COMPUTER SUPPORTED EDUCATION
FOR INDUSTRIAL MECHATRONICS SYSTEMS

Viliam Fedák, Ján Fetyko, Martin Repiščák

ABSTRACT

The paper introduces a concept for utilisation of ICT in teaching of subjects from field of mechatronics, namely mechatronics of production systems that in our case are represented by industrial production lines processing continuous strip materials. These production lines occur in various areas of industry, e.g. paper making machines (paper strip), rolling mills (steel strip), and production lines in chemical industry (plastic material), etc. Such systems are rather complex and their explanation using multimedia is extremely suitable and visible. What is to be explained in the modules: principle of setting up mathematical models of the mechanical subsystems, electrical equipment (electrical machines, electrical drives, and power electronics converters) of production machines, and finally, control systems with implemented control algorithms (up to the artificial intelligence algorithms). In detail there are presented two modules – one form field of setting up mathematical models of mechanical subsystems and the second one from field of production lines. The topics of the modules deal with generalisation of basic principles of the real existing production and finishing lines whose study usually requires practical trainings in industry.

KEYWORDS

Mechatronics, production lines, electrical drives, interactive animations

INTRODUCTION – MECHATRONICS APPROACH

The term of “mechatronics” is known for several decades and the study branch itself started to develop in 70ies of the last century. In its substance *the mechatronics* presents an interconnection of three difference branches: mechanical engineering, electrical engineering and information systems with automation. The mechatronics system presents a complex system consisting of three different kinds of mutually co-operating subsystems: electrical, mechanical and information ones. Behaviour and operation of the mechatronics system is complicated and its understanding requires deep knowledge from all three fields. Due to presented complication, teaching of subjects from field of mechatronics requires *considerable imagination* not only at explanation of physical nature of the phenomena or operation of the apparatus but also at analysis of their behaviour where subsystems at operation are mutually influenced. Complicated phenomena cannot be explained using static pictures or by words. Introduction of e-learning methods into teaching and learning of mechatronics contributed not only to make studying easier but it enabled to perform various analyses of virtual mechatronics systems enabled (i.e. small experiments).

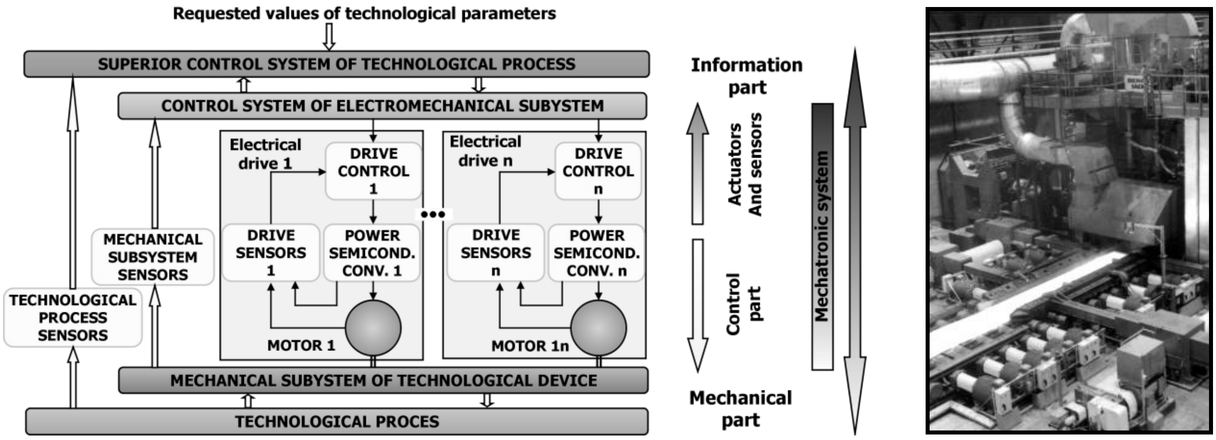
In the contribution we introduce the new curriculum on large mechatronics industrial systems that was recently introduced at the Technical University of Kosice. In field of mechatronics this is rather special curriculum and it is enough demanding field of study. To support the learning we are developing the whole series of e-learning modules with interactive features according to the Weiss, H. et all (2004) and utilising interactive simulations, like pointed out in Zacharia, C.Z., (2003). The built-in interactive simulations are based on the Simulation Programme Caspoc (www.caspoc.com). The most important results are presented although the written paper cannot give a full view on the realised interactivity.

