

# Design of Neural Network Based Sensorless Induction Motor Speed Control Drive

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**ABSTRACT:** Design an Artificial neural network controlled Speed control drive for an 3-phase Squirrel Cage Induction Motor (SCIM) for various application. To Development an artificially intelligent speed controller drive using Neural Network (back propagation type) based speed feedback approach to avoid speed sensor in feedback loop of Induction motor .Target for a cheap design using sensorless speed control approach. In the designing of a speed feedback controller, the main criterion is the controllability of speed of an induction motor without using any speed sensor, these characteristics which can be achieved by speed sensor controller.

**KEYWORDS:** Artificial intelligence techniques, ANN, Induction motor drive, Electrical, Power Electronics.

## I. INTRODUCTION

3-phase, 50 Hz AC supply given as input to “3 Phase Rectifier” and the output DC filtered by RC circuit and fed as input to “3 Phase Inverter circuit” as shown in Fig.1. Inverter controlled 3-phase AC as output to IM for controlled speed, by obtaining controlled gate pulse from “Microcontroller” via “optical fiber” followed by “gate driver”. For that “Microcontroller received input parameters i.e.  $I_r$ ,  $I_y$ ,  $V_r$ ,  $V_y$ ,  $V_b$  by “Hall effect current sensor” & “voltage attenuation”. Microcontroller includes FL (based speed control) & NN (Speed feedback from rotor based on Back-propagation control). The Speed can control by User (by giving command like start, stop, increase Speed, decrease speed etc. from Monitor, which connected to Microcontroller by RS 232 connector & converter.

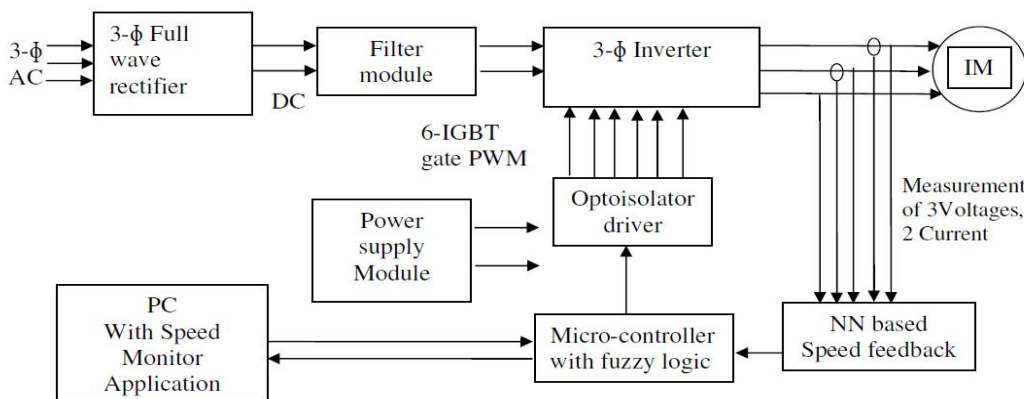


Fig. 1. Major Parts of the Drive System

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## II. RELATED WORK

Recently in Indian railways DC Motor is replaced by Induction Motor, for that it is necessary to apply it with a three phase variable voltage variable frequency (VVVF) inverter and four quadrant converter, whose controls are quite complicated, which is possible only by use of GTOs and microprocessor based control system.

1. IM has no brushes in armature as its squirrel cage type, less wear and tear as no brushes needed
2. Robust, cheaper to build and Technically feasible
3. Power to weight ratio of induction motor is much higher than the DC motor
4. Its 80186/16-bit MICAS S2 Microprocessor based control which is costlier.
5. Here required hall effect type speed sensor for speed feedback.

So, sensorless economical and effective approach is to reduce sensor cost and disadvantageous caused by it [1].

