



# SPEED CONTROL OF INDUCTION MOTOR WITHOUT SPEED SENSOR AT LOW SPEED OPERATIONS

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## ABSTRACT

This paper represents the control strategy for the speed control of induction motor without using any feedback position sensor. The system uses speed, torque and current loops to estimate the actual speed of the motor and to generate the six pulses according to the error signal between the reference speed and the estimated speed. Six pulses are given to the real time inverter, which is supplying AC source to the motor. The change in characteristics of the pulses changes the speed of the induction motor. The hardware setup is made by interfacing between the MATLAB simulink model and the field sensors and the inverter. The proposed system is simulated in the MATLAB/ Simulink, also the system is dumped into the space System and Arduino Board to generate the required six pulses for the six bridge inverter. These pulses are given to the inverter. Thus, the speed of the system is controlled without using the position sensor. This system is mainly proposed to reduce the cost of the system by eliminating the use of position feedback sensor by the current and voltage sensors. This system is having high accuracy, less cost, less complexity and weight of the system and it is highly reliable and efficient system.

**Keywords:** induction motor, six bridge inverter, inverter pulses, speed control, speed estimation.

## 1. INTRODUCTION

During last few decades, all the systems have been employed by using the feedback position sensors to control the speed of the induction motor at a desired speed. But the cost of the system increases due to the high cost of the position sensor. So there is a need to replace this high cost problem of the feedback sensor by using the current and voltage sensors to estimate the speed. It reduces the cost of the entire system to a great extent. However the computation increases to estimate the accurate actual speed of the system. The speed of the induction motor can be controlled in many ways [1]. It can be controlled by variation in number of poles of, variation in rotor resistance and the variation in the frequency. Variation in frequency is the very commonly used method from a long decade.

Now sensor less speed control systems are taking place into the market which also has so many strategies, like direct torque control, field oriented control, model reference adaptive system, artificial neural network, fuzzy, neuro fuzzy etc. [2]. Here, in this system Field oriented control strategy is applied to develop the real time simulink model, which takes the input from the field through current and voltage sensors and gives the output as the six pulses to trigger the six switches of the inverter. Thus, the system controls the speed of the induction motor at a desired value. It reduces the cost of the system to a great extent [3].

## 2. SPEED CONTROL TECHNIQUES FOR INDUCTION MOTOR

In industry, mostly cage- rotor induction motors are preferred due to their less cost, less weight, less volume, less losses and high efficiency than the wound rotor motors. Also wound rotor induction motors have speed limitations and higher inertia. [7] So, by considering

the most often used cage rotor induction motor, fundamentally three types of speed variation methods are developed:

- a) Variation in number of poles
- b) Variation in rotor resistance
- c) Variable frequency method

The first method is to change the number of poles of induction motor which results in the change of the speed of the rotor. The second method can be used for the wound rotor motors only [10]. Its principle is to vary the voltage supplied to the rotor by varying the rotor resistance, which results in the variation in the speed. The third method is a globally adapted method to which most of industry uses [4]. In this, the induction motor is connected to the frequency converter. By changing the frequency of the AC voltage supplied to the induction motor, the speed of the induction motor changes. The variable frequency method consists of the following three methods:

- a) V/f (Voltage per frequency) method
- b) Vector control
- c) Direct torque and flux control

## 3. SENSORLESS SPEED CONTROL OF INDUCTION MOTOR

To maintain the speed at desired value, we various kinds of techniques have been used till now which uses the feedbacks through the speed sensors.[5] It controls the speed of the motor but increase the effective cost of the system. So, one other option can be chosen to reduce the cost of the system through sensor less speed control which uses voltage and current sensors [9]. Though, it increases some more computations and



estimations for the accurate measurement of the speed. Thus, it reduces the total system cost due to removal of the position feedback sensor. [8] The research work on the sensor less speed control is still in progress, especially for the very low speed operations. The general block diagram for the sensor less speed control is given in the following Figure-1

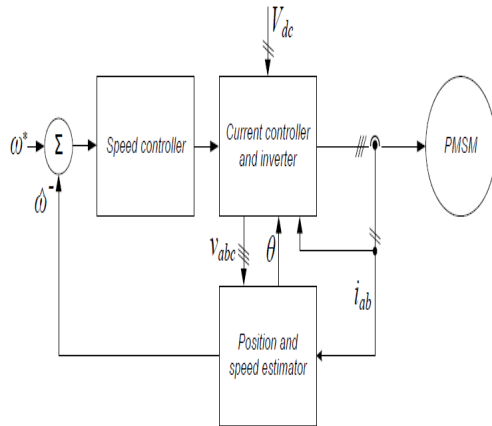


Figure-1. Overview of the system.

