc. Many applications like industrial and domestic requires speed control. When a load is applied, the actual speed differs from the reference speed. Therefore, for a particular application it is very appropriate to maintain the actual speed and reference speed to the same value after load variation. Many control techniques have been introduced for speed control of induction motor. Out of these many techniques, scalar and vector control are the most significant. But the cheapest and most implementable method is scalar control method, because of its advantages and simplicity. Many industrial applications operate with this control technique. Here one of the scalar speed control method of V/f control using conventional PID controller is achieved [1]-[4]. The control method in the industry has recorded tremendous improvement over the years. Consequently, several control methods have been studied, which includes; adaptive-control, neural-control, and fuzzy-control. In the midst of the numerous methods, proportional-integral-derivative controller which has been generally accepted is considered the best in the industry, owing to its simple structure and vigorous performance during operation. Regrettably, it has been a bit difficult to tune properly the gains of a proportional Integral derivative, (PID) controllers because many industrial plants are often loaded with problems such as high order, time delays, and nonlinearities [5]–[9]. The influences of PID controller to the three phase induction motors, such as current, voltage, and power can be seen in the PQM II panel or the SCADA infou display. Then it simplifies the process of collecting data. [10] Another major technique is Space-vector Pulse-width Modulation which over the years has become a successful technique in the construction of three phase sine-wave voltage-source Inverter aligned to control three phase induction motor with v/f control. V.S.I. fed Induction Motor gives rise to a resonant torque because of the application of non-sinusoidal voltages. This method stipulates that three phase V.S.I. produces eight switching states comprising two zero states & six active states. The torque ripples of induction motor are reduced by hybrid PWM technique, and the distinct space vector based sequences used to produce the switching pulse for hybrid PWM. The application of SVPWM technique with other sequence is executed by taking one zero vector instead of two zero vectors as in traditional SVPWM. The applied voltage vector is equivalent to the reference voltage vector only in an average point over the specified sub cycle, and not in an expeditious manner. The difference between the reference vector and the instantaneous applied voltage vector is the instantaneous error voltage vector. The time integral of the error voltage vector, referred to as ''stator flux ripple vector'' is a quantity of the ripple in the line current of the converter. The frequency is considered as input to V/f control for all voltage conversion and pulse generation in the open loop system. ''The sub systems of open loop control are coding for pulse generation, inverter modeling and induction motor modeling.'' VSI fed three phase induction motor drive system where constant v/f' control method is modeled, the error obtained was processed in a Proportional Integral (PI) controller and its output set the inverter frequency and the modulation index. [11] – [14]

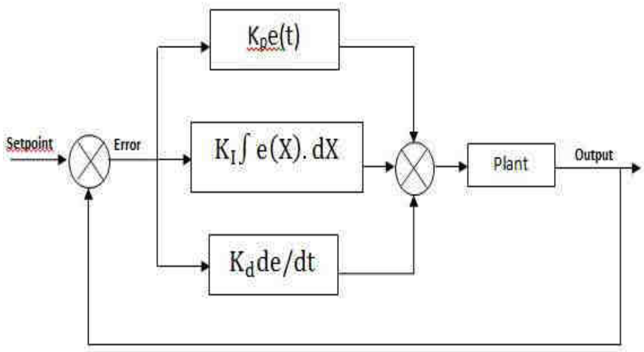

Figure 1: Block diagram of PID controllers

II. PID CONTROLLER

A PID controller is a control loop technique engaging feedback that is employed in the control system of an industry and a collection of other application requiring continuously

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modulated control. A P.I.D. controller enumerates the error value *e*(*t*) continuously as it differentiate between a required set point (SP) and a measured process variable (PV) and applies a modification based on proportional, integral and derivative terms (denoted P, I and D respectively)

III. ASYNCHRONOUS (INDUCTION) MACHINE MODEL IN STATIONARY (QD0) REFERENCE FRAME

In order to obtain dynamic simulation, the model equations of the three-phase Asynchronous Induction Machine in stationary qd0 reference frame can be reorganized as follows

$$\Psi^s_{qs} = \omega_b \int (V^s_{qs} + \frac{r_s}{x_{ls}} (\Psi^s_{mq} - \Psi^s_{qs}) dt \quad (1)$$

$$\Psi^s_{ds} = \omega_b \int (V^s_{ds} + \frac{r_s}{x_{ls}} (\Psi^s_{md} - \Psi^s_{ds}) dt \quad (2)$$

