Performance Analysis of V/f Controlled Inverter Fed Induction Motor under Different Conditions

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Abstract─ The varying industrial requisites demand meticulous control of outcomes of the drives. Induction motors are the most extensively used motors for industrial control and automation. The open loop V/Hz control method is most popular speed control method because of its simplicity. This paper presents a closed loop constant V/Hz control in order to overcome the limitations above and to improve the performance of the drive. This closed loop constant V/Hz control method presents the analysis of speed and torque at different load conditions of a three phase squirrel cage induction motor drive fed with inverter using IGBTS at the power stage with constant volts per hertz control Using PI controller. A 7.5HP, 3-phase, 415v, 50Hz squirrel cage induction is used as a load for inverter. Simulation results of the proposed work are shown in this paper.

Key words─ *constant V/ Hz control, SPWM, ACIM, closed loop control.*

I. INTRODUCTION

Electric drives got a lot of prominence because of the availability of variable-frequency electric supplies at low cost due to the advances in power-electronics switching devices and the increasing concern about the present and future cost and availability of electric energy [1]. In most of the applications, AC machines are much preferred than DC machines due to their simplicity and robust construction without any commutator [2]. In the traditional open loop scalar control the voltage drop across the stator resistance is more dominant compared to the voltage drop for the production of the main flux at low frequencies. In addition to this, the variable voltage variable frequency scalar control scheme provides open loop control, and therefore the system cannot maintain speed accuracy both at low frequency and high load operation. To overcome these limitations, variable voltage variable frequency scalar control with slip frequency regulation is being widely suggested [6, 5]. Constant V/F method is commonly used for constant and variable speed control of induction motor [3]. In this paper, closed

loop constant V/Hz control method is implemented for a three phase squirrel cage induction motor using PI controller. Simulation results are obtained using MATLAB/SIMULINK.

II.CONTROL STRATEGY

Fig.1 shows the block diagram of closed loop constant V/F control strategy which has four different parts: the V/F control, the stator resistance compensation at low frequencies and the slip frequency regulation. A strategic block diagram of close loop constant V/F control is shown in Fig.1. The actual speed of the motor ($\boldsymbol{\omega_r}$) is compared with its reference speed ($\boldsymbol{\omega_r^*}$) and the error is given as input to the PI controller and a limiter to obtain the slip frequency command ($\boldsymbol{\omega_{sl}^*}$). The slip speed command is added to the actual speed of the motor to obtain the synchronous speed, $\boldsymbol{\omega_s^*}$ for generating the frequency command. The frequency command then generates a voltage command. To compensate the stator resistance voltage drop, a boost voltage is added to the generated voltage command. Effect of boost voltage becomes negligible at higher frequencies. The parameters and specifications of induction motor used in the SIMULINK model are given in Table 1.

To determine the parameters of induction motor no load, blocked rotor and stator measurement tests are conducted and the calculated parameters are shown in Table1.
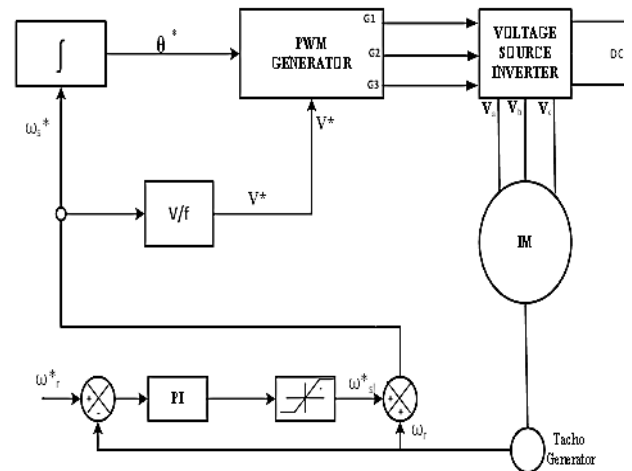

Fig.1 Strategic block diagram of closed loop constant V/F control

Table1. Parameters and Specifications

Parameter	Value
Voltage(line-line)	415V
frequency	50Hz
Number of poles (P)	4
Primary resistance (R_1)	2.698 Ω
Primary leakage reactance (X_1)	7.266 Ω
Magnetizing reactance(X_m)	138.23 Ω
Secondary resistance ($R_2^{'}$)	4.429 Ω
Secondary leakage reactance($X_2^{'}$)	7.266 Ω
RPM	1440
Power	7.5HP

III. SIMULATION RESULTS AND ANALYSIS

The simulation results for the following cases are presented and discussed:

