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Modelling and Time Domain Analysis of Speed Control for AC Inducton Motor Using Space Vector PWM

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ABSTRACT: The induction motor is being used in most of the industrial applications compared to the conventional DC motor. This is because the induction motor has several advantages. Their rugged construction & absence of brushes are some of them. But the main drawback of the asynchronous motor is that it is hard to control with the conventional control systems. But with the advent of the power electronics techniques, the control of the induction motor has become as easy as controlling a conventional DC motor.

The model used in this project implements one such technique to control the speed of the induction motor. It uses the space vector PWM to limit the speed of the motor to the desired set point. Here, the average value of voltage and current fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is finally, the response for variation in control parameters and load changes are tabulated. The results are illustrated for time domain characteristics of the control system.

I. INTRODUCTION

From the very beginning, man has developed several machines to make his life easier and better. The most important and most advantageous one among all the inventions has been the electric motor. Motor is the most fundamental actuator ever developed. It actuates motion according to the given electrical input. There are various types of motor available for practical applications.

Even with the availability of several motors, the induction motor is the most advantageous one for its rugged design and absence of brushes. But one of the main drawbacks of the induction motor is that it is hard to control with simple control systems. This has remained a continuous challenge for the engineers for years. A recent solution proposed for this problem is to use modern power electronics. By using Pulse width modulation, one can control the asynchronous motor with greater ease and efficiency. This can be further improved by using a Space vector PWM speed controller. This technique allows one to design a controller with greater stability.

There is still one challenge unsolved by this proposed method of controlling speed. This method of controlling a system causes a considerable amount of hysteresis. Hysteresis is found to erode and affect the life and efficiency of the system in long run.

The synchronous rotational speed of the rotor, the theoretical unloaded speed with no slip, is controlled by the number of pole pairs, number of windings in the stator, and by the frequency of the supply voltage. However, for a loaded rotor,

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for any given drive frequency and current and mechanical load, synchronous motors should be run in the 'operating zone' for that particular induction motor. This is the shaft rotation speed range above the peak torque. In this zone slightly increasing the slip speed increases the torque, and decreasing the slip decreases the torque. Hence in this zone the motor will tend to run at constant speed. Below the operating zone, the run speed tends to be unstable and may stall out or run at reduced shaft speed, depending on the nature of the mechanical load.
Before the development of economical semiconductor power electronics, it was difficult to vary the frequency to the motor and induction motors were mainly used in fixed speed applications. As an induction motor has no brushes and is easy to control, many older DC motors are now being replaced with the induction motors and accompanying inverters in industrial applications.

Pulse width modulation
Pulse-width modulation (PWM) is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches. The average value of voltage and current fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is [1].

The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switching have to be done from few kilohertz (kHz) to tens of kHz for a motor drive. The term *duty cycle* describes the proportion of 'on' time to the regular interval or 'period' of time. A low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on [2].
The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM works also well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle [3].

SPACE VECTOR PWM

Space vector modulation (**SVM**) is an algorithm for the control of pulse width modulation (PWM). It is used for the creation of alternating current (AC) waveforms. Most commonly to drive 3 phase AC powered motors at varying speeds from DC using multiple class-D amplifiers [5]. There are various variations of SVM that result in different quality and computational requirements. One active area of development is in the reduction of total harmonic distortion (THD) created by the rapid switching inherent to these algorithms [4].

PRINCIPLE

A three phase inverter as shown must be controlled so that at no time are both switches in the same leg turned on or else the DC supply would be shorted. This requirement may be met by the complementary operation of the switches within a leg. i.e. if A^+ is on, then A^- is off and vice versa [6]. This leads to eight possible switching vectors for the inverter, V_0 through V_7 with six active switching vectors and two zero vectors.

Vector	A^+	B^+	C^+	A^-	B^-	C^-	V_{AB}	V_{BC}	V_{CA}	
$V_0 = \{000\}$	OFF	OFF	OFF	ON	ON	ON	0	0	0	zero vector
$V_1 = \{100\}$	ON	OFF	OFF	OFF	ON	ON	$+V_{dc}$	0	$-V_{dc}$	active vector
$V_2 = \{110\}$	ON	ON	OFF	OFF	OFF	ON	0	$+V_{dc}$	$-V_{dc}$	active vector
$V_3 = \{010\}$	OFF	ON	OFF	ON	OFF	ON	$-V_{dc}$	$+V_{dc}$	0	active vector
$V_4 = \{011\}$	OFF	ON	ON	ON	OFF	OFF	$-V_{dc}$	0	$+V_{dc}$	active vector
$V_5 = \{001\}$	OFF	OFF	ON	ON	ON	OFF	0	$-V_{dc}$	$+V_{dc}$	active vector

