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Environment Temperature Degree Control Driving System using Simulink / MATLAB Program

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ABSTRACT

This paper present a new design for building the (smart controller), used to control of the speed motor that lead to reduce the energy consumption. The main aim of this modeling is to reduce the energy consumption according to the environment temperature degree by the implementation of Variable Frequency Drive (VFD) and hence the proper control of fluid flows. MATLAB Program/ Simulink used for implement the modeling and dynamic performance of a variable speed drive system.

Keywords: Variable frequency drive; A.C drive system; Energy saving pump drive system; Simulink / MATLAB Dynamic I.M.

1. INTRODUCTION

The variable speed electrohydraulic drive uses a variable speed electric motor to drive a hydraulic fixed displacement pump, by adjusting the electric motor speed to regulate the hydraulic pump output flow rate so as to meet the load-demand. [1, 2]. The VFD is a system for controlling the rotational speed or torque of an alternating current (AC) electric motor by controlling the frequency of the electric power supplied to the motor. So that the two major functions of a variable frequency drive are to provide power conversion from one frequency to another, and to enable control of the output frequency [3, 4]. Power conservation is necessary because with the ever increasing demand, need for electrical power can only be meet by conserving electrical power in addition to installation of new generating units. A major proportion of electrical power in a plant is consumed by electrical derives. Significant amount of electrical energy can be saved by the use of efficient and rigid type of electrical drives. Variable frequency drive is one of the many well-known energy efficient drives [1]. Frequency Drives are used for variable speed applications reduce the energy consumption of motors and increase the energy efficiency of plants [2]. Many fixed-speed motor load applications that are supplied direct from AC line power can save energy when they are operated at variable-speed, by means of VFD. Such energy cost savings are especially used in variable-torque centrifugal fan and pump applications, where the load's torque and power vary with the square and cube, respectively of the speed. This change gives a large power reduction compared to fixed-speed operation for a relatively small reduction in speed. The hydraulic motor is an important actuator in a hydraulic system. It was used mostly in the pump controlled-motor drive system, which normally responds badly and has poor control precision [1]. The drive system is simulated using MATLAB and the performance of a three-phase induction motor drive is obtained and the model was implemented using MATLAB/ Simulink with PWM controlled inverter [5].

Figure 1 shows the proposed model of Variable Speed Motor centrifugal pump system, it's consists of many units:

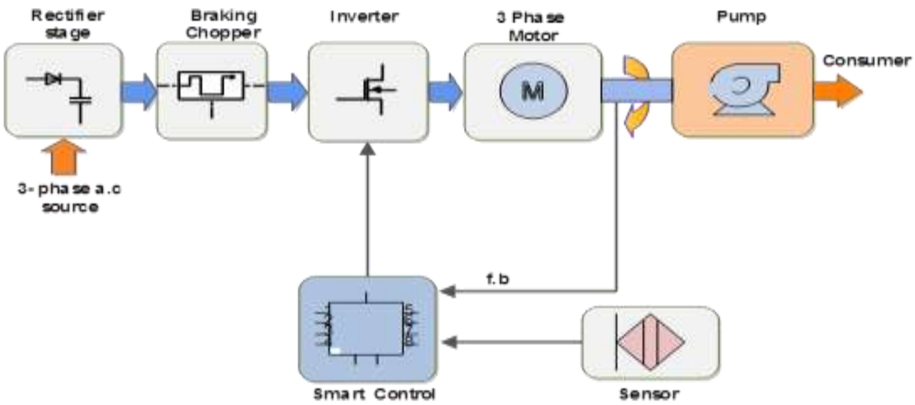

Figure 1: Proposed modeling diagram

1. Three phase voltage source

The three phase voltage source 220V P-P value with constant frequency of 50 Hz which is modeled using equations (1) to (3) [6, 7].

$$Vas = Vm \cos \omega t \qquad (1)$$
$$Vbs = Vm \cos (\omega t + \theta) \qquad (2)$$
$$Vcs = Vm \cos (\omega t - \theta) \qquad (3)$$

2. Rectifier and filter stage

A full-wave, solid-state diode rectifier convert three- phase 50 Hz power from a standard 220 or higher utility supply to either fixed or adjustable DC voltage. The system may include transformers if higher supply voltages are used [3]. The DC bus comprises with a filter section where the harmonics generated during the AC to DC conversion are filtered out [1, 3, 8].

