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Simulation and Analysis of Constant V/F Induction Motor Drive

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Abstract- **Induction motors are used extensively in industries for obtaining motive power, as it has many practical advantages over other types of electrical motors. Low maintenance cost, self starting, simple and rugged construction, multiple methods for obtaining smooth torque-speed control as per the requirement and suitability of the industrial application, are a few advantages of an induction motor. Induction motor characteristics are well suited for Adjustable or Variable Speed Drive, which is, nowadays, preferred over Constant Speed Drive In this paper, Variable Voltage-Variable Frequency (V/f) base torque-speed control of three phase induction motor fed by a PWM Voltage Source Inverter will be simulated using PSim Software. The PWM method, which involves the modulation of conventional sinusoidal reference signal and a triangular carrier to produce pulse width modulated output signals, which are applied to Power Electronic Switches of a 2-Level Voltage Source Inverter, driving a Three Phase Induction Motor, shall be used. The performance analysis of three phase induction motor fed by PWM voltage source inverter in terms of phase current of inverter, rotor and stator current, speed, and electromagnetic torque developed of inverter is simulated.**

***Index Terms*— Constant *V/f* control, Induction motor, SPWM scheme, Voltage Source Inverter.**

I. INTRODUCTION

Three phase induction motors are the most widely used motors for industrial control and automation. Hence they are often called the workhorse of the motion industries. They are robust, reliable, less maintenance and of high durability. When power is supplied to an induction motor with recommended specified voltage and frequency, it runs at its rated speed. However many applications need variable speed variations to improve the quality of the product. The development of power electronic devices and control systems has to mature to allow these components to be used for speed control of AC and DC motors control in place of conventional methods. This type of control not only controls the speed of AC and DC motors, but can improve the motor's dynamic and steady state characteristics. Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. Recently, developments in power electronics and semiconductor technology have lead improvements in power electronic systems. Three phase voltage-fed PWM inverters are recently showing growing popularity for multi-megawatt industrial drive applications. The main reasons for this popularity are easy sharing of large voltage between the series devices and the improvement of the harmonic quality Variable voltage and frequency supply to AC drives is invariably obtained from a three-phase voltage source inverter A number of Pulse width modulation (PWM) schemes are used to obtain variable voltage and frequency supply. The most widely used PWM schemes for three-phase voltage source inverters are carrier-based sinusoidal PWM . Three phase induction motors are most widely used motors for any industrial control and automation. It is often required to control the output voltage of inverter for the constant voltage/frequency (V/F) control of an induction motor. PWM (Pulse Width Modulation) based firing of inverter provides the best constant V/F control of an induction motor. Amongst the various PWM techniques, the sinusoidal PWM is good enough and most popular that provides smooth changeover of V/F, four quadrant operation, harmonic elimination, etc in both closed and open loop applications. Three phase induction motors are reliable, robust, and highly durable and of course need less maintenance. They are often known as workhouse of motion industries. When power is supplied to an induction motor with specified frequency and voltage, it runs at its rated speed. Many advanced semiconductor devices are available today in power electronics market like BJT, MOSFET, IGBT, etc.

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II. 3-PHASE 2-LEVEL VOLTAGE SOURCE INVERTER

The primary function of a voltage source inverter (VSI) is to convert a fixed dc voltage to a three-phase ac voltage with variable magnitude and frequency. A simplified circuit diagram for a two-level voltage source inverter for high-power medium- voltage applications is shown in Fig.1. The inverter is composed of six group of active switches, *S*1 ~ *S*6, with a free-wheeling diode in parallel with each switch. Depending on the dc operating voltage of the inverter, each switch group consists of two or more IGBT or GCT switching devices connected in series.

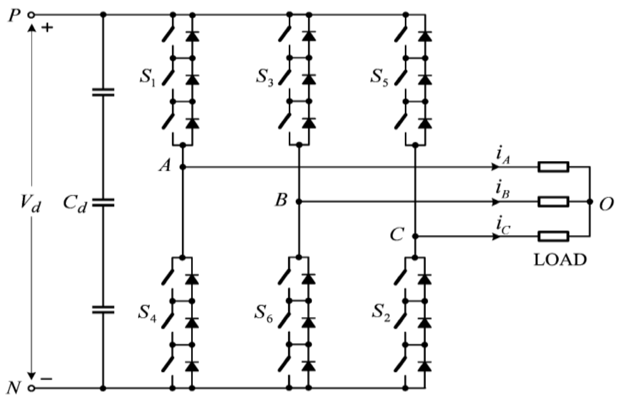

Figure 1: 3-phase 2-level Voltage source Inverter

III. SIN PWM TECHNIQUE

The principle of the sinusoidal PWM scheme for the two-level inverter is illustrated in Fig. 2, where *vmA*, *vmB*, and *vmC* are the three-phase sinusoidal modulating waves and *vcr* is the triangular carrier wave. The fundamental-frequency component in the inverter output voltage can be controlled by amplitude modulation index is

