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DESIGN AND DEVELOPMENT OF 3PHASE INDUCTION MOTOR CONTROL USING V/f METHOD

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Abstract: Induction machines (IM) are mostly used in domestic and industrial applications due to their ruggedness and high reliability. However, controlling its speed is not much easier as compared to its DC counterpart. One of the simpler methods of exercising speed control is through V/f control which is a scalar technique. In such control, Sinusoidal Pulse Width Modulation (SPWM) is used for controlling the V/f ratio constant to a larger extent giving a smooth variation of induction machine's speed. However, at low speeds, the V/f ratio is not maintained constant rather increased to compensate for the stator voltage drop. Many methods are used by various researchers to compensate for the stator voltage drop at low speed. In this design paper, a modified controller is used for such stator voltage drop compensation. The performance of both speed and torque is controlled and enhanced by the modified PI controller using the V/f scalar control. Using this modified PI controller, we could control the frequency of the voltage source inverter (VSI) to maintain the V/f ratio as constant in most of the speed-torque characteristics of the induction machine. The modifications incorporated in the PI controller affect the speed control in such a way that the harmonic characteristic is made better at low-speed operation also offering excellent performance. The performance analysis of the induction motor speed control by SPWM inverter is analyzed by MATLAB/Simulink platform to validate their performance characteristic

KEYWORD: Scalar control, Voltage Source Inverter, V/f control, SPWM technique, Induction machine.

I. INTRODUCTION

The induction motor speed control by a constant volt per hertz mode has been known for many decades with the discovery of solid-state inverter. The constant V/f control becomes more popular and the great majority of variable speed drives are in operation nowadays

A voltage source inverter (VSI) must have a stiff voltage source at the input and ideally, its Thevenin's impedance should be zero. Thus, a large capacitor is connected at the input terminals of the voltage source inverter if the feeding voltage source is not stiff. VSI consists of power bridge devices with three output legs, each consisting of two controllable power switches and two freewheeling diodes that are connected anti-parallel to the power switches. The inverter is supplied from a DC voltage source via LC or C filter.

VSI can be operated as a stepped wave inverter as well as Sinusoidal Pulse Width Modulated (PWM) inverter. When operated as stepped wave inverter, transistors are switched in the sequence with a time difference of T/6 seconds, and each transistor is kept on for a duration T/2 seconds, where T is the time of cycle in seconds.

The actual speed of the Induction motor is sensed and fed into a computation unit to compare it with a reference speed. The obtained error is processed in a proportional-integral (PI) controller and its output sets the frequency of the inverter as well as its modulation index.

It was observed that a closed-loop scheme with a proportional-integral (PI) controller gave a superior way of controlling the speed of an induction motor while maintaining constant maximum torque.

There are two methods in a broad sense for controlling the speed of the induction machine. They are

1. Scalar or Average Torque Control method

2. Vector or Instantaneous Torque Control method

The scalar method is a simple and cost-effective control technique which is employed in places where accurate speed or torque control is not preferred. Because of these advantages many industrial applications employ this technique where speed or torque control satisfy the requirements at a steady state.

Pabihra Kumar behara et.al, 2014 proposed a design and implementation of scalar control for induction motor. This method makes an idea about adjusting the speed of the motor by control the frequency and amplitude of the stator voltage of the induction motor. They also gave a comparative study of open-loop and closed-loop V/F control induction motor.

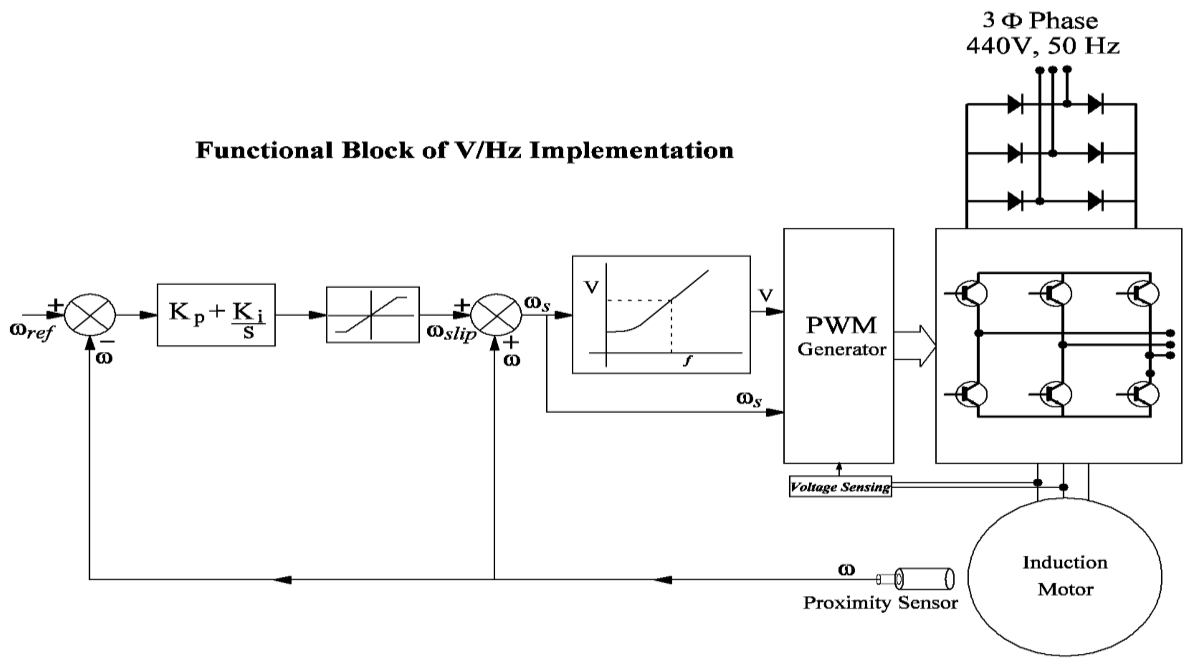
Jay R. Patel, S.R. Vyas 2014 presented a variable voltage variable frequency (VVVF) based torque speed control of 3phase induction motor fed by PWM VSI.

