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MODERN LABORATORY TOOLS FOR EXPERIMENTAL RESEARCH IN THE FIELD OF ELECTRIC DRIVES

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Abstract: *The increasing use of power electronics in applications such as variable speed motor drives, renewable energy sources and flexible alternating current transmission systems impose requirement for modern research and test laboratories. In order to increase research capabilities at the Faculty of Technical Sciences and to follow growing trends in this interest area, existing laboratories have been updated and modernized. These laboratories are designed to provide fully practical and hands-on experience in power electronics converter design, their real-time computer based hardware control and DSP control, which can be used to verify and test various conventional and intelligent control methods. Focus of this paper is to describe three recently developed laboratory stations in the Laboratory of Electric Drives. The laboratory stations are equipped with powerful and fast prototyping control devices such are modular dSPACE system based on the DS1006 processor board and DS1104 single-board hardware and also TMS320F28XX DSP development platform. Some results of experimental testing are given also.*

Key words: ***Experimental research, Modern electric drives, dSPACE and DSP control***

1. INTRODUCTION

Power electronics is still expanding technology. The main goal of the power electronics technology is to convert electrical power from one stage to another stage as efficient as possible with a high level of intelligence [1]. The power electronics technology is used in the power converters. Electric drives using power electronic converters and electric machines play a key role in the industry production and transportation sector, where new technologies are utilized. With good ideas and appropriate research it is possible to improve control methods in power converters and electric drives.

In order to follow current trends in a competitive way, from modern device technology to control theory, Laboratories of the Power Electronics and Converters Group of the Faculty of Technical Sciences has been updated and modernized. These laboratories support educational and research activities of the group. In educational area modern set-ups provide students experimental tools for testing and getting practical experience [2, 3]. In research activities that include modelling, simulation and digital control of electrical systems, special importance is put on constructing real prototypes of power electronics devices, special drives or electrical systems.

Laboratory for Electric Drives supports research work in adjustable speed motor drives and multi-phase motor drives. The Laboratory is equipped with test stations, which include power converter modules along with associated instrumentation for experimental evaluation. Various control methods of AC drives can be realized in the laboratory, including real-time implementation to provide experimental verification.

The Power Electronics Laboratory is a modern research facility. Ongoing research is concentrated on constructing multiphase converters, specialized low power industrial inverters, flexible AC transmission system (FACTS) devices (e.g. STATCOM) and specialized power converters for renewable energy sources (RES). State-of-the-Art control software and modern testing methods are developed and tested. It is equipped with the appropriate instrumentation and powerful and fast prototyping control devices for building a real prototype. Power quality analysis and improvement are also investigated in this laboratory. The new field is research in ultra speed real-time power electronics simulators.

The Laboratory for Renewable and Distributed Energy Sources is focused on wind and solar energy conversion to electrical energy. In this laboratory fully controlled model of wind turbine with synchronous generator connected through back-to-back converter to the grid was developed. A complete solar 1 kW power station is assembled with continuous on-line monitoring and distance reading over Internet. Both wind and solar parameters are monitored.

The Laboratory for Testing of Electrical Machines is oriented on developing modern testing methods and results analysis.

In this paper three modern set-ups or laboratory stations from the Laboratory of Electrics Drives will be presented. The laboratory stations are equipped with state of the art Digital Signal Processor (DSP) and dSPACE single and multi boards that provide versatile solutions that support the development and testing of electric systems and electronic control units for electric drives. The paper gives some details of these stations together with some results obtained during experimental research and testing.

2. FLEXIBLE AC DRIVES LABORATORY

In order to follow research trends and to support projects in control of electric drives, in the Laboratory of Electrical Drives flexible approach using dSPACE technology [4, 5] and modern DSP controllers has established. The laboratory has been modernized with several most recent drive systems controlled by dSPACE DS1104 and dSPACE DS1006 controller boards and TMS320F DSPs. The DS1006 board is part of modular hardware concept intended for very complex, large and processing-intensive models.

