

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

FPGA Based Controlled Inverter Motor Drive

S. K. Rathod¹, S. R. Kumbhar², M. D. Uplane³, P. K. Gaikwad⁴

Ph. D. Research Student, Dept. of Electronics, Shivaji University, Kolhapur, Maharashtra, India¹

Assistant Professor, Dept. of Electronics, Willingdon College, Sangli, Maharashtra, India. Correspondence Author²

Professor & Head, Dept. of Instrumentation, Savitribai Phule Pune, University, Pune, Maharashtra, India³

Associate Professor, Dept. of Electronics, Shivaji University, Kolhapur, Maharashtra, India⁴

ABSTRACT: The industrial revolution changed the face of the world. Since the industrial revolution, more and more machine oriented work was carried out to increase the production with higher efficiency. So the machines were used for the same purpose and the evolution of machine were tremendously changed the working capacity of the process. The rotating machine played important role in the industrial process s. Initially the DC motors were used for the industrial processes due to its limitations and the power consumptions almost all the power oriented applications were replaced by AC drives and now play the dominant role in every part of the control application. Various control strategies were developed, however, the resistance, microprocessor, Microcontroller, PLC based control strategies are used. But to control the process by FPGA is advantageous and for the same the present investigation system is implemented. In the this investigation the FPGA based drive is designed. The firing module is developed using the driver circuit. The drive has amplifier, which is used to drive the inverter module. The isolation is also provided in the driver to separate the control circuit from the power circuit. The three phase inverter is designed using the MOSFET and for the firing of the inverter the FPGA is used. The use of software and the hardware reduces the complexity and helps to implement the control process in better manner. Further the designed drive is tested and its efficiency is calculated under experimental process.

KEYWORDS: FPGA control scheme, 3-phase Induction motor drive, Inverter driver

I. INTRODUCTION

The early development of the AC and DC Electric drives taken place due to the industrial revolution. The AC drives developed much more and dominated the industrial applications in the present scenario. These AC drives developed with single, multi and coupled forms. The working power drives is generally based on the switching of power semiconductor devices. The switching of such devices are tremendously improved with advanced technology and used in the process control. The drives are used in variety of applications and no boundaries are defined in present trends in the electronics. There was unpredictable growth in the power drives during the last 10 years. Now a days smaller, lighter, high performance, control and estimation technologies of induction motor drives are very fascinating and challenging which has due importance.

The development of modular PC based induction motor and its parameter estimation was carried by Uplane and et.al. [1]. This PC based drive found better over operational characteristics than conventional one. The fault detection method also helped the process to operate drive without fail. The redundancy in the drive has gained importance such drives started developing. To have the better control over the process the microcontroller and the PLC based drive has designed and developed [2] and operated in the industrial applications. The three phase induction motor drive developed by Uplane and et.al [3] with PWM techniques and its performance showed better over the previously developed drives. The drives started developing in the complex manner and the implementation of the FPGA based variable frequency drive for three phase boosted the research using the Xilinx software and was performed by R. Thejaswini and R. Sindhuja [4]. The firing signal of different frequency and amplitude is used for firing of the IGBT inverter. This also stated the dead time between the two firing control signals.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Further space vector pulse width modulation (SVPWM) based system has been developed using digital signal processing and FPGA technique by B. Hariram and N. S. Marimuthu [5]. A flexible, high computation and cost effective FPGA based speed control emerged and contributed by C.P. Ooi and et.al. [6]. The FPGA is used for direct torque control of induction motor with the help of MATLAB and Simulink [7]. This reduces the hardware part of the drive and helps to design the simpler drive. Further the performance of the drive is tested under simulink. The Xilinx gave high performance for vector control of the induction motor [8,14-17].

Still to control and monitoring the various parameters online, the use of FPGA plays important role and industrial process requires complex processes to handle, so the FPGA and MOSFET based inverter design is necessary. The present article highlights the design and development of FPGA based induction motor drive with its performance. In the present investigation the various components are done using the optimum result calculations.

II SYSTEM DESIGN

The various speed control techniques are used in industrial applications and day to day life processes developed by different persons. The development of electronic system and software made the control of process very easy. The feedback systems are employed to avoid and detect the errors and to take the corrective action. The accuracy of the system is one of the major issues and for this the design of the compact and good performance of drive is necessary. The design is made possible using the simulation and the required drive is setup and tested for the required condition. Following figure No. 1 gives the basic idea of the drives.