## III. SPEED ESTIMATOR IMPLEMENTATION

Neural Network based Speed Estimation is employed for the purpose of indirect measurement. The Inputs used by the Speed Estimator are three phase voltages and two phase currents The output delivered is an estimate of the current speed. The Motor is subjected to a speed profile based run and the Three phase voltages and current along with the frequency and speed are logged This forms the Training and Test Data for the Speed Estimator . The Neural Network based Speed Estimation in three phases:

1. Uses the Phase Voltages  $V_r, V_y, V_b$  and Phase currents  $I_r$  &  $I_y$  as Inputs
2. NN generates a speed estimate as output which is fed to IM by closed loop control PI/Fuzzy logic controller.
3. Training using Back-Propagation Algorithm

First Phase – Data Generation Phase

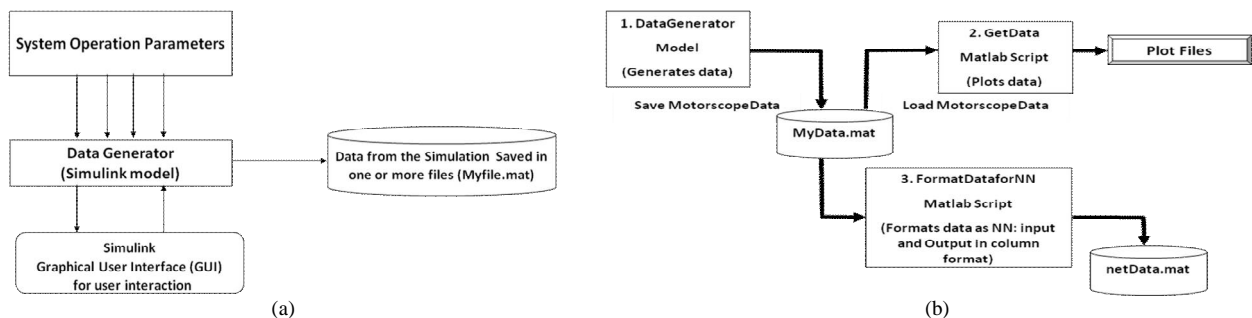
Second Phase – Training Phase

Third Phase –Test/ Application Phase

The Motor is subjected to a speed profile based run and the Three phase voltages and current along with the frequency and speed are logged. This forms the Training and Test Data for the Speed Estimator

## IV. PROCEDURE FOLLOWED: DATA GENERATION, TRAINING & TESTING FOR NNSE

The Data generator is run to simulate the drive system and generates the three phase voltages and three phase currents along with the operating frequency and speed. System Operation parameters : Ramp up time, Highest set Speed, initial set speed, Motor HP. Simulink GUI – allows for user to start the data generation and Stop it after full simulation is over, as shown in (a) Pre-training steps and (b) shows steps to followed after run simulation.



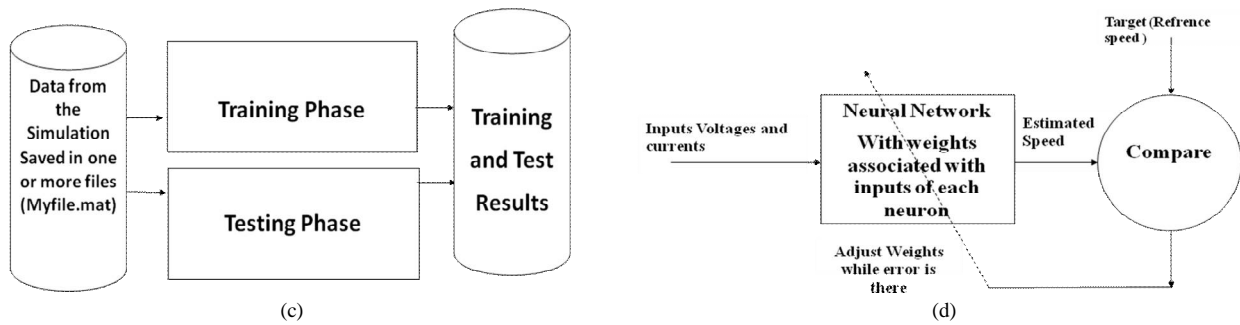
(c) shows overview of Training and testing phase and in (d) shows detailed training Phase is used to train the Neural Network.

