REAL TIME CONTROL OF ELECTRICAL MACHINE AND DRIVES: A REVIEW

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ABSTRACT

Over the last two decades, the available computer has become both increasingly powerful and affordable. This, in turn, has led to the emergence of highly sophisticated applications that not only enable high-fidelity simulation of dynamic systems but also automatic code generates for implementation in real time control of electric machine-drives. Today, electric drives, power electronic systems and their controls have become more and more complex, and their use is widely increasing in all sectors such as power systems, traction, hybrid vehicles, industrial and home electronics, automotive, naval and aerospace systems, etc. Advances in Microprocessors, Microcomputers, and Microcontrollers such as DSP, FPGA, dSPACE etc. and Power Semiconductor devices have made tremendous impact on performance electric motor drives. Due to advancement of the software tools like MATLAB/SIMULINK with its Real Time Workshop (RTW) and Real Time Windows Target (RTWT), real time simulators are used extensively in many engineering fields, such as industry, education and research institutions. As a result, inclusion of the real time simulation applications in modern engineering provides great help for the researcher and academicians. An overview of the Real Time Simulations of Electrical Machines Drives is herewith presented which is used in modern engineering practices. This paper discusses various real time simulation techniques such as Real Time Laboratory (RT Lab), Rapid Control Prototyping (RCP) and Hardware in the Loop (HIL) that can be used in modern engineering.

KEYWORDS: *Rapid Control Prototyping (RCP), Hardware in the Loop (HIL), Real Time Workshop.*

I. INTRODUCTION

Nowadays as a consequence of the important progress in the power semiconductor technologies, real time control of the electrical machines has gained more popularity in the arena of engineering. Due to the increasing complexity and cost of projects, and the growing pressure to reduce the time-to-market, testing and validation of complex systems has become more and more important in the design process. With the great advancement in processor and software technology and their cost decreases, it has become possible to use gradual and complete approach in system design, integration and testing. This approach, which was traditionally reserved for large and complex projects (power systems, aeronautics,) is the Real-Time (RT) simulation. Research on high level modeling, new converter-inverter topologies and control strategies are the major research areas in electrical drives. A system consisting of a loaded motor, driven by a power electronics converter is a complex and nonlinear system. Thus, performing system-level testing is one of the major steps in developing a complex product in a comprehensive and cost effective way requires real-time simulations. One of the most demanding aspects for real-time control systems is to connect the inputs and outputs of the tested control system to a real-time simulation of the target process.

In view of its implication that all control loops are closed via the simulator, this method is often called Hardware-in-the-Loop (HIL) simulation. By using the HIL simulations, we can evaluate different subsystems interaction. In HIL simulation, a device under test is run fully connected to a real-time simulated dynamic equivalent of an apparatus. A unique feature of this approach is that it even permits a gradual change-over from simulation to actual application, as it allows to initiation from a pure simulation to a gradually integrated real electrical and mechanical subsystems and finally into the loop as they become available. An HIL simulation can help reduce development cycles, cut overall costs, prevent costly failures, and test a subsystem exhaustively before integrating it into the system. One of the reasons for real time simulations with HIL is when a particular device is very difficult to model. Therefore it is convenient to use this device directly in the simulations instead of modeling it. Digital Real time simulations are required by hardware in the loop applications and their use allows rapid prototyping and minimizing the design process cost. The real time system structure will allow the implementation of advanced motor drives control algorithms and evaluation of their performance in real time [1,53]. Algorithms implemented in FPGA circuit are even more complicated to test because of number of internal signals. These signals are only accessible through test modules implemented inside the circuit. dSPACE real time platform allows simulation and verification environments to be created from Simulink models. In this way, the same model can be used through the whole development cycle of the control algorithm. dSPACE also allows simulations to be performed in several phases of the design, from a single module to system level. It is also possible to use Simulink in co-simulations with ModelSim to simulate VHDL model together with the Simulink model. This paper presents overview of the various real time simulation technologies and their engineering applications [7-30].

II. BASIC CONCEPT OF THE REAL TIME CONTROL & SIMULATION

The literature about real-time systems presents digital control or computer controlled systems as one of its most important practical application in the field of electrical machines and drives. It is more natural that these applications should be treated as part of digital control. Despite this control system literature rarely includes extensively real-time control of electrical machines and it does not normally pay attention to real-time aspects beyond algorithms and choice of sampling times. The implementation of digital control systems and real-time systems of electrical machines golong together and they should be connected more or less later in the electrical machines due to advancement of the power semiconductor devices and various digital controllers. In general, real-time issues are gradually becoming “transparent” to the control of the various electrical machines. This transparency has been considerably increased in the last few years with the advent of software tools like MATLAB/Simulink with its RTW (Real Time Workshop) and RTWT (Real Time Windows Target). They make the implementation of real-time experiments easier and save time, but on the other hand they put more distance with regard to the real life problems, which can emerge during the real-time implementation of control system of electrical machines. It is possible to find in the available literature several definitions for real-time systems. Here, a definition that does not contradict the one given in the IEEE POSIX Standard (Portable Operation System Interface for Computer Environments) will be assumed.

“A real-time system is one in which the correctness of a result not only depends on the logical correctness of the calculation but also upon the time at which the result is made available”

It is again appropriate to quote one of the great scientists in automatic control, Karl Astrom

“Many important aspects on implementation are not covered in textbooks. A good implementation requires knowledge of control systems as well as certain aspects of computer science. It is necessary that we have engineers from both fields with enough skills to bridge the gap between the disciplines. Typical issues that have to be understood are windup, real-time kernels, computational and communication delays, numeric’s and man machine interfaces. Implementation of control systems is far too important to be delegated to a code generator. Lack of understanding of implementation issues is in my opinion one of the factors that has contributed most to the notorious GAP between theory and practice."

This definition emphasizes the notion that time is one of the most important entities of the system and that there are timing constraints associated with systems tasks. Such tasks normally control or react to events that take place in the outside world, which are happening in "real time". Thus, a real-time task must be able to keep up with external events, with which it is concerned. It should be noted here that real-time computing is not equivalent to fast computing. Fast computing aims at getting the results as quickly as possible, while real-time computing aims at getting the results at a prescribed point of time within defined time tolerances.

Nowadays, it is very difficult to choose a software/hardware configuration for real-time experiments because there are many manufacturers who offer a variety of well designed systems. Thus, it would prudent to be caution at the moment to define the specifications for such systems. Today it is very common to use two computers in a host/ target configuration to implement real-time control systems. The host is a computer without real-time requirements, in which it develops environment, data visualization and control panel in the form of a Graphic User Interface (GUI) reside. The real-time system runs on the target, which can be a second computer or an embedded systems based on a board with a DSP (Digital Signal Processor), a Power PC or a Pentium family processor. The main features of the real –time software, as distinct from other software are, that the control algorithms must be run at their scheduled sample intervals and their existing associate software components, which interact with sensors and actuators. Generally, two methods of the real time control algorithms implementations are used. They are Manual writing of the code and Automatic generation of the controller, using a code translator that produces a real time code directly from the controller model [4]. The main idea using real time control is to smoothen transition from the non real analysis and simulation to the real time experiments and implementation. The various digital real time controller and simulation solutions can be divided into the categories as given in Table.1 [4].

