

WEB ISES CONTROL kit environment for control, communication and simulation of remote laboratories

Prostředí WEB ISES CONTROL kit pro řízení,
komunikaci a simulaci vzdálených laboratoří

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Faculty of Applied Informatics

ZADÁNÍ BAKALÁŘSKÉ PRÁCE

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Téma práce: Prostředí WEB ISES CONTROL kit pro řízení,
komunikaci a simulaci vzdálených laboratoří

Zásady pro vypracování:

1. Vypracujte rešerši na dané téma.
2. Popište současný stav vzdálených laboratoří FAI v celkovém komplexu jejich řízení, komunikace a simulací.
3. Diskutujte možná řešení vzdálených laboratoří z hlediska IKT technologií.
4. Považujte za hlavní metodu řešení softwarový přístup s integrujícím charakterem XML u všech prvků, tj. u řízení, komunikace a simulace a uveďte jeho výhody a nevýhody.
5. Ověřte navrhované koncepce integrované vzdálené laboratoře na vybraném vzdáleném experimentu.
6. Diskutujte dosažené výsledky a závěry práce.
7. Naznačte další vývojové směry předloženého řešení, zejména s jejich vnořením do LMS systémů.

Rozsah bakalářské práce:

Rozsah příloh:

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1. **DULÍK, Tomáš, BLIŽŇÁK, Michal, BUDÍKOVÁ, Věra, KADLEC, Jiří, KŘIVA, Zbyněk, OLŠAROVÁ, Věra, TRBUŠEK, Josef a VAŠÍČEK, Zdeněk. Virtuální laboratoř pro vývoj aplikací s mikroprocesory a FPGA. Brno: Akademické nakladatelství CERM, 2011, 81 s.**
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děkan



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podpis diplomanta

ABSTRAKT

Technologie vzdálených experimentů se v současné době stává stále významnějším ICT prvkem v oblasti vědy a výuky. Systémy poskytující vzdálené ovládání s přenosem dat jsou založeny na rozličných, někdy nekompatibilních, technologiích. Samotný systém ISES, který využívám v této práci, je založený na plug and play měřicích prvcích, které jsou automaticky rozpoznány řídicím softwarem ovládacím software ISESWIN (pro přímo řízené experimenty) and software ISES WEB CONTROL (pro řízení vzdálených experimentů) Nová metodika výuky INTe-L, založená na vzdálených experimentech a simulacích, klade nové nároky na tyto systémy, hlavně s ohledem na propojení se simulacemi a LMS MOODLE.

První kapitola této práce líčí obecně myšlenku vzdálených experimentů a celosvětově používané technologie. Druhá kapitola se zaměřuje detailně na systém ISES a obsahuje popis celé architektury i používaného hardwaru. Třetí kapitola popisuje evropský grant, do kterého je systém ISES zapojen a zároveň i metodiku INTe-L, ze které plyne nový koncept zpracování dat systému ISES. Čtvrtá kapitola se zabývá novým konceptem zpracování měřených dat, integrací měřených dat z experimentu a simulace a následným přenosem k Internetovému klientovi. Tato kapitola rovněž obsahuje popis implementace na vybraném experimentu. Poslední pátá kapitola zhodnocuje dosažené výsledky a obsahuje návrh dalšího rozvoje systému ISES hlavně z hlediska exportu měřených dat do virtualizovaného cloudu a integrace do Learning Management Systémů.

Klíčová slova: ISES, vzdálené experimenty, XML, Easy Java Simulations

ABSTRACT

The technique of remote experiments are currently becoming a significant ICT tool in science and teaching. Systems providing remote control capability is based on different, sometimes incompatible, techniques. ISES system itself is a system based on measuring plug and play components that are automatically recognized by the controlling software ISESWIN (for hands on experiment) and software ISES WEB CONTROL (for remote experiments). The new teaching strategy INTe-L based on remote experimentation sets

new demands on these systems, especially with regard to interconnection with simulations and LMS.

The first chapter of this thesis depicts the general state of the art of remote experiments and current technologies worldwide. The second chapter focuses on the ISES system and contains a description of the entire architecture and used hardware. The third chapter describes the European FP7 call and the project to which the system is supposed to be integrated together with the ISES system, and INTe-L strategy of education, from which follows a new concept of data processing in ISES. The fourth chapter deals with the new concept of data processing, integration of measured data from experiment and simulation and subsequent end client. This chapter also describes the implementation of this concept on the example remote experiment. The last, fifth chapter assesses the achievements and includes a proposal for further development of ISES mainly in terms of the measured data export to the virtualized cloud and integration into Learning Management Systems.

Keywords: ISES, remote experiments, XML, Easy Java Simulations

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INTRODUCTION

A new trend in science, remote control experiments, is currently becoming increasingly important. Ability to measure and verify almost any physical, chemical or biological phenomenon, any day of the week, 24 hours, from anywhere in the world is a very powerful utility, whether in science or teaching. Internet School Experimental System (ISES) is a system which enables the construction of remote experiments. The ISES WEB CONTROL is software that provides ability to control and acquire measurement data from an experiment without the need for direct interaction with the experiment, all control is mediated via the Internet.

The main objective of this thesis is the analysis of the ISES WEB CONTROL in terms of communication between every part of the system as well as communication with the client and data processing. Another objective of this thesis is the integration of the measured data from remote experiment and corresponding simulation. The connection between remote experiment data and experiment simulation data is very significant. Measured data processing in the current system is not ideally solved. The thesis provides a proposal for the new data processing concept including design and test a new concept in the selected experiment.

I. THEORY

1 REMOTE LABORATORIES

Remote laboratories allow clients to perform experiments and laboratory tasks over the Internet without being in the laboratory.

1.1 Principle and functionality

In a traditional proximal laboratory, the client interacts directly with the equipment by performing physical actions (e.g. manipulating, pressing buttons, turning knobs) and receiving sensory feedback (visual, audio and tactile).

In a remote laboratory the same interaction takes place at a distance with the assistance of the remote infrastructure. This is a new layer that resides between the client and the laboratory equipment responsible for conveying client's actions and receiving sensory information on server side.

On the equipment side, the remote infrastructure performs the following key functions:

- Monitors the apparatus, e.g. through the use of video cameras, microphones and other sensors.
- Controls the apparatus, e.g. through the use of I/O interfaces, motors or other actuators
- Ensures that the experiment is 'cleaned up' at the end of a client's session by automatically resetting the apparatus or putting it into a stable state.

On the client's side, the remote infrastructure performs the following key functions:

- Provides a user interface that allows the experiment apparatus to be monitored and operated.
- Manages access to the laboratory, to ensure that only one user can use an experiment at a time from the equipment. [1]

1.2 Remote laboratory technologies

The remote laboratories use wide range of technologies to manage, monitor and control the laboratory. Let me next describe the techniques used in this area. The systems may be divided into two basic groups – those using embedded microcontrollers and those completely software oriented. Several typical examples are given later in this chapter.

