

Computer Controlled Up-to-Date Experimental Equipment for AC Drive Development

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Abstract: The paper deals with experimental equipment designed as research and development tool for AC electrical drives. The hardware and software structure of the rig is described. The motor of the drive under test is loaded by another machine working in four-quadrant torque mode. The machines are fed by static frequency converters controlled from PC via a DS1104 card. There are presented the steps carried through in implementation of a constant Volt/Hertz procedure based induction motor drive: simulation in Simulink environment, definition of the sampling unit, measurement- and protection unit and the implementation of virtual control panel. Experimental results are also included.

Keywords: AC drives, simulation, induction machine, static frequency converter, control unit, protections, development environment

1 Introduction

Latest technological advances impose new challenge in research, design and development of electrical drives. Progresses in computer science permit intensive use of simulations as tool to get information about the dynamic and static behaviour of the system before its physical realisation.

The widespread simulation environment – the Matlab Simulink – is frequently used also in study of electrical drives. The Simulink, by using of the Real Time Interface (RTI) is capable to link the simulation files to the real world, namely is possible to connect the variables of simulation structure to physical input-output units, (analog to digital- and digital analog inverters, digital in/outs etc). Using appropriate hardware it is possible to generate code, (executed on the target processor) based on simulation structure. In this way the time-consuming programming can be avoided and results a very powerful and efficient

development procedure. This approach was used by dSPACE in design of its DS series of controller cards, dedicated for real time control of fast processes like electrical drives. The DS1104 card contains all necessary peripherals and computing power (offered by a PowerPC master-processor and TMS320F240 slave-DSP) for implementation of complex drives structures. The software associated to the card provides the control for the implementation process from simulation up to real time experiment.

2 The Hardware of the Experimental Equipment

The experimental equipment presented in this paper, dedicated for research and development of AC electrical drives, is based on above-mentioned DS1104 controller card. Fig. 1 shows the structure of the equipment.

The experimental set-up is composed of an induction machine (IM) under test (SIEMENS Cage motor Type 1LA7-4AA10). It is supplied by a modified industrial DANFOSS inverter (Type VLT5004) controlled by a PC via a dSPACE DS1104 controller card [3].

The motor (IM) of the tested drive is loaded on the shaft with a permanent magnet synchronous motor (PMSM). Optionally a torque transducer may be also coupled on the shaft. The PMSM is fed also by a static frequency converter.

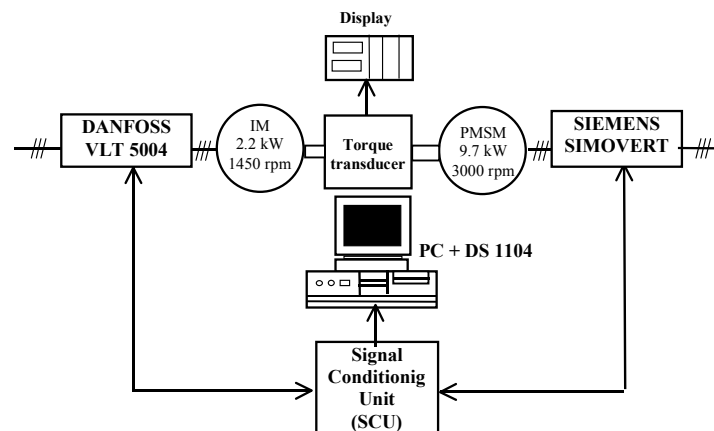


Figure 1
The block schema of the equipment for AC drives development

A Signal Conditioning Unit (SCU) provides the galvanic isolation and adaptation of the measured and control signals.

The DS1104 controller card is placed into the PCI slot of the personal computer (PII/800MHz)

The motor currents are measured using LEM transducers.

2.1 The Structure of the Tested Drive

The drive under test is fed by a modified DANFOSS VLT 5004 static frequency converter. Its original front panel was replaced by an Interface and Protection Card (IPC) developed especial for this purpose [7], [8]. This card provides the hardware protection functions (over-current, over-temperature) and passes also the control function of the static frequency converter to the DS1104. The signals generated by the controller card (the PWM outputs, named in Fig. 2 as UP,UN,VP,VN,WP,WN for inverters IGBTs, the BR for the IGBT which is active in braking mode, and a general enable signal EN) are transmitted to the IPC using optical fibres droved by OPTI VLT unit of the SCU (Fig. 2). The optical signal transmission guarantees an insensibility to the electromagnetic perturbations. The received signals are buffered and transformed in a CPLD circuit according to requirements of VLT5004. The same circuit processes the signals provided by the hardware protection and inhibits the control of the inverter. By pushing the RESET button of the IPC the operation of the inverter is again enabled. The MANUAL TRIP button serves to inhibit the operation of the inverter. It is useful when the control of the system is lost.