STARTING - MECHATRONICS CURRICULUM

Mechatronics for Production Systems

Mechatronics presents an interdisplinary branch of study dealing with computer controlled electromechanical systems that are marked out by interactions of subsystems, by transformations of one energy from into another, one and by precise motion control realised by real-time microprocessor controlled systems with implemented complex algorithms, up to artificial intelligence features.

Mechatronics itself is a wide science covering many field of human activity. In our sense (coming up from the needs of local industry) we deal with mechatronics of production lines. These are marked out by continuously moving strip of material (from steel, paper, plastic, rubber, etc.) with principal structure shown in Figure 2a. Here we can see the whole spectrum of which mechatronics deals with – starting from basic knowledge of production technology (at the bottom of the figure), technological equipment, multi-motor drive system quipped by individually controlled drives (including power semiconductor converters and sensors of various kinds) up to control system (top of the figure).
One can see all features of the mechatronics system of such (industrial) kind where the mechanical, electrical and information parts are clearly distinguished.



a) b)

Figure 1. Production line with continuous moving strip as an example of a mechatronics system
a) Structure, b) Real line (hot rolling mill)

The Curriculum of Mechatronics Study Programme

We have designed the curriculum of mechatronics study programme in such a way that it takes into consideration current needs and expected trends of industry development not only in local region but also in a wider context – in European area. The graduates get basic knowledge from all three fields of mechatronics with specialisation to large industrial mechatronics systems.
The wide spectrum of key subjects to be study in the Bc. and MSc. degrees study programmes of mechatronics follows up from Figure 1 (the details are reported in [1]).
The programme is oriented towards development of creative thinking, widening of theoretical fundamentals and development of experiences and practical skills.

Let’s briefly mention expected knowledge of a graduate from the accredited Bc. study programme *Informatic and Control Systems in Mechatronics* and appropriate fields of study to get the knowledge.

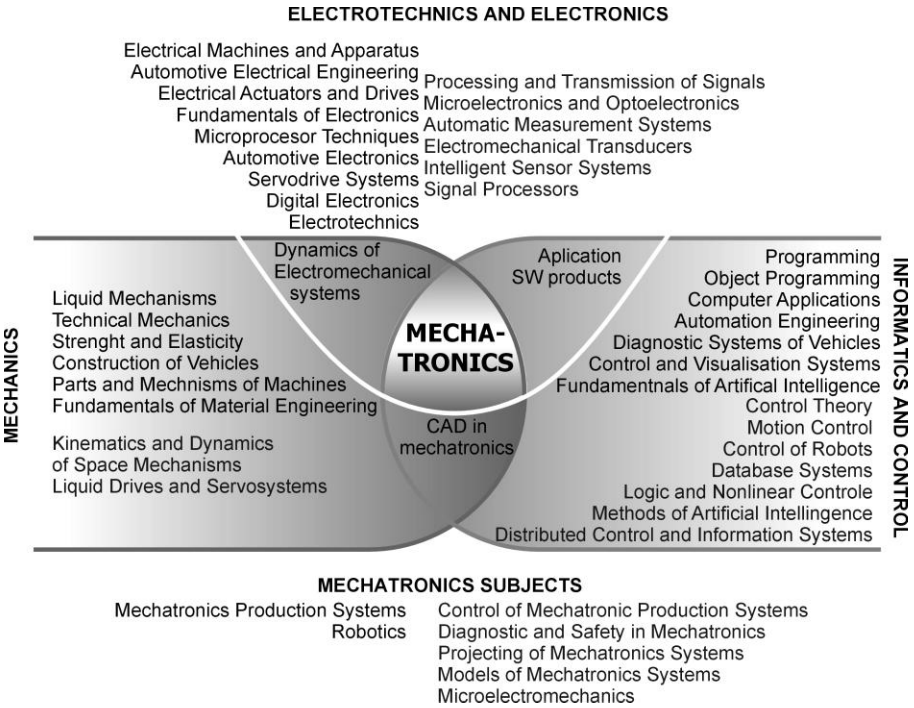


Figure 2. Overview about subjects in the considered field of study
(the subjects in BC. Degree programme are on the left/upper part marked,
in the MSc. programme at the right/bottom)

Table 1. Range of knowledge and ways to get them of a graduate in Mechatronics

The graduate should be able:	What to learn?
• to understand operation of basic mechanic systems	• basic laws of mechanics (in static and dynamic states)
• to master knowledge about mechanic and electronic components and modules	• properties of mechanic and electric components and their interconnection into subsystems
• to adopt knowledge from control theory and informatics to the mechatronics systems	• control theory and selected chapter form informatics
• to solve problems of realisation of mechatronics systems	• to design projects, to solve practical tasks,.