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In the fig (e) shows the Testing phase, which is used to verify that the training is indeed successful or not. If not than trained again with more data.

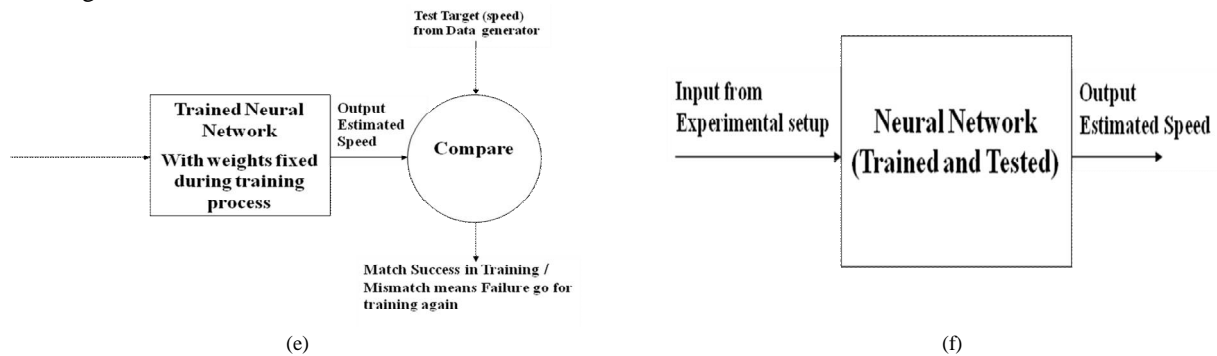


Fig. 2. Procedure followed for Data Generation, Training and Testing (a) Overview of Speed Estimator- Data Generation – Pre-training (b) Speed Estimator- Data Generator (c) Overview of Speed Estimator- Neural Network Training and Testing (d) Speed Estimator- Neural Network Training (e) Speed Estimator- Neural Network Testing (f) Speed Estimator- Neural Network Application

Once proper training is done the network is able to give proper data for the test results also. Generally the test data is separate from the training data and hence unknown to the network before testing. Once training and testing is done the network is considered to be ready for application purpose. The fixed weights of trained steps and tested neural network are programmed in the microcontroller for calculating estimate of the speed which is shown in Fig (f) Application phase which followed after successful testing.

In application mode we provide the current inputs to the neural network and it estimates the speed. This Estimated speed and its derivative (difference from previous value) fed to the FLC for computation of the control input for changing the frequency of the drive.

## V. STANDARD MODEL USE FOR DATA GENERATION TO TRAIN NEURAL NETWORK(NN)

First Phase – Data Generation Phase: Drive system is setup for Data generation phase using Matlab Simulink. Drive uses Vector control for the purpose of PWM generation. The IM model as Fig 3 given below, provides Speed feedback for data generation.

An input profile is provided to the model for running the motor (Power Supply= 3-phase AC, 415 Volts, 50 Hz. Motor Specification= 3-phase, 2 HP, 450 Volt, DC bus voltage = 630 volts, Chopper output/ inverter input= 630 Volts, IGBT O/P = 400 Volts, let Load Torque of SCIM =10 NM) and Microcontroller I/P= 5 Volts.

For this reference Speed profile is provided, let it starts at t=0sec, at t= 50 seconds it reaches the max speed possible (3000rpm), t=50 to 72 retains it at t= 72, the ramp down starts and continues till the motor does not stop (t=122).

The Phase Voltages  $V_r$ ,  $V_y$ ,  $V_b$  and Phase currents  $I_r$  &  $I_y$  along with the current speed and frequency are recorded in a file.