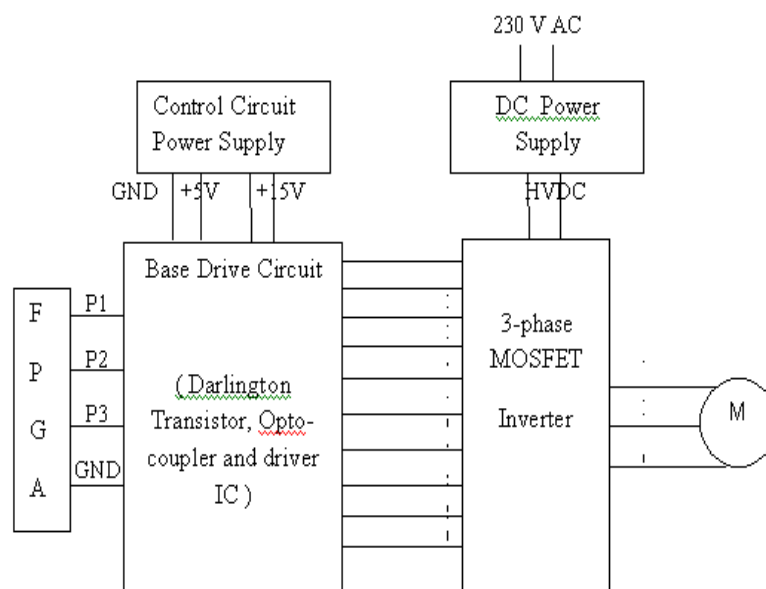


Fig.1 Block diagram of FPGA based system design

The FPGA generates the PWM pulses and the Gate driver IC containing the opto-coupler and driver drives the three phase MOSFET inverter. The inverter provides the proper power to the motor. The control signals from the FPGA Control the firing of MOSFET.

III. GATE DRIVE CIRCUIT

Darlington transistor and opto-coupler

Fig.1 consists of block diagram of FPGA based Induction motor drive system. The base drive circuit consists of three Darlington transistors, opto coupler and driver IC as shown in Fig. 2, which is the block diagram of base drive

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

circuit. The 50 Hz square wave signal was generated from FPGA device. This square was applied to the base of the transistor TIP 122, which is base driver as shown in Fig. 3, details of gate drive circuit. The Darlington transistor is used as medium power linear switching device application [9].

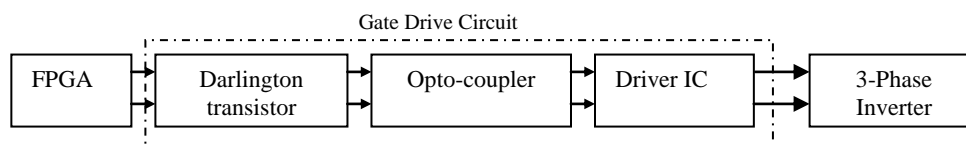


Fig. 2 Block diagram of Gate Drive Circuit

The Darlington transistor will drive the opto-coupler MCT2E. The opto-coupler consists of infrared LED and phototransistor. It provides up to 300 forward direct-current ratio and high voltage electrical isolation typically ± 3.55 kV. It has high switching speed of the order of 5 μ s [10]. The main function of the isolator or opto-coupler is to isolate the control circuit from the power circuit.

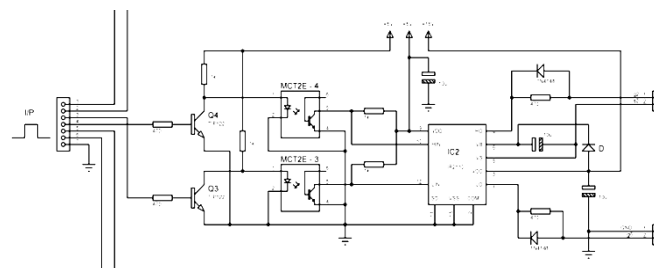


Fig. 3 One Leg of Gate Drive circuit

Driver IC

Fig.3 shows details of gate drive circuit, the driver IC(IR 2110) is high voltage, high speed Power MOSFET and IGBT driver with independent high (HO) and low (LO) side referenced output channels. The driver IC has a feature of high pulse current buffer stage designed for proper conduction. The propagation delays are matched to simplify use in high frequency applications [11]. Input to the base drive circuit is about 3-4 volts and the corresponding output voltage ranges from 12 to 14V, with outputs in phase with input signal.

The floating channel can be used to drive the N-channel Power MOSFET in the high side (HO) configuration which operates upto +500V typically. Floating stage/voltage means before firing of MOSFET, gate voltage (HO) is high and source voltage (Vs) of MOSFET is low but after firing (ON) of MOSFET the status of HO and Vs changes that is near about equal voltages.