The first group may be represented by:

80C537 Microcontroller Remote Lab

The concept is based on the μ de537 microcontroller and professional development environment for microprocessors Keil μ Vision2. The system uses Citrix Application server and the National Instruments LabView8. The Citrix Application Server is the platform which manages the debugging microcontroller software, and National Instruments LabView8 is used to develop the applications which allow the interaction between the system and the remote user. The microcontroller is connected to the Citrix server via RS-232 and through Data Acquisition board to the LabView server. The “Human board interface” is used to control, monitor, manage workplace and allow the users to behave as if they were present in the laboratory. shows 80C537 Microcontroller Remote Lab communication diagram. This system is used on the Technical University of Catalonia and Carinthia University of Applied Sciences. [2]

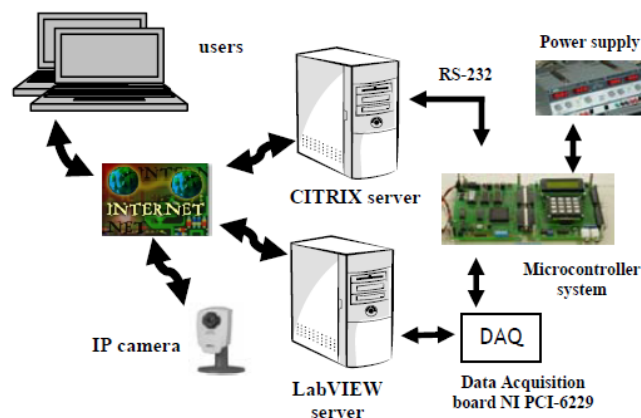


Figure 1 – 80C537 Microcontroller Remote Lab diagram [2]

Centre for Microcomputer Applications

CMA (the Centre for Microcomputer Applications) is a foundation with as main goals to enrich science and technology education with innovative and attractive ICT products and to stimulate the use of ICT in education. The main product line is the Coach environment,

consisting of the software package Coach and hardware (interfaces, sensors and actuators) for measurement and control. [3]

CoachLab II+ is a multifunctional interface for computerized measurement and control. It is an on-line interface with real-time display of the measured data on the computer screen. CoachLab II+ is provided with its own micro-controller and FLASH memory. FLASH memory allows easy updating of the internal operating system software (firmware). It is connected to the computer via the USB; a wide variety of sensors is available for connection to CoachLab II+. [4]

The software Coach 6 is the Learning and Authoring Software Environment. It is a unique environment which integrates all the tools you need for: Collecting data, controlling systems, capturing video, measuring on videos and images, modeling dynamic systems, processing and analyzing data and creating student reports. [5]

Laboratories of integrated automation

The project “Laboratories of integrated automation” (LABI) is a set of labs with real physical models accessible via the Internet. Laboratory includes nine basic control tasks: temperature control, heating plant system, flow meters, continuous motor control, biochemical process, RS232-Internet interconnection, ASI-Ethernet communication (levels of the tanks, light sources, solar panel).

A control system is designed to control and visualize of the LABI system, functionality and access to the models of the technological processes. Functional structure of data transfer is given by the block diagram on the Figure 2.

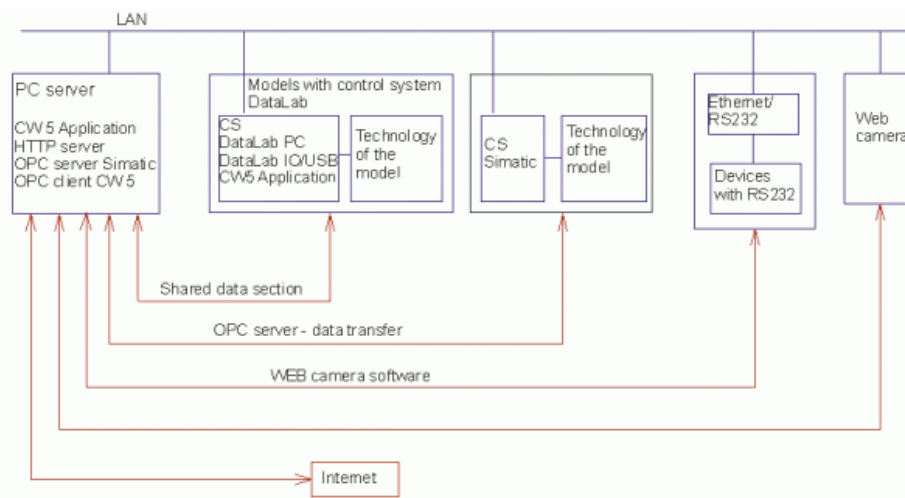


Figure 2 – Data exchange in the LABI system [6]

The PC server is connected through the LAN with DATALAB control units and with the SIEMENS control units. The users of the LABI system can control and work with the experiments.

The project “Laboratories of integrated automation” (LABI) is being built at the Institute of Process Control and Applied Informatics and at the Department of Environmental Technology of the Tomas Bata University (TBU) in Zlín. [6] [7]

Virtual Laboratory of Microprocessor Technology Application

Virtual Laboratory of Microprocessor Technology Application (VLAM) is system based on the virtualization technology. The system provides remote access to any laboratory that contains any number of workstations and desktops with any device which is able to communicate via USB or Ethernet - for example, development boards, measuring instruments, laboratory models, etc. Figure 3 shows VLAM architecture, physical server hosts virtual desktops, which provides computing power for laboratory workplaces and virtual desktop which hosts VlamGateway. VlamGateway provides remote access to the laboratory workplaces.

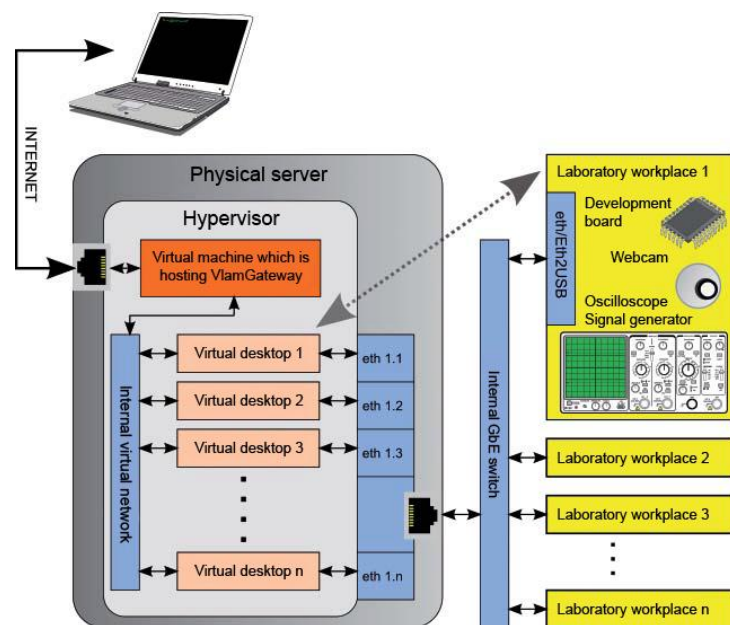


Figure 3 – VLAM architecture [8]

Laboratory workplace is equipped with development board (Freescale, Xilinx etc.), webcam, measurement devices (Agilent) and EthernetToUSB convertor to interconnect

devices with virtual desktop. The system is used at Faculty of Information Technology, Brno University of Technology. [8]

The second group, based on software solutions, is in majority based on the proprietary industrial product of National Instrument LabView. Let me present typical representatives:

FPGA Virtual lab

The main objective of this project was to make available high-end software EDA (Electronic Design Automation) and hardware (measuring instruments, development kits) tools for development and analysis of embedded electronic proposals on the basis of modern FPGA devices. The department is equipped with a logic analyzer and digital oscilloscope. Access to the virtual laboratory is realized by the Dell 690 server, which is accessible through a login and password that is assigned by the server administrator. To configure the FPGA development board is used LabView program from National Instruments. For high-level simulation of the laboratory is available Matlab Simulink environment. Project is located at the Technical University in Košice. [9]

LINKSARE eLab

eLab is a data acquisition and remote control platform through which any teacher or student can perform real experiments in virtual environments. Accessing a real experiment through the Internet or a local network, via eLab, the user may remotely control the parameters for that experiment and receive its data in real time. The user may also share data with other users, talk in a chat room and watch the experience being performed through live video feed from a webcam. Implemented on an open platform and universal standards, eLab allows integrated access, in one unique application, to different experiments available in one or several laboratories assembled on universities, museums or science promotion centers. [10]

NetLab Remote Laboratory

NetLab presents a rich graphical user interface on the computer that looks just like the real instruments. The users operate them with the knobs and buttons in exactly the same way as would with the real thing and see the measurements displayed on the instrument screens. The real system located in the laboratory is connected to the server NetLab via GPIB

(General Purpose Interface Bus) and the server software is based on the LabView environment. [11]

A subgroup for software oriented solutions for middleware may be the group with complete authorized solution, very often based on Java.