Case A: Effect of change in reference speed under No Load
Case B: Compensation of resistance voltage drop at low frequency
Case C: Analysis of speed and torque at different frequencies
Case D: Performance under different load conditions

Case A: Effect of change in reference speed under No Load

To validate the control strategy at no load condition the reference speed is set to change in the SIMULINK model in step of 10% at every 3rd second of motor start due to this the frequency changes. The inverter output voltage also changes proportionally with respect to the motor supply frequency. Thus, the voltage to frequency ratio is maintained constant. Fig.2 shows that, due to change in supply frequency the motor speed varies similar to that of the variation in reference speed.
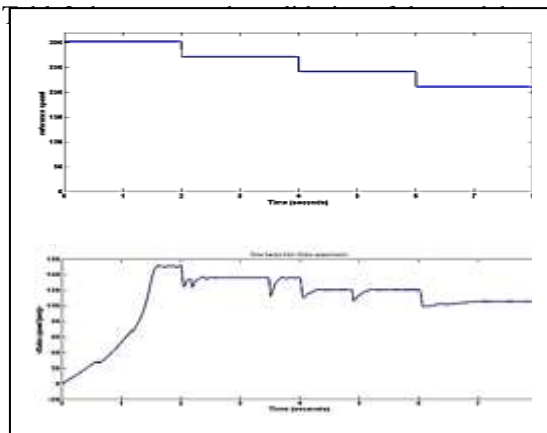

Fig.2: variation of actual speed with respect to change in reference speed due to change in frequency

Table2. Variation of inverter output phase voltage, rotor speed, frequency and V/F ratio

Ref. speed ω_r^*(rad/sec)	Actual speed ω_r (ω_m*2) (rad/sec)	Frequency (Hz)	Voltage (V)	V/F ratio
301.59	301.2	47.93	220	4.59
271.43	269.7	42.92	196.2	4.57
241.28	239.6	38.13	176.8	4.63
211.13	210.1	33.43	147	4.39

Case B: Compensation of resistance voltage drop at low frequency:

By adding the boost voltage, voltage drop due to resistance was compensated. When the drive is operating at 10Hz frequency the model is simulated for a 10 N load applied after two seconds of motor initiation. Torque and speed performance is analyzed with and without boost voltage. The torque and speed characteristics of the drive are shown the Fig.3.
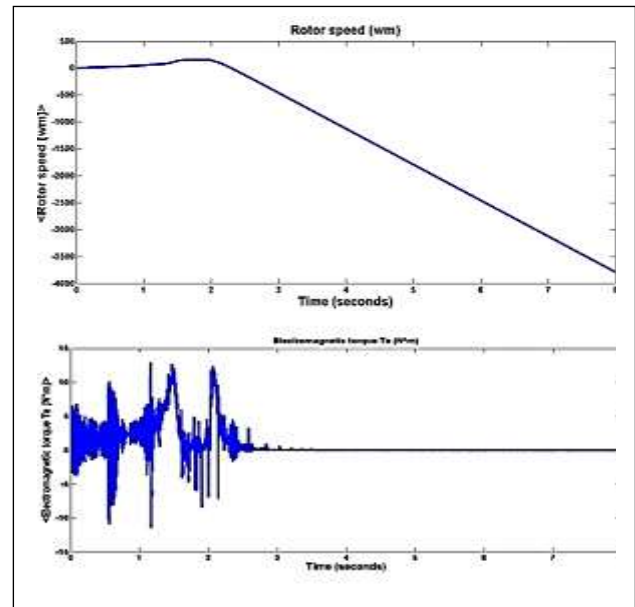

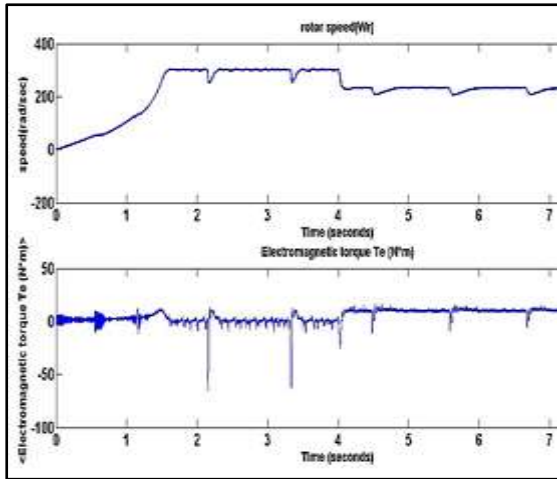Fig.3: Speed and torque response at 10Hz frequency without boost voltage.

Fig.4: Speed and torque response at 10Hz frequency without boost voltage.