The continuing MSc. programme in Mechatronics, titled *Control of Mechatronics Systems*, presents a continuation of getting knowledge from all areas of mechatronics at a higher level. It is oriented towards active application of the student knowledge to design and development of mechatronics systems.
Careful attention during study is devoted to *system approach in the "mechatronics sense"*, to understanding operation of components of mechatronics systems. This approach is represented by mathematic formulation of the analysed subsystem, understanding substance of its operation and finally verified by simulation and by experiments.

BASIC FEATURES OF DESIGNED E-BASED LEARNING MATERIALS FOR COURSE ON MECHATRONICS SYSTEMS

Starting from the curriculum shown above and taking into consideration difficulties at explaining complicated phenomena in most of subjects from field of mechatronics where many of them suppose abstract thinking we have prepared a long-year programme of e-learning materials development.

In the first period we prepared e-learning materials from basic subjects dealing with controlled electro-mechanical conversion of energy up to fundamental principles of mechatronics systems. The following subjects are currently under preparation: *(1) Electrical Machines, (2) Power Electronics, (3) Electrical Drives, (4) Controlled Electrical Drives*. The more advanced modules to be prepared in the second phase are: *(5) Motion Control, (6) Automotive Electrical Systems, (7) Mechatronics Systems, (8) Production Lines, (9) Telematic Systems and Robotics*.
Finally, the list has been completed by a special module dealing production lines (from view of large mechatronics industrial systems).

Proposed e-learning material philosophy
Except of animations explaining principles and physical phenomena the modules contain interactive graphs enabling to provide systems analysis in various working points and to visualise influence of variable parameters and thus to verify system properties. The modules are completed by simulation schemes enabling to provide dynamic simulation and verify influence of changeable parameters. The simulation is based on the CASPOC simulation programme (www.caspoc.com) that is extremely useful for presentation of dynamic systems of such kind. The described solution presents a very strong learning tool where emphasis is put on explanation of basic principles and their verification.

In distinction to known solutions of e-learning materials where the learner sits in front of the computer and reads the screens we accepted the idea that the developed e-learning modules would *satisfy needs both for lecturing and for self-learning*. Moreover, the screens for presentation should have *interactive features* – animations, interactive graphs up to “live” simulation schemes. Our aim was realised by introducing the hierarchy of the screens (Fedák, Bauer, Hájek, Weiss et al, 2003):

- The *main screen* contains interactive graph or animation. This is used for lectures and explanation – basic ideas, key information, larger letters, minimum of text and fundamental equations only.
- The *secondary screens* (sub-screens) are called by hypertext links from the main screens. They contain explanations to the main screens – more text, detailed explanation, full derivation of equations, static figures and finally, the review questions, too. Their number associated to one main screen is not limited.

The chosen principle enables to utilise the same developed e-learning material twice – for presentation (the main screens) and for learning (secondary screens).

DEVELOPED E-LEARNING MODULES

As shown above, mechatronics system is too complex system whose exact solution (design, synthesis, and analysis) requires “mechatronics access”. Basic working method at its design and verification of properties is modelling and simulation (de Bruijn, Brian, and Brouwer, 2003).

Model of mechanical subsystem of large industrial mechatronics systems presented in our case by continuous production lines create the basic part of system solution, the starting platform. The continuous production line can be decomposed into a series of typical subsystems used for transport and processing of the material in form of a strip. The processed strip is known by its elastic and damping properties. Electrical motors drive all working machines in the production line and the interconnecting strip causes that the drives are mutually influenced. This is substance of the mechatronics system complexity and also this is reason why a special care in the module is devoted to derivation of mathematical models of mechanical subsystems that are outlined by vibration properties.