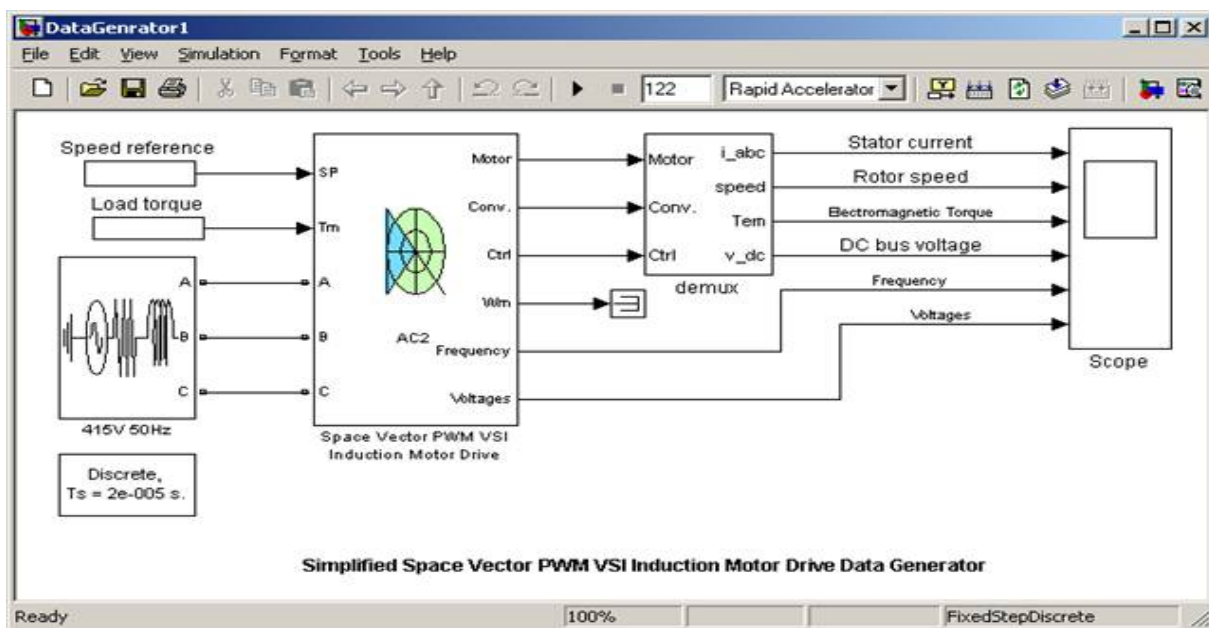


Fig. 3 Major parts of the drive system

## VI. DATA GENERATION-OPERATION

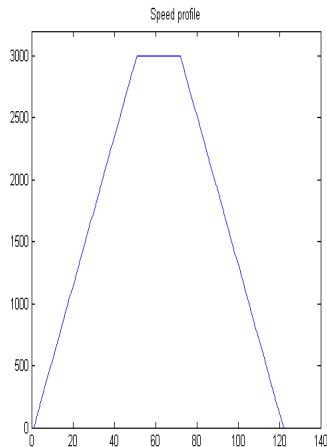
**Speed Profile Generation** : Speed Profile is generated using Matlab timer object. Consists of Speed Ramp Up and final constant speed for some time followed by the ramp down to achieve motor stop. Ramp up is achieved by increasing the frequency, up to the point where speed reaches to maximum limited by slip of the motor. Ramp down is by means of decreasing the Frequency up to the point the motor stops.

**Motor Drive Operation:** Speed Profile is generated using Matlab script is fed to the SVPWM Vector control module. It further generates the PWM trigger pulses for the inverter module. This causes the inverter to give AC waveform as input to the three phase Induction motor. The motor is loaded by a constant torque which user can set. Scope is used to record the Voltages and currents along with the frequency and speed for Data generation.

