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Hardware Implementation of Controller for Synchronous Motor Drive using FPGA

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***Abstract* – The purpose of this paper is to present a FPGA based controller for synchronous motor drive. To achieve a high computation time an FPGA target has been chosen for implementation. For the current regulation, hysteresis current controller is used. The resolver processing unit (RPU) is used for estimation of speed and position of motor. Current controller and RPU are implemented on FPGA. In this system, signals from the motor are not used, instead of signals are generated by using simulator. By observing the PWM waveforms controlling action has been verified.**

***Keywords* – FPGA, ATO, RPU, Synchronous Motor.**

I. Introduction

Many types of electric motors have been used in the industry for different purposes such as cranes, spinning machines, public transportation and so on. AC motors are widely used and AC drives are subjected to study by many researchers.

Traditionally, analog components were used to design the motor control because they are easy to design and can be implemented with relatively inexpensive components but analog system has some drawbacks. Aging and temperature can bring about component variation causing the system to need regular adjustment. The reliability of the system decreases, as part count increases. As the design is hard wired, upgrades are difficult for analog components and analog components raise tolerance issues.

Digital control techniques have predominated over their analog control, with successively improving reliability and performance of digital technologies [1]. Compared with traditional analog control, digital control offers many advantages such as flexibility to modify the control schemes, adaptability to different systems and operating conditions, immunity to noise and in sensitivity to component variations [2].

Digital control techniques are mostly carried out with microcontrollers or digital signal processors. Due to inherent properties of discrete systems that results from sampling nature, quantization and truncation errors, digital control systems based on microprocessor have some disadvantages and limitations. The system bandwidth is limited due to computation delay and the stability of the system is affected by too large delay. DSP processors are limited to complex algorithm structure.

Complex algorithm structures can be implemented by using FPGA to reduce the gap between analog and digital world and to boost the performance of the controller [1]. FPGA can also be considered as appropriate solution. Now, FPGAs are believed as mature technology. Development tools for FPGAs are readily available which are very powerful and can be easily used. The application range of FPGA based design increases everyday because of its flexibility and capability to perform parallel tasks.

Four major trends that confirm the use of FPGA for current power converters and AC drive control are as follows [6]:

1) High level of integration is required to reduce the weight and volume of any embedded system. Due to FPGA, are processing speed is achieved.
2) A high level of performance and accuracy is expected this leads to implement in real time complex control.
3) Enhanced reliability is required due to rough environment.
4) A reduction of the stress of the power components are leading to a segmentation of the power which requires always more parallelism.

To all these new requirements, FPGAs are well adapted because of their high processing speed and their parallelism capability.

This paper is organized as follows: Section II describes proposed system. Section III presents FPGA based RPU (Resolver Processing unit). Section IV presents FPGA based current controller. Section V gives experimental results. Section VI provides conclusion of this proposed paper.

II. Block Scheme

This system only concentrate on implementation of FPGA based controller part, not on motor part. Therefore in this system signals taken from motor are not used, these signals are generated by using simulator.

Figure.1 shows block diagram of the system, this system consist of 4-20 mA current sources, sine wave generator, cosine wave generator, analog to digital convertor, resolver processing unit, current controller, PWM generator. 4-20 mA current source and sine wave and cosine wave generator are used to generate simulation signal. Analog to digital convertor, converts the current signals, sine and cosine wave signal into digital form. Then output of the analog to digital convertor is applied to the current controller and resolver processing unit.

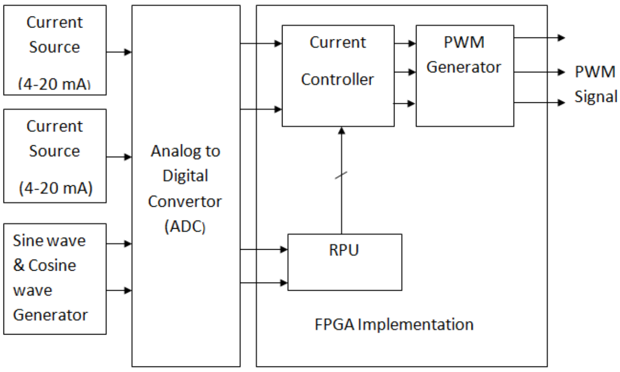

Fig.1. Block diagram of the system

Resolver processing unit is used to extract the rotor position and speed. By using digitally converted current signal and output of the resolver processing unit, current controller produces the appropriate switching signal. Output of this current controller is given to the PWM generator unit. This PWM generator produces the PWM signal which is observed on oscilloscope ,by observing the duty cycle of the PWM signal, verify the speed of motor is controlled or not.