The basic module on mechatronics starts with explanation of arrangement and derivation of mathematical models for basic arrangement of rotational two- and three-mass mechanical subsystems with elastic connection. As the complementary system, the two and three-mass translational systems elastic connection are explained. There are explained principles of setting-up of mathematical dynamic model, derivation of the block diagram from differential equations and its behaviour in time and in frequency domains.

At the figures 3-6 there are illustrated several primary screens of the module on mechatronics with the basic mechanical subsystems of the continuous lines. The reference (Fedák, Fetyko, 2004) contains some more details. Time responses are interactive and they enable to observe influence of the system parameters on behaviour of the system. E.g., figure 6 shows oscillations that are typical for the systems with elastic connections. At each interactive graph the learner can perform small experiments – to observe influence of chosen technological parameters (constant of elasticity and constant of damping) and some mechanical parameters (moment of inertia, etc.) on system behaviour (time responses).

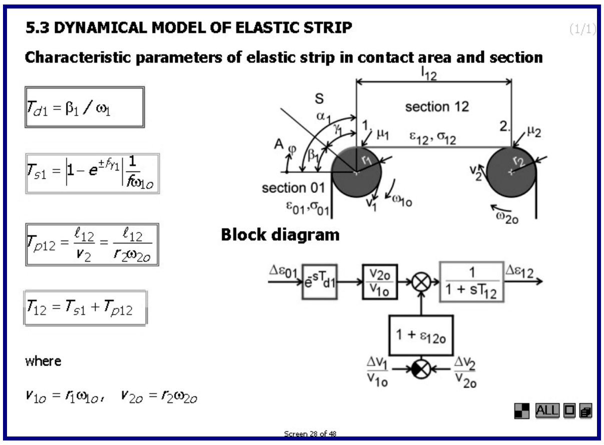


Figure 3. Basic model of processed web with elastic and damping properties in environment of working cylinders

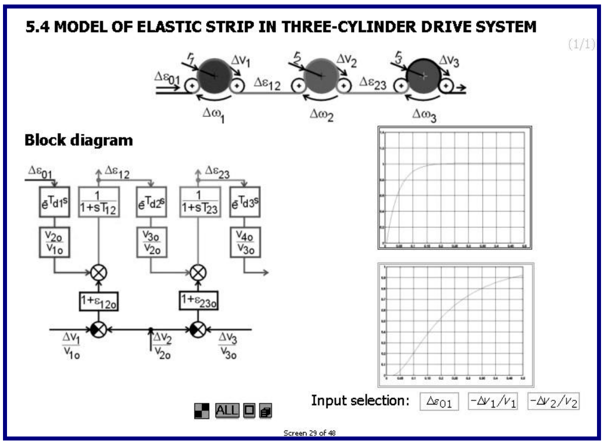
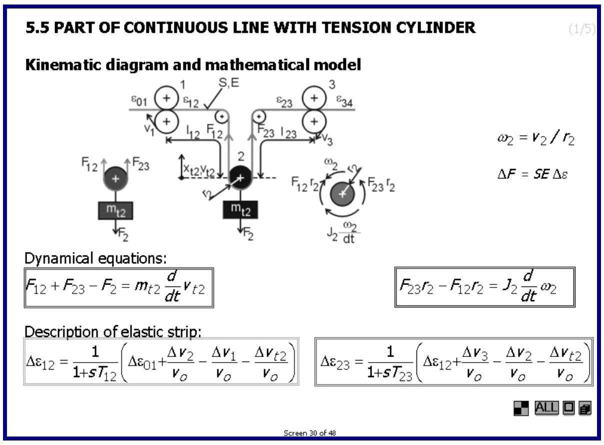


Figure 4. Part of the production line consisting of several working machines with block diagram and time responses of typical variables



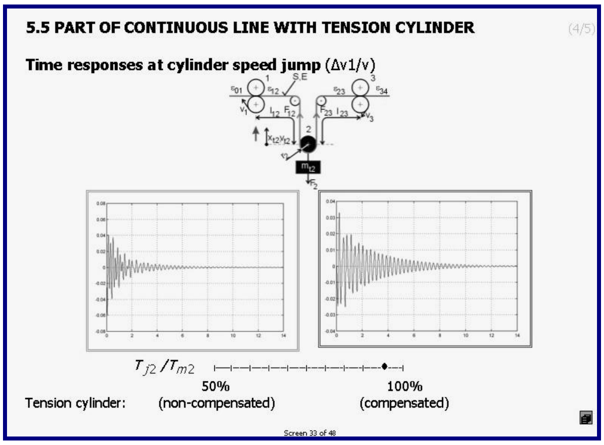


Figure 5. A section of the strip processed line with tension cylinder creating small