Internet School Experimental System

The internet School Experimental System (ISES) is a complex tool for real time acquisition and remote data acquisition, data processing and control of experiments and other processes. It is an open system consisting of a basic ISES hardware with the control software ISESWIN and software ISES WEB CONTROL kit for remote laboratory. [12]

This system is used in my research and it is more described in chapter 2.

2 INTERNET SCHOOL EXPERIMENTAL SYSTEM

ISES is a teaching and scientific experimental system and an example of a teach-ware for the teaching of experimental and laboratory techniques. Its advantage is the diversity of sensing units, versatility, innovative concept, and low price. It is an open system working with Microsoft Windows with all its advantages (OLE and multitasking). The system is composed of an interface card, a set of variable modules and sensing elements, and graphical interface and evaluation program. [13] System is being developed in cooperation of the Charles University Prague, Faculty of Mathematics and Physics and Tomas Bata University in Zlín, Faculty of Applied Informatics.

This chapter describes hardware and software capabilities of the ISES system. ISES consists of ISES hardware which could be used for local measurement via ISESWIN software and for remote measurement using ISES WEB CONTROL software. This thesis focuses on the ISES WEB CONTROL because it provides software resources for creating, controlling and monitoring of the remote laboratories. The proposal for the new system is divided into two parts, first part focuses on the new concept which focuses on the implementation of the control mechanism that is controlled by PSC script, described in the thesis of M. Kovář [14]. The second part focuses on the new concept of data processing and integration of remote laboratory with simulations which is described in this thesis.

2.1 ISES hardware

The ISES hardware consists of computer interface ADDA card, the ISES panel with inputs and outputs and the set of variable modules and sensing elements.

ISES interface card and ISES panel

Computer interface card is DAQ PCI-1202L. It features a continuous, 110 kHz for low gain (40 KHz for high gain), gap-free data acquisition under DOS and Windows. The PCI-1202 provides 32-channel single-ended or 16-channel differential analog inputs, ADDA convertor-12 bits, time of conversion - 0.01 ms. [15] [16]

ISES panel is the interface element which allows connecting modules and sensing elements as well as providing programmable output source. Figure 4 shows ISES PCI Professional panel, this panel features 6 analog inputs (0-5V), 2 analog outputs ($\pm 5V$), 2 digital outputs TTL. ISES PCI panel (Figure 5) is less equipped than ISES PCI Professional; it features 6

analog inputs (0-5V), only 1 analog output ($\pm 5V$) and no digital outputs. Both the above mentioned panels must be connected via ISES interface card to the computer. Maximum sampling frequency is 100 kHz. [17]



Figure 4 – ISES PCI Professional panel [17]



Figure 5 – ISES PCI panel [17]

ISES USB (Figure 6), respectively ISES Blue (Figure 7) is the new product line introduced in 2012. This is a new product set that is able to capture values via the USB interface, respectively wirelessly. ISES Blue is connected to the computer via Bluetooth technology and it enables communications up to a distance of 10 meters, transferred to any computer with Bluetooth input. It is possible to connect up to four ISES Blue panels to one computer at once; each station has 2 input channels. ISES Blue is also recommended as an addition to the known combinations ISES PCI and Professional. ISES USB has the same hardware architecture as ISES Blue, but it is missing Bluetooth communication. Maximum sampling frequency is 100 kHz when panel is connected via USB to the computer. [17]

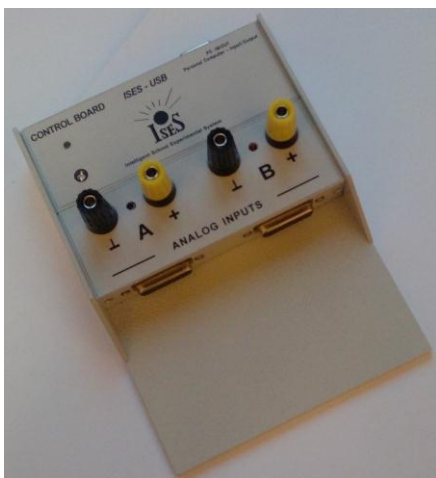


Figure 6 – ISES USB panel [17]



Figure 7 – ISES Blue panel with A-meter and V-meter modules [17]

The ISES modules provide measurement capabilities (input modules) as well as ability to connect output modules. The ISES modules are easily interchangeable, the computer, provided with the automatic calibration, automatically senses their presence and adjusted range. The modules are divided into input and output modules

- Input modules: voltage ($\pm 5 \text{ mV} \div 10 \text{ V}$, Figure 8), current ($\pm 0.5 \text{ mA} \div 1 \text{ A}$), resistance, capacitance, temperature ($-20 \text{ }^\circ\text{C} \div +120 \text{ }^\circ\text{C}$, Figure 9), microphone, deviation sensing unit, adjustable preamplifier, light stop, current booster, relay switch, pressure meter, and many others.
- Output modules: booster, relay (Figure 10), speaker, etc.

The system is equipped with such modules as e.g.: for chemistry the electromagnet valve for liquids and digital burette. [17] [18]



Figure 8 – Module for voltage measurement [17]



Figure 9 – Module for temperature measurement [17]

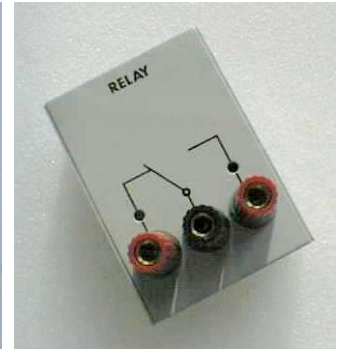


Figure 10 – Output module: relay [17]

2.2 ISESWIN

The data in ISES system is depicted both in analogue or digital form, on variable number of panels, with depicted quantities either those measured by modules or their combinations (addition, subtraction, product, quotient etc.). The software provides data processing (integration, differentiation, fitting, approximation etc.). The data export for another graphical processor is straightforward. Figure 11 and Figure 12 show ISESWIN environment. [19]

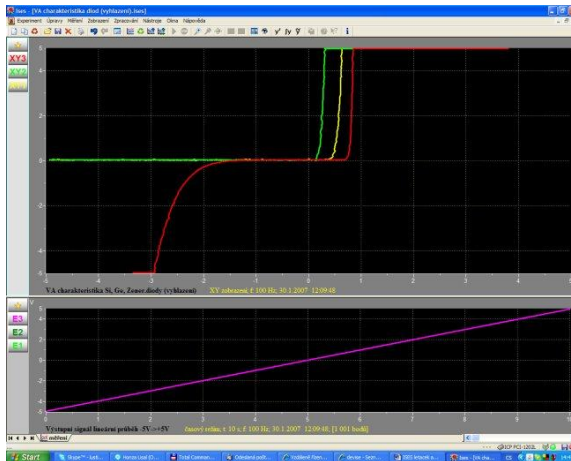


Figure 11 – Software ISESWIN: Voltage-current curve, Ge, Si, Zener diode [19]

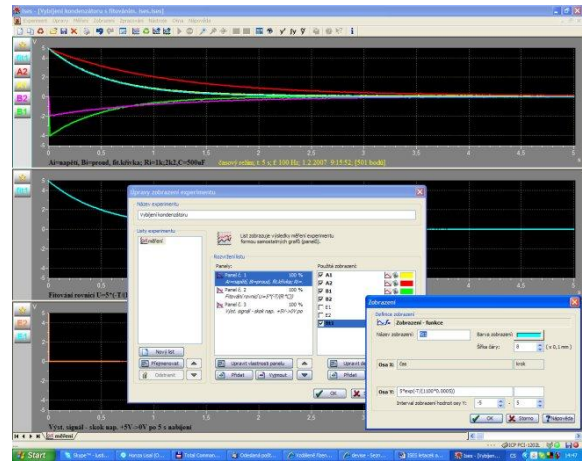


Figure 12 – Software ISESWIN: Fit the experimental data with ideally function [19]

2.3 ISES WEB CONTROL

Figure 13 shows ISES WEB CONTROL general architecture, diagram is divided into two parts: hardware and software. Hardware part contains experiment which is measured via ISES panel and its modules. ISES panel is connected to the PC using ISES interface card (ISES PCI or PCI Professional), USB cable (ISES USB) or wirelessly (ISES Blue). The video view of the experiment is provided by webcam connected via USB port.