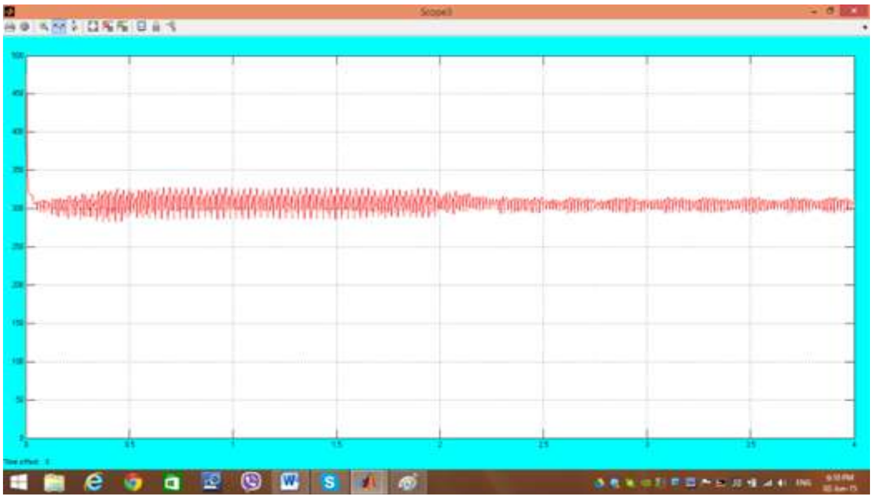

Figure 2: The output of filter

3. Braking chopper

Sometimes also referred to as braking unit,is used in the D.C voltage intermediate circuits of frequency converters to control voltage when the load feeds energy back to the intermediate circuit.

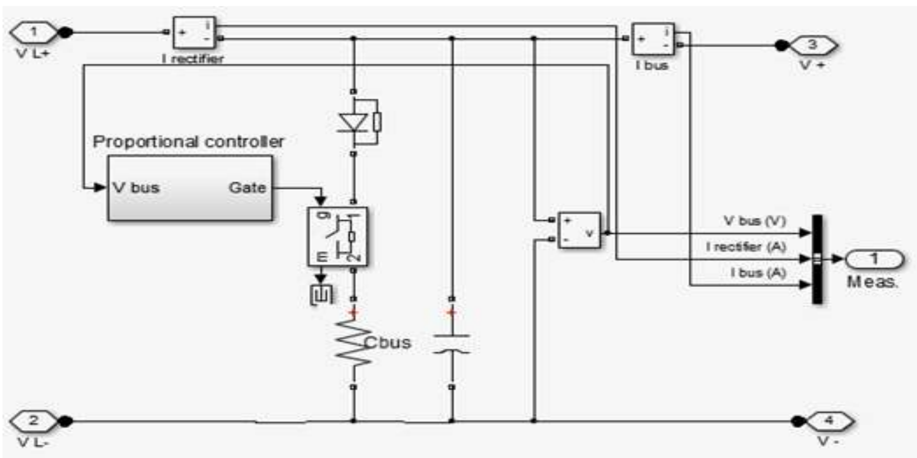

Figure 3: Simulink scheme of the braking chopper circuit

4. Inverter

Converting DC to variable frequency AC is accomplished using an inverter, the inverter controlled by pulse width modulation (PWM) from smart controller, so that the output current waveform closely approximates a sine wave (quadrature-axis). Electronic power switches (IGBT) Insulated Gate Bipolar Transistor, switch the rectified DC **on** and **off**, and produce a current or voltage waveform at the desired new frequency to controls the motor torque. The amount of distortion depends on the design of the inverter and filter [1, 3, 8, 9, 13].

