FPGA Based PWM Control of Induction Motor Drive

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Abstract- With the invention of rotating machine, the motors are used in the industrial applications for the variety of tasks. The speed control is key issue in the control industry. The speed control can be done in various ways and for this purpose microprocessor, PC, microcontroller and PLA are used. Some places speed control and parameter change is necessary and in such cases the monitoring the various parameters is very essential. The simulation technique provides the better control implementation of the monitoring. For the automatic operation of the drive the FPGA is better choice with least cost. The FPGA provides better control characteristics with smaller space with proper design considerations. For control strategy the present research work highlight on the PWM scheme with FPGA. The expectation of the control is faster and accurate with least cost. The design of such expected control is possible through Controller, PLC, PLD, FPGA, etc. In the present research article the digital signals are generated by using the FPGA. The FPGA signals have the control on the pulse width which is used for firing of the inverter. The inverter supplies the power to the drive as per the variation of the PWM. Single phase induction motor control using the simple PWM technique is possible. The complete data acquisition system is presented for control of the drive speed. The efficiency of the drive is also calculated and represented.

Keywords: Speed control scheme, Induction drive, Inverter drive, and FPGA control, Data Acquisition System.

I. INTRODUCTION

As the induction motors are prominently used for industrial applications, the growth in electrical drives have played prominent role in the development of industrial revolution [1]. To speedup the operation most of the industries used DC or AC drives. DC drives were initially used for the industrial applications but not suitable for high voltage and heavy duty applications. Therefore, AC drives with new advance techniques provided better solution in the latter half of the 20th century. The AC drives have ability to work in any adverse conditions and control technique is also easier. The control strategy is easily adaptable with AC feeder supply for various processes under operation. The control of the induction motor is possible with the advance digital techniques and digital devices. The induction motor control strategies changed the face of the control mechanism [2, 3]. The drive technology has changed with course of time since the industrial revolution took place in the Europe and America. Lot of control strategies were used and some of them remained prominent and some have changed with new adoptions. The electronic control specially digital techniques brought the revolution in the control strategy. The small, compact and micro-level development in the drives made it easier to implement as well as control easier. These days high performance control strategies are developed using the PC, Microprocessor, Microcontroller and PLC, which boosted the control technique [4-6]. The control of drive is still made easier by the use of software in the control technique. The proper design and implementation of the hardware is possible with simulation technique. This will reduce the trial and error method of hardware construction. Now a days the software and digital control plays important role by sharing 60 to 70% in control of AC drives. The present investigation represents the FPGA based single phase speed control with PWM strategy. The control scheme is implemented both in open and closed loop configuration. However, the open loop systems do not provide the feedback so no correction action is taken for violation of any parameter. So the closed loop control is used in the present investigation in which the performance parameters are recorded and corrective action is also possible using the software in the system. The various parameters such as voltage, current speed are measured and represented in graphical manner.

II. SYSTEM DESIGN

For any industrial applications the speed control technique is important part. The various control strategies are employed depending on the type of the process used. The different control strategies are also developed by various research personalities. The development in semiconductor technology and electronics control drives made the system more flexible for the control. The initial trend of growth of control technique was low but the present rate is very high due to the development of semiconductor devices and the software simulation implementation in the control strategy. The feedback systems are prominently used now days because they have ability to detect the errors in the parameters sensed and have ability to take the corrective action. The accuracy in the control is one of the major part which is easily possible through software along with the required hardware. Such feedback controls the systems are designed using digital devices such as Microprocessor, microcontroller, PLA, PC, PLC, FPGA or the digital circuits. In the present situation the FPGA will generate the PWM pulses whose width can be varied using the software.

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The required PWM firing pulses are generated by the FPGA to control the gain of the inverter. As the pulses generated by FPGA are not quite sufficient to drive the IGBT of inverter. So buffer and amplifier is used. The isolation is required to separate power circuit from the control circuit. The width of the firing pulse generated is controlled by the FPGA which controls the speed of the induction motor. The system consists of various blocks such as FPGA, microcontroller, single phase rectifier, voltage inverter, Buffer and driver, signal conditioning, etc. shown in Fig. 1.

Inverter module

For control of the induction motor PWM inverter is used for the conversion of DC power to AC. It is a bridge of four IGBTs which are fired by the PWM signal generated by the FPGA. The firing PWM signal is passed through the firing control circuit which controls the firing of the IGBT. In the firing control the width of the pulse is controlled using the software. Two signals generated by FPGA are used sequentially for firing of inverter source. While switching high currents or transient currents are generated which are bypassed using the capacitor bank. This firing inverter circuit provides the power to the drive. The main control unit i.e. FPGA along with microcontroller helps to control the power of the drive and hence the speed of the drive. Depending on the pulse width of the firing pulse firing of the inverter takes place and proportional power is supplied to the drive. The following diagram shows the implementation of IGBT based inverter control module.