Most of the remote laboratory technologies require double-sided middleware software for double-sided communication. The ISES WEB CONTROL makes breakthrough through this barrier and offers the software solution where the client does not need any special program to be installed and uses the standard web services, here the common browser (MS Internet Explorer, Mozilla FireFox, Opera, etc.). The corresponding software solution for remote experiments middleware with ISES system is called ISES WEB CONTROL. [20]

As a matter of fact the controller ISES WEB CONTROL for any remote experiment consists of a general part, identical for all remote experiments with ISES and a state machine PSC script that contains controlling information about the specific remote experiment. This means the only difference between every running experiment is different PSC script and different composition of ISES Virtual Measure Client.

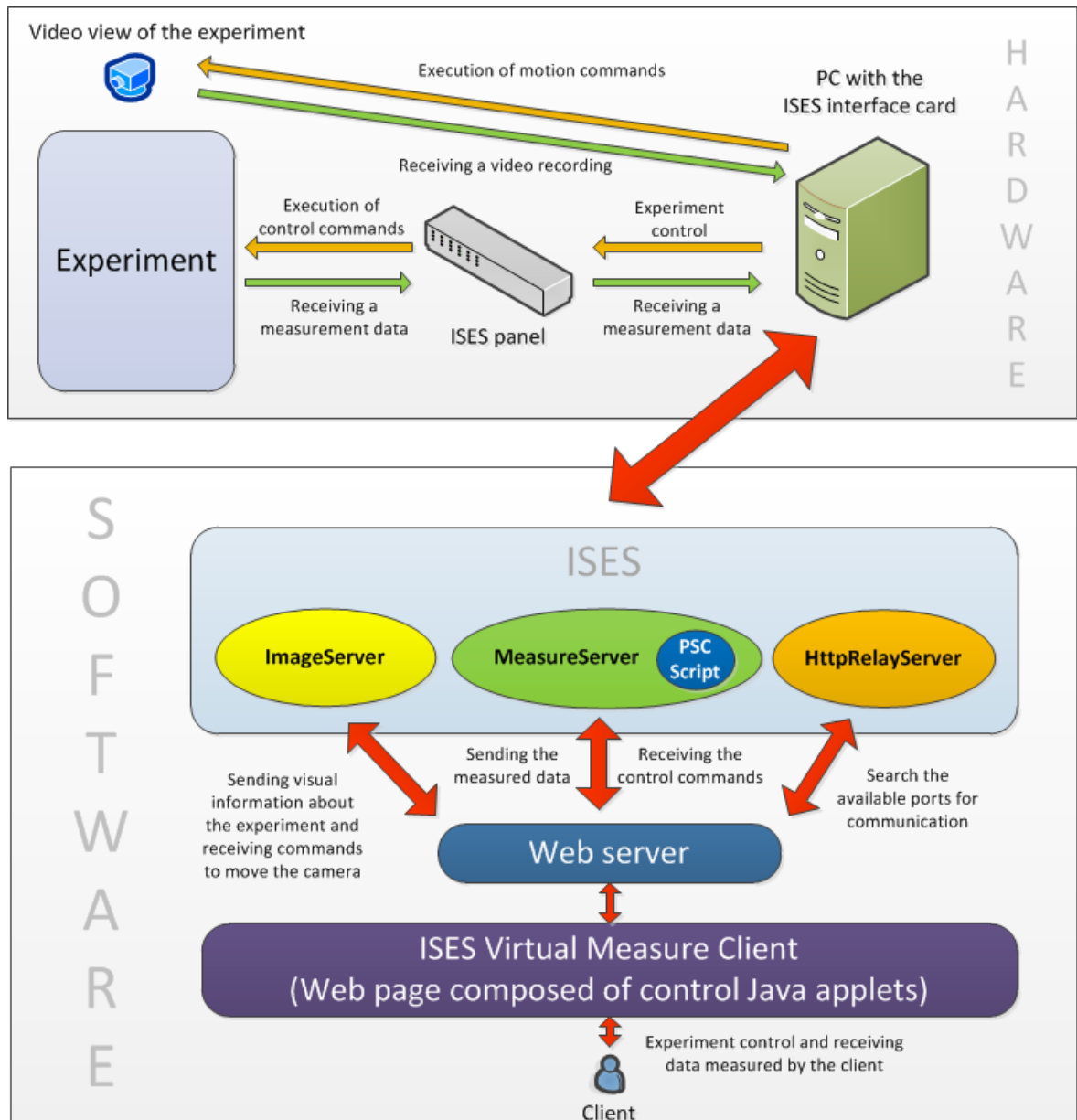


Figure 13 – ISES WEB CONTROL general architecture [21]

The software part starts with ISES kit which contains three programs MeasureServer, ImageServer and HTTPRelayServer. These programs provide control and communication capabilities of the experiment. All three components communicate through web server with ISES Virtual Measure Client. All server side software runs under MS Windows XP system. Figure 14 shows server screen with running MeasureServer and ImageServer. [22] [23]. Let me describe the individual parts of middleware ISES Web Control.