A typical real time control and simulation is shown in Fig.1[4].The Real time simulation requires selection of control strategies, structures and parameter values. The integrated real-time control and simulation environment is a solution enabling the designer to perform the simulations and real time

Table No 1 Various Real Time Controllers

Solution	Reliability	Flexibility	Advanced Algorithms	Cost	Rapid Prototyping Ability
PLC	High	Medium	Low	High	Medium
Microcontrollers	Medium	Low	Low	Low	Low
VME Industrial Comp.	High	Medium	Medium	High	Medium
DSP	Medium	Medium	Medium	Medium	High
PC+ data acq. board	Low	High	High	Low	High

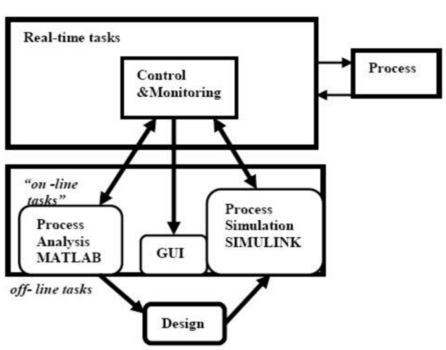

Fig.1 Typical Real Time Control System.

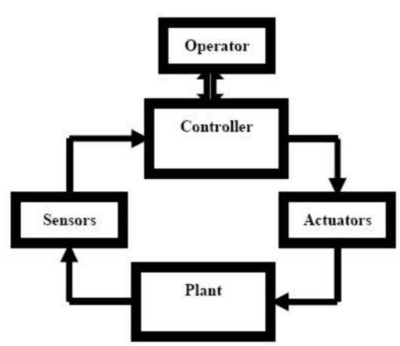

Fig. 2 Block diagram Real Time control for Electrical Machines.

experiments in a structured and simple manner. The system shown in Fig.1 [4] consists of three parts: a Real Time Kernel (RTK), an "on-line" operating analysis, simulation and visualizations tools, and an "off-line" design support libraries. The real-time kernel (RTK) performs the controller algorithms and data logging. Data collected in the buffer of the RTK can be analyzed in "on line" mode using the appropriate software. If necessary, the control algorithms can be redesigned in off line mode using non real facilities and then verified by simulation method and finally downloaded to real time controller. "On-line" simulation provides the best conditions for the parameters tuning [4-5]. The basic real time control system for electrical machines –drives is shown in Fig.2 [3]. A power electronic system, similar a kin to any control system, is usually made of a controller and a plant as shown in Fig. 2[3]; A power circuit consists of power source, power electronics converter and loads. These are usually connected in closed loop by means of sensors sending feedback signals from the plant to the controller and an interface (actuators) to level the signals sent from the controller to the power switches (Firing pulse unit, gate drives, etc)[3].

III. REAL TIME CONTROL TECHNIQUES

Now days, as a consequence of the important progress made in electrical machines and drives because of advancement in power semiconductor devices. With advancement in the digital controllers such as Microprocessor/Microcontroller, Digital Signal Processors (DSP), Field Programmable Gate Array (FPGA), dSPACE and other Artificial Intelligence (AI) techniques such as Fuzzy Logic, Neural Network can now satisfactorily be implemented for real time applications.[5,8]. Traditionally, validation of systems was done by non-real-time simulation of the concept at early stages in the design, and by testing the system once the design was implemented however this method has two major drawbacks: first, the leap in the design process, from off-line simulation to real prototype, is so wide that it is prone to many troubles and problems related to the integration at once of different modules; second, the off-line, non-real-time, simulation may become tediously long for any moderately complex systems, especially for Electrical Machines drives with switching power electronics [3].Various techniques that can be used for real time control and simulation of electrical machines and drives are as under:-

3.1 Microprocessor/Microcontrollers:

Conventional controllers have been replaced by the new dynamic microprocessor based control techniques. The advancement of microprocessor technology has followed a rapid pace since the advent of the first 4-bit microprocessor in 1971. From simple 4-bit architecture with limited capabilities, microprocessors have evolved towards complex 64-bit architecture in 1992 with tremendous processing power. The evolution of microcontrollers has followed that of microprocessor, and consists of three main families: MCS-52, MCS-96 and i960. These families are based on 8-bit CISC, 16-bit CISC and 32-bit and 64-bit RISC microprocessor architecture respectively. The digital technology is developed in an order as outlined here: General-purpose microprocessors, microcontrollers, advanced processors (DSP's, RISC processors, parallel processors), ASIC's and SoC. The recent developments of control techniques for several kinds of electrical machines require better and modern machine drivers, since digital control techniques usually require microprocessor computation for their implementation. A microprocessor based electrical machines control using PWM modulation was implemented by using PMACP16-200 microprocessor for induction motor and results were supported by the experimental setup [6]. As seen in rapid changes in the technology of microprocessor, a newly developed Motorola MC68HC11E-9 microcontroller based fully digital control system has been developed to control the induction motor. The high-performance microprocessor and PC based real time control schemes for electrical machines have been presented in [6-8] and the controller performance was checked and verified experimentally [6-10].

3.2 Digital Signal Processors (DSP)/ Field Programmable Gate Array (FPGA)

Digital signal processors began to appear roughly around 1979 and today, advanced Digital Signal Processors, RISC (Reduced Instruction Set Computing) processors, and parallel processors provide ever more high computing capabilities for the most demanding applications. With the great advances in the microelectronics and Very Large Scale

Integration (VLSI) and Very High Speed Integrated Circuit Description Language (VHDL) technology, high-performance DSP's can be effectively used to realize real time simulation of electrical machines. The basic functions of real time control for electric drive are shown in Fig.3 [8].The real time simulation of electric machine–drives has been developed and successfully integrated in the first course of power electronics and electric drives [8-14].

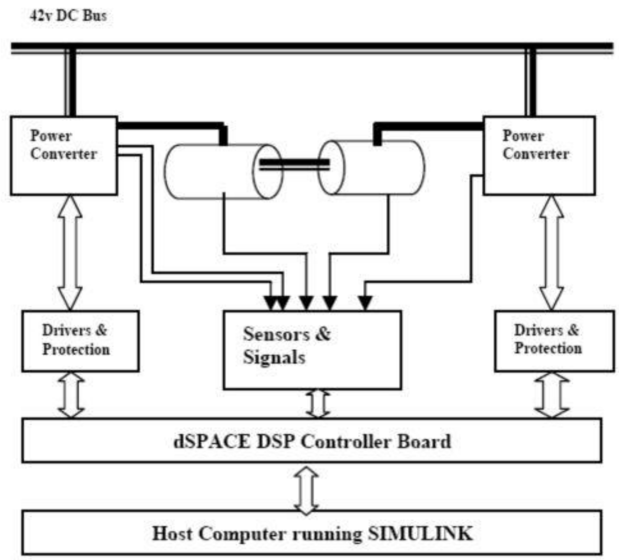

Fig. 3 Real Time Simulation Electric Drives Laboratory.