IV. HIGH VOLTAGE DC POWER SUPPLY

Fig. 4 shows the high voltage DC power supply. For Power circuits the high DC voltage with high currents provided by the DC power supply; which includes the rectifier KBPC 3510. It is a 35 amperes silicon bridge rectifier with voltage rating up to 1000V. It has electrically isolated metal case for maximum heat dissipation, so its efficiency increases [12]. In this power supply capacitor bank is used, so it provides high DC voltage for the inverter circuit.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

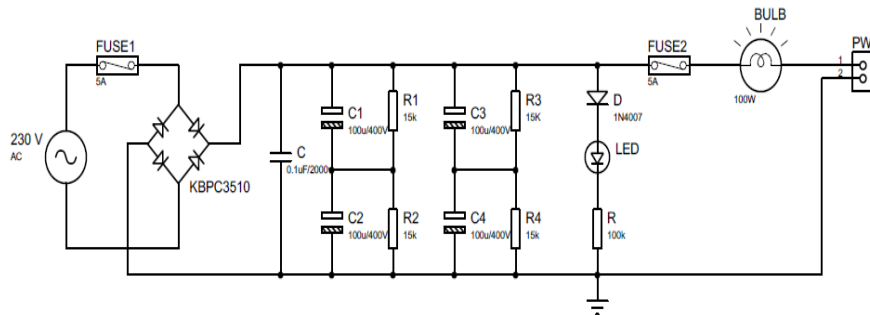


Fig. 4 DC power supply circuit

The RC network as shown in Fig. 4 help to discharge the capacitor C when AC mains is removed. The RC network consists of resistors R_1 , R_2 , R_3 and R_4 as well as the capacitors C_1 through C_4 .

V. THREE PHASE INVERTER

Fig.5 shows the three-phase MOSFET inverter circuit whose one portion is shown. The 3 Phase inverter consists of six, N-channel Power MOSFETs. The IRFP 460 MOSFET has the features of dynamic dv/dt rating and fast switching typically 200ns. It also provides greater creep age (Current leakage) distances between pins to meet the requirements of most safety specifications [13]. The single square wave of 50Hz frequency was generated from FPGA was applied to the input side of the abase drive circuit. Near about 12-14V magnitude square wave is obtained at the output of the driver. The high side output voltage (HO) of first driver IC (IR2110) was connected to the gate of Power MOSFET M1 (Q1) and low side output voltage (LO) terminal to the gate of Power MOSFET M5 (Q5) as shown in Fig.5 Because of this, firing of MOSFETs M1 and M5 was possible. When high DC voltage of 250V was applied to the 3-phase inverter circuit, the AC voltage across the output of Inverter was obtained. The output of inverter circuit was denoted as A,B and C lines. In this case the output AC voltage across AB terminals is obtained, which has the same frequency of the input signal that is 50 Hz. This output a. c. voltage glows the bulb across the terminal A and B. If the bulb is removed and single phase AC motor was connected, it runs.