$$ma = \frac{Vm}{Vcr}$$

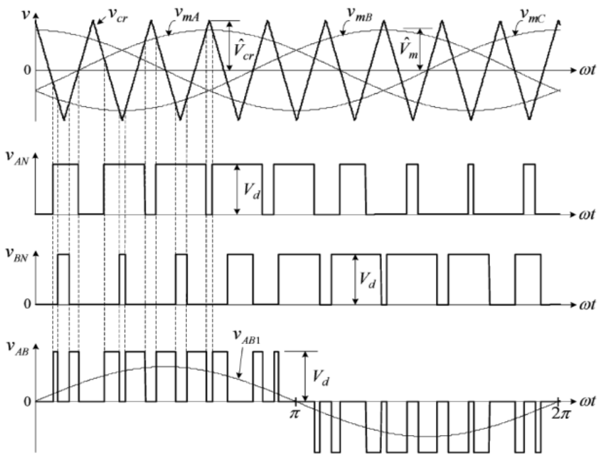

Figure 2: Sinusoidal pulse-width modulation

where ˆ*Vm* and ˆ*Vcr* are the peak values of the modulating and carrier waves, respectively. The amplitude modulation index *ma* is usually adjusted by varying ˆ*Vm* while keeping ˆ*Vcr* fixed. The frequency modulation index is defined by

$$mf = \frac{fcr}{fm}$$

where *fm* and *fcr* are the frequencies of the modulating and carrier waves, respectively. The operation of switches *S*1 to *S*6 is determined by comparing the modulating waves with the carrier wave. When *vmA* _ *vcr*, the upper switch *S*1 in inverter leg *A* is turned on. The lower switch *S*4 operates in a complementary manner and thus is switched off. The resultant inverter terminal voltage *vAN*, which is the voltage at the phase *A* terminal with respect to the negative dc bus *N*, is equal to the dc voltage *Vd*. When *vmA* < *vcr*, *S*4 is on and *S*1 is off, leading to *vAN* = 0 as shown in Fig.2 Since the waveform of *vAN* has only two levels, *Vd* and 0, the inverter is known as a two-level inverter. It should be noted that to avoid possible short circuit during switching transients of the upper and lower devices in an inverter leg, a blanking time should be implemented, during which both switches are turned off. The inverter line-to-line voltage *vAB* can be determined by *vAB* = *vAN* – *vBN*. The waveform of its fundamental-frequency component *vAB*1 is also given in the figure. The magnitude and frequency of *vAB*1 can be independently controlled by *ma* and *fm*, respectively.

IV. CONSTANT V/F CONTROL OF AN INDUCTION MOTOR

The synchronous speed of an induction motor is given by

$$Ns = \frac{120fs}{P}$$

The synchronous speed and, therefore, the speed of motor can be controlled by varying the supply frequency. The emf induced in the stator of an induction motor is given by

$$E = 4.44mfsk\O N1$$

Therefore, if the supply frequency is change, E1 will also change to maintain the same air gap flux. If the stator voltage drop is neglected the terminal voltage V1 is equal to E1 . in order to avoid saturation and to minimize losses, motor is operated at rated air gap flux by varying terminal voltage with frequency so as to maintain (v/f) ratio constant at rated value.

TABLE-1

Induction Motor Rating	
Voltage	**480 volts**
Pole	**6 pole**
Frequency	**60 Hz**
Speed	**1100 Rpm**
Rs	**0.0461 Ω**
Ls	**0.001345 H**
Rr	**0.258 Ω**
Lr	**0.00082 H**
Lm	**0.08154 H**
M.I	**0.5**

V. SIMULATION OF CONSTANT V/F INDUCTION MOTOR

Here constant v/f induction motor closed loop simulation is done using Psim software.For this simulation the speed of an Induction Motor is compared with reference speed the error is given to the PI controller and limiter and the slip is added to frequency and this frequency signal is multiplied by v/f and converted into voltage.This voltage is given to DQO-ABC block and thehree phase sin wave is compared by triangular wave. The frequency signal is also converted into theta angle and theta is given to DQO-ABC block. The SPWM signal is used to operate the inverter leg.Here IGBT switch is used.For PI controller tunning Ziegler-Nichols Method is used.

