

DISTANCE AND VIRTUAL LABORATORIES

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Abstract - The paper deals with basic philosophy and structure of a remote controlled laboratory for experimentation in Electrical Engineering. The laboratory collects experiments from fields of Power Electronics, Electrical Machines, Electro-Mechanical and Motion Control Systems. The workbenches in the real laboratory are used over internet. Real experiments of the laboratory are distributed at various universities across Europe. A special care is devoted to preparation of learners to experimentation, including examining their knowledge before joining to the experiment. To have a feeling of participation in the experiment, except of the measurement data, also the signal from web camera is transferred to a distance operator.

I. INTRODUCTION

Rapid development of ICT technologies since beginning of 90ties enabled expansion of online distance laboratories. Their utilisation presents the latest trends in education – to get practical experience by experimentation with measurements, verifying properties of complex equipment and well as analysis of the equipment in various operation points. Tacking advantage of the internet and development of related technologies, an increasing number of remote access solutions are being developed. A remote hardware experiment are adapted in such a way that it can also be accessed from the Web that enables distance sharing of the experiment by other individuals and/or institutions. Currently we can find numerous solutions for remote controlled experiments in various fields of practical education. There are running numerous projects focused to their developments that are presented in special conferences [2], or in special sessions of scientific conferences.

II. A BRIEF OVERVIEW OF SOLUTIONS FOR DISTANCE EXPERIMENTS

Let's present a brief overview of several typical examples from field of electrical engineering, namely of *electrical machines, drives, power electronics and their*

applications that we are interesting in, concentrating ourselves to used technology and experimentation.

Simple remote experiments with power semiconductor devices (diodes, BJT, J-FET, and phototransistors) are reported in [3]. A student can get output characteristics of each device and to study its behaviour in different conditions.

Development of a remote-access control system allowing users to perform control through Internet is reported in [4]. A DC motor control module is used to illustrate the design. The system consists of an internal distributed system and application system linked by a data acquisition (DAQ) interface card. Web server, video server and LabVIEW controller server are designed based on a client-server structure.

Importance of teaching PID control techniques at undergraduate level is pointed out in the paper [5] that introduces a remote experiment where the DC motor is controlled by the PID controller. The remote user can test PID digital algorithms and parameters, change reference velocity values and register the motor output velocity profile. Again the LabView environment is used there.

An example of design and construction of virtual laboratory for electrical machines (AC and DC motors) is presented in [5]. The remote experiment consists of a three – axis positioning system, measurement technique with GPIB bus, server and measured circuits. Position system is used to switching the circuit among different inputs and outputs on measured boards and measurement technique. The subsystems are interconnected by GPIB bus and measured values for current, voltage, frequency and revolution are transferred into the server. Server applications are programmed in software LabView, providing measurement, calculations, control and web publishing for complete virtual laboratory system.

The paper [6] presents an education kit based on a real system consisting of a controlled AC drive. The power system consists of a cage induction motor supplied from power electronic converter. The control is provided by two ways: locally on a computer directly connected to the

inverter and simultaneously serving as a network server. The second one is held remotely by computer connected to the network fulfilling part of network client.

A more complex experiment is presented in [8] showing web based interactive teaching of PWM methods on example of the most widely used three-phase bridge converter. In the first part there are basic methods of PWM: carrier based sinusoidal (CB-SPWM), carrier based PWM with zero sequence signal (CB-ZSS-PWM), and space vector modulation (SVM) are described. Special emphasis is given to relations between CB-ZSS-PWM and SVM. In the second part selected developed applets for individual training of PWM methods are briefly described

An example of advanced and more complex control and teleoperation is presented in [9] where experimental equipment is explained on background of a course based that is included as a part of mechatronics education. Employed HW is in-house developed embedded DSP-2 control system, which applies MATLAB/Simulink for the control algorithm design, for simulations and also for practical implementation. DSP-2 is supported by specially developed library for Simulink where basic programming blocks are included. For more advanced algorithms, the possibility to include user's C programming language code in the executable Simulink model is utilized. The control course is upgraded with remote control course, where the students learn how to control through internet their previously developed advanced control experiment.

The above brief overview of some typical solutions presents only a fragment of published references of remote laboratories, of course. In our case we are developing a more complex system of distance or virtual laboratory containing not only single experiments but the whole set of the experiments [20] that are distributed across Europe and the experiments allocated there cover basic fields of electrical engineering. They are placed in different laboratories at universities. The system to be developed presents an open system enabling later expansion. The virtual (distance) laboratories are not any web-based simulation. They present real electro-technical experiments conducted in the laboratory, but they are remotely controlled and monitored by web-based tools with

visualization of measuring apparatus, electronic components and many more factors.