Controlling is an important action to any system in which output quantity is controlled by varying the quantity which controls the plant with or without feedback.

II. LAYOUT OF IMPLEMENTATION

The block diagrammatic layout to design and implement the V/f method of speed control is shown below. The DC power input to the 3-phase inverter is derived from a conventional 3 phase 50 Hz power supply by rectifying with the help of a 3-phase uncontrolled rectifier. To provide a feedback to the control system an inductive proximity sensor is used to sense the speed of the induction machine. Another feedback signal is a voltage signal, derived from the output terminals of the 3-phase inverter. The circuit meant for deriving the induction machine terminal voltage is a buffered voltage attenuator configured around an operational amplifier.

The entire control algorithm implementing the V/f technique is deployed with the help of a Digital Signal Controller (DSC). The DSC used in the implementation is dsPIC33FJ32MC202, which is a 16-bit controller having digital processing capability. The controller's PLL is configured to make it to work at its maximum 40 MIPS operation.



III. POWER INVERTER DESIGN

The power circuit of the drive consist of a 3-phase bridge inverter. The inverter is configured using 6 IGBTs whose part number is FGA25N120ANTD. The IGBT used has a rating of 25A with a nominal voltage rating of 1200V. The output of the inverter is fed to a LC filter to reduce the harmonic contents of the inverter output. The value of L is 3mH and that of the Capacitor is 1 micro Farad. The switching control of IGBTs is designed by the software such that no two IGBTs in the same leg should never conduct to prevent shoot through. This strategy is implemented by invoking a dead time between the ON and OFF instances of the IGBTs of the same leg. The dead time invoked is 4 micro seconds. The dead time is configured in the dsPIC33F controller by setting the Dead Time Control Register. The actual configuration used in the Dead Time Control Register is such that the Pre-scaler is set to 2 and the Dead Time Counter value is set as 160.

To protect the IGBTs from the switching surge voltages produced on account of the stray inductance of the main Power circuit during abrupt current changed at switching instances a RC snubber circuit is designed and connected across each IGBT in the power inverter.

The snubber capacitor is designed using the relation as given in the equation.

$$C_s = \frac{L_s I_c^2}{\left(V_{c\max} - V_{DC}\right)^2} \quad (1)$$

Where L_s is the stray inductance of the main power circuit.

I_c is the collector current at turn off time.

$V_{c\max}$ is the maximum capacitor voltage.

V_{DC} is the DC link voltage.

The value of the capacitor designed is 0.01 micro farad, as the stray inductance measured on an average is 100 nano Henry.

and the snubber resistoris designed using the relation as given in the equation. .

$$R_s \le \frac{1}{6C_s f_s} \quad (2)$$

Where

C_s is the snubber capacitor. f_s is the switching frequency.

As the switching frequency used in the implementation is 10kHz, the value of the resistor designed is 1.5k ohms.