New emerging technologies in semiconductor industry offered the means to create high-performance digital components allowing implementation of more complex control applications. Embedded Systems (ES) are computers incorporated in devices in order to perform application-specific functions. Application Specific Integrated Circuit (ASIC) is a generic term which is used to designate any integrated circuit designed and built specifically for a particular application. ES can contain a variety of computing devices, such as microcontrollers, Application Specific Integrated Circuits (ASICs), Application Specific Integrated Processors (ASIPs), and Digital Signal Processors (DSPs). Recently, the System-on-Chip (SoC)(Eshraghian,2006;Nurmi, 2007) capabilities have provided the opportunity to have more performance digital control solution[19].There is now renewed interest in devoting to Field Programmable Gate Arrays (FPGAs) for full integration of all control functions. New FPGA technology (Rodriguez-Andina *et al.*, 2007) containing both reconfigurable logic blocks and embedded cores, becomes quite mature for high-speed power control applications. Hard Ware (HW) and Soft Ware (SW) components interact in order to perform a given task. Such systems need a co-design expertise to build a flexible embedded controller that can execute real time closed-loop control. The power of these FPGAs has been made readily available to embedded system designers and SW programmers through the use of SW and HW tools. Field-programmable gate arrays (FPGA's) are a special class of ASIC's which differ from mask programmed gate arrays in that their programming is done by end-users at their site with no IC masking steps. The main advantage of FPGAs is the reconfiguarablity of the hardware as compared to DSP processors where in the latter hardware resources are fixed and cannot be reconfigured. During the last ten years embedded systems have moved towards a System-on-a-Chip (SoC) and high-level multi chip module solutions. A SoC design is defined as a complex IC that integrates the major functional elements of a complete end-product into a single chip or chipset [17-20]. Today System-on-a Chip (SoC) devices target high performance applications in which transition from fast time to market is of prime importance. The evolution of VLSI and microprocessor technologies is expected to continue with an accelerating pace during the next decade. The FPGA based real time simulation of electrical machines has been implemented [19-27].

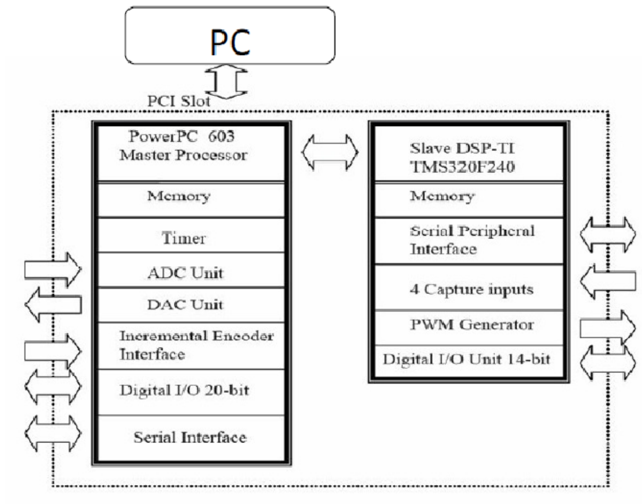

Fig.4 Block Diagram of a dSPACE DS1104 R&D Controller Board.

3.3 dSPACE Controller

Testing and verification of motor control algorithms is very demanding and time consuming. Test systems use usually electrical connections to signal lines or pins to get information from a tested device. Algorithms implemented in FPGA circuit are even more complicated to test because of the amount of internal signals. These signals are accessible only through test modules implemented inside the circuit [32]. dSPACE hardware platform is based on Digital Signal Processors (DSP). This platform has two characteristics which discern it from other similar products. In the first characteristic microprocessor board is mounted in the PCI slot of a personal computer, where as in the other system uses MATLAB/Simulink as a software development tool. Hardware platform consists of two DSPs, which share different application-communication tasks in order to achieve real-time application running.

dSPACE uses all Simulink features for creating a user algorithm[28].dSPACE software package includes additional Simulink toolboxes which define different hardware characteristics like timers, counters, PWM generators, encoders, etc[31].When a user algorithm is created in Simulink, the target DSP code must be generated. MATLAB’s Real time workshop and the specific builder, installed with dSPACE software package, provides building and downloading of user algorithms which are possible directly from Simulink. When the user algorithm is downloaded, real time debugging, parameters adjustment and signals observing, are realized with the Control Desk software package. dSPACE real time platform allows simulation and verification environments to be created from Simulink models [33]. This way, the same model can be used throughout the whole development cycle of the control algorithm. dSPACE also allows simulations to be performed in several phases of the design, from a single module to a system level. It is also possible to use Simulink in co simulations with ModelSim’ to simulate VHDL model together with the Simulink model [30-32]. dSPACE real time platform including powerful power PC processor with general purpose I/O device as shown in Fig. 4 [32]. It also includes separate DSP processor that can be used for PWM-outputs and inputs. dSPACE is capable of executing DTC modulator with rest of the motor control algorithms as well as emulate electric drive system in real time [32].The real time simulation of the electrical drives has been presented.[31-32].

3.4 Artificial Intelligence Control

Amongst recent trends, there is an increased interest in combining artificial intelligence controls with real time control techniques. In this paper, a review on the different techniques used, based on the fuzzy logic and neural network in vector control of induction motor drive, are presented[27,30,36].The efficiency of the controller has been verified through hardware and MATLAB implementation [29].The real time implementation of IRFOC using dSPACE controller is presented. The performance of complete vector control of the single phase induction motors and PI controllers have been investigated and verified experimentally [31].

IV. COMPARISION OF VARIOUS REAL TIME SIMULATION TECHNIQUES

In the past motor controller were typically developed and used by using a real motor drive in early design process. However today, it is more common to test controller using simulated motor model in a real time environment. Testing and verification of motor control algorithms is very demanding and time consuming. The various controller and their performance for real time control of electrical machine are listed in Table.-I.DSP is optimised for digital signal processing however it is not optimised for the specific algorithms implemented in software are results in poor performance. FPGA provides the means for achieving hardware performance and software versatility. The main advantages of FPGA are the reconfiguarablity of the hardware as compared to DSP processors in which the hardware resources are fixed and cannot reconfigured. The bit length of digital word is not limited in FPGA where in DSP and other processors it is limited. Algorithms implemented in FPGA circuit are even more complicated to test because of number of internal signals. These signal are only accessible through test modules implemented inside the circuit. Space hardware platform is based on DSP and Microprocessors. dSPACE real time platform allows simulation and verification environments to be created from Simulink model. Artificial Intelligence techniques such as neural network, fuzzy logic leads to improved performance when properly tuned. They are easy to extend and modify and also can be easily made adaptive by the incorporation of new data or information, as they become available.