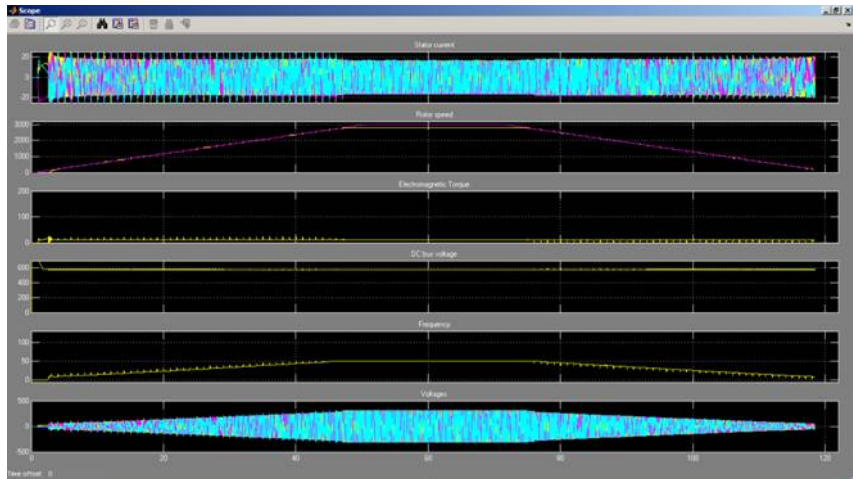
## VII. TRAINING PHASE SPEED PROFILE AND ITS RESULTS

Training Speed Profile: apply this profile for data generation in model setup as given in (a). The motor is provided non zero Set speed at time = 0 seconds, then at  $t=50$  seconds it reaches the max speed possible, 3000rpm and retains it. After that at  $t=72$  the ramp down start s and continues till the motor does not stop ( $t=122$ ).

There are six signals plotted by the Scope/ Recorded wave forms after simulation, as shown in (b), and saved in MotorScopeData at end of simulation. The variables are of Fig (b) first plot shows stator voltages ( $V_r$ ,  $V_y$ ,  $V_b$ ), second plot shows Rotor speed (Set and actual), third plot shows Electromagnetic torque, fourth plot DC voltage, fifth plot Frequency and sixth plot Currents ( $I_r$ ,  $I_y$ ,  $I_b$ ).

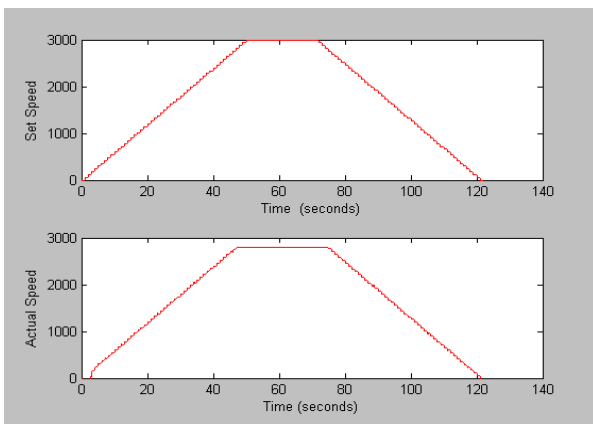


(a)

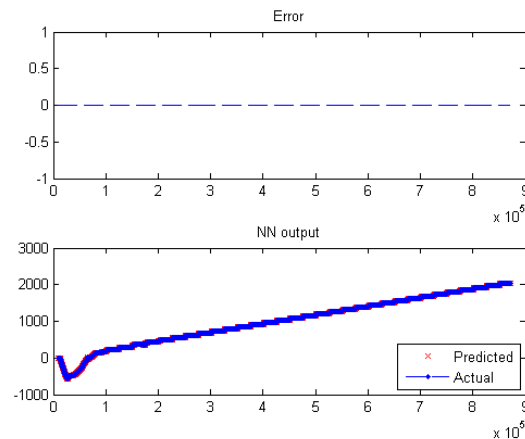


(b)

The Set speed and Actual speed mentioned in (c), first plot shows the reference or set speed and second plot shows actual or rotor speed, so both can compare easily. Similarly (d) is Estimated Error & Actual Speed, in first plot shows the error i.e. the difference between these and second plot shows the predicted and actual speed given below.