VI. ZIEGLER-NICHOLS TUNNING STEPS

1. Reduce the integrator and derivative gains to 0.
2. Increase *Kp* from 0 to some critical value *Kp*=*Kc* at which sustained oscillations occur
3. Note the value *Kc* and the corresponding period of sustained oscillation, *Tc*
4. The controller gains are now specified as follows:

PID Type	K_p	T_I	T_d
P	0.5Kc	Inf	0
PI	0.45Kc	Tc/1.2	0
PID	0.6Kc	Tc/2	Tc/8

VII. Simulation Results

In this section the simulation results for constant v/f Induction motor are demonstrated by PSIM6.0 software module.

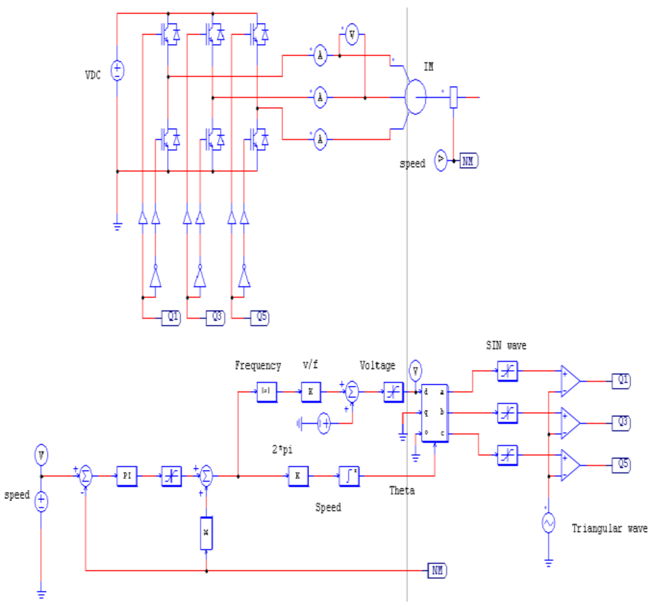

Figure 2: Volt/Hertz Closed Loop Speed Control of Induction Motor Simulation Circuit

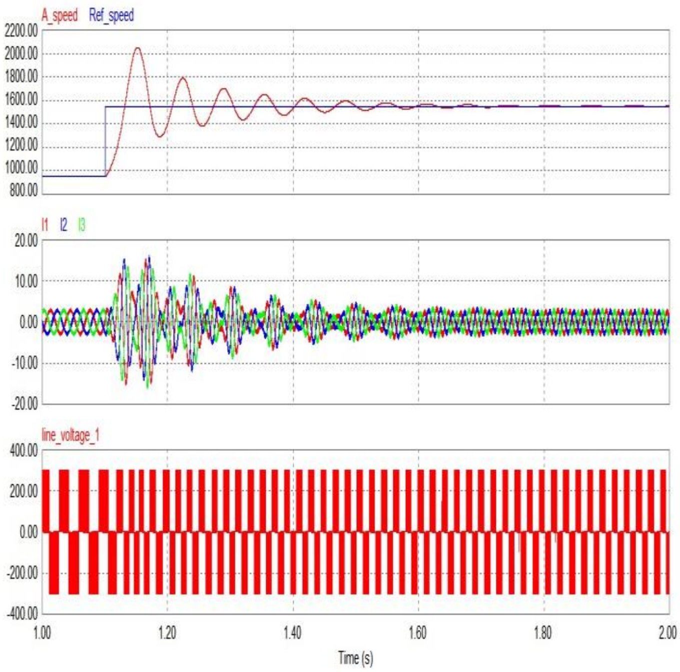

Figure 3: Speed, line current and Voltage profile for Speed reference change (low to high).

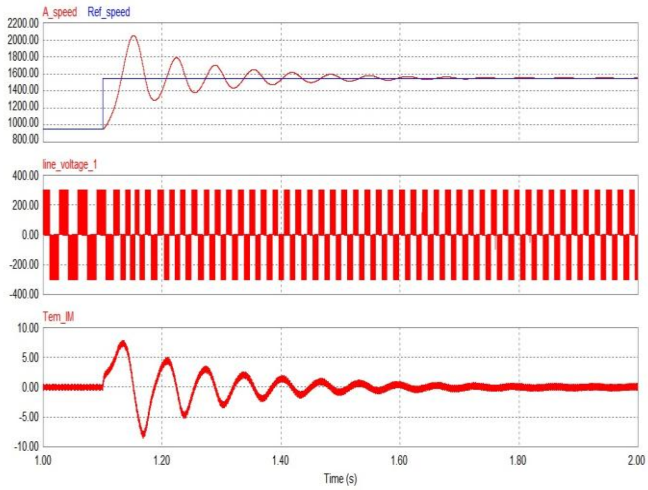

Figure 4: Speed, line voltage and torque profile for Speed reference change (low to high)

