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Direct Torque Control of Four-Switch Inverter for Single Phase Induction Motors

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ABSTRACT: In this project, we demonstrate in the simulation model, the feasibility of controlling the speed of an induction motor using only four switches and compare its performance under dynamic- and steady-state conditions with those obtained by using a wire-based position feedback control. Since only four switches are used, this project opens a new gateway to reduce the number of switches with the same three phase input supply. Hence all the control circuitry are made with less number of switches. This has an advantage of using single induction motor also, under four switch combination. It also raises the possibility of using a low-resolution, low-cost sensor, which, along with the use of simple estimation algorithms, may potentially provide an alternative to or backup support for conventional position sensorless control for a wide range of motors and speeds. We evaluate the performance at a maximum speed of around 1000 rpm. And the dynamic conditions are analysed from a shift from 800 rpm to 1200 rpm.

The major objectives of the work would be

- To simulate a three phase induction motor drive system with 4 switches in simulation
- To design the pulse generation block using matlab tools for 4 switches using a closed loop control system.
- Model and run a single phase induction motor with open loop control of speeds and controlling a single phase induction motor at low voltages as hardware model.

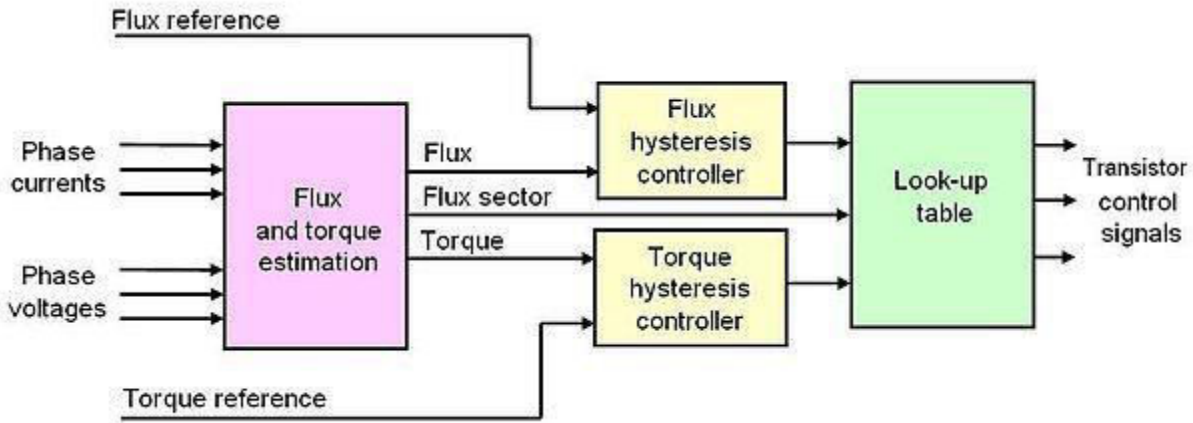
I. INTRODUCTION

Speed control of an induction motor usually requires position feedback information [as illustrated in Fig. 1(a)] from an encoder, a resolver, or a Hall sensor to a controller unit [1]. These feedback signals, which often pickup noise due to electromagnetic interference, can affect the performance of the motor control system. As such, the feedback cable is shielded and the signals are provided in differential form, which increases the sensing cost. Therefore, motor-drive manufacturers have been focusing on position sensorless control [2], [3]. However, universal applicability of the position sensorless algorithms for speed control, especially at or near-zero speed and at full-load torque, has not been fully achieved yet.

Conventional position sensorless control schemes require complex estimation algorithms, and have limitations regarding the speed range and applicability. However, such schemes save the cost of an expensive position sensor. So, if a low-cost, low-resolution position sensor is used that transmits information over an RF link (thereby precluding the cable cost), then a simple position-estimation algorithm [2] operating along with the lower resolution but discrete-time- interval position updates can be potentially as powerful as the complex position sensorless control (which has no position feedback). Because the cost of the high-resolution sensor is higher to begin with, the proposed wireless information-exchange-based scheme, which can potentially use cheaper low-resolution sensors, can be a more cost-effective approach. However, because wireless transmission over an RF link is susceptible to channel disruptions [8], [9], it is important to investigate the impact of time delay on the stability and performance of the overall system, so that controllers can be designed to ensure operation within the desired bounds.