(c)



(d)

Fig. 4. Training Phase Speed Profile and its Results (a) Training phase Speed Profile (b) Scope/ Recorded wave forms (c) Training phase Set speed and Actual speed (d) Training phase Estimated Error & Actual Speed.

### VIII. TESTING PHASE SPEED PROFILE AND ITS RESULTS

Testing by changing reference speed profile as per (a) of the drive system and observing error as difference in set & actual speed:

1. The motor starts at  $t=0$  sec, then at  $t= 20$  seconds it reaches the max speed possible, 2800rpm and retains it. After that at  $t= 30$  the ramp down starts and continues till the motor does not stop ( $t=47$ ).
2. The motor starts at  $t=0$  sec, then at  $t= 20$  seconds it reaches the max speed possible, 2900rpm and retains it. After that at  $t= 25$  the ramp down start s and continues till the motor does not stop ( $t=44$ ).

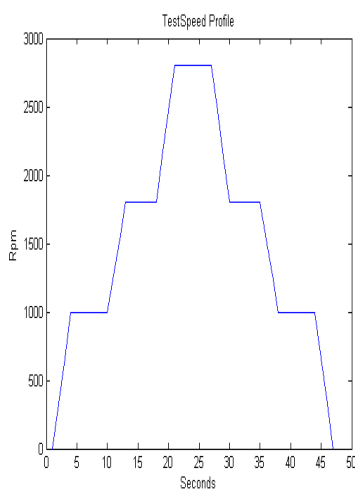
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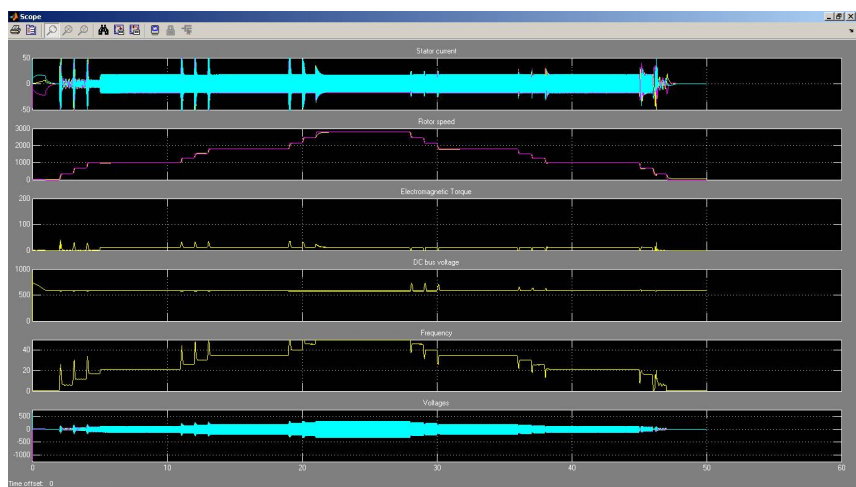
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There are six signals plotted by the Scope/ Recorded wave forms after simulation, as shown in (b), and saved in MotorScopeData at end of simulation. The variables are of Fig (b) first plot shows stator voltages ( $V_r$ ,  $V_y$ ,  $V_b$ ), second plot shows Rotor speed (Set and actual), third plot shows Electromagnetic torque, fourth plot DC voltage, fifth plot Frequency and sixth plot Currents ( $I_r$ ,  $I_y$ ,  $I_b$ ).