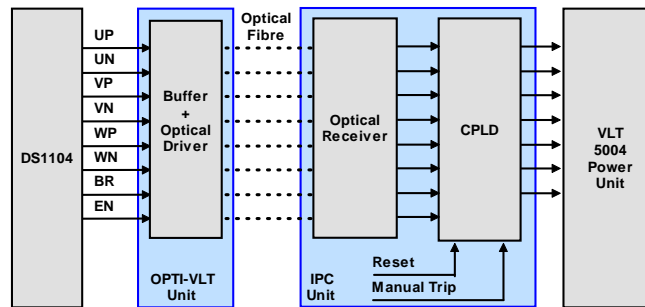


Figure 2

Generation of the inverter control signals

2.2 The Structure of the Mechanical Loading

The PMSM provides the mechanical loading of the tested drive. It is controlled by the SIMOVERT MC DRIVE system [10]. The „add-on” cards of the system fulfil the interfacing functions. The SBM card process the resolver signals and emulates the signals of an encoder (A+, A-, B+, B-, N+, N-). The CMCU card provides the digital and analog input and output functions. The torque of the PMSM is controlled in closed-loop by the VECON control strategy running on the processor of the SIMOVERT system. The reference signal of the loop (TQ-REF) is generated on the DS1104 analog output. The actual torque (TQ-ACT) is computed

and available on the analog output of the CUCM card. The torque signals are transmitted via a galvanic separation unit ISO-SIMO (Fig. 3).

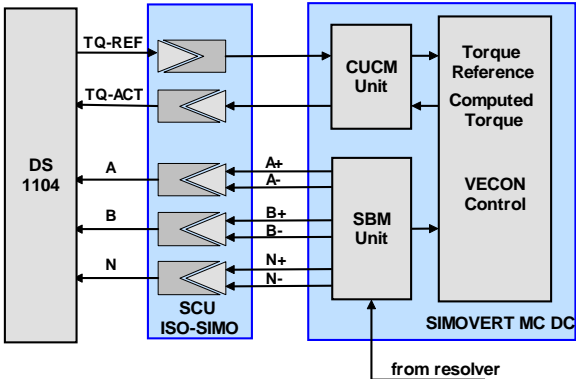


Figure 3

Connections of SIMOVERT MC drive system to the DS1104 controller card

The software of the SIMOVERT MC system has a modular structure. The configuration of the system according to the application is performed by appropriate connection of the software modules [10]. This procedure is known as “parameterization” and can be executed from the local control panel of the system or from a PC using serial communication. In this application the last one is used. It is supported by the SIMOVIS software [11].

2.3 The Signal Conditioning Unit (SCU)

The SCU transmits the signals provided by different parts of the system to the controller card [7]. It performs also the conditioning and galvanic isolation of the transmitted signals. The SCU is composed by some electronic cards placed in a rack. The OPTI-VLT card contains the optical fibre drivers of the PWM signals and displays their logic states. The ISO-SIMO card carries out the galvanic isolation of the digital signals (emulated encoder outputs) and of the analog signals (representing the torque reference and actual torque) to and from SIMOVERT system. The LEM-ADC card adapts the current transducer signals. The LEM-U card performs the measurement of the DC link voltage.

2.4 Control System of the Equipment

All subsystems of the experimental equipment are controlled from the PC via the DS1104 controller card. The MPC8240 PowerPC 603e processor and TMS320F240 DSP on the card provide the computing power necessary for real time control tasks.

The card contains also all required peripherals (ADC, DAC, counters/timers, PWM etc.). The communication between the processors and peripherals has place on the internal 24 bit wide bus. An efficient interrupt system enhances the performances of the card.

The powerful software environment supports all phases of the development of an application from the simulation to physical measurements. Due to the Matlab-Simulink compatibility the simulation files may be completed with RTI elements realising in this way the connection to the hardware. The resulted Simulink structures are compiled automatically yielding the real time program code executable on the controller card's processors. The variables of the application may be traced and saved for future processing [4], [5].