DTC

Direct torque control (DTC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors. This involves calculating an estimate of the motor's magnetic flux and torque based on the measured voltage and current of the motor.



SPACE VECTOR MODULATION

Principle

A three-phase inverter as shown to the right converts a DC supply, via a series of switches, to three output legs which could be connected to a three-phase motor.

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



$V_6 = \{101\}$	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

- Space Vector Modulation is an algorithm for the control of Pulse Width Modulation
- It is used for creation of alternating Current waveform.
- SVM became a standard for the switching power converters.

II. LITERATURE SURVEY

1. Direct Torque Control of Permanent Magnet Synchronous Motor With Reduced Torque Ripple and Commutation Frequency

Yongchang Zhang, *Member, IEEE*, and Jianguo Zhu, *Senior Member IEEE*

2. A Wide-Speed High Torque Capability Utilizing Overmodulation Strategy in DTC of Induction Machines With Constant Switching Frequency Controller

Auzani Bin Jidin, *Member, IEEE*, Nik Rumzi Bin Nik Idris, *Senior Member, IEEE*, Abdul Halim Bin Mohamed Yatim, *Senior Member, IEEE*, Malik E. Elbuluk, *Senior Member, IEEE*, and Tole Sutikno, *Student Member, IEE*

3. A General PWM Strategy for Four-Switch Three-Phase Inverters

Maurício Beltrão de Rossiter Corrêa, *Member, IEEE*, Cursino Brandão Jacobina, *Senior Member, IEEE*, Edison Roberto Cabral da Silva, *Fellow, IEEE*, and Antonio Marcus Nogueira Lima, *Member, IEEE*

4. Predictive Direct Torque Control for Flux and Torque Ripple Reduction

Jef Beerten, *Student Member, IEEE*, Jan Verwecken, *Student Member, IEEE*, and Johan Driesen, *Member, IEEE*

AC MOTOR FUNDAMENTALS

An **induction motor** or **asynchronous motor** is a type of alternating current motor where power is supplied to the rotor by means of electromagnetic induction.

An electric motor turns because of magnetic force exerted between a stationary electromagnet called the stator and a rotating electromagnet called the rotor. Different types of electric motors are distinguished by how electric current is supplied to the moving rotor. In a DC motor and a slip-ring AC motor, current is provided to the rotor directly through sliding electrical contacts called commutators and slip rings. In an induction motor, by contrast, the current is induced in the rotor without contacts by the magnetic field of the stator, through electromagnetic induction. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Unlike the normal transformer which changes the current by using time varying flux, induction motors use rotating magnetic fields to transform the voltage. The current in the primary side creates an electromagnetic field which interacts with the electromagnetic field of the secondary side to produce a resultant torque, thereby transforming the electrical energy into mechanical energy. Induction motors are widely used, especially polyphase induction motors, which are frequently used in industrial drives.

Induction motors are now the preferred choice for industrial motors due to their rugged construction, absence of brushes (which are required in most DC motors) and—thanks to modern power electronics—the ability to control the speed of the motor.

AC Induction Motor

where

n = Revolutions per minute (rpm) $f = AC$

power frequency (hertz)

p = Number of poles per phase (an even number) Slip is

calculated using:

$$s = \left(\frac{n_s - n_r}{n_s} \right)$$

where s is the slip.