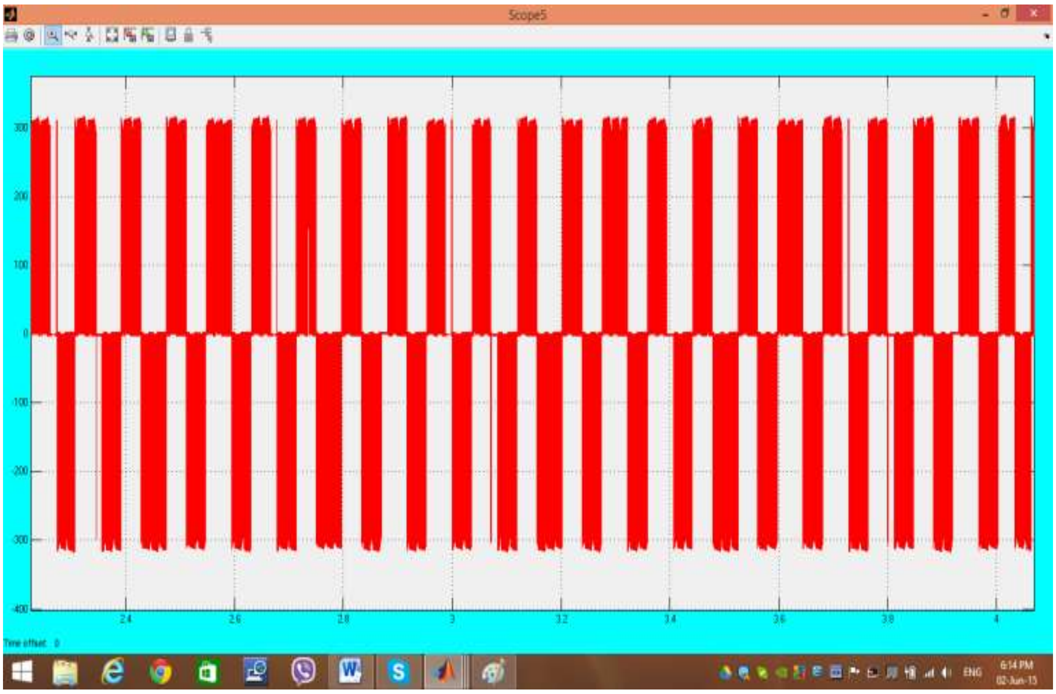

Figure 4: The output of inverter

5. Induction motors (IM)

The three phase induction motor works as a converter of electrical energy to mechanical energy that exerts the electromagnetic torque to centrifugal pump [10]. Squirrel-cage induction motors (I.M) are the workhorse of industries for variable speed applications in a wide power range that covers from fractional watt to megawatts. However, the torque and speed control of these motors is difficult because of their nonlinear and complex structure [11, 12, 14].

6. Sensor

The environment temperature degree is measured by a sensor as a criterion and is transmitted to PID controller.

7. Smart controller circuit

This controller is essential unit in the circuit and it's used to vary the output speed of induction motor, where the speed of the motor will change according to the environment temperature degree, the pumping will change according to speed of motor. Smart controllers unit may incorporate many complex control functions (figure 5).

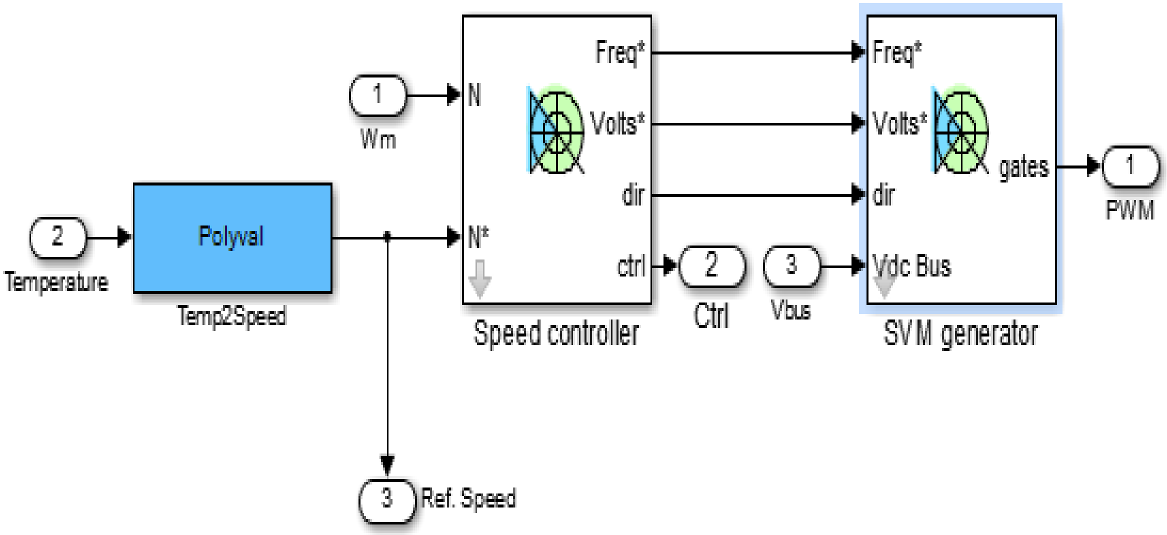

Figure 5: Simulink scheme of the smart controller

The Smart controller circuit receives three feedback signals:

- Environment temperature degree signal.
- Real time speed signal.
- DC voltage signal.

It may incorporate many complex control units:

a. Polynomial function:

Is a unit for mathematical equation related with environment temperature degree to generate the reference speed, this speed as a function of temperature (figure 6).