The Control Desk software package supports all activities related to DS1104 card based real time control [9]. In the sense of the Control Desk the "application" means the executable simulation file developed for a given scope. (in case of the Simulink they are the *.mdl files). The "experiment" means all files derived from an application (description files, virtual control panel file, data files, extern files, etc.).

3 Implementing the Drive Structures

The implementation of a drive structure on DS1104 based experimental equipment is performed going through the following steps:

- Creation the working simulation model of the desired drive structure (under Simulink), its extension with RTI blocks;
- Defining of the sampling unit;
- Implementation of the software measuring, protection and command subsystem;
- Implementation of the virtual control panel.

The resulted structure shown on the Fig. 4 has a general character [7], [8]. To implement different drive systems the measurement, protection and command block and the control structure block must be adapted to the given task. On the figure the block *DS1104SLAVE_PWMINT* represents the RTI block that connects the simulation structure to the real PWM interrupt of the DS1104 card.

3.1 Defining the Sampling Unit

In case of the PWM inverter fed motor drives (most of the modern electrical drive are of this type) it is suitable to synchronize the control strategy computation and data acquisition with PWM clock-frequency. This is easy to perform on DS1104 controller card based systems, where the slave processor accomplishes the PWM.

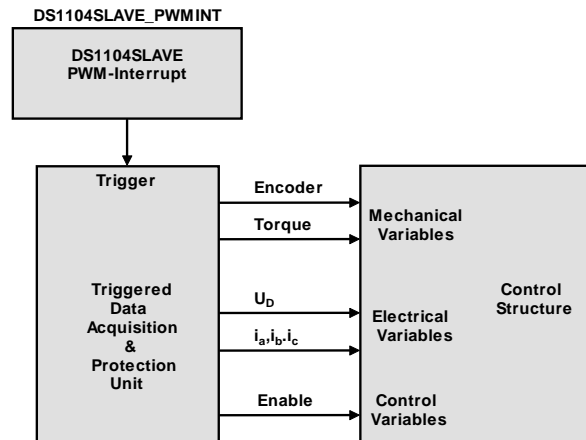


Figure 4
Structure of an implemented drive system

Therefore the TMS320F240 DSP will generate an interrupt request on middle of every PWM period according to the settings in the *DS1104SLAVE_PWMINT* interrupt management RTI block. The interrupt will trigger the data acquisition and the computing of the control strategy. This is known as “single timer tasking mode”.

3.2 Implementation of the Measuring, Protection and Command subsystem

The measuring, protection and command subsystem is shown on Fig. 5. It has three units:

- *Measuring unit*: takes over the acquisitioned data (stator currents, DC link voltage, mechanical torque, rotor speed) and process them;
- *Protection unit*: inhibits the drive system in case of an over-current, under- or over-voltage in DC link, over-speed. These functions are performed in software;
- *Command unit*: It performs two tasks. It enables or disables the drive system, according to the output of the protection unit and state of the “start” and “stop” buttons of the virtual control panel. Generates the PWM control of the DC-link chopper IGBT.

The “enable” signal controls the whole system. The drive is enabled if the protection unit has not detected an out of range condition and the user has started the system. The enable signal acts on software level enabling the running of the control strategy program, and also on hardware level, enabling the drive of the inverters IGBTs.

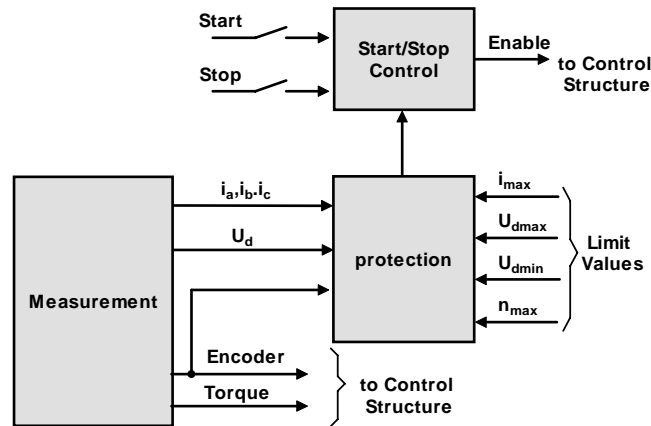


Figure 5

Block schema of the measuring, protection and command subsystem

3.3 The Control Strategy Implementation Subsystem

The implementation of the control system for the electrical drive is based on the Simulink structures.