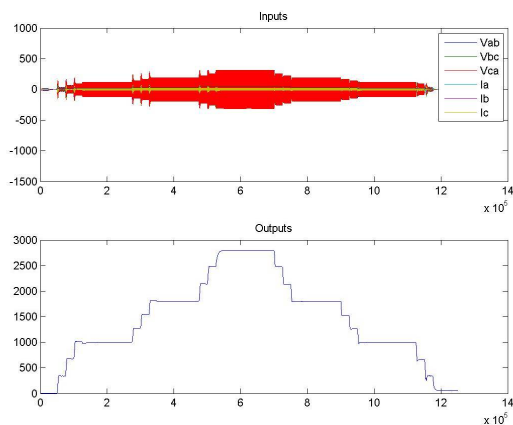


(a)

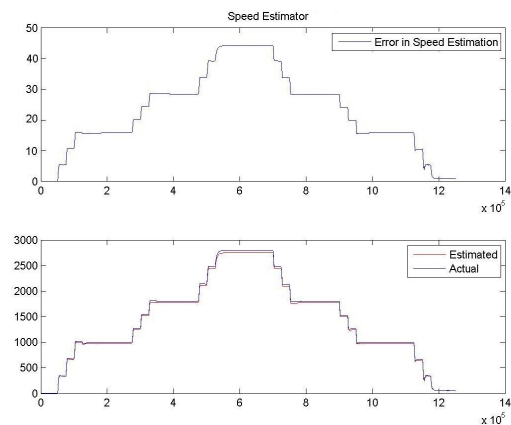


(b)

(c) shows Testing input Output plots, first plot shows the three phase voltages and three phase currents and in second plot shows current rotor speed, similarly in (d) shows Estimated Error & Actual Speed, in first plot given estimated error between reference and rotor speed and second plot shows waveform of estimated and actual speed.



(c)



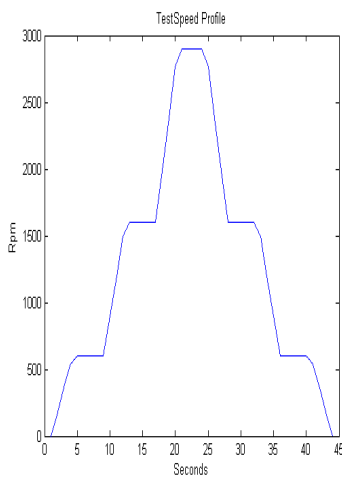
(d)

Fig. 5. Testing phase speed profile and its results (a) Testing Speed Profile of drive system (b) Scope/ Recorded wave forms (c) Testing phase input Output plots (d) Testing phase Estimated Error & Actual Speed

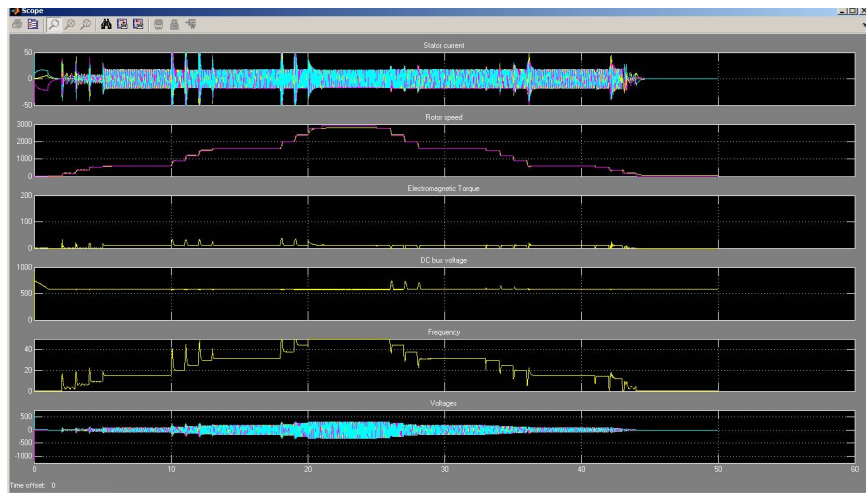
## IX. APPLICATION PHASE

Apply speed profile as shown in (a) upon the trained and tested neural network for data generation in model setup. Speed Ramps up with two stops. Starts from 0 Ramps up to 600 stabilise for short time. Again ramps up to 1600 stabilise for short time. Further Ramps up to 2900. A total of about 44 sec simulation time.