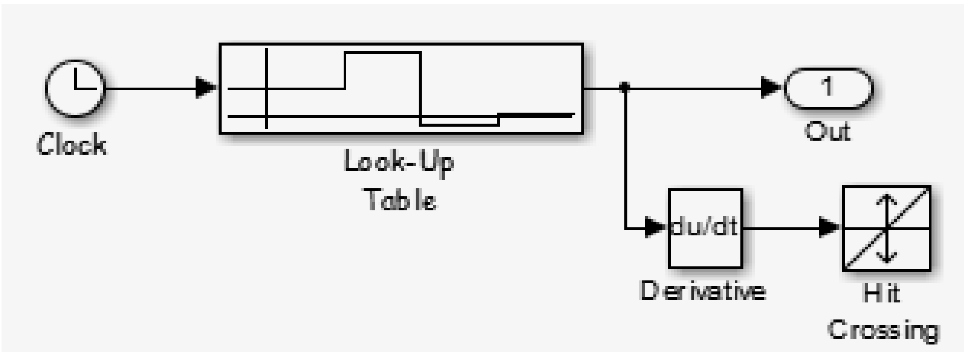

Figure 6: Simulink scheme of the polynomial function

Speed controller

Is consists from a proportional-integral-derivative (PID), the input for this unit are two values one is drive speed of the motor and the second is reference speed, the PID will comparative these values and generate three control signals [1, 4]:

- Frequency.
- Voltage.
- Direction of the motor.

The controller is sending these signals to SVM generator unit as shown in fig.7:

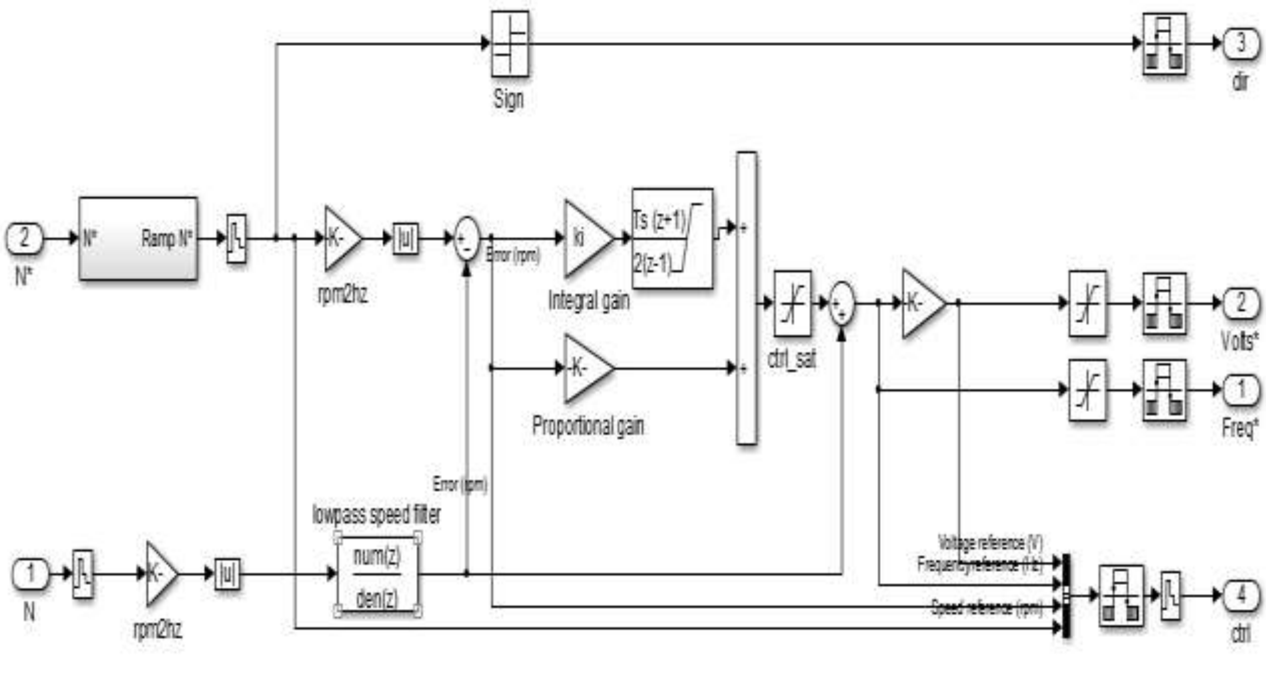

Figure 7: Simulink scheme of the speed controller

C. SVM generator

Space vector modulation (SVM) strategy is one of the modern control strategies for controlling the speed of the induction motors, this unit is generate a three phase PWM to Control the inverter. The inverter adjusts the output voltage or frequency values of the motor (figure 8).