The Fig. 6 presents the implementation scheme of constant Volt/Hertz scalar control strategy based induction motor drive. In order to compensate the resistive voltage drops, an initial boost-voltage is added to the computed supply voltage according the following relation:

$$U_s = U_{so} + (U_{sN} - U_{so}) \frac{f_s}{f_{sN}} \quad (1)$$

where U_s is the computed stator voltage, U_{s0} the boost-voltage, U_{sN} the rated stator voltage, f_s the actual stator frequency, while f_{sN} is the rated stator frequency [2], [6].

In the Matlab/Simulink environment the voltage computation is made by a common *function*- type block.

The sine-wave generator generates a three-phase system, which will be transformed in duty factors. These will be the control signals of the RTI DS1104SL_DSP_PWM block, which generates the PWM signals. For safety reasons, the duty factor is limited between 0.5% minimum and 99.5% maximum values. The EN enable signal from the control subsystem can also block the PWM signals. If the variation speed of the rated frequency exceeds a certain limit, the rotor will not be able to follow the rated frequency, and will stop. This limitation of the variation speed is made in the presented structure by the „*freq-ramp*” block.

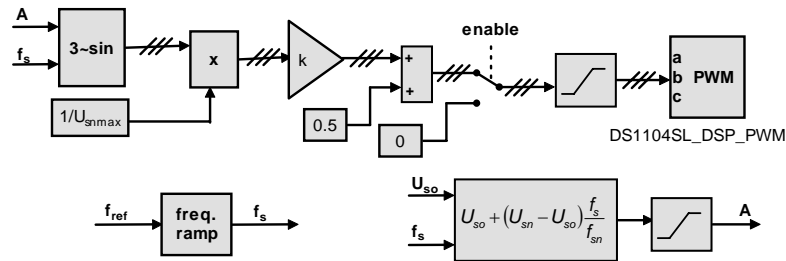


Figure 6
The scheme of the control system

3.4 The Implementation of the Virtual Control Environment

The virtual control environment refers to the development of the virtual control panel, which consist in completion of the following steps:

- placing the data acquisition unit on the workspace;
- placing of the virtual control units on the workspace;
- placing the virtual monitoring units on the workspace;
- parameterisation of the units on the workspace;
- assignment of the variables to the units on the workspace.

The unit, which controls the data acquisition, i.e. the *Control Settings* unit, is a feature of the development system. By means of this unit the user is able to set the: duration of the data acquisition, choosing between single or continuous acquisition, starting and stopping point of the acquisition, the trigger event of the acquisition, the corresponding trigger variable and its value. This acquisition control unit must to be used in every application's virtual control panel. By means of the *control units* (pushbuttons, radio buttons, switches, potentiometers) the user gives instructions and ensures data transfer to the environment. The data monitoring units (LED-s, digital and analog visualization units, $Y-t$ and $Y-X$ plots) offers information on the variations of the variables of the application. The Fig. 7 presents an example of a virtual panel for a specific electrical drive control application.

4 Experimental Results

Fig. 8 shows the evolutions of the most important quantities in case of a no load start. The reference frequency is set to 30 Hz, the frequency ramp to 10 Hz/s, and the voltage boost to 18 V.