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$V_6 = \{101\}$	ON	OFF	ON	OFF	ON	OFF	$+V_{dc}$	$-V_{dc}$	0	active vector
$V_7 = \{111\}$	ON	ON	ON	OFF	OFF	OFF	0	0	0	zero vector

SWITCHING ALGORITHM

II. RESULT AND DISCUSSIONS

VARIATION OF MODEL PARAMETERS

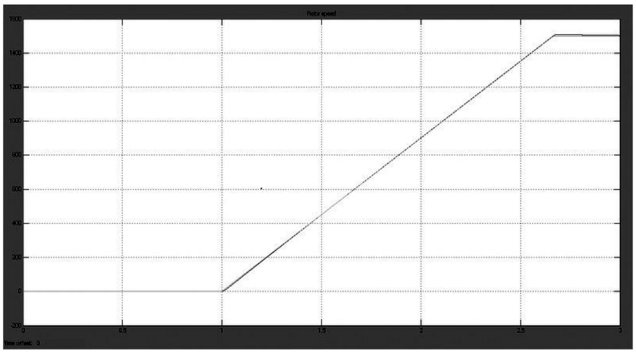
Here the model parameters namely K_P & K_I of the speed controller are varied with a constant Δ.And then the corresponding output is tabulated [7].

CASE 1:

In this exercise, a set point for desired speed of 1500 rpm is given at T=1s. The motor is kept devoid of any load. Then the proportional and the integral gains are varied. It is either increased are decreased simultaneously. The time domain characteristics are then tabulated as below.

The Set point:-
Time = [0 1]
Amplitude = [0 1500]
Load Demand = 0

Proportional Gain	Integral Gain	Delay Time (t_d)	Rise Time (t_r)	Peak Time (t_P)	Maximum Overshoot (M_p)(%)	Settling Time (t_s)
25	**190**	0.838	1.6719	1.7	0.667	1.91
30	**200**	0.837	1.6725	1.697	0.5733	2.04
40	**220**	0.835	1.671	1.694	0.4466	2.198
50	**240**	0.838	1.674	1.686	0.366	1.92
60	**250**	0.838	1.671	1.683	0.313	1.95



SCOPE OF CASE 1

Here the motor is initially given with no set point to follow. After a time period of 1s, a desired speed of 1500 is input to the controller. The controller being stable from such real time disturbances tracks the reference speed with almost no overshoot. The small overshoot visible in the graph is well within the tolerance range [8]

CASE 2:

In this exercise, a set point of 500rpm is given as the initial condition. After an interval of 2s, the desired speed in incremented to 1500. A load of 792 is also applied across the motor at T=0.5. Then the integral gain is increased keeping the proportional gain constant. The corresponding output is tabulated. Later, the proportional gain is varied keeping the other constant. The output characteristics is then documented

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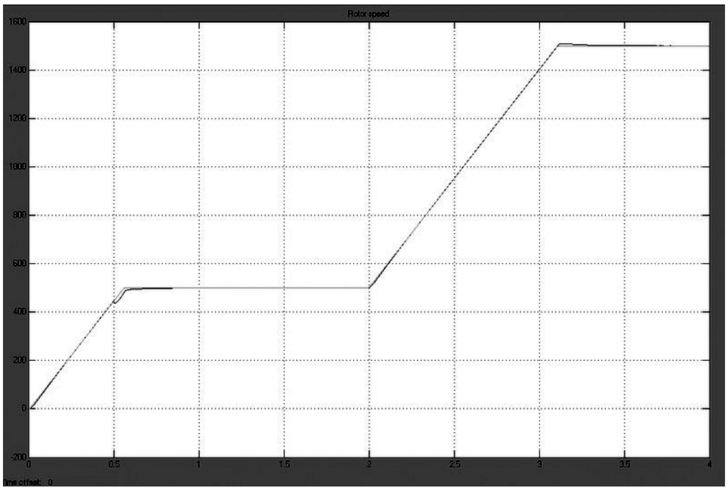
The Set point:-
Time = [0 2]
Amplitude = [500 1500]
Load Demand:-
Time = [0 0.5]
Amplitude = [0 792]

Proportional Gain	Integral Gain	Delay Time (t_d)	Rise Time (t_r)	Peak Time (t_P)	Maximum Overshoot (M_p)(%)	Settling Time (t_s)
30	**300**	0.275	3.1	3.135	0.566	3.45
30	**400**	2.275	3.107	3.132	0.553	3.286
30	**500**	2.257	3.108	3.132	0.54	3.257
30	**600**	2.275	3.109	3.13	0.52	3.224
40	**200**	2.277	3.11	3.13	0.46	3.31
60	**200**	2.277	3.11	3.117	0.233	3.17
70	**200**	2.277	3.11	3.12	0.246	3.19

TABLE CASE 2

FIG: SCOPE OF CASE 2



Here, the lad is applied across the motor at T=0.5. This makes the motor to lag a bit at that particular instance. This is visible from the graph. Even with a presence of such a disturbance, the controller tracks the reference speed without any much overshoot. Then when the speed of the motor is increased to 1500rpm, the controller again tracks with a overshoot well within the prescribed tolerance range [9].