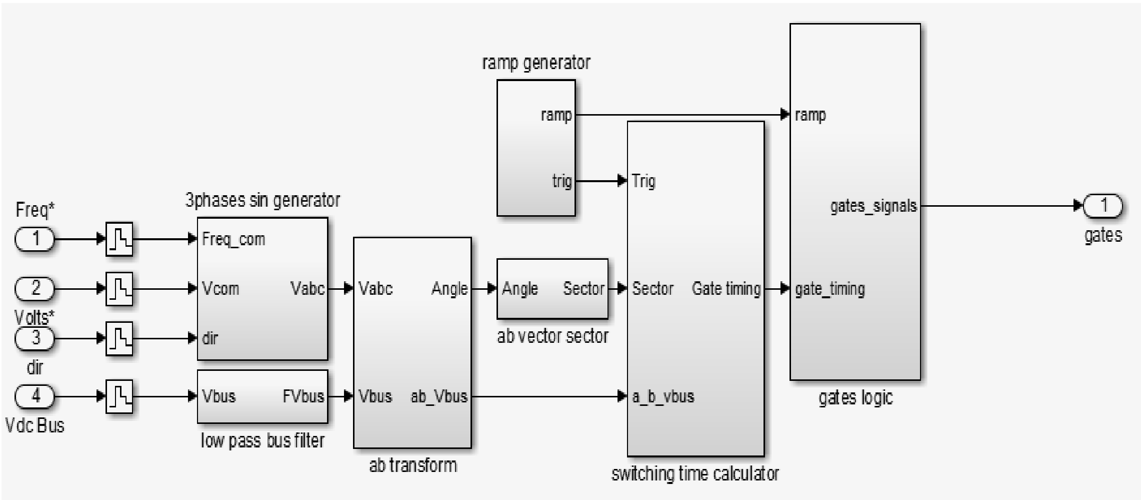

Figure 8: Simulink scheme of the SVM generator

The three phase pulse width modulation output (pulse signal) to inverter is shown in figure 9, where the phase shift between the signals is 120^{O}

Figure 9: Three Phase PWM

II. VARIABLE SPEED CONTROL STRATEGY

At this strategy, the three phase voltage is applied to induction motor through a three phase Variable Frequency Drive. The VFD unit changes the three phase AC sinusoidal voltage into DC voltage by passing from a three phase diode rectifier and then to L-C filter,where the harmonics generated during the AC - DC conversion are filtered out and then to braking chopper unit [4]. The last section consists of an inverter section which comprises six insulated gate bipolar transistors (IGBT) where the filtered DC supply is being converted into quasi-sinusoidal wave of AC supply which is supplied to the induction motor connected to it. It is known that the synchronous speed of an electric motor is dependent on the frequency. Therefore by varying the frequency of the power supplyaccording to the environment temperature degree through VFD the speed of the motor can be controlled [8], see figure 10. There are several methods for determination of the switching frequency of IGBTs. The frequency control method is based on stability of electromagnetic flux and so, the stability of voltage-frequency ratio may be stated as equation (4).