The rotor speed is:

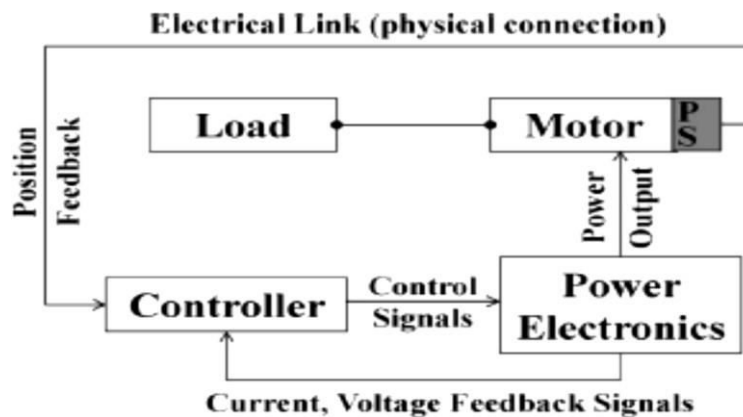
$$\text{Rotor speed, } n_r = n_s(1 - s)$$

Speed control

The synchronous rotational speed of the rotor (i.e. 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. Under load, the speed of the induction motor varies according to size of the load. As the load is increased, the speed of the motor decreases, increasing the slip, which increases the field strength of the rotor to bear the extra load.

III. EXISTING SYSTEMS

SYSTEM WITH POSITION SENSOR (WIRED FEEDBACK)

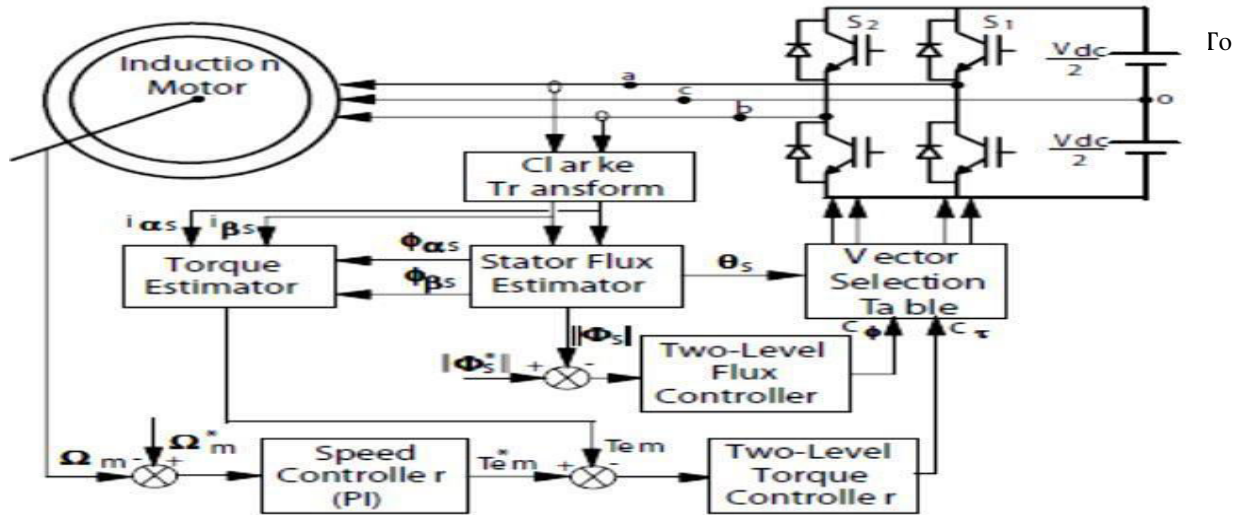


PROBLEMS IN THE EXISTING SYSTEM

1. The cost of the system with high accuracy sensors is very high and not affordable.
2. The system cost increases because of the shielding expenses in wired feed backs.
3. Sensorless position sensors gives great complexity in find the dynamic conditions, also higher calculation time degrades the stability.
4. Apart from everything, the existing methods uses, 6 switches (3 Arms) for a three supply to energise the three phase induction motor.

