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Digitization of Vector Control Algorithm Using FPGA

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Abstract: The paper is concerned with the new approach to the modeling simulation,designand implementation of a vector controlled induction motors.The novel technique uses a hardware description language as unique EDA environment for all phases of the design process, easy FPGA prototyping is facilitated and the modular design allows for the reuse of VHDL code for the range of vector control strategies.Simulation results are presented validating the vector control scheme model.

Key words - vector control; FPGA; Induction motor

I. INTRODUCTION

Induction motors are perhaps the most rugged and the best understood motors presently available.Due to complexity of the equation describing the behaviour, the control systems are complicated and expensive on the other hand, it has been estimated that induction motors are used in 70-80% of all the industrial drive applications due to their simple mechanic construction, lowmaintenance requirement and lower cost compared to brushless d.c.. motor
To obtain the performance required by servo applications, induction motor control is achieved using the vector control strategy. This allows high performance control of torque, speed or position to be achieved. The complete drive system was modeled, simulated and evaluated using Very High Speed Integrated Circuit Hardware Description Language (VHDL)]. This is now one of the most popular standard HDLs. It is supported by all major Computer Aided Engineering (CAE) platforms and synthesis tools can compile VHDL designs into a large variety of target technologies. The VHDL digital control solution presented in this paper is reusable as a whole or parts of it in different vector control architectures for induction motor. The design flow in VHDL is shown in Fig.1

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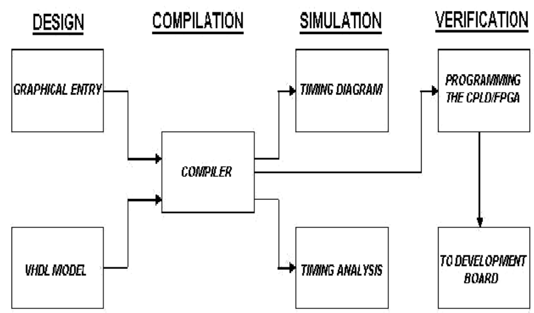

FIG 1. Design Flow in VHDL

II. VECTOR CONTROL

2.1 INTRODUCTION

High performance control of a.c. induction motors and permanent magnet synchronous motors most often relies on the principles of vector or Field Oriented Control (FOC). Vector controllers mainly aim to maintain the flux producing the direct component of the stator current space vector in phase with the rotor flux space vector under all operating conditions. The quadrature axis current component, which then lies in quadrature with the rotor flux vector,
directly controls the torque developed by the machine. When correctly implemented, vector control permits the independent control of the torque and flux of the a.c.machines, in a manner identical to that of the separately excited D.C. motor. Most often there is no direct measurement of either the produced torque or flux, so the control is implemented by a closed loop current regulation structure known as the Indirect Rotor Field Oriented Controller [1]. Such a system is illustrated in Fig. 1. Although VHDL is a hardware description language and as such, it is used primarily for circuit design, it has the basic properties of any software programming language.FPGA can carry out parallel processing

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by means of hardware mode, which occupies nothing of the CPU, the system can get a very high speed level as well as an exciting precision. This new design methodology has been used in high performance motion control field, such as [2]-[4], which realize different current controller. In [2], the designed digital current controller integrates both nonlinear Δ modulator and linear PI regulator and can obtain a very high bandwidth. Literature [3] provides a co-processor scheme based on the indirect vector control with current feed forward, and literature [4] proposes a digital hardware implementation where it can operate under different instructions

Though the large majority of variable speed applications require only speed control in which the torque response is only of secondary interest, more challenging applications such as traction applications, servomotors and the like depend critically upon the ability of the drive to provide a prescribed torque whereupon the speed becomes the variable of secondary interest. The method of torque control in ac machines is called either ***vector control*** or, alternatively *field orientation*. Vector control refers to the manipulation of terminal currents, flux linkages and voltages to affect the motor torque while field orientation refers to the manipulation of the field quantities within the motor itself. Since it is common for machine designers to visualize motor torque production in terms of the air gap flux densities and MMFs instead of currents and fluxes which relate to terminal quantities.