Design of such a system except of technical solutions dealing with access and sharing of remote experiments requires solving number of other tasks that is pointed out in the following.

III. PEMCWEBLAB AND ITS FUNCTIONALITY

To support distance learning in electrical engineering we developed a set of remotely controlled real experiments from fields of electrical engineering mainly from Power Electronics and Electrical Drives, so that they create the *PEMCWebLab* (Fig. 1).

An Integrated Learning System

The *PEMCWebLab* creates an integrated learning platform. Several learning issues are addressed such as:

- Learning objectives
- Education
- Animation
- Simulation
- Experiment

In the first part the learning objectives of each experiment are addressed. In the part education a theoretical background of the each individual experiment is given. Interactive animations developed in the previous project are addressed further. The last educational method before experiment is the simulation.

The main task of *PEMCWebLab* is to provide a web-based remote control for designed experiments. The learning process includes several, specially designed, experimental tasks. However, for safety reasons no one will be allowed to perform any experiment until he, or she, has shown adequate knowledge of the experiment. Entering wrong input parameters, due to insufficient knowledge of the experiment, may also lead to improper operation of the experiment. Therefore, a learning routine is designed for learners to gain the prerequisite knowledge which is required before attempting the experiment.

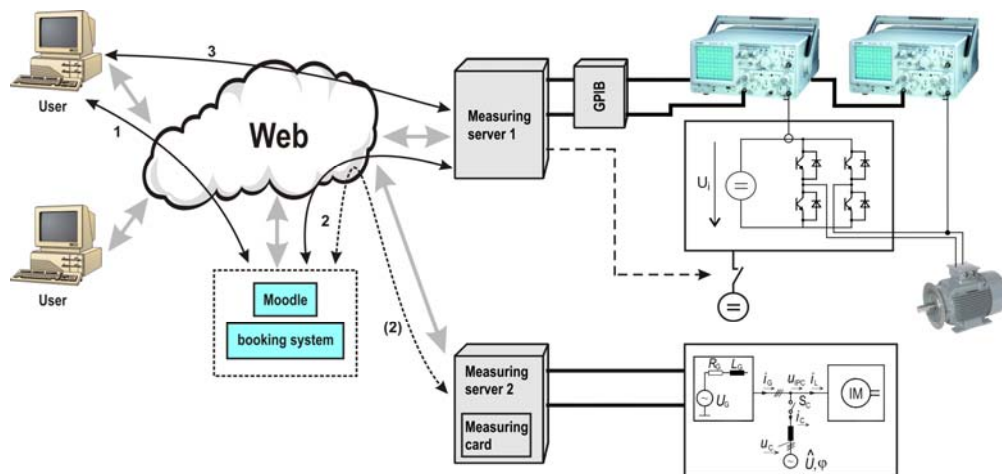


Fig. 1 Principal structure of the distance laboratory

After completion of the online experiment, the learners have an opportunity to take a simple questionnaire or alternatively to submit their report through the available feedback subsystem for its final evaluation (depending on the requirement enforced by the instructor). All learning procedures are recorded for future reference and analysis.

B. Evaluation Subsystem

To use *PEMCWebLab* in order to achieve desired learning effect, the system first has to assess the learners' prerequisite knowledge of experiments. This is done throughout an evaluation subsystem before it permits the learners to access online experiments. Several types of evaluations are used in this system. The simplest method is to use a questionnaire that only contains true or false type questions, single questions, and multiple-choice questions. Instructors may also ask learners to submit simulation results or reports of the simulation tasks via e-mail, and then evaluate the results manually. Another possible method of online evaluation that is currently being considered is a peer review method. An experienced learner who has been trained can be assigned as a *Teaching Assistant* (TA) for that experiment. The TA can talk then to, or correspond with, anyone who requests permission to do that experiment. Once this TA believes that the new learner has adequate knowledge of the experiment, he or she can grant this learner access to that experiment. In this way the instructor's workload can be reduced.