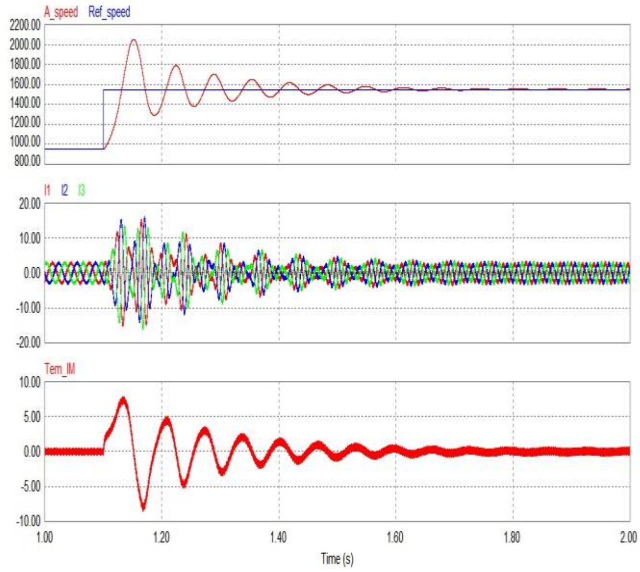

Figure 5: Speed, Line current and torque profile for Speed reference change (low to high).

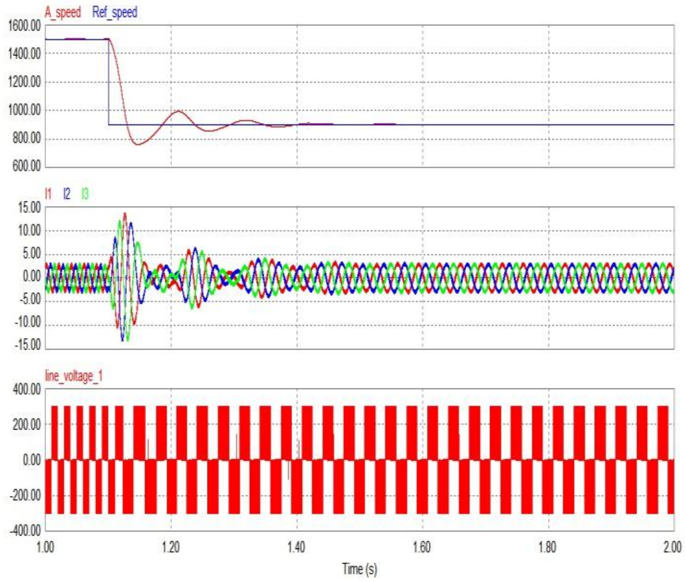

Figure 6: Speed, Line current and Line voltage profile for Speed reference change (high to low).

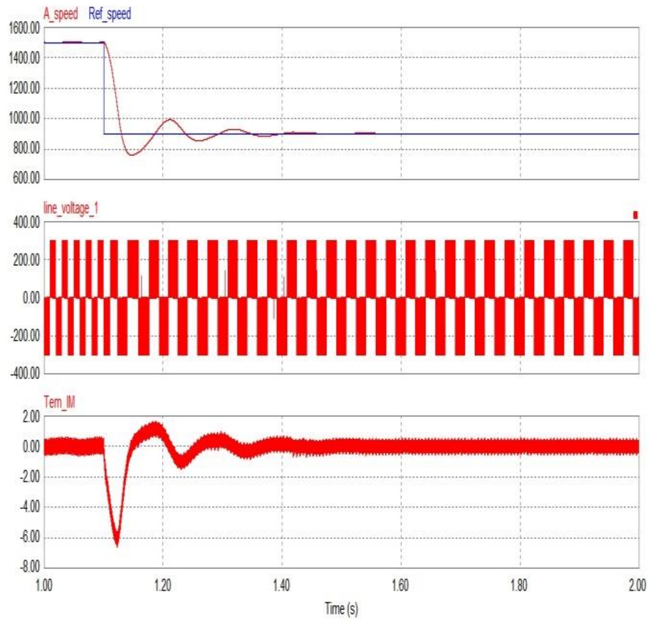

Figure 7: Speed, Line voltage and torque profile for Speed reference change (high to low).

VIII. CONCLUSION

Simulation results illustrate the performance and effectiveness of constant V/F Induction Motor drive. The actual speed follows the reference speed and change in the speed from high to low and low to high makes change in the voltage and current profile accordingly .

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