III. FPGA Based RPU

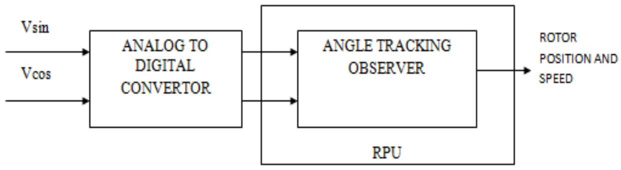

Fig.2. RPU Principle

The resolvers are basically rotating transformers. The resolver consists of one reference winding and two output windings. Two output windings are placed in quadrature of one another to generate the sine and cosine voltages. The sine winding is phase advanced by 90˚ with respect to cosine winding. In this system sine wave and cosine wave generator is used to generate this sine and cosine voltages. Resolvers are usually used for position and speed measurement in permanent magnet motors.

Modern systems, however, uses the digital approach to extract rotor angle and speed from the resolver output signals. They are called resolver to digital converters (RTDs). Most of the RTDs are either trigonometric or angle tracking observer [5].

Modern control algorithms for electric drives require knowledge of both the rotor angle and the rotor speed. But, only rotor angle is estimated by trigonometric method. This drawback is eliminated by using angle tracking observer. A great advantage of the angle tracking observer method as compared to trigonometric method is that it yields smooth and accurate estimations of both the rotor angle and rotor speed [5].

A. ATO

The angle tracking observer compares values of the resolver output signals Usin, Ucos with their corresponding estimations Ûsin, Ûcos. This observer consists of closed loop. The objective is to minimize the observation error. The observation error is given by subtraction of the estimated resolver rotor angle θ' from the actual rotor angle θ [1].

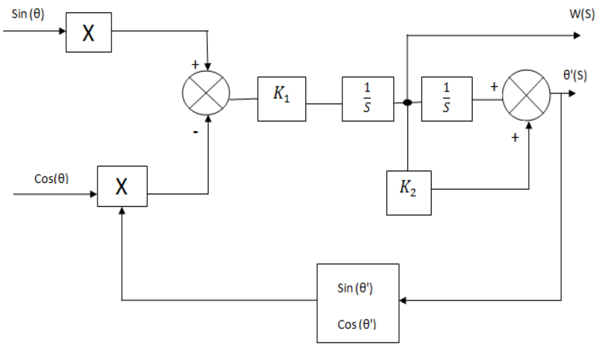

Fig.3. Block scheme of the Angle tracking observer [5]

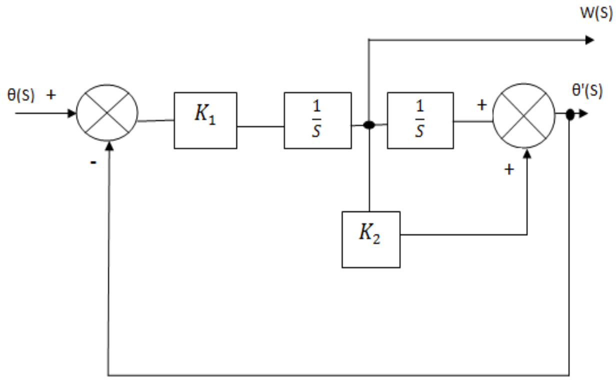

Fig.4. Simplified block scheme of the Angle tracking observer [1]

Mathematical expression of observer error is known as the formula of the difference of two angles [1]:

$$\sin(\theta - \theta') = \sin(\theta)\cos(\theta') - \cos(\theta)\sin(\theta') \quad (1)$$

For small variations of observation error, the observer error may be considered in the form (θ - θ'). The angle tracking observer transfer function is expressed with the help of its simplified block scheme in fig.4 as follows [1]:

$$H_\theta(s) = \frac{\theta'(s)}{\theta(s)} = \frac{k_1(1+k_2 s)}{s^2 + k_1 k_2 s + k_1} \quad (2)$$

$$H_w(s) = \frac{W(s)}{\theta(s)} = \frac{k_1 s}{s^2 + k_1 k_2 s + k_1} \quad (3)$$

These are second order transfer functions. Two factors namely $K_1=W^2o$, K2=2ξ/Wo have to be selected according to the dynamic requirement of the speed and position loop of a drive [1].