The sensor less control of speed is achieved by using state observer that can be said as the simulation of a real time system, which gives the approximate state vector of the induction motor and whole system and replaces the industrial encoder mounted on the motor shaft at low price, less weight and less complexity. [6] This system needs two current sensors as a position sensor as the feedback for estimating the speed of the induction motor. The sensor less speed control is done using the following techniques:

- Flux and Torque observers,
- Model reference adaptive system
- Open loop estimation technique, Etc.

#### 4. SYSTEM DESCRIPTION

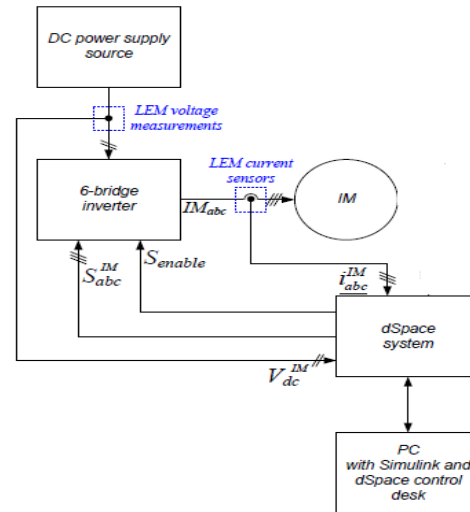
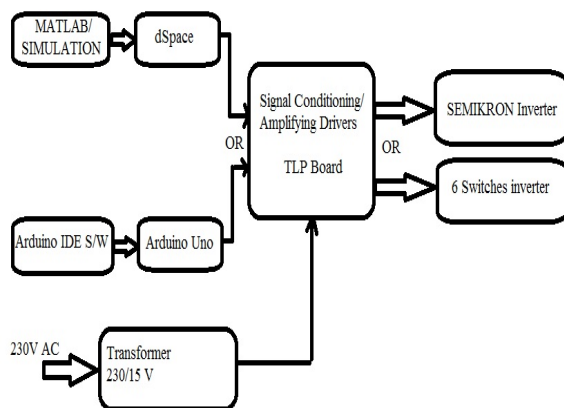
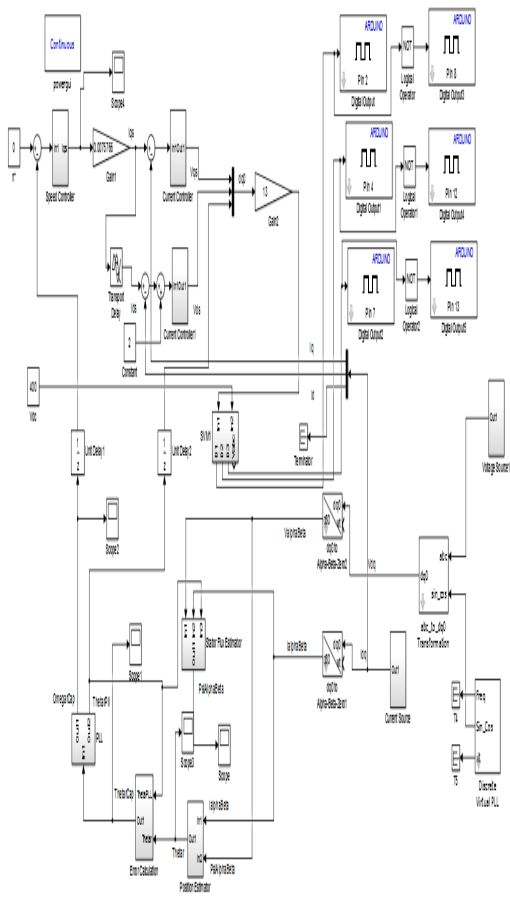


Figure-2 (a) & (b). Block diagram of the system.