4.1.1. CASE 3:

In this exercise, the motor is allowed to reach a constant rotor speed of 500rpm. And then a load of 792 is applied across the motor. Simultaneously the desired speed is increased to 1500rpm. The motor is found to follow the deviations without any significant lag [10].

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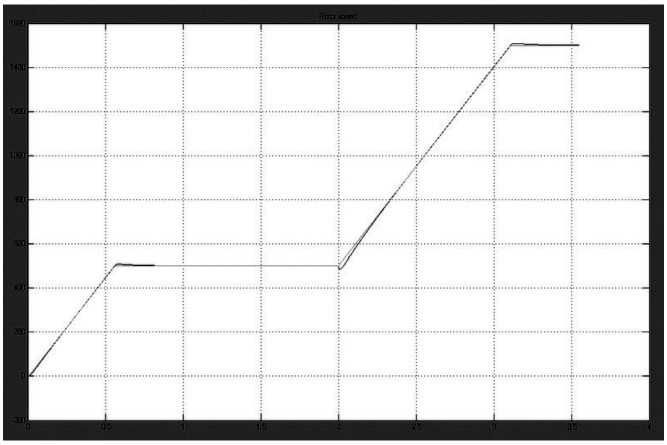

FIG: SCOPE OF CASE 3

CASE 4:

In this exercise, the speed of the asynchronous machine is made to reach 1500rpm. Then its switched off when T=0. The motor tracks the variations with deviations well within prescribed tolerance range.

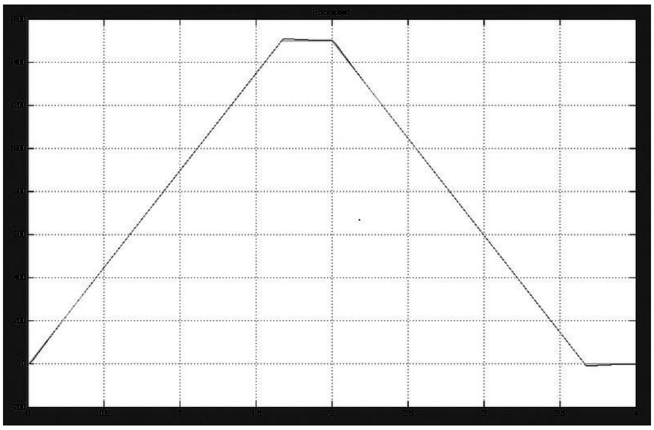

FIG :SCOPE OF CASE 4

The response of the speed controller designed in MATLAB Simulink was tabulated as explained before. Studying the output in detail shows that the speed controller thus designed tracks almost all the parameter variations [11]. The speed controller adapts quickly to the changes made in K_P and K_I. The peak overshoot is well behind the prescribed tolerance value. This shows that the controller thus designed is stable and can adjust to the real time disturbances [12].

The controller also remained unaffected by the varying load demands. This again proves the stability of the speed controller.

III. CONCLUSION

With the advancement of modern control techniques, the induction motor finds more application than any other type of motor. In this project, the speed control for the induction motor was modeled using a space vector PWM generator. This modeling was done in MATLAB Simulink. It was then simulated till the system become stable. The report of the

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response analysis is very positive and encouraging. The result proves that the controller is very stable. The controller was tested for varying model parameters and varying load demands.

This controller has made use of the modern power electronic techniques and has provided a very good reliable control system for the induction motor. The asynchronous motor backed by a control system of such magnitude can be used for several other industrial applications such as position control. The motor actuator is used to operate and control a control valve. A well calibrated gear system is used to link the motor to the control valve. With the use of gears, the rotary movement of the motor is converted to a linear motion. The linear motion is then used to control the valve.

By using speed control of the induction motor to control position of the valve, one can achieve position control without any position feedback from the valve. This also reduces the number of sensors required to achieve the control action. This, on the whole, increases the efficiency of the control system and the corresponding operating cost involved.

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