The Field Orientated Control (FOC) [1][3] consists of controlling the stator currents represented by a vector. This control is based on projections which transform a three-phase time and speed dependent system into a two co-ordinate (d and q co-ordinates) time invariant system. These projections lead to a structure similar to that of a DC machine control. Field orientated controlled machines need two constants as input references: the torque component (aligned with the q co-ordinate) and the flux component (aligned with d co-ordinate). As Field Orientated Control is simply based on projections the control structure handles instantaneous electrical quantities. This makes the control accurate in every working operation (steady state and transient) and independent of the limited bandwidth mathematical model. The FOC thus solves the classic scheme problems, in the following ways:

The ease of reaching constant reference (torque component and flux component of the stator current).The ease of applying direct torque control because in the (d,q) reference frame.

By maintaining the amplitude of the rotor flux (ψ*R*) at a fixed value we have a linear relationship between torque and torque component ($_{isq}$). We can then control the torque Current vector. Two motor phase currents are measured. These measurements feed the Clarke transformation module.

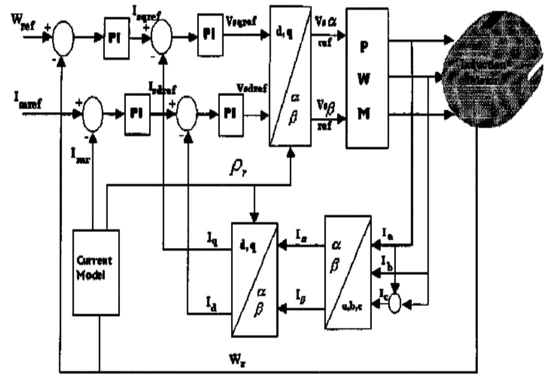

Fig 2 Basic scheme of FOC for AC-motor

The outputs of this projection are designated as i_{Sa} and i_{Sb}. These two components of the current are the inputs of the Park transformation that gives the current in the d,q rotating reference frame. The i_{Sd} and i_{Sq} components are compared to the references i_{sdref} (the flux reference) and i_{Sqref} (the torque reference). At this point, this control structure shows an interesting advantage: it can be used to control either synchronous or induction machines by simply changing the flux reference and obtaining rotor flux position. As in synchronous permanent magnet motors, the rotor flux are fixed (determined by the magnets) there is no need to create one. Hence, when controlling a PMSM, i_{Sdref} should be set to zero. As induction motors need a rotor flux creation in order to operate, the flux reference must not be zero. This conveniently solves one of the major drawbacks of the “classic” control structures: the portability from asynchronous to synchronous drives. The torque command i_{Sqref} could be the output of the speed regulator when we use a speed FOC. The outputs of the current regulators are v_{Sdref} and v_{Sqref}; they are applied to the inverse Park transformation. The outputs of this projection are v_{Saref} and v_{Sbref} which are the components of the stator vector voltage in the a,b stationary orthogonal reference frame. These are the inputs of the Space Vector PWM. The outputs of this block are the signals that drive the inverter. Note that both Park and inverse Park transformations need the rotor flux position.

Obtaining this rotor flux position depends on the AC machine type (synchronous or asynchronous machine)

III. REALIZATION OF VECTOR CONTROL IN VHDL

3.1 INTRODUCTION

High performance control of a.c. induction motors and permanent magnet synchronous motors most often relies on the principles of vector or Field Oriented Control (FOC). Vector controllers mainly aim to maintain the flux producing the direct component of the stator current space vector in phase with the rotor flux space vector under all operating conditions. The quadrature axis current component, which then lies in quadrature with the rotor flux vector, directly controls the torque developed by the machine. When correctly implemented, vector control permits the independent control of the torque and flux of the a.c. machines, in a manner identical to that of the separately excited d.c. motor. Most often there is no direct measurement of either the produced torque or flux, so the control is implemented by a closed loop current regulation structure known as the Indirect Rotor Field Oriented Controller [4 Although VHDL is a hardware description language and as such, it is used primarily for circuit design, it has the basic properties of any software programming language. A system model can therefore be initially developed. A vector control structure with the entity named “motor” can be configured in VHDL as

```
ENTITY MOTOR IS
PORT (vds,vqs,Tl :in real:
        ids, iqs,wr : out real);
END MOTOR,
```

3.2 DESCRIPTION

A new approach has been developed for the modeling design and analysis of a complete vector controlled induction motor drive. motor drive. Two reusable VHDL modules are presented, together with simulation results. These prove an expected behaviour of the motor model.

i.A unique environment for modelling, simulation and evaluation of complete drive systems, including controllers, power electronics and induction motors.

ii.The same environment (VHDL) is used for the design itself of the digital vector controller and for silicon **(FPGA)** implementation. Fast design development and short time to market.

iii.CAD platform independent models and designs are being developed (VHDL operates with ASCII files) and therefore valuable reusable IPS can be produced.