Figure 6. Time courses of controlled variable in the analysed section of the production line

Each primary screen contains basic information only that is used for explanation at lectures. In the right bottom corner of each animated figure there are buttons to control the animation. There is also the button enabling access to the secondary screen that contains full information with text and that is suitable for self-learning.

The colours present a very strong tool in interactive materials design that enables to see at the first glance coherence and continuity among various mutually belonging parts of the system. In the whole module and associated modules there is preserved a united colour system and performed animations: the same colour belongs to the part of mechanical subsystem, to the frame round equation describing the subsystem behaviour and to the block diagram. There are not any static figures at the screen but the corresponding parts are coloured when the mouse is moving across them. This arrangement helps the

learner easier to understand the presented matter – he learns immediately which equation, part of the block diagram or time courses and characteristics are mutually corresponding.
The advanced module on mechatronics systems deals with explanation of typical strip producing and strip processing production lines. The primary screen at the figure 7 explains basic arrangement of a typical production line. In the figure 8 there are presented typical production lines in the metallurgical industry.

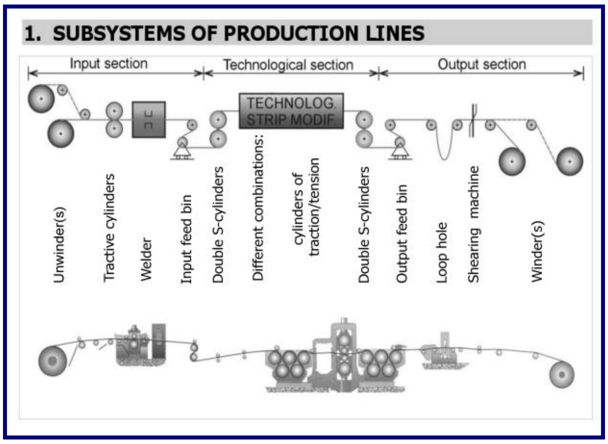


Figure 7. Basic parts of a strip processing line

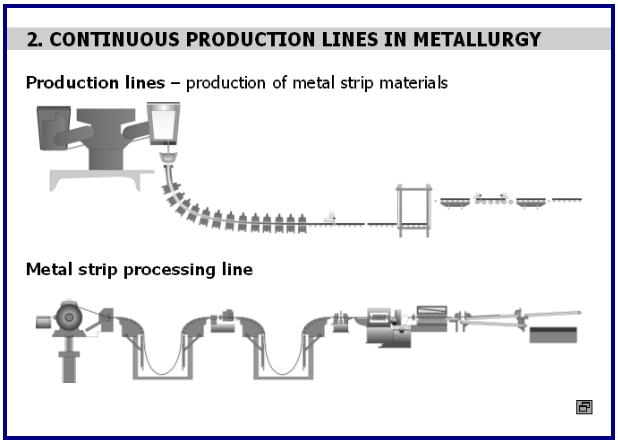


Figure 8. Explanation of production lines in metallurgical industry

Afterwards, the module goes in detailed structure of the control ad driving system production lines that is shown on example of the continuous hot rolling tandem mill line (figure 9). At each production line, derivation of basic mathematical models is shown (figure 10) and afterwards there is block diagram of subsystems.