2.1 AC Drives test platform based on DS1104 single computing board

The experimental setup is composed of two AC machines. Induction test machine (IM) is supplied by inverter (developed at Power Electronics Laboratory) controlled by DS1104 controller card. The induction machine (IM) of the tested drive can be loaded on the shaft with another induction machine or with a permanent magnet (PM) synchronous machine supplied by industrial SIEMENS MASTERDRIVES inverter. The torque of the load machine is controlled in closed loop. Both inverters are connected via DC link and only one is connected to the mains supply. In such configuration breaking resistors are not necessary. Block scheme of the computer controlled laboratory station for AC drives development is presented in Fig. 1. The Fig. 2 presents physical view of the laboratory.

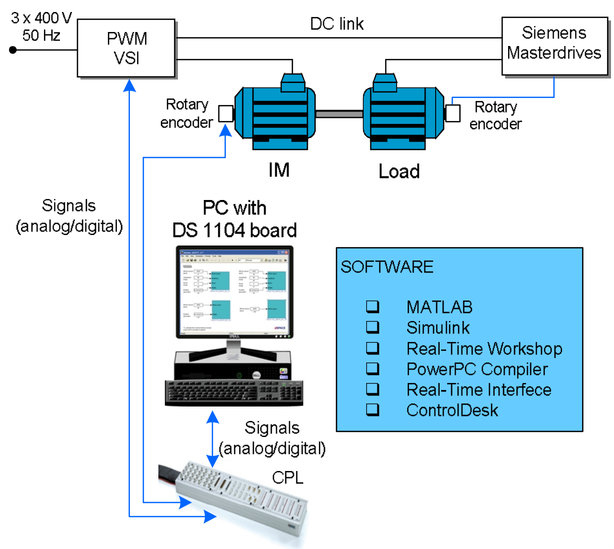

Fig. 1. *Block scheme of the computer controlled laboratory station for AC drives*

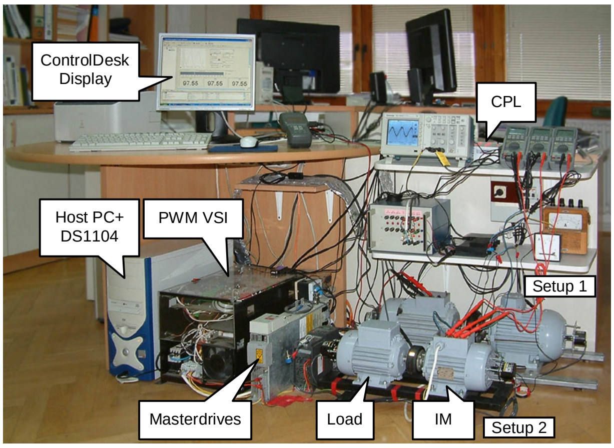

Fig. 2. *AC drives laboratory station – A physical view*

The new AC drive laboratory station featuring the novel concept introduced by dSPACE that allows a full visual block-oriented programming of dynamic real-time systems [6]. All subsystems of the experimental equipment are controlled from the PC via the DS1104 controller card which provides necessary computing power for real time applications. The most relevant features of DS1104 are: MPC8240 PowerPC 603e microprocessor for floating point calculations running at 250 MHz, slave DSP TMS320F240 subsystem, 1x16-bit ADC with mux, 4x12-bit ADC, 8x16-bit DAC, Digital Incremental Encoder Interface (2x24 bit), and 20-bit parallel I/O [4]. The communication between the processors and peripherals has place on the internal bus.

Software development tools support all phases of the development of an AC drive control, from the simulation to real time implementation. Matlab/Simulink is used as the base environment for designing the models and for off-line simulations. The Real Time Interface is used to connect the model to the physical hardware. The Real Time Workshop converts the model to C code. The C code is then automatically compiled to the assembly language of the target processors, assembled, link-edited and downloaded. At last, ControlDesk software is used to run, adjust and monitor the running electric drive.