$$i_{os} + \frac{\omega_b}{x_{ls}} \int (V_{os} - i_{os} r_s) dt \quad (3)$$

$$\Psi'^s_{qr} = \omega_b \int \left(V'^s_{qr} + \frac{\omega_r}{\omega_b} \Psi'^s_{dr} \frac{r_r}{x_{lr}} (\Psi^s_{mq} - \Psi'^s_{qr}) \right) dt \quad (4)$$

$$\Psi'^s_{dr} = \omega_b \int \left(V'^s_{dr} - \frac{\omega_r}{\omega_b} \Psi'^s_{qr} + \frac{r_r}{x_{lr}} (\Psi^s_{md} - \Psi'^s_{dr}) \right) dt \quad (5)$$

$$i_{os} + \frac{\omega_b}{x_{lr}} \int (V'_{os} - i'_{or} r'_r) dt \quad (6)$$

$$\Psi^s_{qs} = x_{ls} i^s_{qs} + \Psi^s_{mq} \quad (7)$$

$$i^s_{qs} = \frac{\Psi^s_{qs} - \Psi^s_{mq}}{x_{ls}} \quad (8)$$

$$\Psi^s_{ds} = x_{ls} i^s_{ds} + \Psi^s_{md} \quad (9)$$

$$i^s_{ds} = \frac{\Psi^s_{ds} - \Psi^s_{md}}{x_{ls}} \quad (10)$$

$$\Psi'^s_{qr} = x_{lr} i'^s_{qr} + \Psi^s_{mq} \quad (11)$$

$$i'^s_{qr} = \frac{\Psi'^s_{qr} - \Psi^s_{mq}}{x'_{lr}} \quad (12)$$

$$\Psi'^s_{dr} = x_{lr} i'^s_{dr} + \Psi^s_{md} \quad (13)$$

$$i'^s_{dr} = \frac{\Psi^s_{dr} - \Psi^s_{md}}{x_{lr}} \quad (14)$$

Where,

$$\frac{1}{x_M} = \frac{1}{x_m} + \frac{1}{x_{ls}} + \frac{1}{x'_{lr}} \quad (15)$$

$$\Psi^s_{mq} = x_M = \left(\frac{\Psi^s_{qs}}{x_{ls}} + \frac{\Psi'^s_{qr}}{x'_{lr}} \right) \quad (16)$$

$$\Psi^s_{md} = x_M = \left(\frac{\Psi^s_{ds}}{x_{ls}} + \frac{\Psi'^s_{dr}}{x'_{lr}} \right) \quad (17)$$

The rotor equation of motion is achieved by linking the torque of inertia to the

Accelerating torque, as follows

$$J + \frac{d\omega_r}{dt} = T_{em} + T_{mech} - T_{damp} \quad (18)$$

Where

ω_b= base speed,
ω_r= rotor speed
r_s = stator resistance
x_{ls} =stator reactance
r_r' = rotor referred resistance
x_{lr}' =rotor referred reactance
x_m =magnetizing reactance
x_M =machine equivalent star reactance
T_{em} = electromechanical torque
T_{mech} =externally applied mechanical load torque
T_{damp} = damping torque
J =combined moment of inertia
v^s_{qs} = q-axis stator voltage
v^s_{ds} =d-axis stator voltage
v'^s_{dr} =d-axis referred rotor voltage
v'^s_{qr} = q-axis referred rotor voltage
v_{0s} =zero sequence stator voltage
v_{0s} = zero sequence rotor voltage
i^s_{qs} =q-axis stator current
i^s_{ds} =d-axis stator current
i_{0s} =zero sequence stator current
i'^s_{qr} =q-axis referred rotor current
i'^s_{dr} =d-axis referred rotor current
i_{0r}=zero sequence rotor current
ψ^s_{qs}=q-axis stator flux linkage per second
ψ^s_{ds}=d-axis stator flux linkage per second,
ψ'^s_{qr}=q-axis referred rotor flux linkage per second
ψ'^s_{dr}=d-axis referred rotor flux linkage per second
ψ^s_{md}=d-axis magnetizing flux linkage per second
and ψ^s_{mq} =q-axis magnetizing flux linkage per second.

IV. SIMULINK MODELLING

The induction machine is modeled in SIMULINK/MATLAB environment with a subsystem which characterized the operation of the machine. The subsystem functions in a way that it produces the required pulse which activates the three phase inverter switches, namely; insulated-gate bipolar transistor (IGBT) and metal-oxide semiconductor field effect transistor (MOSFET), it uses pulse width modulation (PWM) technique which enables it compare a high frequency constant amplitude carrier wave (triangle wave) with modulating signal (sine wave).