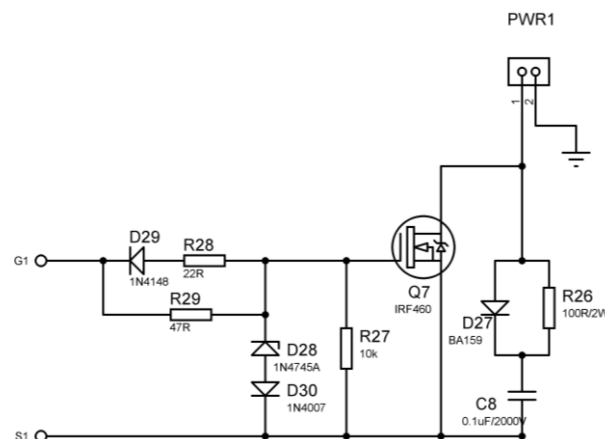


Fig. 5 a MOSFET Inverter Leg

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

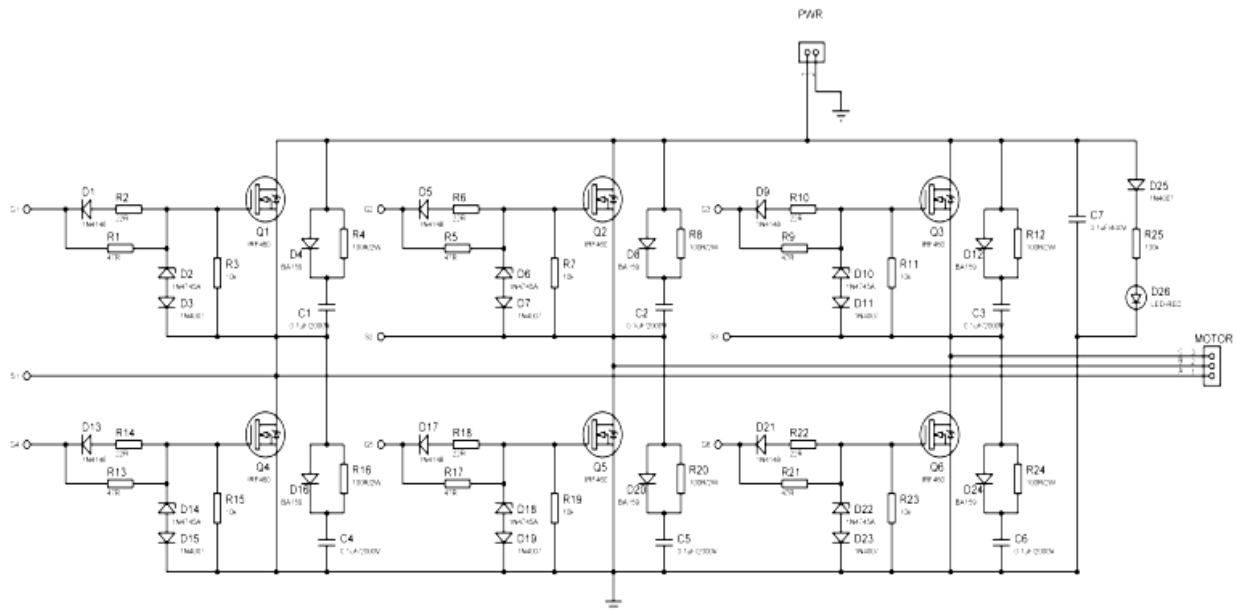


Fig. 5 MOSFET Inverter circuit

Similarly when input square wave from FPGA was given to the second driver IC (IR2110), then the output a.c. voltage across BC terminals of the inverter was obtained. The bulb or single phase AC motor also runs. Similarly with the help third driver IC, the output voltage between C and A terminals was obtained. The three phase induction motor was connected to output terminals of inverter A, B and C. When the three- square of 120 degree phase shift were applied to the input of base drive circuit, then AC voltage was obtained across the A, B and C terminals and the 3 phase induction motor would run. This is shown in the Fig. 5 in which six MOSFET inverter assembly blocks are used.

VI. SYSTEM PERFORMANCE

The designed system is tested with the simulated results and its performance is studied. While testing it was observed that the initial efficiency is less as compared to the simulated results. The system calibration is performed for the various parameters and then correction factor is introduced for each parameter to get the correct reading the fig. 6 shows the corrected results of the system. It is observed that as speed increases the efficiency also increases till it reaches the 1100 rpm and it attains the maximum value then it starts decreasing. This decrease in trend is due to the internal machine losses or heating.

Table 1. Speed efficiency data

Speed	100	200	300	400	500	600	700
Efficiency	37	40	44.3	48	52	55	58.5
Speed	800	900	1000	1050	1100	1200	1300
Efficiency	62.3	66.3	70	71	70.9	67	67