Some of projects which are realised on this laboratory station deal with: Advanced control of AC drives, Sensorless control of IM drives, Energy efficient control of low cost IM drives, Stand alone self-excited induction generator using PWM-VSI. As a project example, sensorless vector control of IM under parameters variation is presented in Fig. 3 [7].

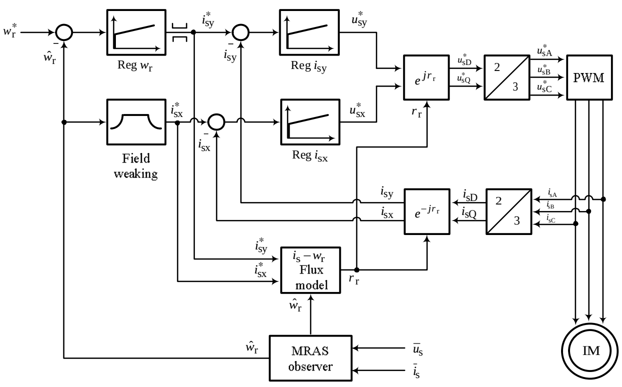

Fig. 3. *Sensorless vector control scheme*

The effects of the stator resistance detuning in MRAS speed estimator is illustrated in Fig. 4, where sensorless vector controlled IM drive was loaded with nominal torque load produced by SIEMENS MASTERDRIVES inverter.

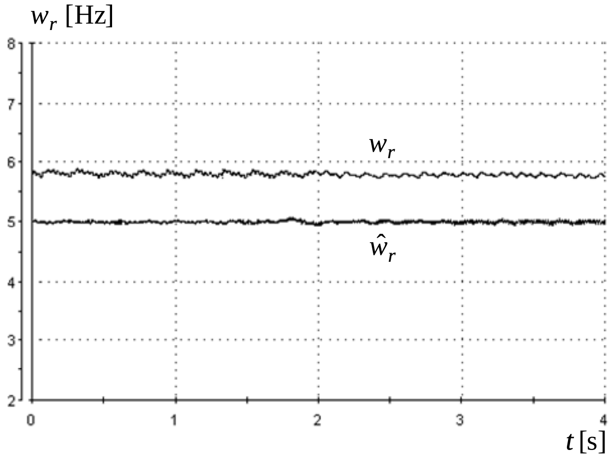

Fig. 4. *Actual ($\hat{w}_r$) and estimated (w_r) electrical rotor speed affected by parameter variation*

2.2 AC drives test platform based on DS1006 computing board

The application areas of electric drives are many and varied. Their control units are complex and versatile. dSPACE prototyping systems provide flexible and model-based development environments. They consist of a dSPACE hardware and software solutions. Using modular dSPACE system, it is possible to design, optimize and test various control strategies of highly complex electric drive systems.

Laboratory of Electrical Drives is recently equipped with modular dSPACE solution. Modular dSPACE prototyping system has the greater performance and flexibility compared to single board system. Such modular dSPACE system, based on up to date DS1006 processor board, has been established and it is part of electric drives test platform (Fig 5).