V. APPLICATIONS OF THE REAL TIME SIMULATION IN ELECTRICAL MACHINE DRIVES

Real time application can be used in modern engineering and technologies as:

5.1 Rapid Control Prototyping (RCP):

A critical aspect in the deployment of motor drives lies in the early detection of defects in the design process. Rapid prototyping of motor controllers is one methodology that enables the control engineer to quickly deploy control algorithms and detect eventual problems. This is typically performed using a small real-time simulator called a Rapid Control Prototyping system (RCP) connected in closed-loop with a physical prototype of the drive to be controlled. Modern RCPs take advantage of a graphical programming language (such as Simulink) with automatic code generation support. Later in the design process, when this code has been converted and fitted into a production controller (using mass-production low-cost devices), the same engineer can verify it against the same physical motor drive, often a prototype or a preproduction unit[22]. In RCP applications, an engineer will use a real-time simulator to quickly implement a controller and connect it to the real plant. This methodology implies that the real motor drive is available at the RCP stage of the design process. Furthermore, this set-up requires a 2nd drive (such as a DC motor drive) to be connected to the motor drive under test to emulate the mechanical load. This is a complex setup; however it has been proven to be very effective in detecting problems earlier in the design process. In cases where a physical drive is not available, or where only costly prototypes are available, an HIL-simulated motor drive can be used during the RCP development stage. In such cases, the dynamometer, real IGBT converter, and motor are replaced by a real-time virtual motor drive model. This approach has a number of advantages. For example, the simulated motor drive can be tested with borderline conditions that would otherwise damage a real motor. In addition, setup of the controlled-speed test bench is simplified since the virtual shaft speed is set by a single model signal, as opposed to using real bench, where a 2nd drive would be needed to control the shaft speed. Other advantages of using a virtual motor drive system include the ability to easily study the impact of motor drive parameter variations on the controller itself [3].A typical rapid control prototyping is shown in Fig.5[3].

Rapid Control Prototyping (RCP) consists of quickly generating a functioning prototype of the controller, and to test and iterate this control algorithm on a real-time platform with real input/output devices. Rapid control prototyping differs from HIL in that the control strategy is simulated in real-time and the "plant," or system under control, is real The applications of RT-LAB real-time system for rapid control prototyping are numerous;(a) It is found in the development of a biped locomotor applicable to medical and welfare fields [10];(b) In autonomous control to manoeuvring a ship along a desired paths at different velocities [3], where RT-Lab is used for rapid prototyping of the ship real-time feedback controller;(c) In real-time control of a multilevel converter using the mathematical theory of resultants]; and in several research and teaching labs for the control of electric motors. A typical setup using the Drive Lab experimental set has been implemented [44-68].

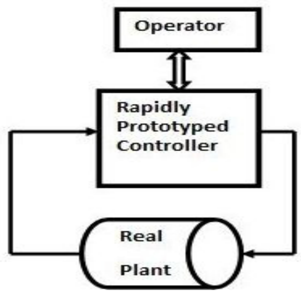

Fig .5 Rapid Control Prototyping.

5.2 Hardware –in –the –Loop testing (HIL)

Hardware-in-the-loop (HIL) Simulation of either the controller (Rapid Control Prototyping) or the plant (plant-in-the-loop, or generally called hardware-in the-loop) is shown in Fig.6[3]. At this stage, a part of the designed system is built and available to be integrated to the other part that is being simulated in real-time. If the hardware (controlled equipment) is available, rapid control prototyping and testing is done with the real hardware.

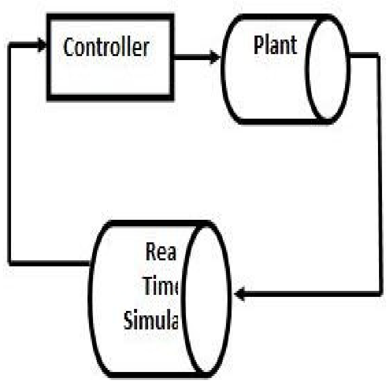

Fig.6 Hardware in the Loop Simulation.

But, for complex systems, like a hybrid car power drive, or a complex industrial drive, in most cases, the controller will be ready before the hardware it controls; so, HIL testing, where the real hardware is replaced by its RT digital model, is used to debug and refine the controller. This is done with a key characteristic of this design process: i.e. code generation. The block diagram based model is automatically implemented in real-time through fast and automatic code generation. The long, error prone hand coding is avoided; prototyping and iterative testing is therefore greatly accelerated [3]. HILS differs from pure real-time simulation by the use of the "real" controller in the loop (motor drive controller, electronic control unit for automotive, FADEC for aerospace, etc). This controller is connected to the rest of the system that is simulated by input/outputs devices. So unlike RCP, in HILS, it is the plant that is simulated and the controller is real. Hence, aircraft flight simulators can be considered as a form of HIL simulation.HIL permits repetition and variation of tests on the actual or prototyped hardware without any risk for people or system. Tests can be performed under realistic and reproducible conditions. They can also be programmed and automatically executed [48].The HIL simulation is discussed in detail [46-61].

5.3 Software in the loop (SIL)

SIL represents the third logical step beyond the combination of RCP and HIL as shown in Fig.7. With a powerful enough simulator, both controller and plant can be simulated in real time in the same simulator. SIL has the advantage over RCP and HIL that no inputs and outputs are used, thereby preserving signal integrity. In addition, since both the controller and plant models run on the same simulator, timing with the outside world is no longer critical; it can be slower or faster than real-time with no impact on the validity of results, making SIL ideal for a class of simulation called accelerated simulation. In accelerated mode, a simulation runs faster than real-time, allowing for a large number of tests to be performed in a short period. For this reason, SIL is well suited for statistical testing such as Monte-Carlo simulations. SIL can also run slower than real-time. In this case, if the real-time simulator lacks computing power to reach real-time, a simulation can still be run at a fraction of real-time, usually faster than on a desktop computer.

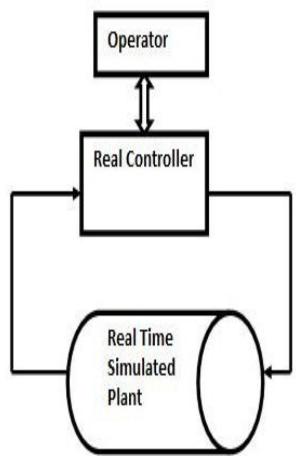

Fig.7 SIL Simulation

5.4 Rapid Batch Simulation (RBS)

RBS is typically used to accelerate simulation in massive batch run tests, such as aircraft parameter identification using aircraft flight data [44-70]

5.5 RT Lab Real Time Platform

RT-LAB is an integrated real-time software platform that enables model-based design by the use of rapid prototyping and HIL simulation and testing of control systems, according to the V-cycle design process. RT-LAB is a powerful, modular, distributed, real-time platform that lets the engineer and researcher to quickly implement block diagram. Simulink models on PC platform thus supporting the model-based design method by the use of rapid prototyping and hardware-in-the-loop simulation of complex dynamic systems [3]. The major elements integrated in this real-time platform are: distributed processing architecture, powerful processors, high precision and very fast input/output interface, hard real-time scheduler and modelling libraries and solvers specifically designed for the highly non-linear motor drives, power electronics and power systems. The RT Lab applications are verified experimentally [44-70].