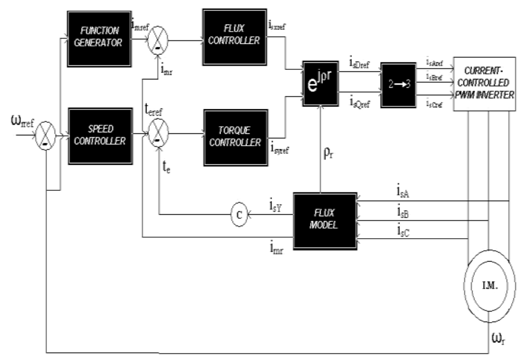

Fig 3. BLOCK DIAGRAM OF VECTOR CONTROL DESIGNED IN VHDL

IV. SIMULATION RESULTS

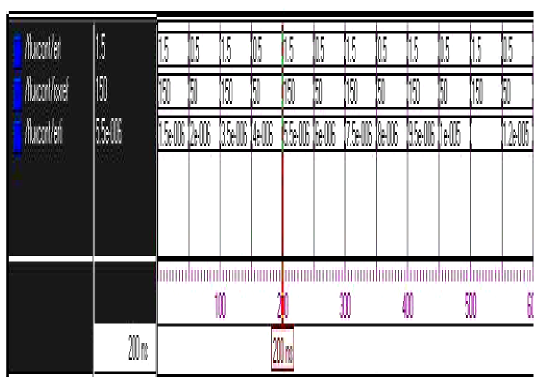

FIG 4 Result of flux controller

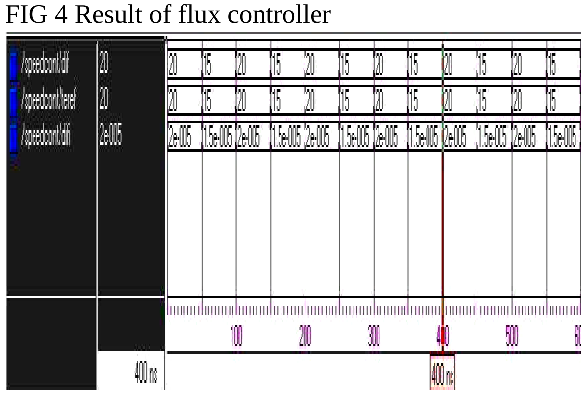

FIG.5 Result of Speed Controller

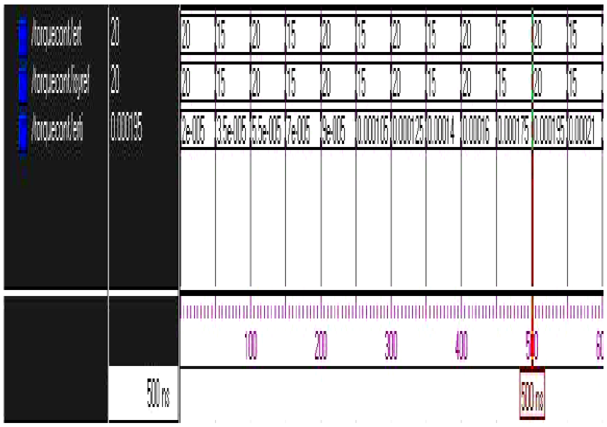

FIG.6 Result of Torque controller

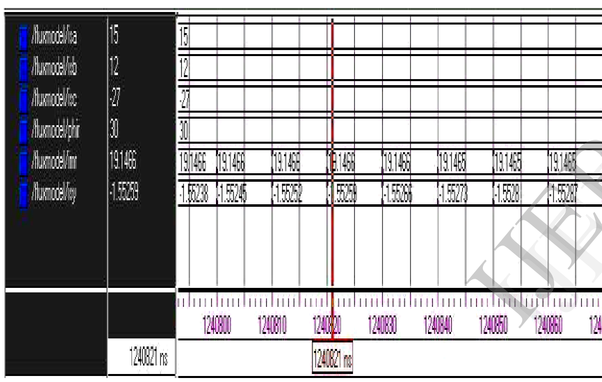

FIG.7 Result of Flux model

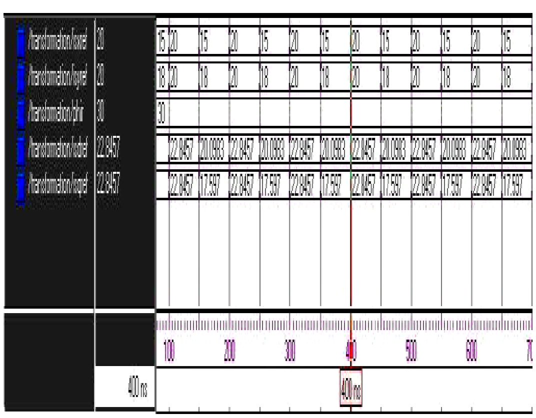

FIG.8 Result of Transformation Block

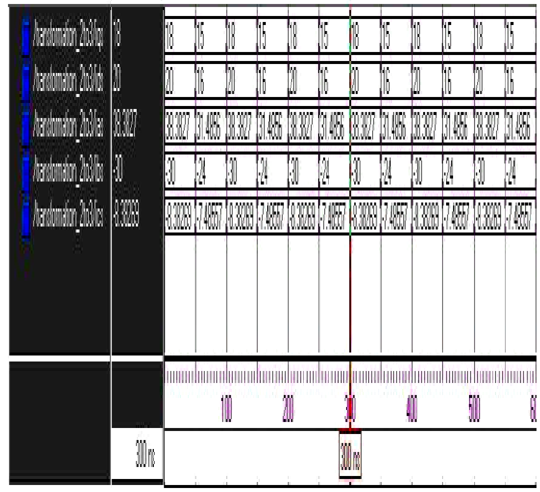

FIG.9 Result of Inverse Transformation Block

Fig 10. Result of the implemented Vector Control

V. CONCLUSION

A new approach has been developed for the design and analysis of a complete vector controlled induction motor drive. The basic modules necessary for Vector Control of an Induction Machine has been coded in VHDL and simulated. The same is downloaded into a FPGA/CPLD and the results are to be compared with existing schemes in terms of speed and memory occupied.

The future enhancement of this work is to implement the digital Control Technique (Vector Control) on a Single Chip which results in System on a Programmable Chip(SOPC).

VI. REFERENCES

[1] An efficient FPGA implementation of the space vector modulation algorithm ,Alecsa, B.; Onea, A.; Cirstea, M. Signals, Circuits and Systems (ISSCS), 2011