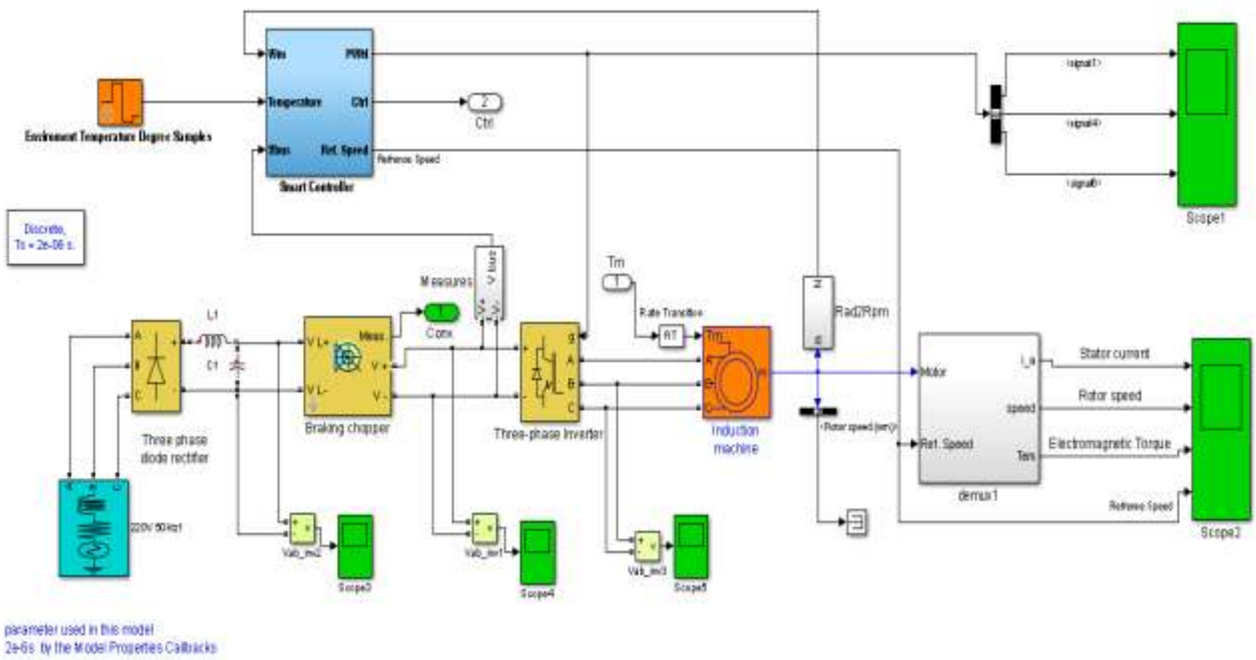

Figure 10: MATLAB/Simulink model of drive induction motor

The smart controller circuit receives feedback information from the driven motor and sensor to adjust the output voltage or frequency to the selected values [1]. Usually the output voltage is regulated to produce a constant ratio of voltage to frequency (V/Hz).

$$\frac{V}{f} = 4.44N\,\phi \max \quad (4)$$

III. SIMULATION RESULTS

The computer simulation result of the variable frequency drive fed induction motor is done by MATLAB/SIMULINK and the results are presented below, where the specifications used for simulation are:

- Voltage source parameters are: 220V; 3phase; 50 Hz.
- Induction motor parameters are: 220V; 3phase; 50 Hz; 4 poles; 1480 rpm; 55 KW; 0.87 P.F.

1. Open Loop speed control of induction motor using VFD Tables

In this type of control, the simulation result and gating signals are shown in figures 11and 12. Figure 11 shows the rotor speed and the reference speed with open Loop control, it is clear that the rotor speed is constant and don’t variation with the environment temperature degree.

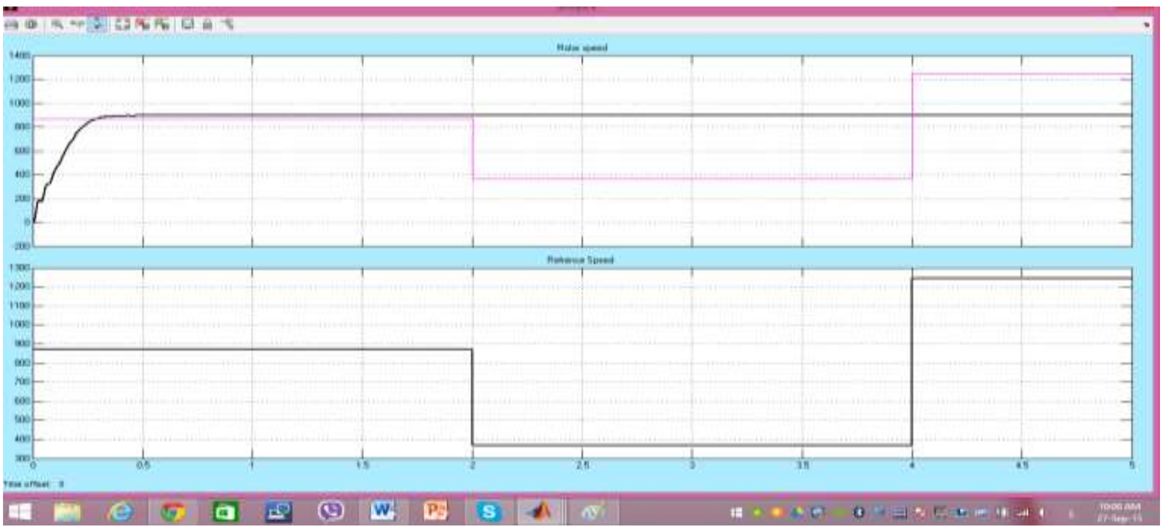

Figure 11: Open Loop speed waveforms

Figure 12 shows the stator current and electromagnetic torque, it is clear that the speed constant leads to constant current and constant torque.