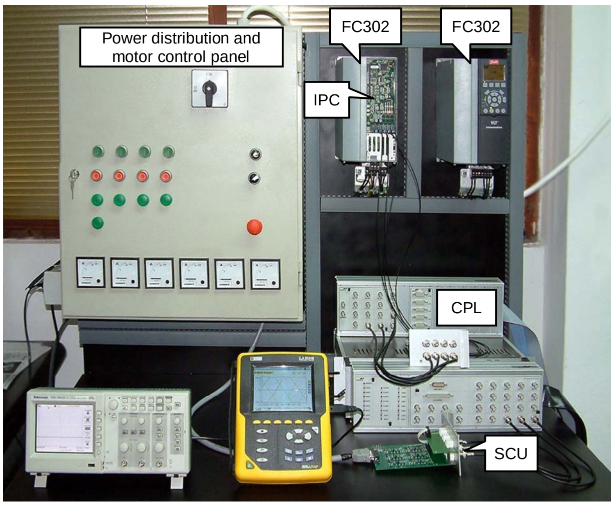

Fig. 5. *AC drives test platform based on DS1006 processor board*

The DS1006 is the ultimate in processor boards for very complex and processing intensive models. The board is built around the 2.6 GHz AMD Opteron 64-bit technology. The DS1006 also has 256 MB local memory for executing real-time models, 128 MB global memory for exchanging data with the host PC and 2 MB on board flash memory [5]. The DS1006 board has installed into a PX expansion box together with DS2201 multi I/O board, DS3001 encoder interface board and DS5101_2 digital PWM waveform output board.

In addition to DS1006 computing board, test platform consists of power distribution and motor control system and two industrial converters Danfoss FC 302, including Signal Conditioning Unit (SCU) that provides the galvanic isolation and conditioning of the measured and control signals. Industrial converters Danfoss FC 302 are modified. Their original control unit were replaced by an Interface and Protection Cards (IPC) developed especial for this purpose at Aalborg University, Denmark. The IPC card provides the hardware protection functions (over-current, over-temperature and over-voltage) and passes the control function of the converter to the DS1006 system in order to have overall control of the system.

Presented test platform (Fig. 4) is designed for advanced regenerative four quadrant AC drives control, multi-phase electric drives control and variable speed wind and hydro turbines with back-to-back topology applications.

2.3 Multi-phase AC drives test platform

The potential advantages of multi-phase electric drives over the conventional three-phase drives have been widely discussed in the literature. In the last few years the volume of research related to these drive systems has been increase at the Faculty of Technical Sciences. The drive system consists of a six-phase inverter (Fig. 5) feeding a six-phase induction machine, which is adequate to develop for high power system with current rating restrictions. Most of the existing work applies to the asymmetrical six-phase machine (two three-phase windings shifted in space by 30° degrees) with two isolated neutral points (Fig. 6).

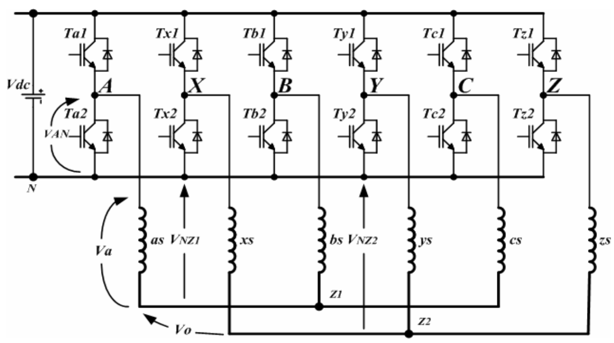

Fig. 6. *Six-phase inverter connected with dual three-phase machine*

Current researches associated with six-phase machines are focussed on PWM methods based on space vector approach for dual three-phase AC drives. The inverter contains a network of 12 power switches arranged in 6 legs, so 2^6 configurations can be obtained. This increases the number the possible PWM strategies [8]. Novel developed techniques simplify problems related to direct DSP implementation (by means of novel switching pattern per sector) and are able to deal with current harmonics generated in double stator induction motor supplied from voltage source inverter (VSI) [9].

As a project example, test rig of six-phase prototype VSI, together with six-phase machines, is illustrated in Fig. 7 Control system is realised using low cost fixed point TMS320F2808 DSP.

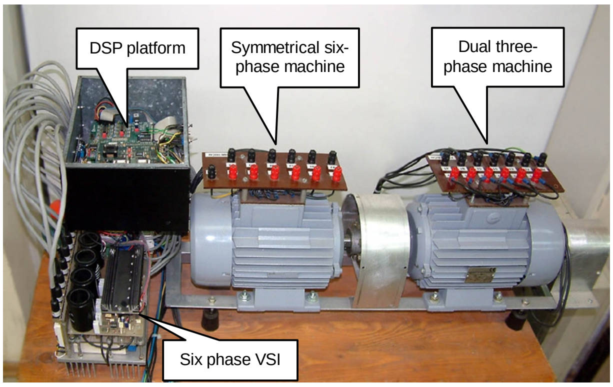

Fig. 7. *Six-phase test rig*

Fig. 8 shows A and X phase currents collected using Texas Instrument’s Code Composer DLOG module. Fig. 9 shows α-β plane current trajectory. It is obvious from Fig. 8 and Fig. 9 that new modulation technique correctly generates phase currents (current vector in α-β plain have circumference trajectory). The technique reduces software and hardware complexity. Good DC bus utilization is retained [9].