VI. CONCLUSION

This paper presents a literature survey on the artificial intelligence based on real time control of electrical machine-drives. An overview of various real time simulation techniques of electrical machines –drives and its applications in modern engineering technologies has been presented. The real time simulation allows for physical controller to be simulated so that its performance can be evaluated. Once the controller is designed in MATLAB/SIMULINK, it can be physically implemented using the rapid control prototyping of the dSPACE platform. FPGA based digital platform is more suitable for real time control of electrical machines. The FPGA based real time control of electrical machine is to able to support both software and hardware customisation. It allows inserting additional interfaces and controllers as software tasks to enable system use with control application. The fully System on Chip(SOC) integrated real time control system provides for lower cost and high speed execution. The use of FPGA's in real time control applications not only increases the performance of the system but also reduces the cost and size of the controller. dSPACE platform and MATLAB/SIMULINK environment gives powerful tools for teaching and research for electrical machine-drives. Artificial intelligence techniques do not require any mathematical modelling, that is why these techniques are more popular in real time control. All these techniques work well under normal operating conditions. The various approaches available for real time control such as RT real time platform, Rapid Control Prototyping (RCP) and Hardware in the Loop Simulation (HIL) of the electrical machine drives have been discussed elaborately. At present most of the electric drive have been controlled using dSPACE. Therefore, a review report on microcontrollers, DSPs, FPGAs and dSPACE are also discussed in detail. The real time simulation allows for physical controller to be simulated system so that it performance can be evaluated. Once the controller is designed in MATLAB/SIMULINK, it can be physically implemented using the rapid control prototyping of the dSPACE platform. The various approaches available for real time control such as RT real time platform, Rapid Control Prototyping (RCP) and Hardware in the Loop Simulation (HIL) of the electrical machine drives have been discussed systematically. HIL simulation is a valuable technique that has been used for decades in the development and testing of complex systems such as missiles, aircraft, and spacecraft. By taking advantage of low-cost, high-powered computers and I/O devices, the advantages of HIL simulation can be realized by a much broader range of system developers. As modern engineering becoming more complex and costlier, simulation technologies are becoming increasingly crucial to their success. An attempt is made to provide quick references for the researcher, practising engineers and academicians those are working in the area of the real time control.

REFERENCES

[1] C. Dufour, C. Andrade and J. Bélanger, "Real-time simulation technologies in education: a link to modern engineering methods and practices," Proc. 11th Int. Conf. on Engineering and Technology Edu. (INTERTECH 2010), March 7-10, 2010.

[2] Simon Abourida, Christian Dufour, Jean Bélanger "Real-Time and Hardware-in-the-Loop Simulation of Electric Drives and Power Electronics: Process, problems and solutions," Proc. Int. Conf. on Power Electronics Conference 2005.

[3] Wojciech Grega, Krzysztof Kolek and Andrzej Turnau "Rapid Prototyping Environment for Real Time Control Education," Proc. IEEE Real Time System Education III, 1998, pp 85-92.

[4] J. P. da Costa, Eng. H. T. Câmara, M. Eng. E. G. Carati "A Microprocessor Based Prototype for Electrical Machines Control Using PWM Modulation," Proc. IEEE Int. Symposium on Industrial Electronics (ISIE 03),09-11 June 2003, Vol 2, pp1083-1088.

[5] Senan M. Bashi, I. Aris and S.H. Hamad "Development of Single Phase Induction Motor Adjustable Speed Control Using M68HC11E-9 Microcontroller," Journal of Applied Sciences 5 (2) 2005, pp-249 -252.

[6] Ned Mohan, William P. Robbins, Paul Imbertson,Tore M. Undeland, Razvan C. Panaitescu, Amit Kumar Jain, Philip Jose, and Todd Begalke "Restructuring of First Courses in Power Electronics and Electric Drives That Integrates Digital Control," Proc. IEEE Transactions on Power Electronics, Vol. 18, No. 1, January 2003, pp 429-437.

[7] Rajesh Kumar, R.A. Gupta, S.V. Bhangale "Microprocessor/Digital Control and Artificial Intelligent Vector Control Techniques For Induction Motor drive: A Review," IETECH Journal of Electrical Analysis, Vol: 2, No: 2, 2008, pp 45-51.

[8] K. H. Low, Heng Wang Michael Yu Wang "On the Development of a Real Time Control System by Using xPC Target: Solution to Robotic System Control," IEEE International Conference on Automation Science and Engineering, August 1 - 2, 2005, pp 345-350.

[9] Sung Su Kim and Sed Jug "Hardware Implementation of a Real Time Neural Network Controller with a DSP and an FPGA," IEEE Int.Conf. on Robotics 8 Automation, April 2004, pp- 4639-4644.

[10] Venkata R. Dinavahi, M. Reza Iravani, and Richard Bonert "Real-Time Digital Simulation of Power Electronic apparatus Interfaced With Digital Controllers," IEEE Tran. on Power Delivery, Vol. 16, No. 4, Oct 2001, pp775-781.

[11] K. Jayalakshmi and V. Ramanarayanan "Real-Time Simulation of Electrical Machines on FPGA Platform," India International Conference on Power Electronics 2006, pp259-263.

[12] N. Praveen Kumar and V.T. Ranganathan "FPGA based digital platform for the control of AC drives," India International Conference on Power Electronics 2006, pp 253-258.

[13] Ahmed Karim Ben Salem, Slim Ben Othman and Slim Ben Saoud "Field Programmable Gate Array -Based System-on-Chip for Real-Time Power Process Control," American Journal of Applied Sciences 7 (1),2010, pp127-139.

[14] Christian Dufour, Vincent Lapointe, Jean Bélanger, Simon Abourida "Hardware-in-the-Loop Closed-Loop Experiments with an FPGA-based Permanent Magnet Synchronous Motor Drive System and a Rapidly Prototyped Controller, IEEE International Symposium on Industrial Electronics(ISIE 2008), pp 2152-2158.

[15] Christian Dufour ,Handy Blanchette, Jean Bélanger "Very-high Speed Control of an FPGA-based Finite-Element-Analysis Permanent Magnet Synchronous Virtual Motor Drive System," 34th Annual Conference of the IEEE Industrial Electronics Society (IECON-08) Nov. 10-13, 2008.

[16] Christian Dufour, Jean Bélanger, Simon Abourida, Vincent Lapointe "FPGA-Based Real-Time Simulation of Finite-Element Analysis Permanent Magnet Synchronous Machine Drives," IEEE Power Electronics Specialists Conference (PESC 2007) 17-21 June, 2007, pp 909 – 915.