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IV. FPGA Based Current Controller

This current controller has two modules. These are dq – abc coordinate transformation module and three phase hysteresis regulator. Hysteresis current control is a method of controlling a voltage source inverter so that an output current is generated which follows a reference current. Hysteresis control is the easiest control method to implement.

The dq - abc module generates the three phase current references with regard to the expected dq current references and rotor position [1]. Hysteresis regulator is implemented with a closed loop control system. Hysteresis regulators compared these references with the measured currents. An error signal is used to control the switches [3].

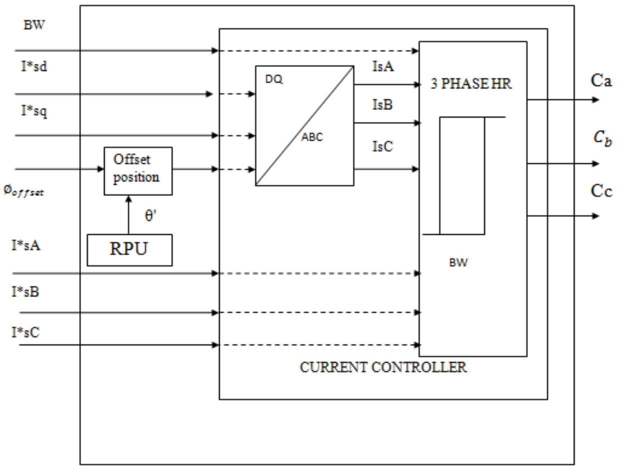

Fig.5. FPGA based current controller architecture [1]

V. Results

Fig.6. shows the experimental setup. Here speed range is considered as 0-3000 RPM. if we adjust the set point to the 20% of rated speed ,then we observed that PWM signal is obtained with 20% duty cycle as shown in fig.7. same procedure is applied for 50% & 80% of rated speed, results are shown in fig.8 &fig.9.

By observing PWM waveforms shown in fig.7 to fig.9, we mentioned that controller takes proper action.