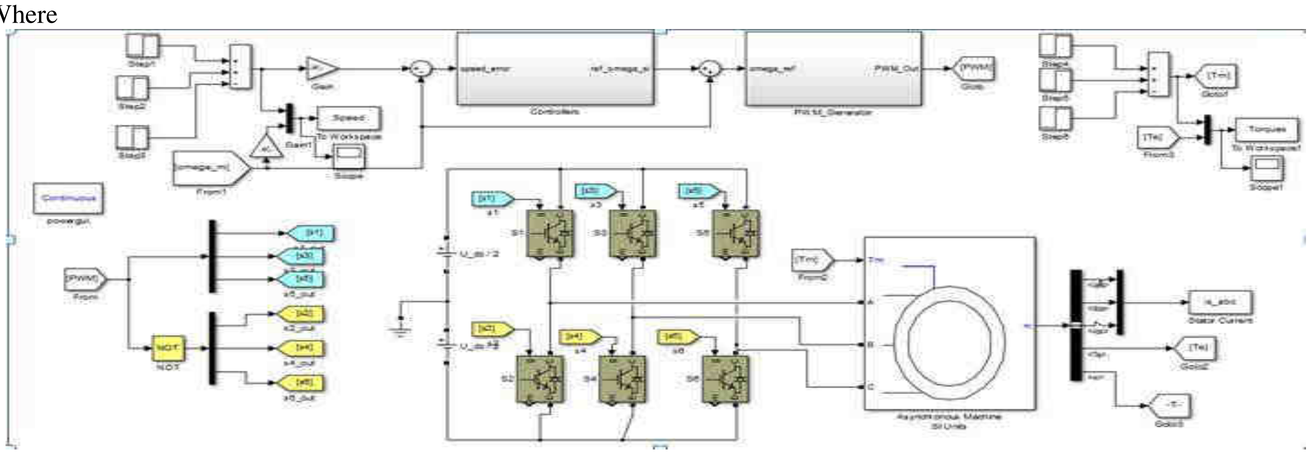

Figure 2 the resultant Simulink model of the induction motor

The Induction Motor Parameters

The induction motor employed in this simulation is 7.5KW, 460V, 50Hz, asynchronous motor having the parameters listed in table 1 below. The induction motor stator is fed by a three-phase current controlled source. The currents in the stator are controlled by hysteresis controller which produces inverter drive signals for the inverter switches to control the induction motor. The motor torque is controlled by the quadrature-axis current component and the motor flux is controlled by direct axis current component. The motor speed is regulated by a PID controller which generates the required torque current component signal

Table 1: Machine parameters

S/N	Parameter	Value
1	Rated power	7.5kW
2	Supply frequency	50Hz
3	Rated voltage	400V
4	Rated speed	1440rpm
5	DC-bus voltage	460V
6	Stator resistance	0.09961Ω
7	Stator inductance	0.000867H
8	Rotor resistance	0.05837Ω
9	Rotor inductance	0.000867H
10	Mutual inductance	0.03039H
11	Inertia	0.4kg.m^2
12	Number of pole pairs	2
13	**Kp**	**0.01**
14	**Ki**	**10**
15	**Kd**	**0.00557**

5. RESULTS AND DISCUSSION

The Simulink model of an induction motor is detailed in figure 2. In MATLAB environment the model is simulated and the computer traces are exhibited in figure 3, 4 and 5 Figure 3 displays a speed response at constant load of 20Nm, it is observed that the rise time is decreased under free acceleration to the reference value of 1500rpm. However, the machine experienced a slight overshoot, but the response under load application at 1 s had the machine performing optimally with a low undershoot of 6.67% making the PID controller very efficient for the control of an induction motor. Figure 4 shows that without load the machine produces a high electromagnetic torque, at 1 s the machine was loaded and the torque matched the reference speed of 1500rpm, at 2 seconds the electromagnetic torque reduces, with a steady state performance. Between 3.5 and 4.0 seconds the load was removed and the electromagnetic torque reduced minimally.
In figure 5 The machine develops a high starting torque as a result of the high starting current required by an induction motor that resulted in an overshoot which causes a spike and the speed hits saturation before the load torque of 20Nm was introduced at 0.7 seconds, the current keeps increasing as time increases, after 2 seconds the motor develops a higher torque to enable it accelerate the required speed until a steady state was attained at about 3.7 second