In this system, the DC source is used to supply the 6- bridge inverter. Induction motor is connected to the inverter which requires pulses to operate the 6 switches of the inverter. Pulses to the inverter are given either by space system or Arduino. The voltage and current inputs are taken using the voltage transducer and current transducer respectively. These feedback signals are given to the interfacing system either as space system or Arduino board. A simulation is made to estimate the actual speed of the induction motor and to generate the pulses for the inverter according to the error signal by comparing the reference speed value and the estimated speed through current and voltage sensors. The simulation file is then dumped into the space or Arduino Board to operate the hardware system. Till now, open loop system has been made and tested on the real time hardware, to control the speed of the motor. The system is made for the motor of 1KW induction motor

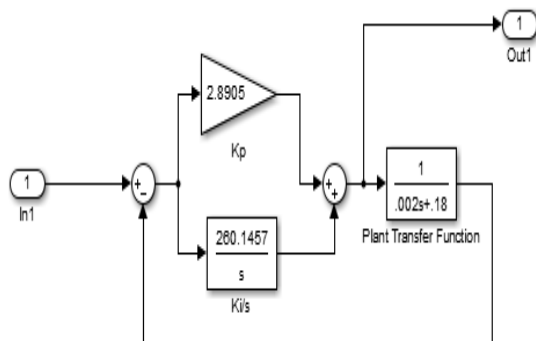
#### 4.1. Simulink model

The simulink model is made in MATLAB simulink to interface with the voltage and current sensors and to generate the 6 pulse outputs according to the desired speed. The simulink model consists of getting the actual current and dc link voltage measurements and estimating the actual speed of the induction motor through it. Stator flux estimator model is made to calculate the stator flux which gives input to the block to calculate the rotor position through it. Stator flux controller is used with the drift compensation loop. After estimating the speed, the speed signal is compared with the reference speed which gives the error signal. Then it is fed through the speed and the current controller to generate the 6 pulse outputs to give to the real time inverter to control the speed of the motor. The simulation model is shown in the following figure.

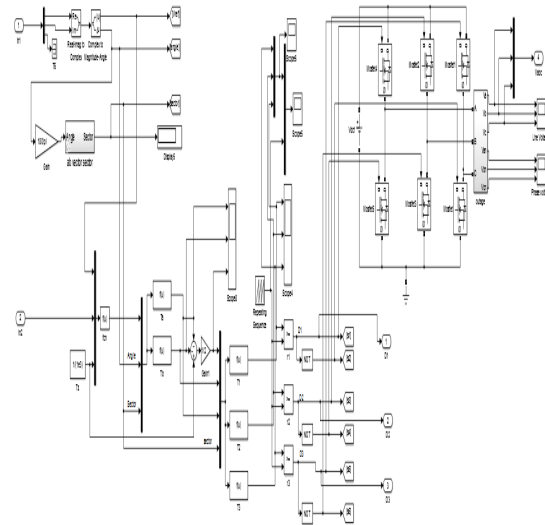


**Figure-3.** Simulation diagram for the real time system.

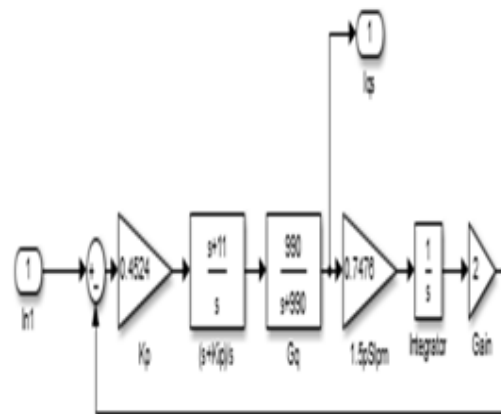
The simulink model is constructed through the non adaptive, back elf based technique for the speed estimation and control.



**Figure-4.** Current controller.



**Figure-5.** SVM Simulink model with 3 Phase Inverter.



**Figure-6.** Speed controller.

#### 4.2. Hardware setup

For hardware interface, 2 systems are used. space system and Arduino board. space system and Arduino both are an interfacing platform between the hardware and the software like MATLAB. space system(CP1104) has been used in this system which has 8 ADC Channels, 8 DAC Channels, 37 pin digital I/O, 37 pin slave PWM and various other communication ports. In this setup, both digital I/O pins and Slave PWM pins are tested to get the output. The simulation model is dumped into the system through ControlDesk. Then the space system starts to generate the PWM pulses for the 6- bridge inverter. Then, Arduino board has also been tested to get the pulse output for the inverter. The MATLAB simulink model is dumped into the Arduino board and hardware is interfaced through the Arduino board.