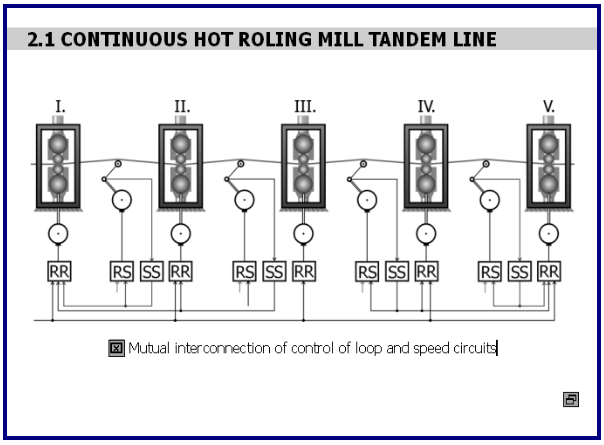


Figure 9. Basic parts of a strip processing line

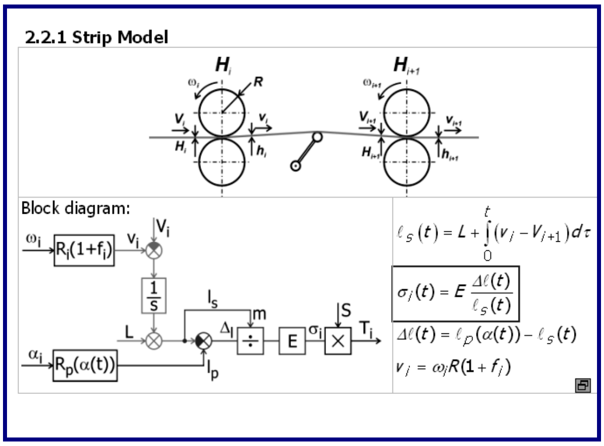


Figure 10. Explanation of production lines in metallurgical industry

Explanation goes gradually into details, as shown in figures 11 (the principal block diagram) and 12 (detail of the block “LOOPER DRIVE SYSTEM” ant further detailed scheme of the block “MOTOR”).

CONCLUSIONS

The contribution shows wide range of utilisation computer based learning in field of mechatronics. The mechatronics systems present extremely complicated systems and using computer based learning enables to make the learning easier and visual. Well-designed e-learning material enables a deeper understanding of the presented matter and moreover, the involved interactive solutions enable to perform some experiments and analyse influence of system parameters to the system behaviour without necessity to switch among various programs.

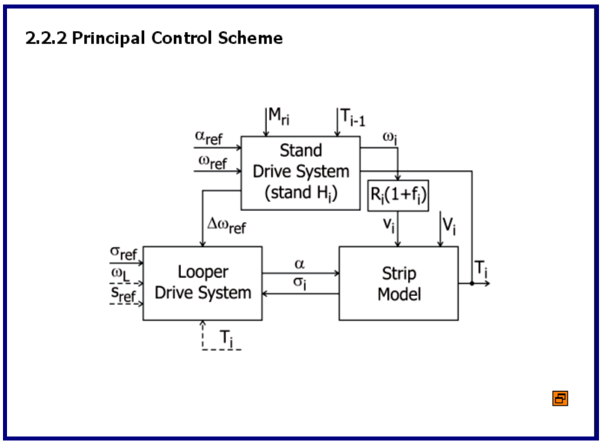


Figure 11. Block diagram of the control scheme

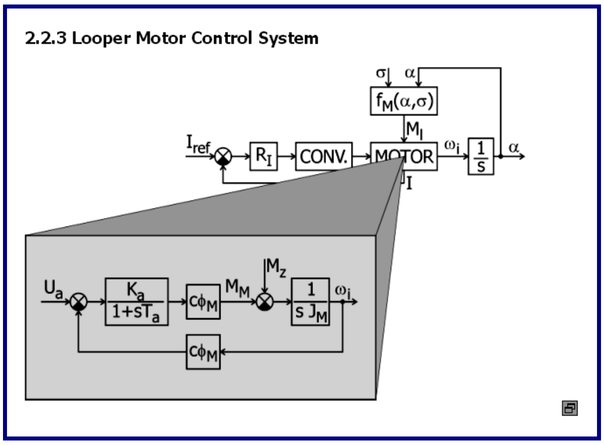


Figure 12. Details of the subsystems

Based on the preliminary analysis of existing e-learning solutions two e-learning modules on mechatronics systems (for beginners and on advanced level) were designed and realised. The animations in the modules were realised in Macromedia Director environment and finally implemented in the html using Macromedia Dreamweaver. In the paper there are shown some samples from the modules dealing with analytic derivation of the mathematical models of mechanical subsystems with elastic connection and with analysis of their behaviour using interactive graphs. The module on advanced level presents continuation and explains behaviour of large mechatronics systems presented by continuous production lines.
The presented modules are already in use and feedback from teachers and the students shows that that are positively accepted – they enable to make easy explanation of complicated phenomena and interactive simulations enable small experiments that contribute to deeper insight of the learner in the system behaviour.