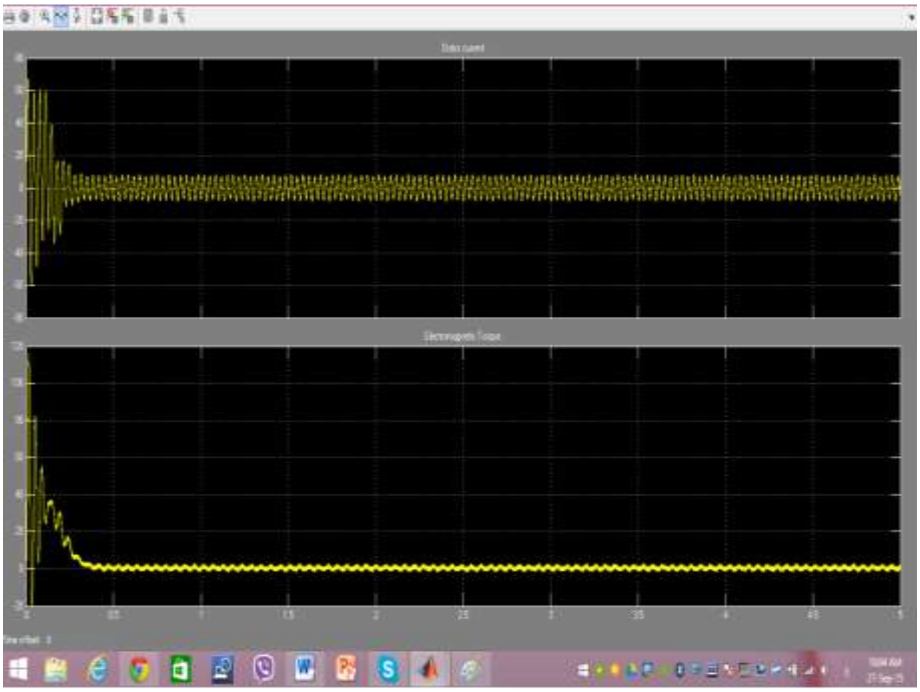

Figure 12: Open Loop stator current and electromagnetic torque waveforms

2. Closed Loop speed control of induction motor using VFD

The simulation result and gating signals for closed loop are shown in figure 13 and 14,from the analysis and figure 13 it is clear that the frequency variation leads to the change in the speed of rotor. Where the frequency is a function of the environment temperature degree

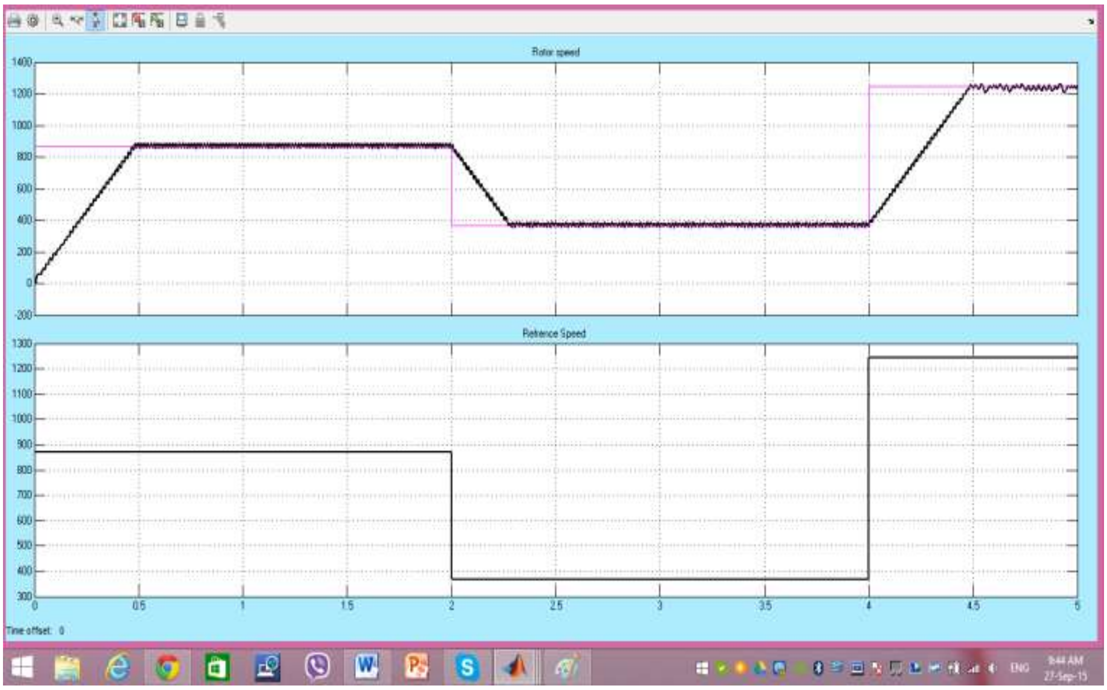

Figure 13: Closed Loop speed waveforms

Figure 14 shows the stator current and electromagnetic torque, it is clear that the speed variation leads to the change in the current and torque