The hardware setup for the open loop speed control of the induction motor is shown in the following figures.

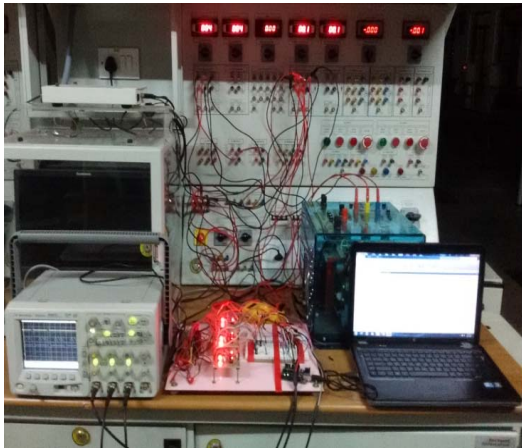


Figure-7. Complete experimental setup.

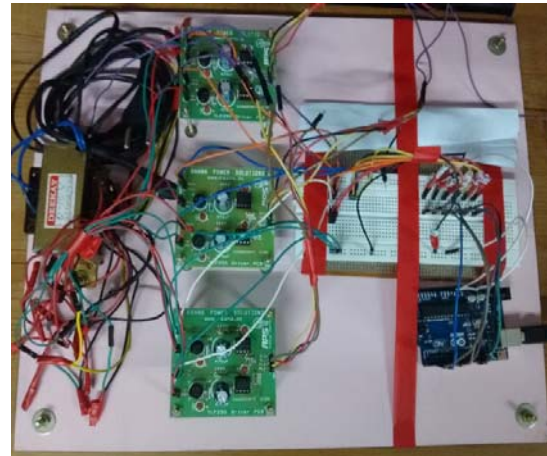


Figure-10. The hardware circuit using Arduino board.

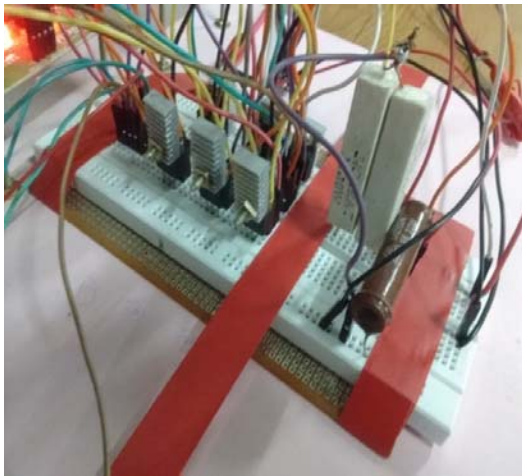


Figure-8. Inverter through 6 switches and star connected resistive load.

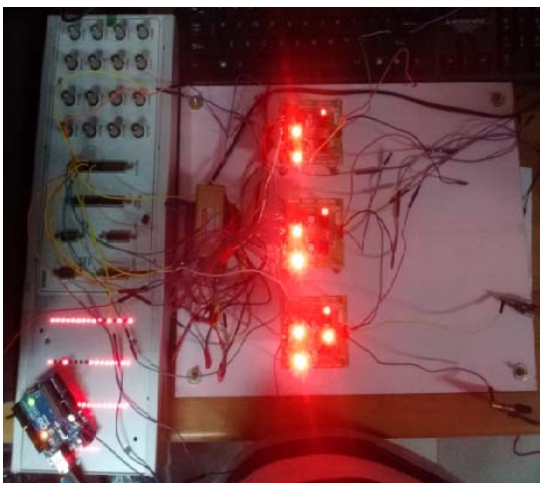


Figure-9. The hardware circuit using space System.