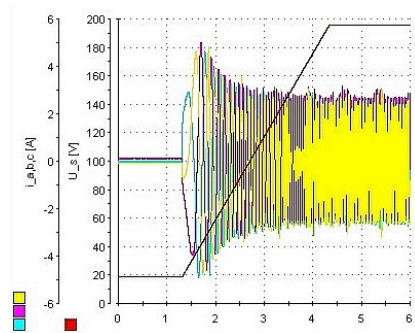


Figure 8a

Stator currents $i_{a,b,c}$ and stator voltage $U_{s,r.m.s.}$ values versus time

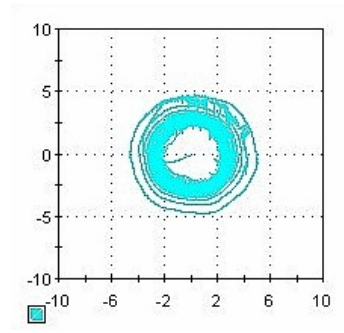


Figure 8b

Stator-current space-phasor trajectory

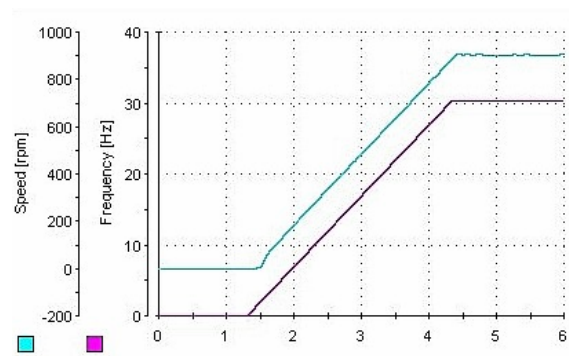


Figure 8c

The reference stator frequency and the measured speed versus time

Conclusions

The built DS1104 controller card based experimental equipment is a very useful tool in research and development of high performance AC electrical drives.

The possibilities to obtain real time executable code by direct compilation of the simulation file save the user from the time consuming programming process.

The data acquisition and evaluation is supported in a very efficient manner.

The galvanic isolations of the signal path provide a good immunity to electromagnetic perturbations.

The implementation is performed going through the following steps:

- Creation the working simulation model of the desired drive structure (under Simulink), and inserting of the RTI blocks;

- Defining of the sampling unit;
- Implementation of the software measuring, protection and command subsystem;
- Implementation of the virtual control panel

The implementation of the structures is accomplished according to the principle “from simple to complex”. This offers the most reliable way regarding the fail-safe operation of the hardware.

The implemented, “constant Volt/Hertz” principle based induction motor drive behaves according to expectations. This confirms the correctness of implementation and of the software-hardware structures.

The elasticity and efficiency of the equipment permits experimental study of the classical- and also of the advanced high complexity drive structures (like sensorless vector-control).

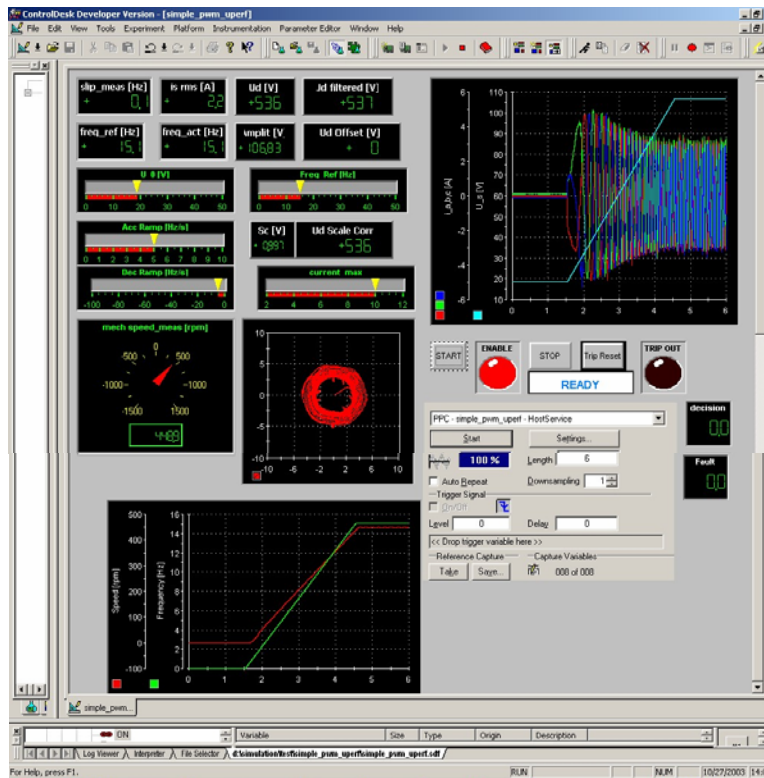


Figure 7
The virtual control panel (start at 15 Hz reference frequency)

The described equipment is also a useful research tool in field of power electronics.

Acknowledgment

The Sapientia Hungarian University of Transylvania supported the development work of the described equipment.

Special thanks to Prof. Frede Blaabjerg and Assoc. Prof. Remus Teodorescu from Institute of Energy Technology, Aalborg University, and to the Danfoss Drives A/S, Denmark, for their generous support.

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