IV. PROPOSED SYSTEM

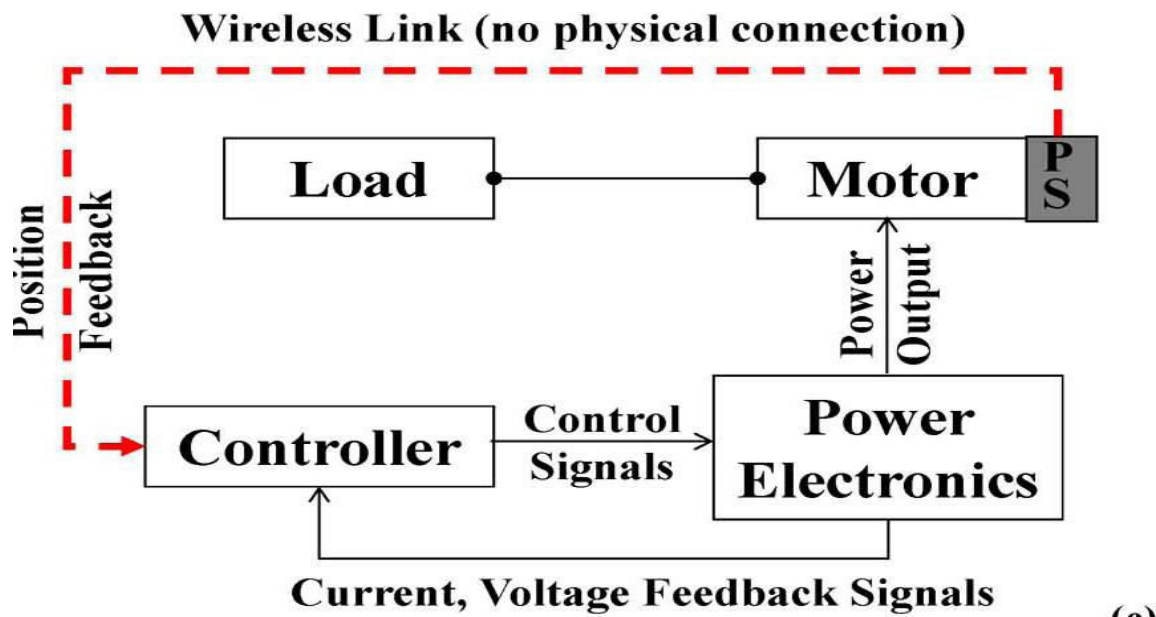
Simulation block diagram



To simplify the analysis, the following assumptions have been made.

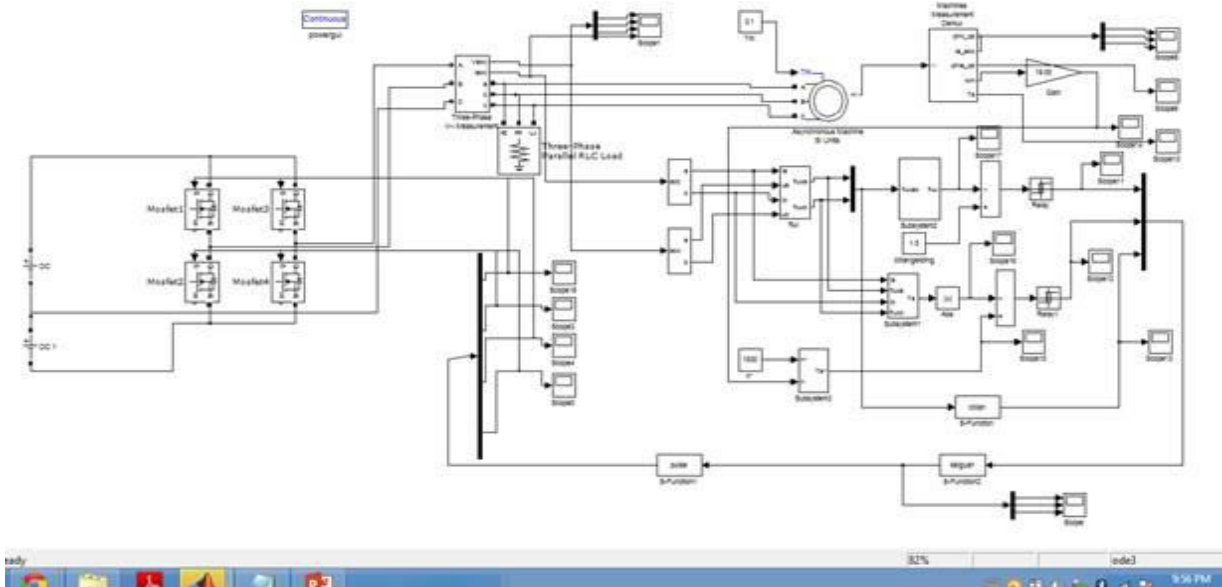
1. All semiconductor components are ideal. According to this assumption, the primary switch and the rectifiers do not have parasitic capacitances and represent ideal short and open circuits in their ON and OFF states, respectively.
2. The power transformer does not have the leakage inductances because of the ideal coupling.
3. All the capacitors are high enough so that the voltage across them is considered constant.
4. Finally, the input voltage of the converter is considered constant during a switching cycle because the switching frequency is much higher than the line frequency.