[17] Christian Dufour Simon Abourida Jean Bélanger Vincent Lapointe "Real-Time Simulation of Permanent Magnet Motor Drive on FPGA Chip for High-Bandwidth Controller Tests and Validation," IEEE International Symposium on Industrial Electronics 9-13 July 2006,Vol 3, pp 2591 – 2596.

[18] Erkan Duman Hayrettin Can, Erhan Akin "Real Time FPGA Implementation of Induction Machine Model - A Novel Approach", IEEE International Aegean Conference 2007, pp 603-606.

[19] S. Usenmez, R.A. Dilan, M. Dolen, A.B. Koku "Real-Time Hardware-in-the-Loop Simulation of Electrical Machine Systems Using FPGAs", International Conference on Electrical Machines and Systems,ICEMS 2009, pp 1-6.

[20] R. Arulmozhiyaly, K. Baskaran "Implementation of a Fuzzy PI Controller for Speed Control of Induction Motors Using FPGA", Journal of Power Electronics10 (1)(2010), pp65-71.

[21] R.Arulmozhiyal, K. Baskaran, N. Devarajan, J. Kanagaraj "Real time MATLAB Interface for speed control of Induction motor drive using dsPIC 30F4011", International Journal of Computer Applications 1(5)(2010), pp85-90.

[22] B.Subudhi,Anish Kumar A.K , D. Jena "dSPACE implementation of Fuzzy Logic based Vector Control of Induction Motor", IEEE Conference TENCON 2008, pp1-6.

[23] C. Versèle, O.Deblecker, J. Lobry "Implementation of a Vector Control Scheme using dSPACE Material for Teaching Induction Motor Drive and Parameters Identification", International Conference Electrical Machines 2008, pp1-6.

[24] Mohamed Jemli, Hechmi Ben Azza, Moncef Gossa " Real-time implementation of IRFOC for Sine-Phase Induction Motor drive using dSpace DS 1104 control board", Simulation Modeling Practice and Theory ELSEVIER (Jul)17(6)(2009), pp1071-1080.

[25] Ossi Laakkonen, Kimmo Rauma, Hannu Saren, Julius Luukko, Olli Pyrhonen "Electric drive emulator using dSPACE real time platform for VHDL verification",47th IEEE International Midwest Symposium on Circuits and Systems (3) 2004, pp279-82.

[26] Razvan C. Panaitescu,Ned Mohan,William Robbins Philip Jose, Todd Begalke, Chris Heme "An Instructional Laboratory for the Revival of Electric Machines and Drives Courses", IEEE 33rd Annual Conference on Power Electronics Specliest PESC(2) 2002, pp 455- 460.

[27] HU Hao, XU Guoqing, ZHU Yang “Hardware-in-the-loop Simulation of Electric Vehicle Power train System”, Power and Energy Engineering Conference,(APPEEC 2009Asia-Pacific)2009,pp 1-5.

[28] R.Arulmozhiyal, K.Baskaran “ Speed Control of Induction Motor using Fuzzy PI and Optimized using GA”, International Journal of Recent Trends in Engineering 2(5) (2009), pp 43-47.

[29] Nalin Kant Mohanty, Ragnath Muthu, M Senthil Kumaran “ A Survey on Controlled AC Electrical Drives”, International Journal of Electrical and Power Engineering 3(3)(2009), pp175-183.

[30] Simon Abourida, Jean Belanger “Real-Time Platform For The Control Prototyping and Simulation of Power Electronics and Motor Drives”, Proceedings Third International Conference Modeling, Simulation and Applied Optimization 2009, pp1-6.

[31] Fong Mak, Ram Sundaram, Varun Santhaseelan ,Sunil Tandle “Laboratory set-up for Real-Time study of Electric Drives with Integrated Interfaces for Test and Measurement”,38th Annual Fronters Education Conference (FIE)2008), ppT3H-1-T3H-6.

[32] Jean-Nicolas Paquin, Christian Dufour, Jean Bélanger “ A Hardware-In-the-Loop Simulation Platform for Prototyping and Testing of Wind Generator Controllers ”,CIGRÉ Conference Power Systems Winnipeg 2008.

[33] Christian Dufour, Guillaume Dumur, Jean-Nicolas Paquin, Jean Bélanger “A Multi-Core PC-based Simulator for the Hardware-In-the-Loop Testing of Modern Train and Ship Traction Systems ” 13th Power Electronics and Motion Control Conference (EPE PEMC) 2008, pp1475-1481.

[34] A.Bouscayrol “Different types of Hardware-In-the-Loop simulation for electric drives”, IEEE International Symposium Industrial Electronics (ISIE) 2008 pp 2146-2151.

[35] O. A. Mohammed, N. Y. Abed ,S.C. Ganu “Real Time Simulations of Electrical Machine Drives with Hardware-in-the-Loop”, IEEE Power Engineering Society General Meeting 2007, pp 1- 6.

[36] Gustavo G.Parmaand,Venkata Dinavahi “ Real-Time Digital Hardware Simulation of Power Electronics and Drives”, IEEE Tran. Power Delivery 22 (2) (2007), pp1235-1246.

[37] Christian Dufour, Tetsuhiro Ishikawa, Simonc Abourida, JeanBélanger “Modern Hardware-In-the-Loop Simulation Technology for Fuel Cell Hybrid Electric Vehicles”,IEEE Vehicle Power and Population Conference 2007 ,pp 432-439.

[38] Christian Dufour, Jean-NicolasPaquin,VincentLapointe, JeanBélanger, LoicSchoen “PC-Cluster-Based Real-Time Simulation of an 8-Synchronous Machine network with HVDC link using RT-LAB and Test Drive”,7th International Conference Power Systems Transients (IPST07) 2007.

[39] Christian Dufour,Jean Bélanger “Real-Time Simulation of Fuel Cell Hybrid Electric Vehicles”, International Symposium on Power Electronics, Electrical Drives, Automation and Motion SPEEDAM 2006, pp 69-75.

[40] Simon Abourida, Christian Dufour, Jean Bélanger, Takashi Yamada, Tomoyuki Arasawa “ Hardware-In-the-Loop Simulation of Finite-Element Based Motor Drives with RT-LAB and JMAG ”, IEEE International Symposium Industrial Electronics 2006 ,pp 2462-2466.

[41] Moon Ho Kang, Yoon Chang Park “A Real-Time Control Platform for Rapid Prototyping of Induction Motor Vector Control ”,Springer l (88) (6) (2006), pp 473-483.

[42]Masaya Harakawa, Hisanori Yamasaki, Tetsuaki Nagano, Simon Abourida, Christian Dufour,Jean Bélanger “Real-Time Simulation of a Complete PMSM Drive at 10 µs Time Step”, International Power Electronics Conference(IPEC)2005.

[43] Christian Dufour, Simon Abourida, Jean Belanger “ Hardware-In-the-Loop Simulation of Power Drives with RT-LAB”, International Conference Power Electronics and Drives Systems (PEDS) 2005(2) 2005 , pp 1646-1651.