There are six signals plotted by the Scope/ Recorded wave forms after simulation, as shown in (b), and saved in MotorScopeData at end of simulation. The variables are of Fig (b) first plot shows stator voltages ( $V_r, V_y, V_b$ ), second plot shows Rotor speed (Set and actual), third plot shows Electromagnetic torque, fourth plot DC voltage, fifth plot Frequency and sixth plot Currents ( $I_r, I_y, I_b$ ).

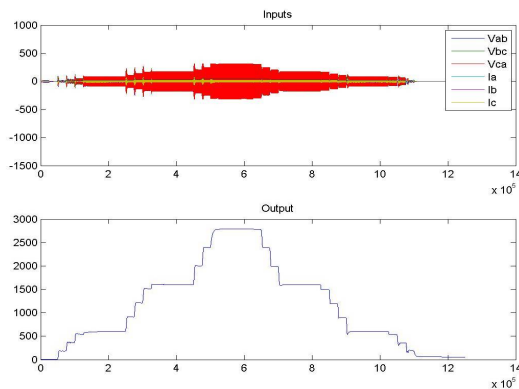


(a)

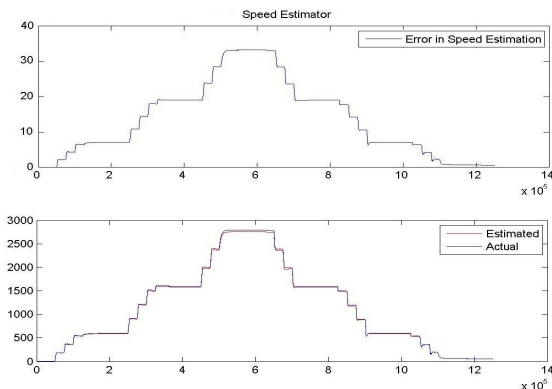


(b)

(c) shows Testing input Output plots, first plot shows the three phase voltages and three phase currents and in second plot shows current rotor speed, similarly in (d) shows Estimated Error & Actual Speed, in first plot given estimated error between reference and rotor speed and second plot shows waveform of estimated and actual speed .



(c)



(d)

Fig. 6. Application Phase (a) Application phase Speed Profile of drive system (b) Scope/ Recorded wave forms (c) Application phase input Output plots (d) Application phase Estimated Error & Actual Speed

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## X. EXPERIMENTAL RESULTS

Simulation provides useful insight into operations. Matlab and Simulink can be considered as essential tool for simulation. Neural Network based speed Estimation is practically possible using simulation. In this paper proposed an neural network based speed observer and PI/ fuzzy logic speed controller algorithms using PIC 18F4431 microcontroller to increase the speed-sensorless drive. By using MATLAB simulation from the experimental setup, the results carried on a 2HP Induction motor with PIC18F44431 micro-controller. This has robust speed observation and tracking performances even at load variation or variable-speed operation, shows that the proposed algorithms observe and correct respectively the speed over the entire speed range.

The conclusion of all the tests carried out is that the estimated motor response and the reference or actual speed are quite similar, and there is nearly no error in the steady state.

## XI. CONCLUSION

In this paper, we are limited to the neural network based speed observer and further planning is to speed control using fuzzy logic approach on place of PI controller. PIC18F4431 Microcontroller based control, development and Simulation of complete drive circuit including FLC Simulation, PWM Simulation and NN Simulation on MATLAB. Software Development is at two levels On Microcontroller using Embedded C language Firmware, FLC, NNSE. On PC/ Desktop GUI programming using Visual Basic 6 and Communicating with the Drive unit using Serial Port.

## XII. ACKNOWLEDGEMENT

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