Block diagram of the proposed system





MATLAB MODEL



Simulation

Start the simulation. You can observe the motor stator current, the rotor speed, the electromagnetic torque and the DC bus voltage on the scope. The speed set point and the torqueset point are also shown.

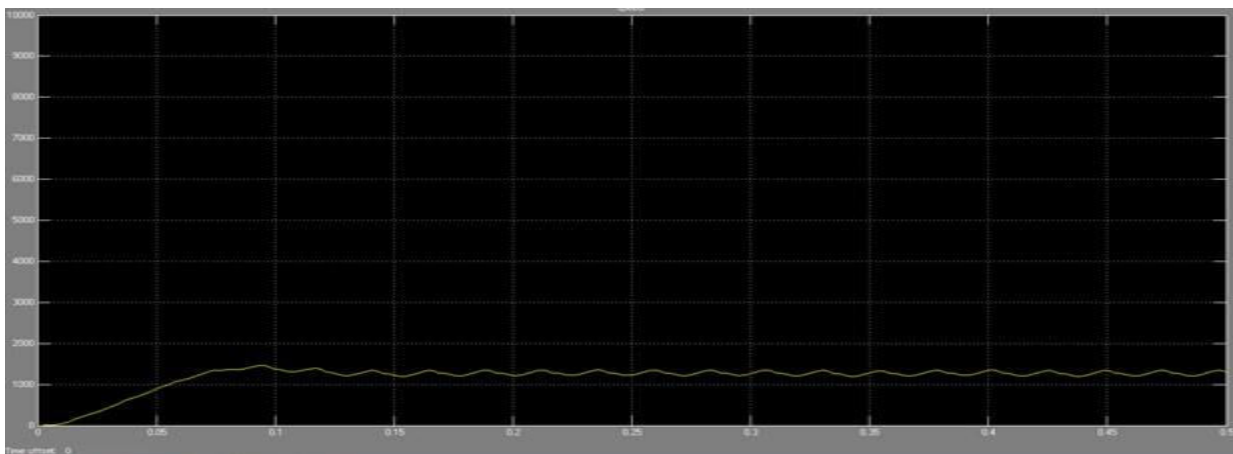
At time $t = 0$ s, the speed set point is 1000 rpm. As shown in Figure 0-10, the speed follows precisely the acceleration ramp.

At $t = 0.5$ s, the full load torque is applied to the motor shaft while the motor speed is still ramping to its final value. This forces the electromagnetic torque to increase to a high value and then to stabilize at 11 N.m once the speed ramping is completed and the motor has reached 1000 rpm.