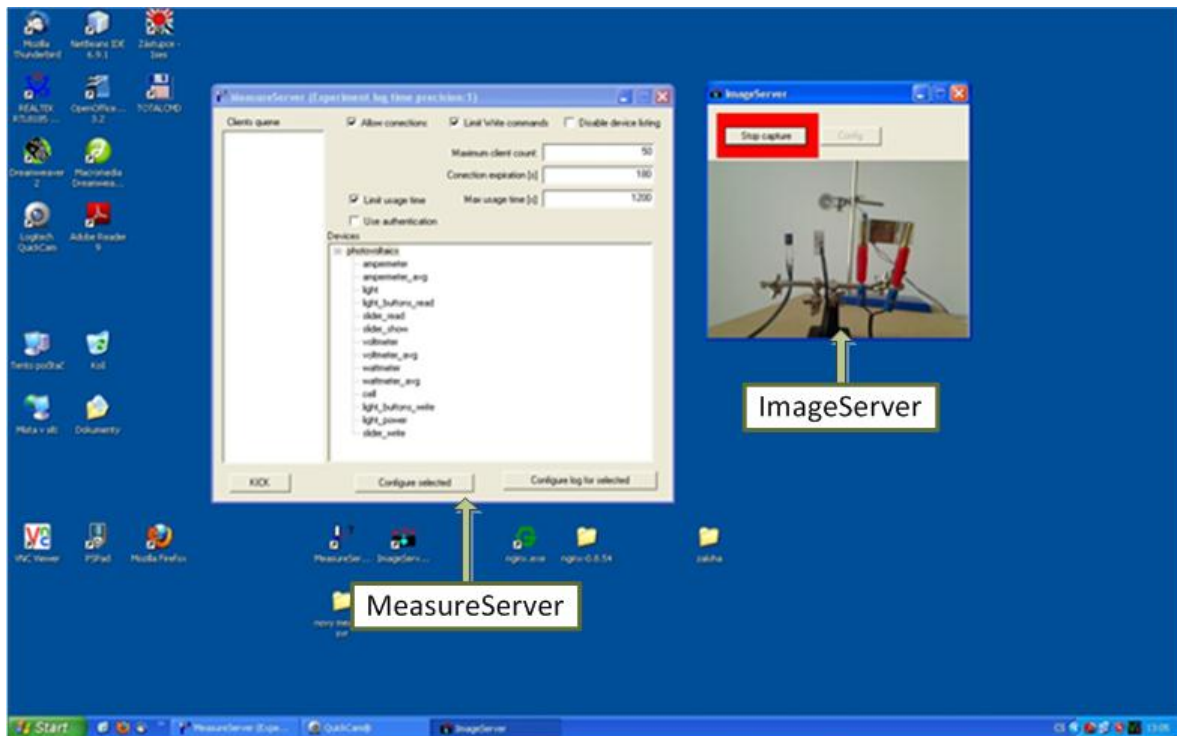


Figure 14 – The server screen with running MeasureServer and ImageServer [21]

MeasureServer

It is the core of the system, which communicates with the physical ISES hardware, processes the measured data and control commands. The main feature of the server is setting of the ISES panel, the sensors for data collection and processing the control commands. Server dynamically responds to signals from the hardware, as well as the commands transmitted from the ISES WEB CONTROL user interface. Figure 15 shows MeasureServer GUI on the server side. [21]

Figure 16 shows architecture of the MeasureServer. MeasureServer has three main components: MeasureServer core, Hardware plugin and PSC Script file. MeasureServer core is responsible for data and command transfer, client handling and for execution of the control commands. Execution is controlled by the PSC Script file that is imported to the MeasureServer, PSC Script is unique programming language specially designed for ISES. PSC Script is non-compliable programming language which defines MeasureServer core behavior of experiment control. Hardware plugin provides required functionality to control ISES hardware. Hardware plugin is exchangeable and thus provides control of other equipment (currently not implemented).

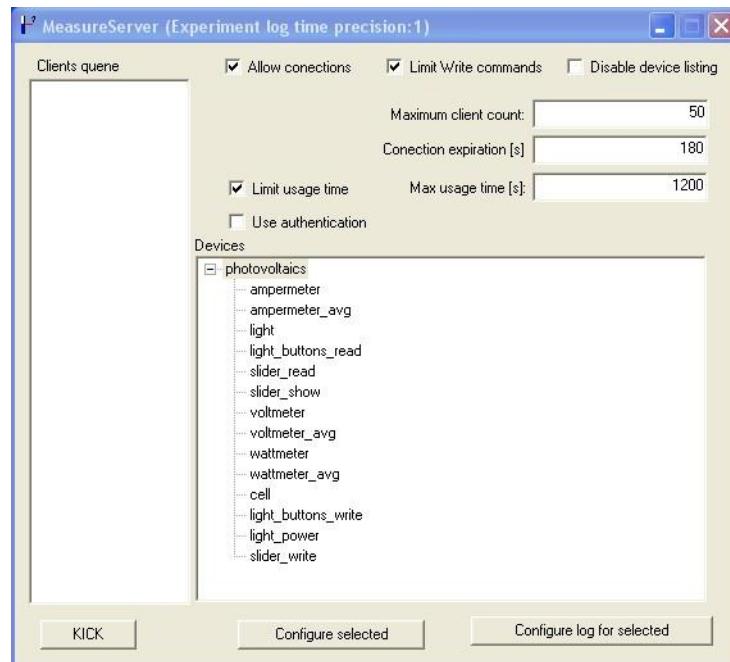


Figure 15 – MeasureServer GUI [21]

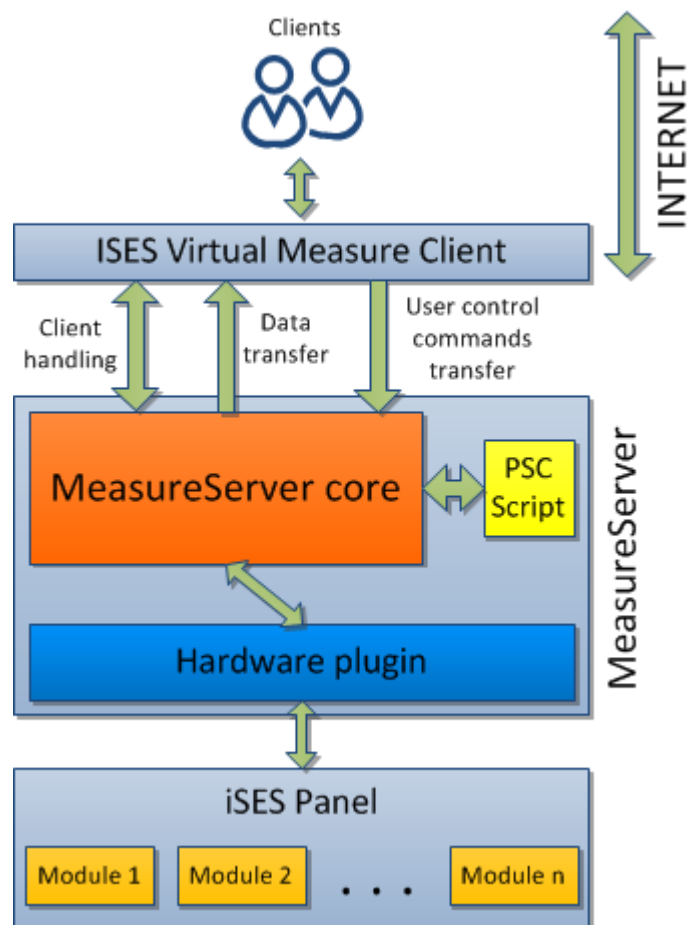


Figure 16 – MeasureServer architecture

ImageServer

Transferring image information to the client provides ImageServer. Server periodically stores snaps (stream) acquired by the webcam, which is then displayed by the special Java applet to the client. Server stores the image in two sizes to ensure large and small resolution depending on the Internet speed rate. If the camera is equipped with controls of position and zoom, ImageServer is able through Java applet to respond to client's requests and it is available to move the camera directions. Figure 17 shows ImageServer GUI. [21]



Figure 17 – ImageServer GUI [21]

The ImageServer functionality is illustrated in the Figure 18. Webcam provides video view of the experiment that is connected via USB to the server. ImageServer periodically saves actual image from webcam in two resolution sizes. The experiment view is provided to the client via Java applet on the ISES Virtual Measure Client. This applet periodically shows image which is saved by the ImageServer, the client can switch from small to large resolutions depending on his Internet connectivity speed. If the webcam is equipped with motion mechanism, the Java applet provides functionality to move the webcam to sides and to zoom in and out.