[2] FPGA-based Vector PI regulator for electrical drives control Abdellatif, M.; Naouar, M.W.; Slama-Belkhodja, I.; Monmasson, E. Power Electronics and Applications, 2007.

[3] New space voltage vector modulation inverter based on FPGA considering voltage saturation for speed servo system of induction motor Kanmachi, T.; Takahashi, K.; Ohishi, K. Power Electronics and Applications, 2007

[4] Unified motor controller based on space vector modulation technique Wiangtong, T.; Dechsuwan, P. Circuits and Systems, 2006. ISCAS 2006. Proceedings. 2006

[5] Toshio Takahashi, "Digital Hardware Control Method For High Performance AC Servo Drive" Presented at Military Electronics Conference Sept 24-25, 2002.

[6] J.O.Hamblen & M.D.Furman, "Rapid Prototyping of Digital Systems, Second Edition, A tutorial Approach", Georgia Institute of Technology, Kluwer Academic Publishers, London.

[7] L.Charaabi, E.Monmasson, I.Slama-Belkhodja, "Presentation of an Efficient Methodology for FPGA Implementation of Control Systems Application to the Design of an Antiwindup PI controller" IEEE Transactions on Industrial Electronics " 2002.

[8] Bimal K. Bose, Life Fellow, IEEE Department of Electrical Engineering The University of Tennessee, Knoxville USA," High Performance Control of Induction Motor Drives".