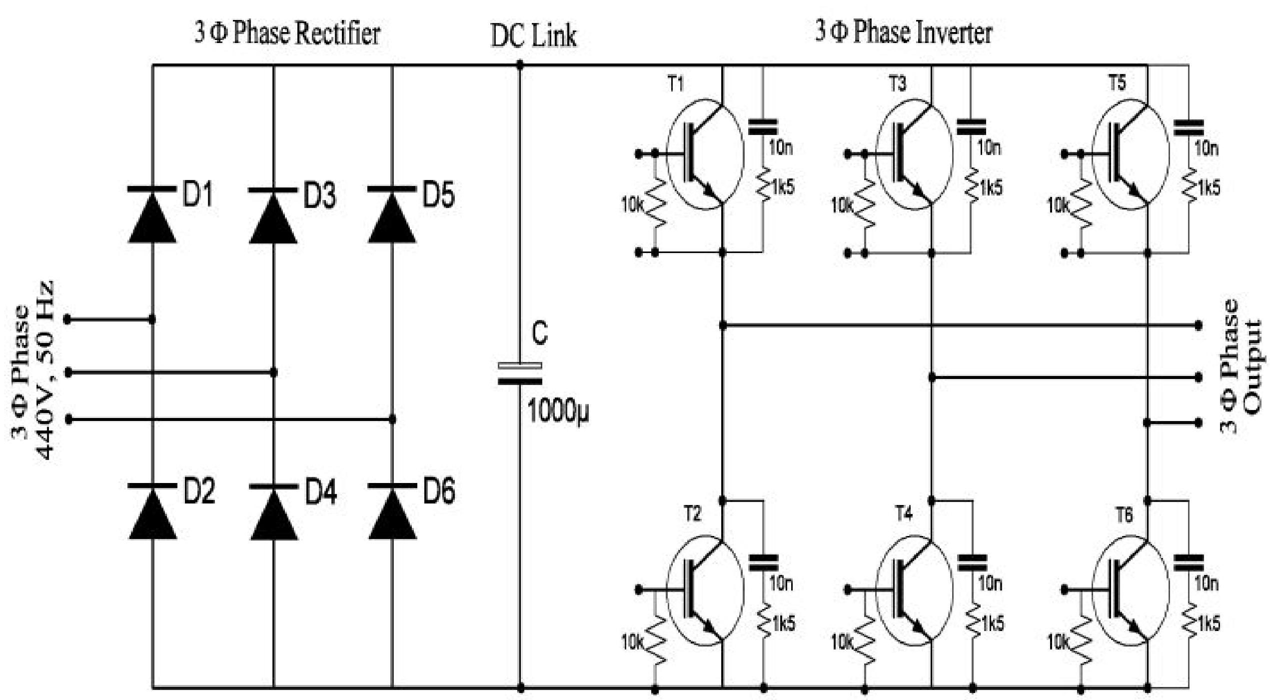


Figure 1.Power Inverter

IV. SCALAR CONTROL USING SLIP COMPENSATION

The speed at the induction machine is running is measured at the current instance and compared with the reference speed at which the induction machine is intended to run. The resulting difference or error is fed to an PI controller. The output of the PI controller, which is the correction required to be carried out, is given as input for a saturator. The intention of the saturator is, to limit the correction required to limit the raise in the induction machine's current. The correction required in the speed, from the

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saturator is further added with the actual running speed to obtain the synchronous speed. The frequency corresponding to the computed synchronous speed is fed to the PWM generator. Also, the voltage corresponding to the computed frequency is obtained from the V/f profiler and fed to the PWM generator to calculate the modulation index.

With the computed modulation index and the frequency, the PWM generator produces required trigger signals which will then be fed to the IGBT drivers to drive the inverter to accelerate/ decelerate the machine. This closed loop action is continuously carried out until the speed reaches the reference speed. The current information provided by the current sensor is monitored to detect any malfunction in the inverter.

V. COMPUTER SIMULATION

The V/f Scalar control described in the previous section is simulated with the help of a computer simulation software for Power Electronics and Drives. The software used to verify the performance of the V/f control technique is PSIM. The functional block configuration used to simulate the said technique is shown in the figure 4.