C. Feedback Subsystem

A feedback subsystem plays an important role in improving the performance of learners and the use of the *PEMCWebLab*. Feedback to the learners often includes the evaluation results and suggestions on learning, while feedback to instructors and supervisors includes problem reports on the *PEMCWebLab* and questions during the learning process. Peer or learner-instructor interactions are both significant in this feedback subsystem. In framework of the *PEMCWebLab* the authors have developed several feedback mechanisms. Feedback to learners may be provided instantly from predefined functions or from an instructor or administrator with a certain time delay. E-mail is one of the easiest ways for learners to communicate with instructors. Discussion forums or online chat rooms also provide different environments for the feedback.

IV. EXPERIMENT ADMINISTRATION

Every experiment has its own server, because it is located at the different location. Remote users first log onto a main booking server, after which they will be directed to the specific server for actually performing the experiment.

A. Experiment Administration

A central booking system is available at the project page *PEMCWebLab.com*. Booking system is provided through Moodle software. Layout of the Moodle pages for all experiments is uniform. This page will contain menu with the following submenus:

1. Learning objectives
2. Education

3. Animation
4. Simulation
5. Experiment

All the submenus at the booking system are to be accessed without restriction of number of students. The actual booking is provided in the *submenu Experiment*. The experiments can be booked one week ahead, the length of the offered time window for the experiment varies from 5 to 30 min. Before the experiment becomes available online, it should be tested to verify the correctness of the experiment results as well as the stability of the experimental set-up. The power to some experiment is available 24 hours a day; other experiments are available for safety reasons in the working hours only. An administrator of each experiment can restrict the use if the experiment for his purposes during some days or hours only. Supervisors have to routinely check the status of each experiment to make sure that each of them is functionally correct and is available for use.

Several clients can connect to *PEMCWebLab.com* simultaneously. However, Internet bandwidth becomes extremely limited when too many remote users request to use this system. Several concurrent, remote users are allowed via an Internet connection for each experiment. However, each experiment in the *PEMCWebLab* can be operated only by a single remote user at a time. The system thus considers each experiment as a "resource", and remote users who wish to operate a specific experiment should first get permission to operate the experiment. Once the resource is in use, other remote users cannot access that resource, because it is then marked as "locked." All the remote users without access permission can see only the online, real-time video of that experiment.

B. Server Site Administration

As it was already said each experiment has its own server and it is located at a different location. Remote users first logged onto a main booking server, after which they are directed to a specific server performing the experiment and to get into the page of the experiment.

V. SET OF REMOTE EXPERIMENTS

A Leonardo da Vinci EU project titled "*E-learning Distance Interactive Practical Education - EDIPE*" [2] is suggested and approved to create a full set of distance laboratories. Twelve universities with the span across the EU (from the countries: NL, F, D, PL, CZ, SK, HU, RO, GR) are participating in the project.

The expected specific results are:

- Learning objectives for distance experimental education,
- Guidelines for project oriented measurements with learning objectives for distance and /or virtual practical education,
- Synthesis oriented experimental measurements,
- Technology and technical documentation for distance practical education and measurements via the Internet,
- Different designed measurements each with its own philosophy.

The outputs from the project will present:

- teaching material (in electronic form; guidelines, manuals, documentation in English and national languages),
- distance and virtual laboratories approached via web,
- visualization and layout of the measured system,
- measurement results obtained via Internet.

The following modules are proposed (grouped into sets of modules) in such a way that they cover fundamentals and basic applications of the EE and advance topics including the application as well:

1. Fundamentals of Electrical Engineering

- Single Phase and Three Phase Rectifier Circuits
- DC Circuit Measurements and Resonant AC Circuits

2. Power Electronics

- Power Converters
- Power Factor Correction
- PWM Modulation
- DC-DC Converter for Renewable Energy Sources and Microgrid
- Power Quality and Active Filters
- Power Quality and/or Electromagnetic Compatibility

3. Electrical Machines

- Basic Electrical Machinery – Synchronous Generator
- DC Machines
- Basic Electrical Machinery – DC Motor
- Basic Electrical Machinery – Asynchronous Motor

4. Electro-Mechanical and Motion Control Systems

- Basic Elements of Internet based Tele-manipulation
- Mechatronics, HIL (Hardware in the Loop) Simulation
- High Dynamic Drives - Motion Control
- Automotive Electrical Drive
- Complex Control of a Servodrive by a PLC
- Intelligent Gate Control by a PLC

VI. SUMMARY

Basic philosophy, structure and tasks of the laboratories for remote experimentation in various fields of Electrical Engineering is here introduced and placed in the context of an integrated learning system. The experiments are performed in framework of the Leonardo da Vinci project PEMCWebLab.com which is collecting experiments distributed at various European universities.

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