The speed and torque response from Fig.3 and Fig.4shows that when a 10 N load is applied after two seconds of motor initiation and at 10Hz frequency the drive is unstable without boost voltage , whereas the system remains stable with boost voltage applied at 4th sec of motor initiation with a same load and frequency.

Case C: Analysis of speed and torque at different frequencies

In this case, the load on the motor is fixed at 10N load and the reference speed is decreased in steps of 10% accordingly the frequency and the synchronous speed changes. The torque and speed responses with respect to the change in frequency are shown in Fig.5. It is observed from the Table3 that the torque will not change at any frequency region as both the V/F ratio and slip frequency are constant. The variations in speed and torque response of the drive with respect to change in frequency are shown in Fig.5 and Table 3.
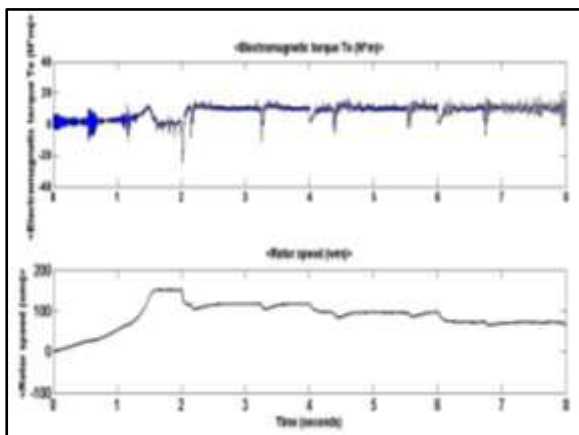

Fig.5: Speed (ω_m) and torque response with the variation in frequency.

Table3. Speed, torque, slip speed, voltage, frequency and V/F ratio at load 10 N

S. N O	Speed (ω_r) (rad/sec)	Phase Volta ge (V)	Freque ncy (Hz)	Slip speed (rad/s ec)	V/F ratio	Tor que (N)
1	215	226	47.7	85	4.73	9.8
2	192	184.5	43.76	83	4.21	9.6
3	144	172	35.49	79	4.84	9.9

Case D: Performance under different load conditions

This case presents the performance of the drive at different load conditions. From the Fig.6 and Fig.7, it is observed that, even though different loads are applied to the drive along with variations in the frequency the torque remains constant. The load is applied at 2nd sec of motor start and the reference speed is changed by 10% at every 3seconds interval.

This proves that the drive is capable of operating in different load conditions maintaining constant torque at different frequencies.
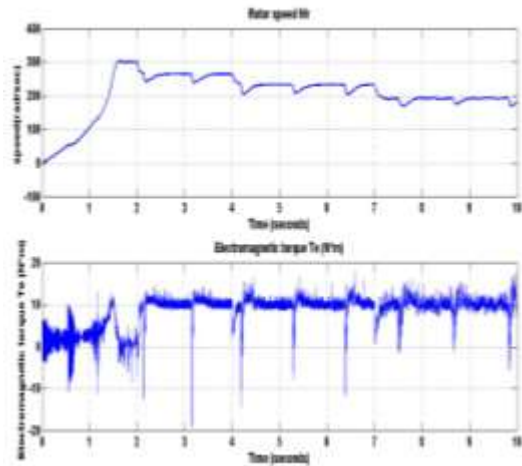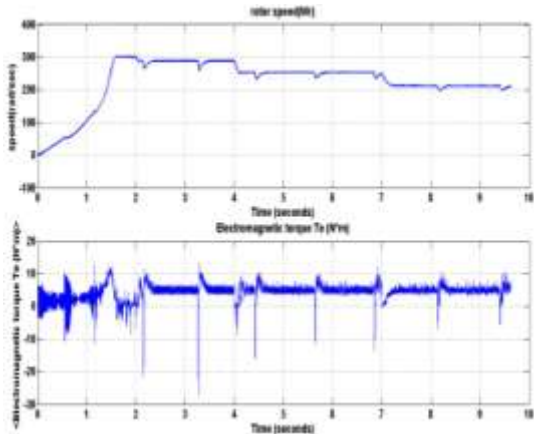

Fig.6: variation speed and torque at 10N-m load

Fig.7: Variation speed and torque at 5N-m load

IV. CONCLUSION

The open loop V/F control method has the disadvantage of small output torque at low frequency and poor speed precision at different loads. To overcome the disadvantages of open loop control, closed loop constant V/F control is designed and implemented in this paper. The incorporation of boost voltage improves the system stability even at lower frequencies. By keeping both the slip frequency regulation and V/f ratio constant the torque remains constant under different frequency conditions. Also the system performance is analyzed at different load conditions.

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