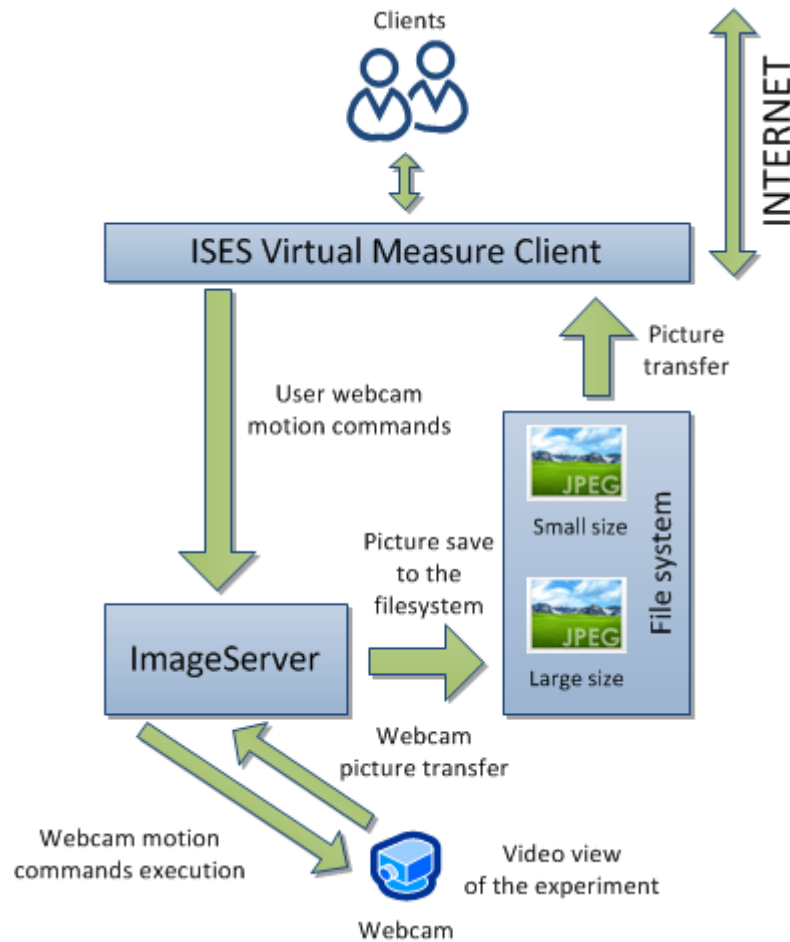


Figure 18 – ImageServer functionality diagram

HTTPRelayServer

HTTPRelayServer searches for available communication TCP ports for the clients who use the system with blocked communication ports. A classic example are blocked all ports except ports 80 and 443. Server in this case dynamically switches the available communication ports; standard ISES WEB CONTROL communication goes through port 8899. [21]

The behavior of the HTTPRelayServer is shown in the Figure 19. For security reasons, in some institutions, most of the communication TCP ports are blocked besides the commonly used (e.g. HTTP, email, telnet, etc.). MeasureServer communicates on port 8899 in default, when HTTPRelayServer detects that port 8899 is blocked it will find another open port and redirect communication to the open port.

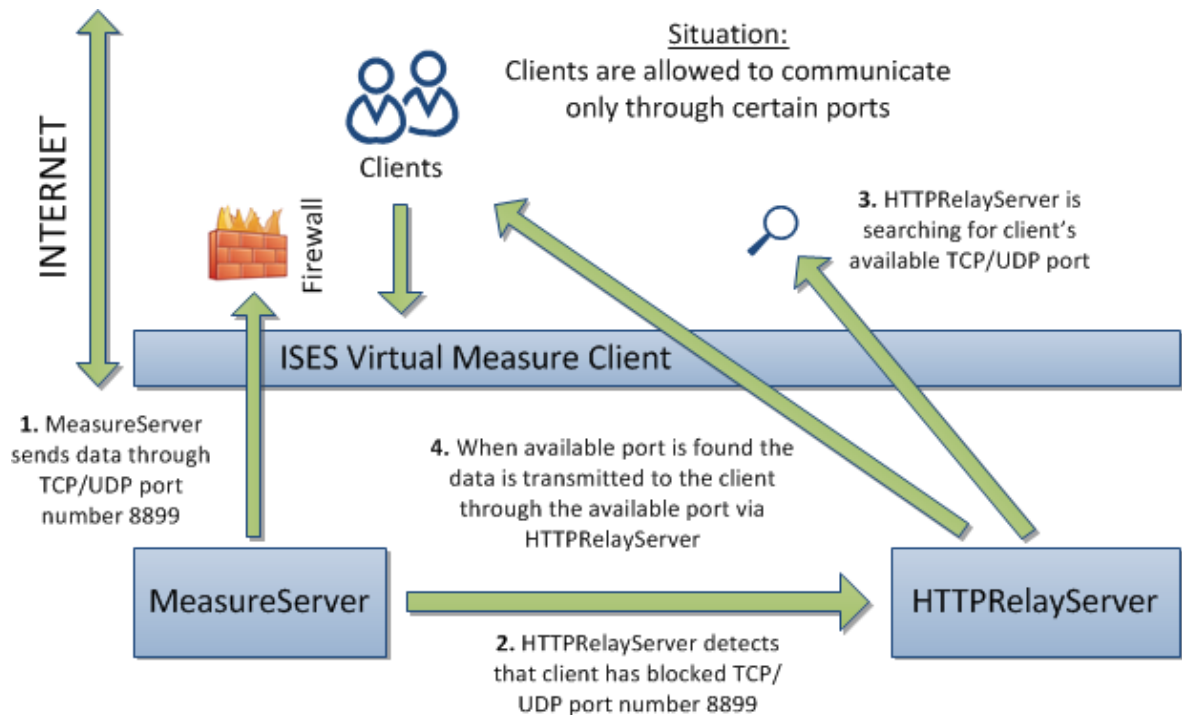


Figure 19 – HTTPRelayServer functionality diagram

ISES Virtual Measure Client

ISES Virtual Measure Client is part of the system running on a web server, through which the client communicates with the server, receives the measured data and sends control commands to the server. ISES Virtual Measure Client serves as a thin-client; this means any client does not need any special desktop software (eq. National Instruments runtime engine for LabView) installed on his/her desktop. The ISES Virtual Measure Client is composed of Java applets. Every Java applet handles partial functions of the entire system (see Appendix P I for example HTML source codes). This provides modularity to compose different applets depending on the experiment. An example is the applet for creating graphs, the display of measured data, or video camera view in conjunction with ImageServer. Also there are the applets providing control options such as starting the measuring process, switching relays, or change the intensity of input sources (e.g. change in light intensity emitting from the lamp). [22]

Figure 20 displays a view of the ISES Virtual Measure Client, experiment “Transients in RLC circuit” which runs the lab at TBU FAI.