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

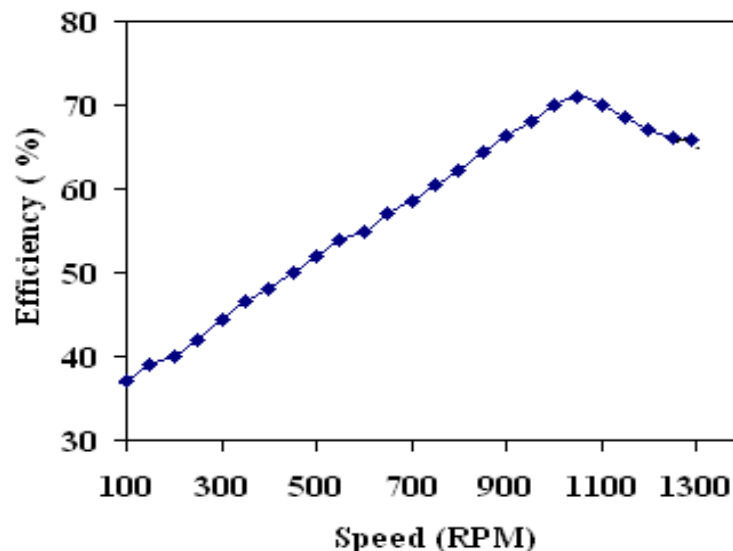


Fig. 6 Speed Efficiency characteristics

VII. CONCLUSION

The FPGA based drive design for three phase induction motor and its implementation is the basic aim of the present investigation. The required signal strength for firing of the inverter is achieved by gate driver circuit. The Isolation is also provided to isolate the power circuit from the control circuit. The MOSFET based three phase inverter design helped to achieve the required power to the motor. The three phase signal is achieved through MOSFET inverter which is fired by three signals generated by FPGA with less than 120° to generate the power to the motor. The firing pulse decides the power fed to the motor and hence the speed. The speed is controlled by varying the pulse width of the firing signal through FPGA. The compact designed drive results are tested with the simulated drive and it is observed that the experimental results are comparable to the simulated result. Hence the designed drive can be implemented for the industrial process for speed control application. Its performance characteristics are also well within the comparable range.

REFERENCES

- [1] M. D. Uplane, S. R. Kumbhar, M. S. Gaikwad, and M. S. Chavan, "Data acquisition system for simulation and online parameter estimation of induction motor using computer", Journal of IETE, New Delhi, Vol.41, pp. 23-28, 2000.
- [2] S. K. Rathod, and S. R. Kumbhar, Design and development of remote controlled switching system for single phase induction motor drive using PLC, Minor research project. Submitted to UGC., pp 50-51, 2013
- [3] S. R. Kumbhar, A. P. Ghatule, and M. D. Uplane, "Design of single phase induction motor drive and its fault detection using personal computer", International journal of research in computer Science and information technology, ISSN: 2319-5010, Vol. 1, Issue 1, pp 33-37, 2012.
- [4] R. Thejaswini and R. Sindhuja, and A. P. Yoganandini, "Voltage/ frequency control of induction motor using FPGA", International Journal of Emerging Engineering Research and Technology, Vol. 2, Issue 2, pp. 101-106, May 2014.
- [5] B. Hariram and N. S. Marimuthu, "Evolution of FPGA based speed control of induction motor", Journal of electrical Engineering, pp-1-6.
- [6] C. P. Ooi, W. P. Hew, N. A. Rahim and L. C. Kuan, "FPGA based field oriented control for induction motor speed drive", IEICE Electronics Express, Vol. 6, No. 6, pp 290-296, March 2009.
- [7] A. A. Kalage, V. M. Jape, S. V. Tade, M. M. Hapse and R. G. Dabhade, "Modelling and simulation of FPGA based direct torque control of induction motor drive", International journal of recent trends in engineering, vol.1, no.4, pp. 72-74, May 2009.
- [8] J. G. Mailloux, S. Simard, and R. Beguenane, "FPGA implementation of induction motor vector control using Xilinx system", 6th WSEAS International Conference on circuit, system, Electronics, control and signal processing, Cairo, Egypt, pp. 252-257, Dec. 2007.
- [9] 2001 Fairchild semiconductor corporation, data sheet, www.fairchildsemi.com.
- [10] Texas Instruments, data sheet. of MCT2E, pp.1.
- [11] International rectifier, www.irf.com, IR2110 data sheet, pp 1.
- [12] Collmer Semiconductor, inc., KBPC3510 data sheet. pp 1.
- [13] www.vishay.com, data sheet of IRFP460. pp.1

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

- [14] S. K Rathod and S. R. Kumbhar, "Single to Three phase PLC based external voltage control induction motor drive, International journal of Research in Computer Science and Information Technology, ISSN: 2319-5010, Vol.-2, Issue 2(A), pp. 106-110., March 2014.
- [15] B. N. Jamadar, S. R. Kumbhar, P. A . Lohar, D. S. Sutrave, PWM technique employed for Speed control of three phase Induction motor using Microcontroller", Proceedings of National conference on Advanced Nanomaterials, sensors and instrumentation-2011, DBF college, Solapur, pp.94-97, 2011.
- [16] S. R. Kumbhar, A. P. Ghatule," Mobile operated Remote control of PLC based Induction drive using DTMF", International Journal of research in Engineering and Technology, ISSN 2321-7308, eISSN 2319-1163, Volume 3, Special issue 3, pp. 280-285, 2014.
- [17] S. R. Kumbhar, "Poly phase inverter drive and its parameter estimation using PIC Microcontroller", A journal of Research In Electronics, ISSN 2349-8226, A Special Issue, Society for Promotion of Excellence in electronics Discipline (SPEED), pp. 223-225, 2015.