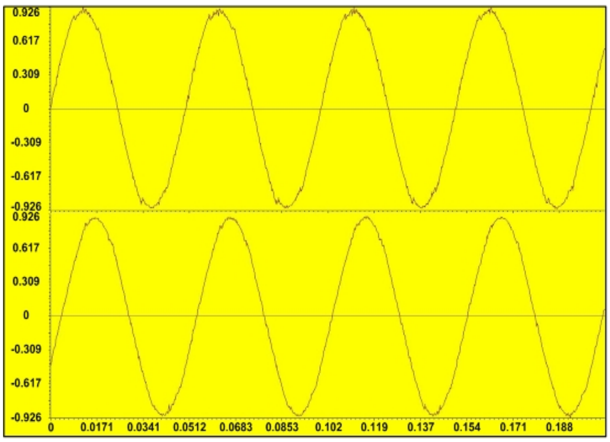

Fig. 8. *A and X phase currents*

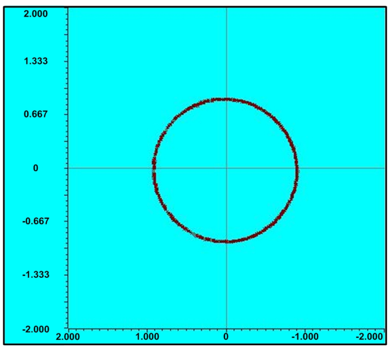

Fig. 9. *α-β current plane trajectory*

2.4 Test stand with SIMOVERT MC converter and AFE rectifier-regenerative feedback unit

Electric drives are occasionally subjected to extreme voltage drops, torque changes or must often deal with frequent changing between driving and braking operation. For that purposes, test platform with SIMOVERT MC converter and active front end (AFE) rectifier, regenerative feedback unit is established. The test platform, shown in Fig. 10, is used both for research purposes as well as for educational purposes.

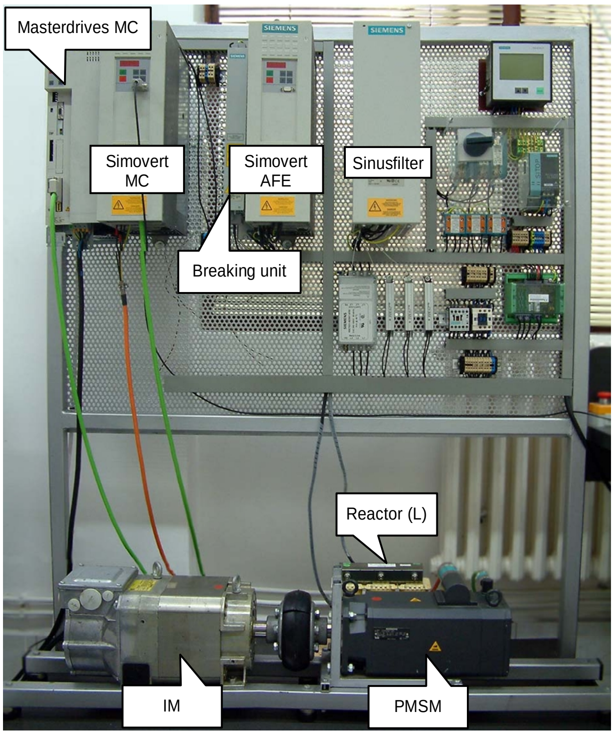

Fig. 10. *Test platform with AFE rectifier-regenerative feedback unit*

This setup is used for grid connection of a permanent magnet (PM) synchronous machine developed for variable speed drives. PM machines have been applied to more demanding applications in electric drives, primarily as the result of low-cost power converters and the improvement of permanent magnet characteristics. In general, modern PM machines are competitive with many types of machines.