[44] Christian Dufour, Jean Bélanger, Tetsuhiro Ishikawa, Kousuke Uemura “Advances in Real-Time Simulation of Fuel Cell Hybrid Electric Vehicles”**,** Proceedings 21st Electric Vehicle Symposium (EVS-21) 2005, pp1-12.

[45] C.Dufour, S. Abourida, Girish Nanjundaiah, JeanBélanger “RT-LAB Real Time Simulation of Electric Drives and Systems ”,National Power Electronics Conference (NPEC) 2005.

[46] Roger Champagne, Louis-A Dessaint, Handy Fortin-Blanchette, Gilbert Sybille “Analysis and Validation of a Real-Time AC Drive Simulator ”,IEEE Trans. Power Electronics 19(2)(2004) , pp 336-345.

[47] Christian Dufour, Jean Bélanger “A PC-Based Real-Time Parallel Simulator of Electric Systems and Drives” ,International Conference Parallel Computing in Electrical Engineering (PARELEC’04)2004, pp105–113.

[48] Christian Dufour, Simon Abourida, Jean Bélanger " Real-Time Simulation of Electrical Vehicle Motor Drives on a PC Cluster",10th European Conference Power Electronics and Applications EPE)2003.

[49] Simon Abourida, Christian Dufour, Jean Bélanger;Vincent Lapointe "Real-Time, PC-Based Simulator of Electric Systems and Drives", International Conference Power Systems Transients (IPST) 2003, pp1-6.

[50] Christian Dufour, Simon Abourida, Jean Bélanger "Real-Time Simulation of Induction Motor IGBT drive on a PC-Cluster", International Conference Power Systems Transients (IPST) 2003, pp 1-6.

[51] Artur Krukowski,Izzet Kale "Simulink/Matlab-to-VHDL Route for Full-Custom/FPGA Rapid Prototyping of DSP Algorithms", Matlab DSP Conference (DSP'99)1999, pp 1-10.

[52] Surekha P,S.Sumathi "A Survey of Computational Intelligence Techniques in Industrial Applications", International Journal of Advanced Engineering & Applications, (2010), pp177-183.

[53] Panayiotis S. Shiakolas, and Damrongrit Piyabongkarn " Development of a Real-Time Digital Control System With a Hardware-in-the-Loop Magnetic Levitation Device for Reinforcement of Controls Education" IEEE Transactions On Education, Vol. 46, No. 1, February 2003,PP 79-87.

[54] Simon Abourida, Christian Dufour, Jean Bélanger, Vincent Lapointe "Real-Time, PC-Based Simulator of Electric Systems and Drives" International Conference on Power Systems Transients – IPST 2003 ,pp 1-6.

[55] Christian Dufour, Simon Abourida, Jean Bélanger "Real-time simulation of induction motor IGBT drive on a PC-cluster" International Conference on Power Systems Transients – IPST 2003, pp 1-6.

[56] Ali Keyhani, ,Mohammad N. Marwali,Lauis E. Higuera, Geeta Athalye,and Gerald Baumgartner, "An Integrated Virtual Learning System for the Development of Motor Drive Systems" IEEE Transactions On Power Systems, Vol. 17, No. 1, February 2002 ,pp 1-6.

[57] Thomas M. Jahns,, and Edward L. Owen "AC Adjustable-Speed Drives at the Millennium: How Did We Get Here?" IEEE Transactions On Power Electronics, Vol. 16, No. 1, January 2001 ,pp 17-25.

[58] Ch. Salzmann, D. Gillet, And P. Huguenin "Introduction to Real-time Control using LabVIEW with an Application to Distance Learning " International Journal of Engineering Education Ed. Vol. 16, No. 2, 2000,pp 252- 272.

[59] Jun Li Peter H. Feiler "Impact Analysis in Real-time Control Systems" IEEE International Conference on Software Maintance (ICSM-99) Proceedings 30 Aug -3 Sept 1999 ,pp 443-452.

[60] P. Vas "Electrical Machines And Drives: Present And Future" Electro technical Conference, 1996. MELECON '96., 8th Mediterranean 13-16 May 1996 vol.1 ,pp 67 – 74.

[61]S.M. Gadoue, D. Giaouris, J.W. Finch "Artificial intelligence-based speed control of DTC induction motor drives—A comparative study" ELSEVIER Electric Power Systems Research, Vol -79,Issuse-1 ,Jan 2009), pp210–219.

[62] C. Versèle, O. Deblecker and J. Lobry "Implementation of a Vector Control Scheme using dSPACE Material for Teaching Induction Motor Drive and Parameters Identification" International Conference on Electrical Machines 2008,pp 1-6.

[63] K. H. Low, Heng Wang Michael Yu Wang "On the Development of a Real Time Control System by Using xPC Target: Solution to Robotic System Control" IEEE International Conference on Automation Science and Engineering Edmonton, Canada, August 1 & 2, 2005 ,pp 345-350.

[64] P. Vas "Electrical Machines And Drives: Present And Future" Electrotechnical Conference, 1996. MELECON '96., 8th Mediterranean 13-16 May 1996 vol.1 ,pp 67 – 74.

[65] Narpat Singh Gehlot and Pablo Javier Alsina "A Discrete Model Of Induction Motors For Real-Time Control Applications" IEEE Transactions On Industrial Electronics, Vol. 40, No. **3,** June 1993 pp 317-325.

[66] Fiorenzo Filippetti, Giovanni Franceschini, Carla Tassoni, and Peter Vas, "AI Techniques in Induction Machines Diagnosis" IEEE Transactions On Industry Applications, Vol. 34, No. 1, January/February 1998 ,pp 98-108.

[67] Jianxin Tang **"**Real-Time DC Motor Control Using the MATLAB Interfaced TMS320C31 Digital Signal Processing Starter Kit (DSK)**"** IEEE International Conference on Power Electronics and Drive Systems, PEDS'99, July 1999, Hong Kong, pp 321-326.

[68] Panayiotis S. Shiakolas, and Damrongrit Piyabongkarn " Development of a Real-Time Digital Control System With a Hardware-in-the-Loop Magnetic Levitation Device for Reinforcement of Controls Education" IEEE Transactions On Education, Vol. 46, No. 1, February 2003,pp 79-87.

[69] Christian Dufour, Jean Bélanger, Simon Abourida "Real-Time Simulation of Onboard Generation and Distribution Power Systems" 8th International Conference on Modeling and Simulation of electrical Machine, Converters and Systems, (ELECTRIMACS 2005), April 17-20, 2005,.

[70] Besir Dandil ,Muammer Gokbulut Fikrat Ata " A PI Type Fuzzy –Neural Controller for Induction Motor Drives" Journal of Applied Sciences 5(7) 2005,pp 1286-1291.

[71] Masaya Harakawa, Hisanori Yamasaki, Tetsuaki NaganoSimon Abourida, Christian Dufour, Jean Bélanger " Real-Time Simulation of a Complete PMSM Drive at 10 µs Time Step" International Power Electronics Conference, Niigata, Japan (IPEC-Niigata 2005).