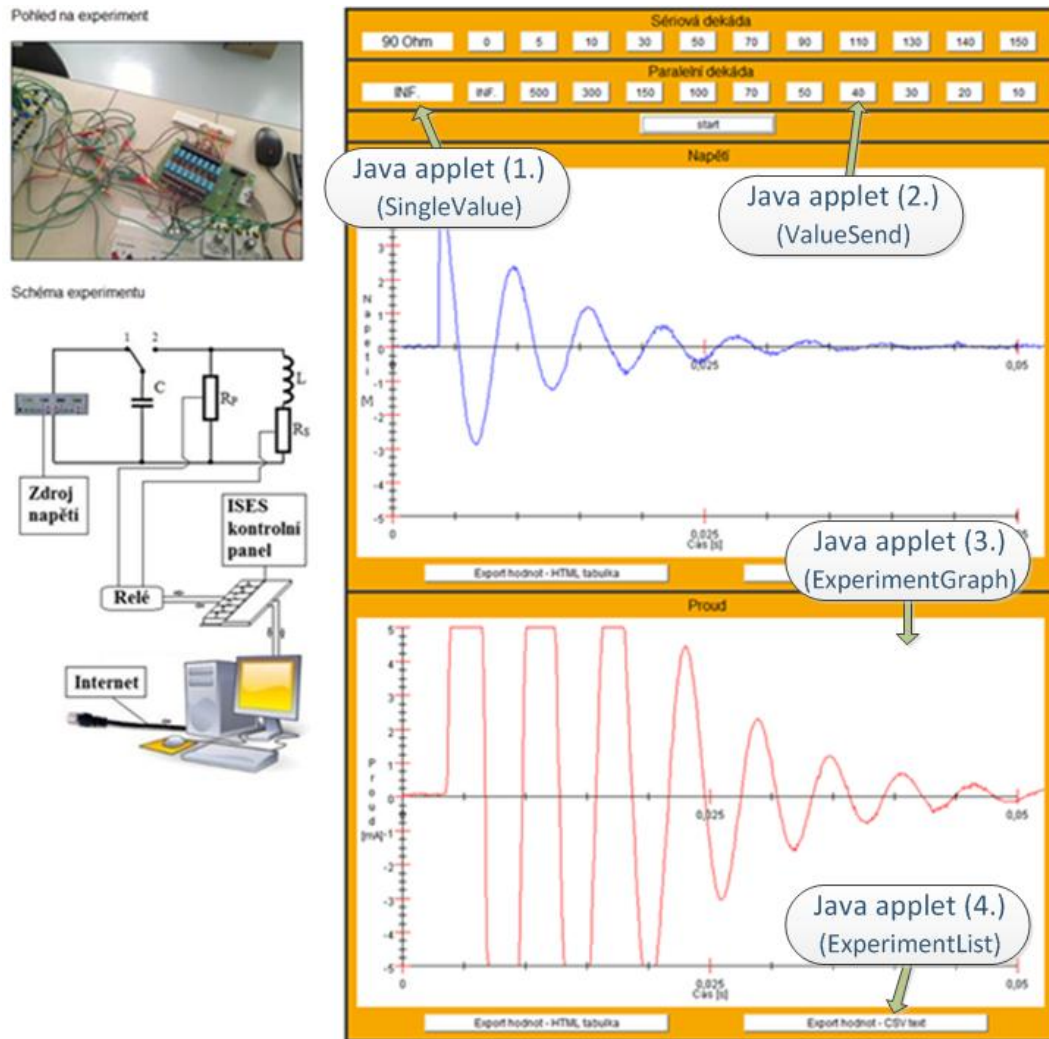


Figure 20 – ISES Virtual Measure Client,
TBU FAI “Experiment Transients in RLC circuit”
(see Appendix P I for source codes)

ISES Virtual Measure Client functionality diagram (Figure 21) shows architecture and actions executed by the server. The client connects to ISES Virtual Measure Client which is common webpage containing all necessary Java applets. When the client is connected, ConnectionHub (also Java applet) sends signal to the MeasureServer and MeasureServer determines which client will gain control over the experiment (if more than one client is connected). MeasureServer sends information about its status and selected client back to the ConnectionHub, also initialize communication with the client on TCP/UDP port (default port is 8899). If connection is not established, communication is redirected to another port found by the HTTPRelayServer. After MeasureServer’s information (status, selected client) is received by ConnectionHub, it starts initialization of the partial applets. The initialization is process when every partial Java applet starts, after successful startup,

the applet sends signal to the ConnectionHub. After all initialization signals are received by ConnectionHub, it begins data transmission to the client.

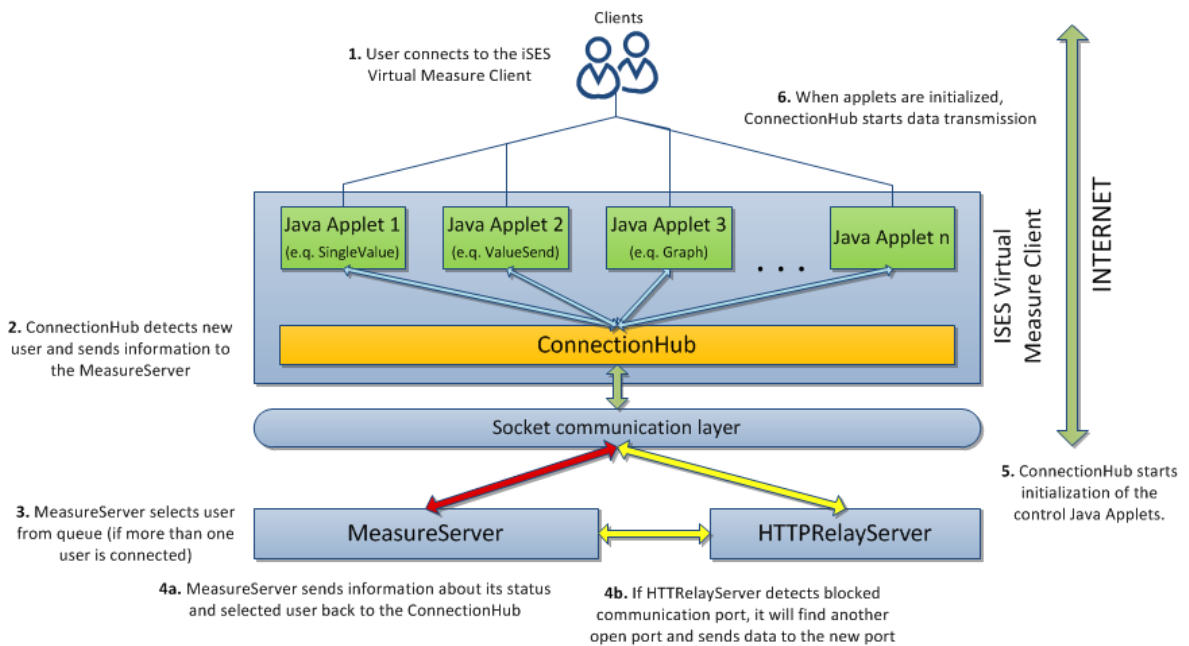


Figure 21 – ISES Virtual Measure Client functionality diagram

ISES Virtual Measure Client contains up to 40 different applets to provide wide range functionality and variability for use in any experiment. Table 1 shows list of the most frequently used applets. Any applet is defined in HTML by tag `<applet></applet>`; the properties of the applet are set using tag `<param>`. Refer to the web page source codes on the CD for ISES Virtual Measure Client web page source code of the “Transients in the RLC circuit”

Table 1 – Examples of the ISES Virtual Measure Client’s applets

Name of the applet	Brief description
ConnectionHub	The core of the ISES Virtual Measure Client. It provides connection to the MeasureServer and to the client. Also it control and monitor any other applet running on the ISES Virtual Measure Client.
ExperimentGraph	The basic plotter of the ISES Virtual Measure Client. There are almost 10 another plotters
ExperimentList	The MeasureServer saves predefined number of past measurement so client can easily receive old experimental data.
SingleValue	This applet shows current value of one input from ISES Hardware (e.q. module) or MeasureServer status information (e.q. measurement started/stopped)

Name of the applet	Brief description
ValueSend	Classic webpage button which provides control capabilities to the client.
Visualize	The view of the experiment acquired by the ImageServer is shown by this applet. Applet periodically refresh the image and client can choose between two resolutions

2.4 Remote laboratories at TBU FAI based on ISES

We are currently running three remote experiments at TBU FAI laboratory:

- Transients in RLC circuit (Figure 22)
- Photovoltaic energy transformation (Figure 23)
- Water level control (Figure 24)

The time-domain RLC experiment provides clients the opportunity to study and characterize all components of the RLC circuits. The client inserts artificial damping by serial or parallel resistors in the range of 0-150 Ω for serial and 10 – 500 k Ω in parallel connection. [23]

The photovoltaic energy transformation experiment measures the I(U) characteristic and the efficiency of the power transformation on the photovoltaic cell. The client can switch between four silicon and two organic cells. The solar energy is simulated by the lamp with adjustable light intensity. [24]

The Water level control experiment allows client to fill the container to an exact point and let out the pre-adjusted volume of the liquid the in a controlled manner. The water level is measured using static sensors and process is recorded in the graph.