PID Controller Speed Response at Constant Load with PID

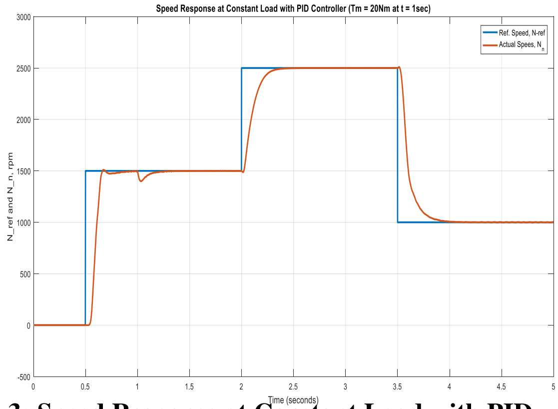

Fig. 3: Speed Response at Constant Load with PID

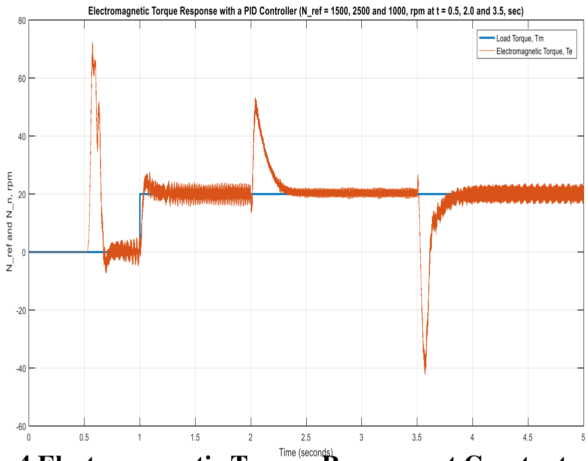

Fig. 4 Electromagnetic Torque Response at Constant Load with PID controller

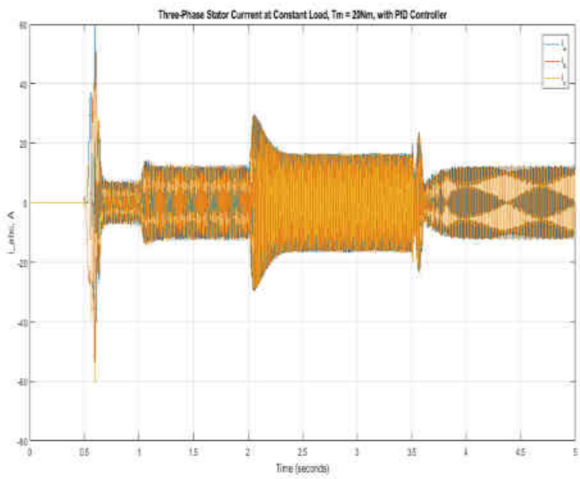

Figure 5 Three-Phase Stator Current at Constant Load with PID Controller

CONCLUSION

P.I.D. speed controlled model of a three phase induction motor using SIMULINK been a very successful one as it helps in the conservation of energy and encourages the usage of high performance application such as robotics, hybrid vehicles, paper and textile mills wind generation systems, high power laboratory equipment such as x-ray imaging system, pump and compressor load applications. This paper states clearly how optimal a controlled machine with PID controller can perform. From the results it is observed that the PID controller catches the reference speed fast and settles the machine as fast as possible. Hence the need for a PID controller for effective speed control of induction motors

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AUTHORS

Engr. Dr. Eko .J. Akpama received his B. Eng in Electrical/Electronic Engineering from the Federal University of Technology, Owerri, Nigeria in 1996. He received his M.Eng. and PhD in 2008 and 2014 respectively in Power Devices UNN. He is presently a lecturer in the Department of Elect /Elect. Eng'ring, Faculty of Engineering, Cross River University of Technology Calabar, Nigeria. His research interest is in the area dynamic simulation and control of A.C. machines. He is a member of NSE, IEEE and IAENG. He is registered with COREN

Emmanuel. E. Effiong received his B.Eng degree in Electrical and Electronics Engineering from Cross River University of Technology. He is currently a research student in control system Engineering in the department of Electrical and Electronics Engineering,Cross River University of Technology. Calabar, Nigeria .His research area of interest include , control of electrical machines ,automation and power electronics

Iwara. E. Omini received his B.Eng degree in the department of Electrical and Electronics Engineering,Cross River University of Technology. He is currently a research student in machines and control in the department of Electrical and Electronics Engineering of Cross River University of Technology ,Calabar, Nigeria. His research area of interest is in electrical machines and control

Raymond. U. Ezenwosu received his bachelor's degree with honours (first class) in electrical engineering from the National Research University "Moscow Power Engineering Institute", Moscow, Russian Federation. He is currently working as a graduate assistant at Cross River University of Technology as part of his one-year mandatory national service.

His research area of interest is in power electronics and control of electrical machines