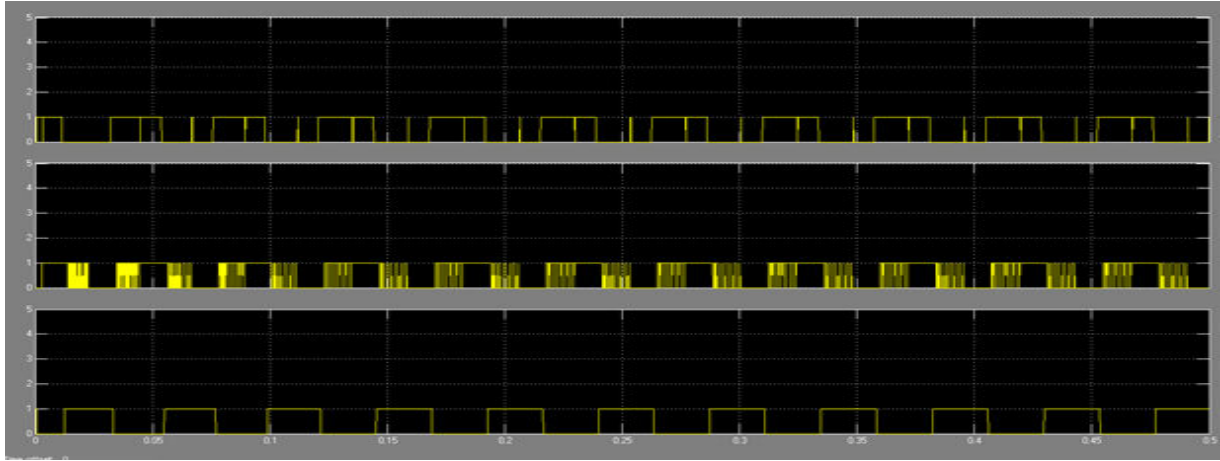
At $t = 1$ s, the speed set point is changed to 1500 rpm and the electromagnetic torque reaches again a high value so that the speed ramps precisely at 1800 rpm/s up to 1500 rpm under full load.

At $t = 1.5$ s, the mechanical load passed from 11 N.m to -11 N.m, which causes the electromagnetic torque to stabilize at approximately at -11 N.m shortly after. Note that the DC bus voltage increases since the motor is in the braking mode. This increase is limited by the action of the braking chopper.

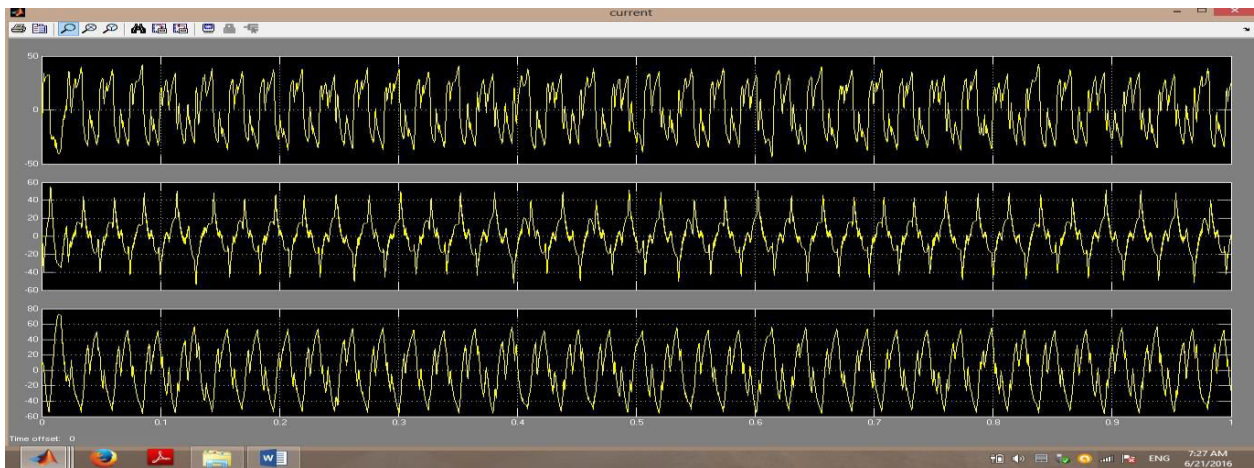
OUTPUT (SPEED WAVEFORMS)