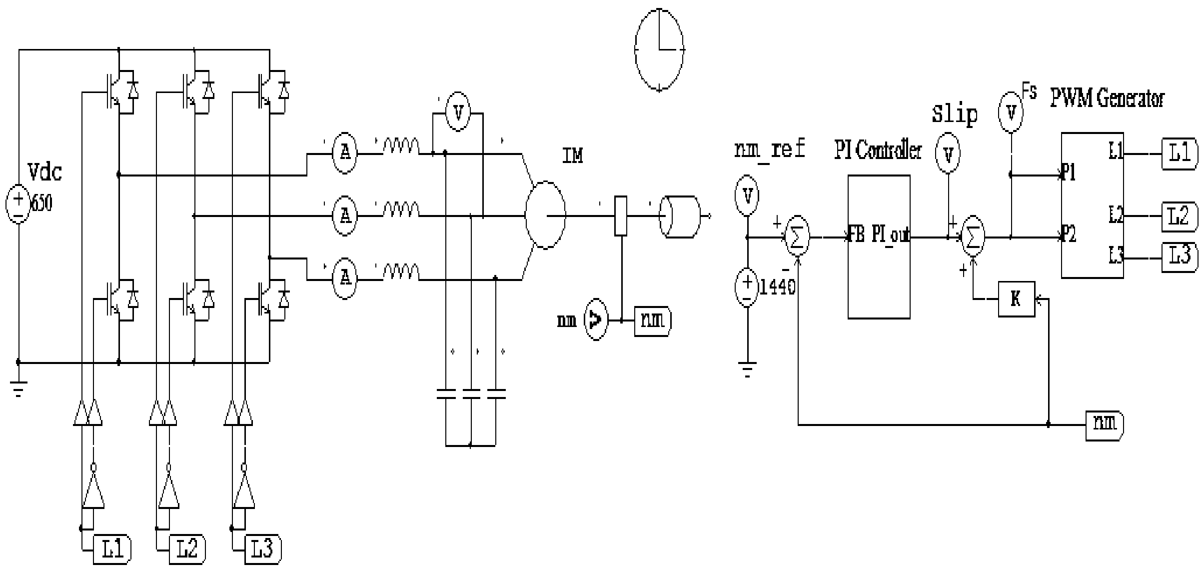

Figure 4.Functional Block implementation for Simulation in PSIM

The configuration meant for verification through computer simulation used a power inverter followed by a filter and an induction machine. The DC power is supplied by a DC power source of 650V. Following the laid-out algorithm, the PWM generator produced appropriate trigger signals which trigger the IGBTs of the Power Inverter.

VI. SIMULATION RESULTS

In the computer simulation, different reference speeds were given to check the performance of the V/f method of speed control. It was found out that for all reference speeds the output performance of the control technique was promising. The performance of one such speed reference of 1000 RPM is shown in the figure 5.

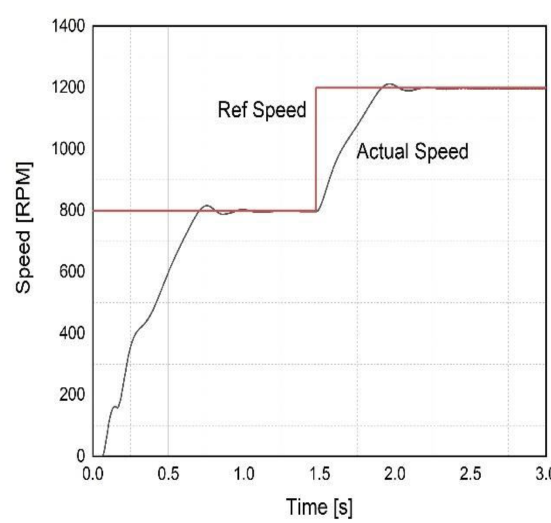

Figure 5.Step response from Standstill

From the illustration shown in figure, it is clear that the induction machine reached the reference speed in 1.5 seconds, which is a good performance.

Also, it is obvious from the performance shown in figure 6 that when a step change in the reference speed is given from 800 RPM to 1200 RPM, the V/f control technique excellently invokes its algorithm to bring steady state operation within almost 1 second.

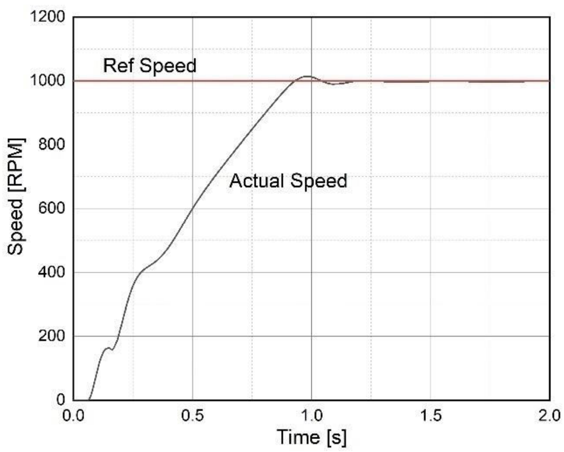

Figure 6.Step response under running condition

VII. EXPERIMENTAL WORK

An experiment was carried out with the circuits shown in the earlier sections. An induction motor of rating 2HP, 400V, 50 Hz was used. The motor experiences smooth acceleration without any humming noise, which was due to the algorithm written for the dsPIC33FJ32MC202 and presence of the LC filter at the output. The performance of the experimental work in conjunction with the simulated graphs shown are presented in Table 1.

Table 1

Reference Speed	Actual Speed	Time Taken
1000	1010	6 Seconds (From Standstill)
800-1200	1225	4 seconds

VIII. CONCLUSION

In this paper, a detailed design and implementation of V/f speed control technique for induction motor is presented. The algorithm to implement the V/f technique is laid out carefully and simulated with the help of PSIM software. Subsequently, for carrying out experimentation, necessary power and control circuits are carefully designed. The results obtained through experiments are closely matching with the simulated results obtained. This clearly shows that the V/f technique of speed control is effective and efficient.

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