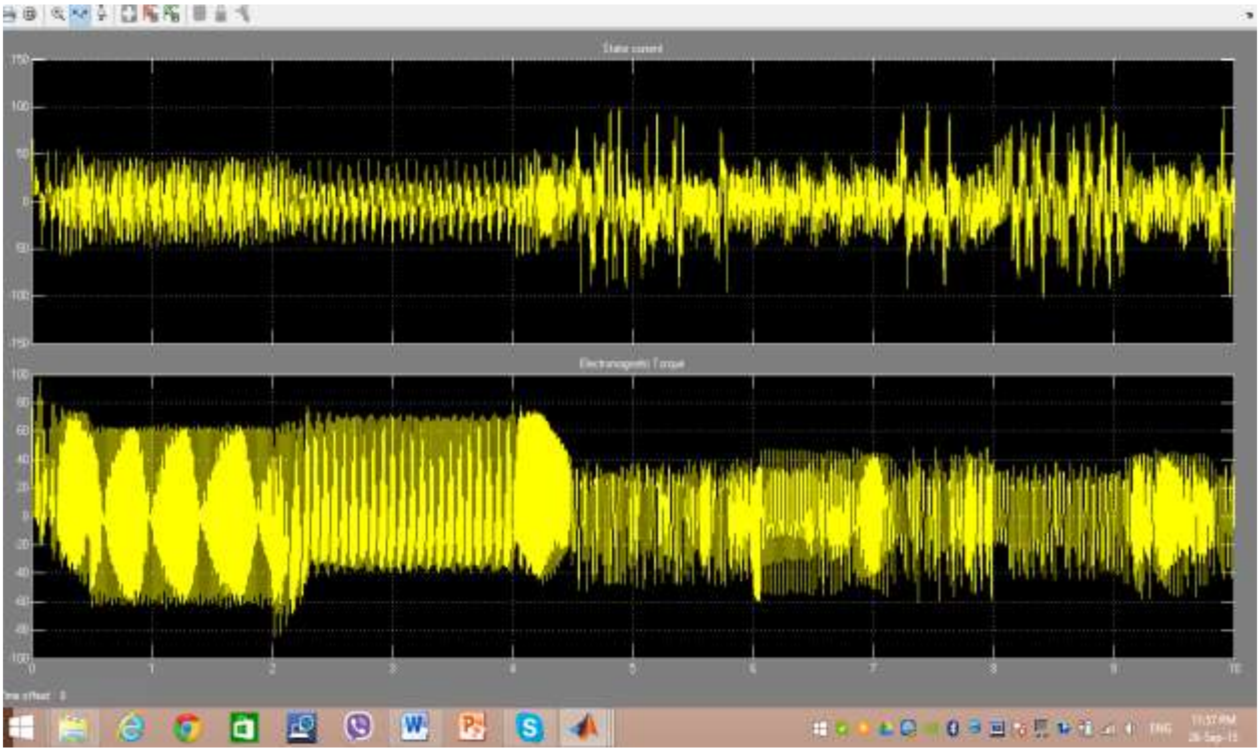

Figure 14: Closed Loop stator current and electromagnetic torque waveforms

CONCLUSION

The proposed Simulink model shows:

- The effect of applying variable frequency drive control on the speed of motor, where changing the environment temperature degree, using the VFD will changes the electrical frequency of the supply voltage and changing the frequency that lead to changes the rotor speed of the motor and hence the flow rate of water (figure13), so that the flow rate will be a function of environment temperature degree.
- The speed control of induction motor using VFD can save energy according to affinity law.
- Large amount of energy saved according to small reduction in speed.
- The decrease in energy consumption from conventional energy sources leads to conservation of energy and reduce service life of motor.
- The VFD unit is a good solution for improving the response and control precision of hydraulic motor.
- Using a smart control will increase the cost of the drive system and control complexity, but achieves the expected energy savings target.

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