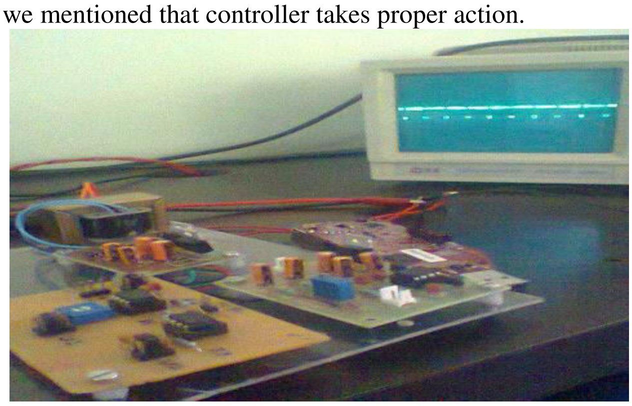

Fig.6. experimental setup

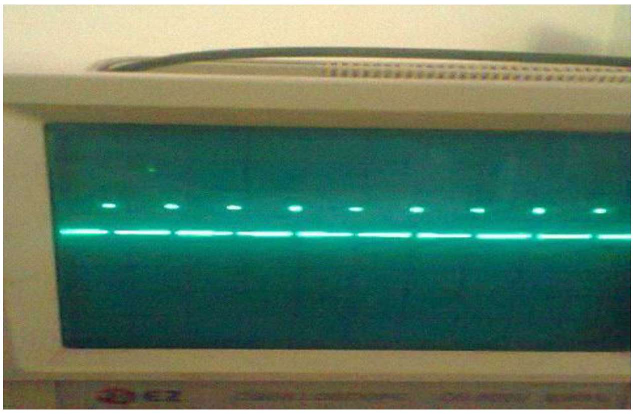

Fig.7. PWM waveform for 20% duty cycle

Fig.8. PWM waveform for 50% duty cycle

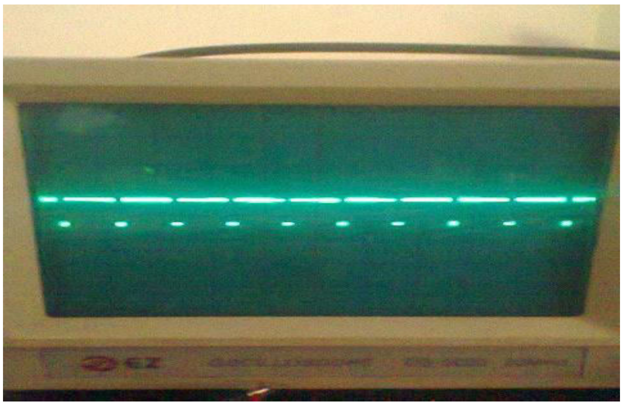

Fig.9.PWM waveform for 80% duty cycle

VI. Conclusion

This paper has presented an FPGA based controller for synchronous motor drive. The system designed in this paper is reliable & has simple system structure. Digital control algorithms, including vector control, current regulation, & speed and position estimation have been implemented in the FPGA. Behavior of the controller is detected by observing the PWM waveforms. The system is highly effective and efficient with relatively low cost.

REFERENCES

[1] L. Idkhajine, A. Prata, E. Monmasson, K. Bouallaga, and M.-W. Naouar,“ Fully Integrated FPGA-Based Controller for Synchronous Motor Drive”, IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4006–4017, Oct. 2009.

[2] M.-W. Naouar, E. Monmasson, and A. A. Naassani, “FPGA-based current controllers for AC machine drives—A review,” IEEE Trans. Ind. Electron., vol. 54, no. 4, pp. 1907–1925, Aug. 2007.

[3] L. Idkhajine, A. Prata, E. Monmasson, K. Bouallaga, and M.-W. Naouar, “System on chip controller for electrical actuator,” in Proc. ISIE Conf., Cambridge, U.K., Jul. 2008, pp. 2481–2486.

[4] L. Idkhajine, M. W. Naouar, E. Monmasson, and A. Prata, “Fully FPGA based system on chip solution for current control of AC machine,” in Proc. EPE Conf., Alborg, Denmark, Sep. 2–5, 2007, pp. 1–10.

[5] R. Hoseinnezhad and P. Harding, “A novel hybrid angle tracking observer for resolver to digital conversion,” in Proc. 44th IEEE Conf. Decis. Control, Eur. Control Conf., Seville, Spain, Dec. 2005, pp. 7020–7025.

[6] E. Monmasson, I. bahery, L.Idkhanjine, A. Maalouf, W.M. Naouar, satie Iup Geil,” Recent advancements in FPGA based controller in AC drives applications”.

[7] M. P. Kazimierkowski and L. Malesani, “Current control techniques for three-phase voltage-source PWM converters,” IEEE Trans. Ind. Electron., vol. 45, no. 5, pp. 691–703, Oct. 1998.

[8] A. Fratta, G. Griffero, and S. Nieddu, “Comparative analysis among DSP and FPGA- based control capabilities in PWM power converters,” in Proc. IEEE IECON, Busan, Korea, Nov. 2004, pp. 257–262.

[9] J. J. Rodriguez-Andina, M. J. Moure, and M. D. Valdes, “Features, design tools, and application domains of FPGAs,” IEEE Trans. Ind. Electron., vol. 54, no. 4, pp. 1810–1823, Aug. 2007.

[10] E. Monmasson and M. N. Cirstea, “FPGA design methodology for industrial control systems—A review,” IEEE Trans. Ind. Electron, vol. 54, no. 4, pp. 1824–1842, Aug. 2007.

[11] X. Lin-Shi, F.Morel, A. Llor, B. Allard, and J.-M. Retif, “Implementation of hybrid control for motor drives,” IEEE Trans. Ind. Electron., vol. 54, no. 4, pp. 1946–1952, Aug. 2007.

[12] J. Acero, D. Navarro, L.-A. Barragán, I. Garde, J.-I. Artigas and J.-M. Burdío, “FPGA-based power measuring for induction heating appliances using sigma–delta A/D conversion,” IEEE Trans. Ind. Electron., vol. 54, no. 4, pp. 1843–1852, Aug. 2007.