Fig. 2 IGBT Based Inverter Control

The power supplied to the IGBT inverter is from the power rectifier KBP 2510. This is a built in rectifier directly used for conversion of 230V AC to DC voltage. The high voltage capacitor banks are connected across the inverter which helps in rectifying and provides the bypass path to the AC. The transients generated easily make ground by these capacitors.

Snubber module

While construction the various devices there is always weak construction features in the design. This may lead to damage of the device due to the over heating. In the inverter firing the rapid pulses are provides which may generate the surge pulse. To avoid the surge, capacitor and transistor circuit is used. The inductance coils is also parallel with this combination. The module is active during the turn off of the firing device. The snubber circuit is used in series with the load to avoid the damage of the load due to reapplication of the input pulses.

Buffer and driver module

The FPGA generated PWM signal is not enough to drive the IGBT so it is essential to increase the strength of the signal in terms of current. To do so the butter circuit is used. In the buffer the gain remains the same but the required current strength is boosted and will help to turn ON and OFF of the circuits at the desired rate. The opto-isolator will isolate the power circuit from the control circuit. This is used for safeguard against any damage if short circuit. The control circuit will be safeguarded using the isolator.

Buffer  Isolator & amplifier  → drive

III. POWER CIRCUIT DESIGN

The inverter is designed for one Hp single phase motor. For which the maximum voltage across the diode bridge is 230 + 10% = 253 V.

The maximum dc output of the bridge is

\[ 253 \times 1.44 = 357 \text{ V dc.} \]

Thus the minimum device voltage rating must be 700 V as the diodes are connected in bridge.

The selection of the diode in the power circuit is done whose withstanding line voltage is 10% more than the actual. The diode must withstand the reverse voltage so the voltage withstand capability of the diode selected should have
around 700V. The capacitor for such combination is 700 μF with 440 V is selected. The IGBT is also selected that it will withstand the above voltage rating.

IV. SIGNAL SENSING AND PARAMETER ESTIMATION

i. Voltage Sensing

The peak detector circuit is used for AC voltage sensing. The sensed voltage is in the range of 0-5V, for the variation of 0-230V. After sensing the scaling is essential to get the desired result. The Fig. 4(a) shows the variation of input voltage and sensed voltage. It is observed that the input voltage and the sensed voltage do not vary in linear way at the initial period, so the correction factor is necessary. The correction factor is applied through the software and the corrected voltage is shown in the Fig. 4(b). The graph shows the linear variation of the sensed voltage and corrected voltage.

![Fig. 4(a) Input voltage versus sensed voltage](image)

![Fig. 4(b) Sensed voltages versus corrected voltage](image)

ii. Current Sensing

For current measurement a shunt wire having 1 ohm resistance is used in series with the load. The current flowing through the shunt wire is proportional to the voltage developed across the shunt. It is passed through the transformer and signal conditioning circuit for the recording of the current. It is a simple and cost effective technique and easy to implement. The sensed current is found well within the acceptable range and no correction is required.

iii. Speed Sensing

For sensing the speed, a circular disk is used which is connected to the shaft of the motor. A hole is drilled across the periphery of the disk. Opto-interruptor device is used having source of light and the detector at other end. The disk rotates between the light source and detector and one pulse per revolution is generated. The number of pulses generated is counted over a specific time interval and the speed is represented in terms of RPM. The Fig. 5(a) shows the input speed versus sensed speed.

![Fig. 5(a) Plot of input speed and measured voltage](image)

![Fig. 5(b) Plot of Tachometer speed and Corrected speed](image)

The input speed shown by tachometer and the experimental measured speed shows some non-linear variation at the initial stage. Using the correction factor the variation of the corrected sensed speed is shown in the Fig. 5(b). The variation is now linear in nature. All the above sensing techniques uses hardware and software and calibration is used wherever required. The calibration of the system gives the correct data of the parameter which is required in the system for further processing or for the process.
V. RESULTS AND CONCLUSION

The speed efficiency characteristics are shown in Fig. 6 for single, three, five, seven and nine pulses per half cycle. It is observed that the variation is linear up to the speed 1050 RPM and then efficiency decreases. It is also observed that the speed increases the efficiency also increases till the 1050 RPM. The efficiency of nine PWM is less than the seven PWM scheme indicates that the switching losses increase. The best firing scheme is seven pulses per half cycle should be implemented for better results and efficiency of the machine.

The PWM technique used for precise speed control of the drive. The firing of the inverter is done by PWM pulses generated by the FPGA. The variation of the pulse width of the generated by FPGA varies the speed i.e. increase in pulse width will provide more power to the drive as IGBT will fire for longer time and speed is more. While decrease in pulse width, speed is less. The width of the firing pulse controls the power and hence the speed of the drive. The results indicated are well within the acceptable range. The deviation the results are due to the losses in the machine and switching of the inverter. The developed drive is suitable for the industrial application.

REFERENCES