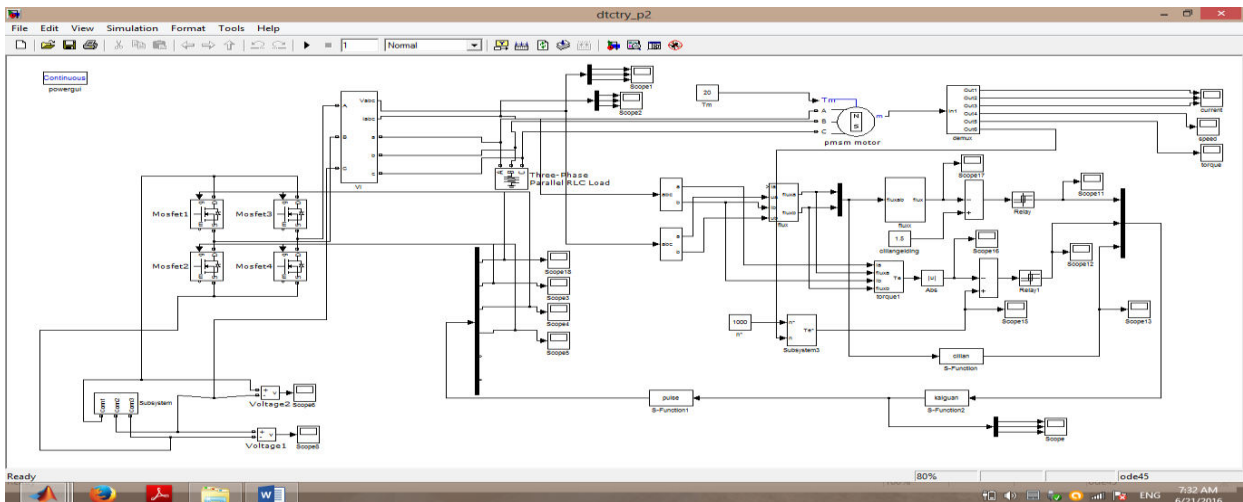
PULSES APPLIED TO ALL PHASES



CURRENTS IN ALL THREE PHASES



ENHANCEMENT IN THE SIMULATION MODEL





The proposed work is method to reduce the THD in the output of the stator currents. The DC battery in the previous implementation has been replaced by a controlled rectifier using 4 switches. The duty cycle of the controlled rectifier can be adjusted to vary the stator current for improvements in both hysteresis and harmonics. The harmonics are reduced approximately half of the existing work. Because of this, huge hum noise in the PMSM will be reduced and most of the power is utilized and saved. Because of less harmonics, unnecessary heating is avoided.

PERFORMANCE TABLE

THD	Phase A	Phase B	Phase C
Existing	43.85%	86.03%	67.34%
Proposed	24.66%	22.63%	11.33%

ADVANTAGES

Because the cost of the 6 switches, the cost was enormously high, and hence it was reduced to 4 switches.

DISADVANTAGES

- The waveforms of current has certain amount of harmonics and other frequency components because of approximation in the space vectors. receiver.
- It may produce some electro magnetic interference to the electronic equipments.

FUTURE DEVELOPMENTS

1. In future, the frequency of operation may be increased to 2 GHz so that a direct control of this equipment shall be extended to the space observation also, to monitor the health of the motors in space vehicles.
2. This equipment at present is not equipped with the camera module and types of modules can be added in future, so physical process can even be monitored live. So every operation of the system can be visually monitored using a visual system also.
3. It is a clear fact that the power required can be extracted from the solar panel which we can keep on the equipment to be controlled if it is on open space.

V. CONCLUSION

Thus we have established a simulation model, with position feedback to control the motor speed upto 1500 rpm. The dynamic conditions have been obtained by varying the speed from 1000 rpm to 1500 rpm with various wireless delays from 0.000001 s to 0 seconds. From the simulations it is very clear that the few micro seconds delay does not affect the performance of the closed loop control. Any how when the delay becomes in the order of milliseconds, the delay is appreciable and the system performance degrades.

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