Following table describes about the specifications of all the components used in this project-

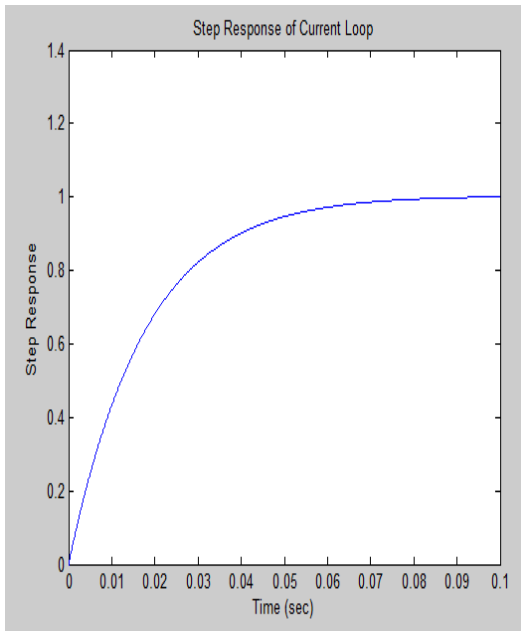
Table-1. Components specifications.

Components	Specifications
Induction Motor	1 KW, 2.2 Amp, 1440 rpm, 415V
Transformer	230/15V, 9 separate output
Signal Conditioning IC	A 3120
space	Slace DSP Pins- 10,11 & 29 with separate grounds
Arduino	Arduino Uno
MOSFET	IRF 840
NOT Gate IC	7404
Inverter	Semicron, 800V DC I/P, 415V AC O/p, 3 Phase
Resistor	1 K Ohm, 10 W
Heat Sink	Aluminium

## 5. RESULTS

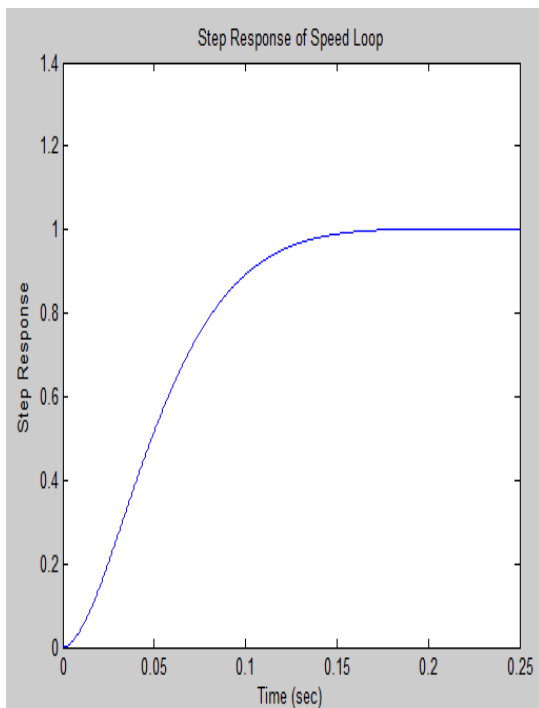
### 5.1. Simulation results

Following figure shows the step response of the current loop.

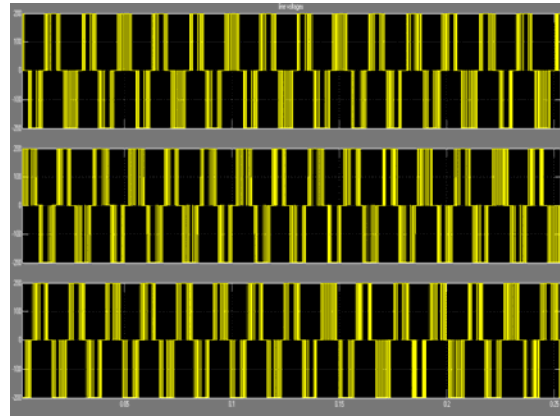


**Figure-11.** Step response of the current loop.

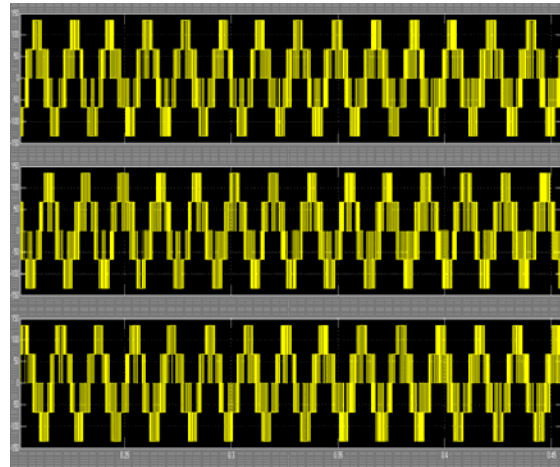
Following figure shows the step response of the Speed loop.