Fully interactive solution has to contain a possibility to change the structure, not only the parameters. This means involvement of a programme for digital simulation. The project team has lately experimentally interconnected the used SW with a multilevel simulation programme Caspoc into the e-learning module using a special, purpose oriented viewer that presents an interface between CASPOC and Macromedia. Is has shown that the CAPOC programme is extremely suitable for such purposes not only due to the property of multilevel modelling but also due to easy animation of the simulation scheme (showing colour of the wires depending on the level of the signal flowing through the wire. The advantage of presented solution is that the learner does not need to have knowledge on simulation environment and programming; he just pushes buttons to increase/decrease values of the input variables and/or parameters and/or switches to change the pre-set simulation scheme. The utilization of several tools still needs a substantial knowledge of programming.

The modules were designed in such a way that they are multifunctional – they are suitable both for lecturing (basic ideas, principles, schemes and interactive graphs that present content of so called primary screens) and for self-learning (using secondary screens containing full information and simulation schemes). Each chapter is completed by review questions.

In the future we intend to continue in: (1) development of further modules from field of mechatronics; (2) to involve full simulation schemes; (3) to involve video sequences from a real industrial environment (in order to bring closer theory to practice).

The presented e-learning modules from mechatronics are completed by other modules: 2 modules on Fundamentals of El. Engineering (AC, DC circuit, magnetic and electrostatic fields), 4 modules on Electrical Machines (DC, AC, Transformers), 7 modules on Electronics, Power Electronics and Power Eelctronics Applications and 3 modules about SW in Electrical Engineering, that altogether create an e-learning system. The complete list of the modules is to be found in (Fedák, 2002).

REFERENCES

Bauer, P., Fedák, V. (2003). E-learning for Power Electronics and Electrical Drives. Proceedings of the 15th International Conference on Electrical Drives and Power Electronics (EDPE 2003), The High Tatras, 368-373, ISBN 80-89114-45-4, (www.tuke.sk/edpe).

Buchanan R.J., (2001). A Virtual Laboratory for Data Communications. Proceedings (CBLIS 2001)

de Bruijn, I., Brian, M., and Brouwer, W., (2003). Simulations, Applets and Learning in Schools. Proceedings (CBLIS 2003)

Fedák, V. (2002). Interactive and Unified E-based Education and Training in Electrical Engineering. Leonardo da Vinci project No CZ 134009, (www.tuke.sk/inetele).

Fedák, V., Bauer, P., Hájek, V., Weiss H., Nagy I., Korondi P. et al (2003). Interactive e-Learning in Electrical Engineering. Proceedings of 15th International Conference on Electrical Drives and Power Electronics (EDPE 2003), the High Tatras, 368-373, ISBN 80-89114-45-4, (www.tuke.sk/edpe).

Fedák, V., Fetyko, J. (2004). Interactive Solutions Design for E-learning Course on Mechatronics. Proceedings of the 3rd International Conference on Emerging Telecommunications Technologies and Applications (ICETA 2004), elfa, Košice, 431-433, ISBN 80-89066-85-2.

Forinash, K., Wisman, R. (2003). Building Real Laboratories on the Internet. CBLIS 2003.

Simulation Programme Caspoc, www.caspoc.com

Varsavsky C. (2001). Adoption of New Technologies: The Next Challenge, Proceedings (CBLIS 2001).

Weiss, H., Schmidhofer, A., Schmid, A., et all (2004). Animated and Interactive e-Learning Concept and Realization. Proceedings of the international conference on Web-Based Education (WBE 2004), The International Association of Science and Technology for Development (IASTED), Innsbruck, paper No 416-210, ISBN 0-88986-377-6.

Zacharia, C.Z., (2003). Using Interactive Simulations to Enhance Students' Explanations Regarding Physical Phenomena. Proceedings (CBLIS 2003).

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V. Fedák, Associate Professor
M. Repiscak, Ing.
J. Fetyko, Associate Professor
Department of Electrical Drives and Mechatronics
Technical University of Kosice
042 00 Kosice
Slovakia
Email: viliam.fedak@tuke.sk,