[72] J.P.Zhao,J.Liu "Modeling, Simulation and Hardware Implementation of an Effective Induction Motor Controller" International Conference on Computer Modeling and Simulation ICCMS 2009, 20-22 Feb. 2009,pp 136 – 140

[73] Jean-Nicolas Paquin, Christian Dufour, Jean Bélanger "A Hardware-In-the-Loop Simulation Platform for Prototyping and Testing of Wind Generator Controllers" CIGRÉ Canada Conference on Power Systems Winnipeg, October 19-21, 2008.

[74] Christian Dufour, Guillaume Dumur, Jean-Nicolas Paquin, Jean Bélanger "A Multi-Core PC-based Simulator for the Hardware-In-the-Loop Testing of Modern Train and Ship Traction Systems" 13th Power Electronics and Motion Control Confrenece EPE PEMC 2008 1-3 Sept 2008 ,pp 1475-1481.

[75] Christof Zwyssig, Simon D. Round, , and Johann W. Kolar"An Ultrahigh-Speed, Low Power Electrical Drive System" IEEE Transactions On Industrial Electronics, Vol. 55, No. 2, February 2008,pp 577-585.

[76] Artur KRUKOWSKI and Izzet KALE "Simulink/Matlab-to-VHDL Route for Full-Custom/FPGA RapidPrototyping of DSP Algorithms**"** Matlab DSP Conference (DSP'99), Tampere, Finland, 16-17 November 1999,pp 1-10.

[77] Ion Boldea"Control Issues In Adjustable Speed Drives"IEEE Industrial Electronics Magazine Sept 2008 ,pp-32-50.

[78] A. Bouscayrol "Different types of Hardware-In-the-Loop simulation for electric drives"IEEE International Symposium on Industrial Electronics (ISIE 2008) June 30 2008 July 2 2008,pp 2146 – 2151.

[79] O. A. Mohammed,N. Y. Abed, , and S.C. Ganu "Real–Time Simulations of Electrical Machine Drives with Hardware-in-the-Loop" IEEE Power Engineering Society General Meeting, 24-28 June 2007, pp 1- 6.

[80] Gustavo G. Parma*,* , and Venkata Dinavahi Real-Time Digital Hardware Simulation of Power Electronics and Drives" IEEE Transactions On Power Delivery, Vol. 22, No. 2, April 2007, pp 1235-1246.

[81] Christian Dufour, Tetsuhiro Ishikawa, Simon, Abourida, Jean Bélanger "Modern Hardware-In-the-Loop Simulation Technology for Fuel Cell Hybrid Electric Vehicles" IEEE Vehicle Power and Population Conference 2007 9-12 Sept 2007, pp 432-439.

[82]Christian Dufour, Jean-Nicolas Paquin, Vincent Lapointe, Jean Bélanger, Loic Schoen "PC-Cluster-Based Real-Time Simulation of an 8-Synchronous Machine network with HVDC link using RT-LAB and Test Drive" 7th International Conference on Power Systems Transients (IPST '07), Lyon, France June 4-7, 2007.

[83] Christian Dufour , Jean Bélanger "Real-Time Simulation of Fuel Cell Hybrid Electric Vehicles" International Symposium on Power Electronics,Electrical Drives, Automation and Motion SPEEDAM 2006, pp 69-75.

[84] Simon Abourida, Christian Dufour, Jean Bélanger Takashi Yamada, Tomoyuki Arasawa Hardware-In-the-Loop Simulation of Finite-ElementBased Motor Drives with RT-LAB and JMAG" IEEE International Symposism on Industrial Electronics 2006 9-13 July 2006, pp 2462-2466.

[85] Moon Ho Kang · Yoon Chang Park "A Real-time control platform for rapid prototyping of induction motor vector control" Springer EE,Vo l 88, l 88,No -6 Aug 2006,pp 473 - 483.

[86] Masaya Harakawa, Hisanori Yamasaki, Tetsuaki NaganoSimon Abourida, Christian Dufour, Jean Bélanger " Real-Time Simulation of a Complete PMSM Drive at 10 µs Time Step" International Power Electronics Conference, Niigata, Japan (IPEC-Niigata 2005)

[87] Christian Dufour, Simon Abourida, Jean Belanger "Hardware-In-the-Loop Simulation of Power Drives with RT-LAB" International Conference on Power Electronics and Drives Systems, 2005. PEDS 2005,Volume: 2, 28-01 Nov. 2005,PP 1646 – 1651.

[88] Christian Dufour, Jean Bélanger, Tetsuhiro Ishikawa ,Kousuke Uemura "Advances in Real-Time Simulation of Fuel Cell Hybrid Electric Vehicles**"** Proceedings of the 21st Electric Vehicle Symposium (EVS-21), April 2-6 2005, Monte Carlo, Monaco ,PP 1-12.

[89] C.Dufour, S. Abourida, Girish Nanjundaiah, JeanBélanger"RT-LAB Real Time Simulation of Electric Drives and Systems" National Power Electronics Conference, NPEC 2005,Indian Institute Of Technology, Kharagpur 721302, December 21-23, 2005.

[90] G. Jackson, U.D. Annakkage, A. M. Gole, D. Lowe, and M.P. McShane "A Real-Time Platform for Teaching Power System Control Design" International Conference on Power Systems Transients (IPST05) in Montreal, Canada on June 19-23, 2005.

[91] Roger Champagne, Louis-A. Dessaint, Handy Fortin-Blanchette, and Gilbert Sybille "Analysis and Validation of a Real-Time AC Drive Simulator" IEEE Transactions On Power Electronics, Vol. 19, No. 2, March 2004,PP 336-345.

[92] Christian Dufour, Jean Bélanger "A PC-Based Real-Time Parallel Simulator of Electric Systems And Drives" International Conference on Parallel Computing in Electrical Engineering (PARELEC'04) 2004 IEEE Computer Society PP-105 – 113.

[93] Marius Marcu, Ilie Utu, Leon Pana, Maria Orban **"** Computer Simulation of Real Time identification For Induction Motor Drives" International Conference on Theory and Applications of Mathematics and Informatics ICTAMI 2004, Thessaloniki, Greece,PP 295-305.

[94] Christian Dufour, Simon Abourida, Jean Bélanger "Real-Time Simulation of Electrical Vehicle Motor Drives on a PC Cluster"10th European Conference on Power Electronics and Applications (EPE-2003), Sept. 2-4, 2003, Toulouse, France.

[95] M. Ouhrouche, R. Beguenane , A.M. Trzynadlowski , J.S. Thongam and M. Dube-Dallaire "A PC-Cluster Based Fully Digital Real-Time Simulation of A Field Oriented Speed Controller for An Induction Motor**"** International Journal of Modeling and Simulation Dec 2003,PP 1-25.

[95] S.M. Gadoue, D. Giaouris, J.W. Finch, "Artificial intelligence-based speed control of DTC induction motor drives—A comparative study", ELSEVIER Electric Power Systems Research (Jan)79(1)(2009), pp 210–219**.**

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