**Figure-12.** Step response of the speed loop.

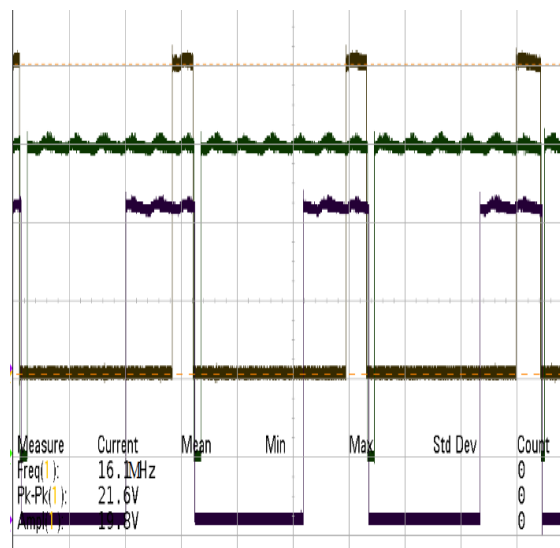


**Figure-13.** Line voltages.



**Figure-14.** Phase voltages.

## 5.2. Hardware results



**Figure-15.** 1<sup>st</sup> three pulses outputs in CRO.



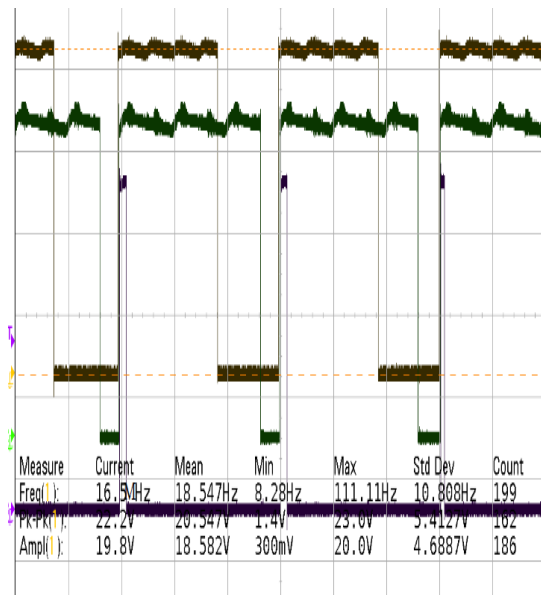


Figure-16. Another 3 inverted pulses outputs in CRO.

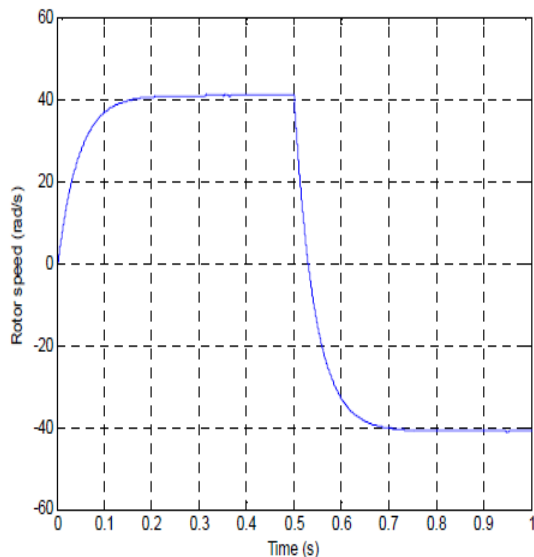


Figure-17. Estimated rotor speed.

## 6. CONCLUSIONS

The project is developed to control the speed of the induction motor without using any feedback position sensor and to reduce the cost of the entire system to a great extent by replacing the position sensor by the current and voltage sensors. The system is interfaced with the real time hardware and effective outputs are taken from the system. The proposed system is developed using the field oriented control scheme to control the speed of induction motor at a desired speed.

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