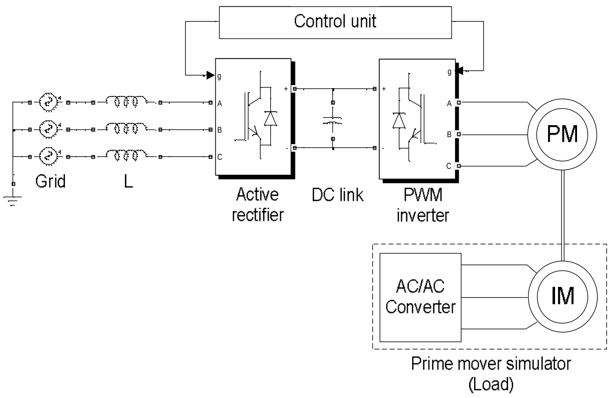

Fig. 11. *Block scheme of the test platform with AFE rectifier-regenerative feedback unit*

The power electronic converter (Fig. 10, Fig. 11) that provides a grid connection for the PM synchronous machine consists of three main modules: the Active Front End (AFE) supply unit, the DC link bus with braking chopper and the Simovert Motion Control inverter connected to the PM synchronous machine. AFE converter operates as step-up controller with a DC link voltage which lies above the peak line supply voltage. For line supplies with significant voltage fluctuations, the DC link voltage level, which can be parameterized, can be kept constant. Important part for the operation of the AFE is the reactor (L) at the grid side connection (one in each supply line). Reactor allows transfer of power from the grid to the DC bus and vice versa (regenerative mode). The Simovert Motion Control inverter which connects the PM synchronous machine to the DC link bus (Fig. 10, Fig. 11) consists of an IGBT bridge inverter and a control unit. The control unit uses vector control algorithm to control the torque and speed of the PM machine (servomotor or generator). An induction machine is also the component of the machine side of the test platform. It is fed by Masterdrives MC AC/AC converter and acts as prime mover simulator or load for PM machine. The torque of the induction machine is controlled in closed loop.

An illustration of electric drive from Fig. 11 in motor mode and regenerative mode is presented in Fig. 12 where measured total active power from supply line is shown.

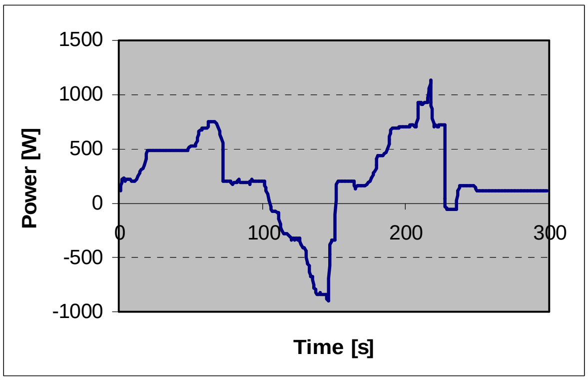

Fig. 12. *Diagram of active power of the tested drive*

The complete test platform can also be used for PM variable speed wind and hydro generators development. Using this configuration it is possible to feed the power into the utility grid whatever the output frequency and voltage of the PM synchronous generator is.

3. CONCLUSION

A set of modern laboratory stations developed at the Power Electronics and Converters Group at the Faculty of Technical Sciences has been established. These stations are used both for research purposes as well as for educational purposes. Using the laboratory equipment, the research activities and analysis of grid-connected power converters and advanced electric drives systems has been greatly facilitated. The modern concept includes control units based on dSPACE technology or application of the most advanced motor controlled DSPs. Besides detailed explanation of the content of the laboratory stations, some results of experimental researches are presented. The results affirm the new approach and shows high research capabilities of such designed stations.

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