Other experiments in Czech Republic and Slovak Republic based on ISES were built and are running at the Charles University in Prague, Palacký University in Olomouc or Trnava University in Trnava.

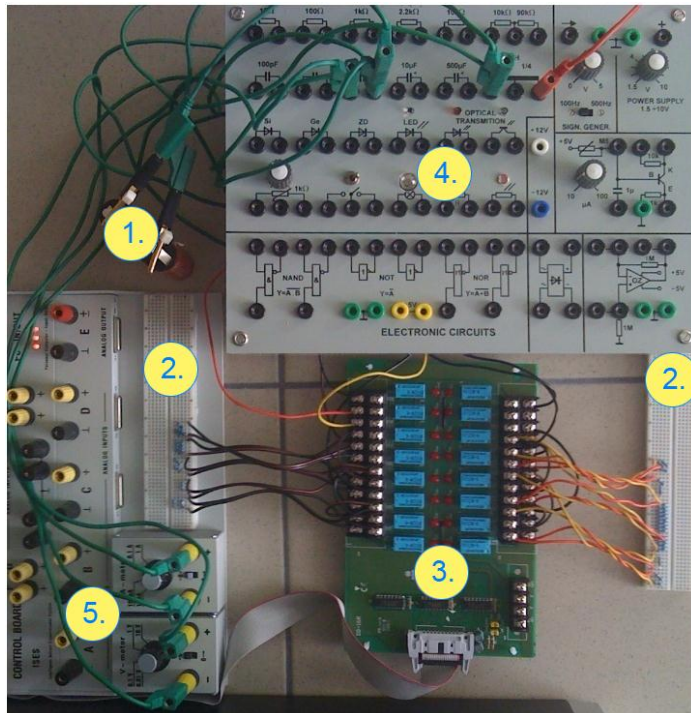


Figure 22 legend:

1. Electric energy source
2. Solderless contact field
3. Relay board
4. The ISES set of electronic components
5. ISES Panel with modules

Figure 22 – Transients in RLC circuit experiment [23]

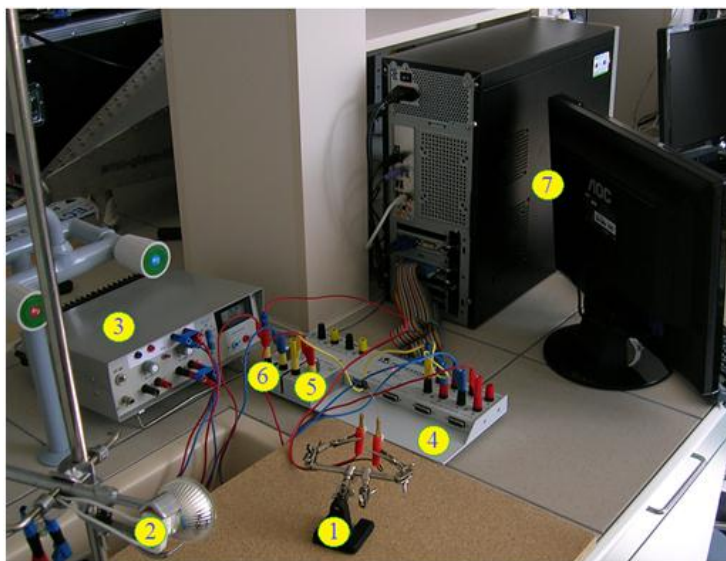
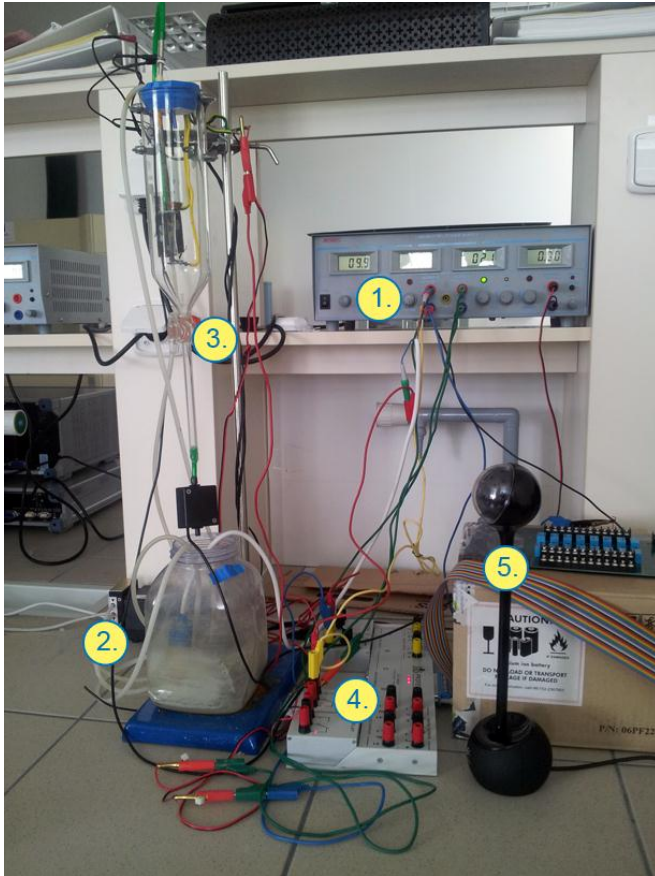


Figure 23 legend:

1. Solar cell
2. Solar simulator (lamp)
3. Controlled source voltage
4. ISES Panel
5. V-meter module
6. A-meter module
7. Server

Figure 23 – Photovoltaic energy transformation [24]

**Figure 24 legend:**

1. Electric energy source
2. Water pump
3. Laboratory aperture
4. ISES Panel with modules
5. Webcam

Figure 24 – Water level control

3 EUROPEAN UNION PROJECT

European Union project “European Remote Laboratories for Technology-Enhanced Teaching and Learning” (ICT Call 8; FP7-ICT-2011-8) is collaboration of 18 universities and 5 companies from 15 countries in Europe. The project focuses on the integration of remote and virtual laboratories, based on different technologies.

3.1 EU Project abstract

A network of remote laboratories and virtual experiments will be built to promote discovery-learning through on-line interactive experimentation with real instruments and associated simulations. The direct combination of experimental studies with simulations is essential to contextualize the learning, connect it with theoretical reflection and thereby promote deep understanding. The approach starts from the broad knowledge base of an international group of experts in the teaching and learning of science and technology, taking into account what is needed for better learning. Based on that, hardware and software will be developed and integrated into a user platform that will accommodate existing excellent teaching resources and easily accept new ones.

Large scale pilots will be carried out to make sure that the outcome will be easy plug-and-play learning resources and research based rules for teaching and learning with remote controlled laboratories. Teachers from schools and universities all over Europe will be skilled-up to develop, design and to use these materials. Components of a learning model and training resources will be available to support a more efficient, timelier and more cost-effective education in science and technology. An extendible Europe-wide ICTnetwork will exist that will offer the possibility of improved personalized learning and simultaneously encourage collaborations between schools and universities that can engage and inspire students at all levels and in all EU countries. [25]

The project idea is based on the new teaching strategy – INT-eL.

3.2 Integrated e-Learning

Integrated e-Learning (INTe-L) is a new strategy of education of physics based on the method sciences use for the cognition of Real world. Formally, it is based on the e-laboratory with remote experiments across the Internet, e-simulations and e-textbook. Its main features are the observations of the real world phenomena, possibly materialized in

data and their evaluation, search for relevant information, its classification and storing. Only then come the explanation and the mathematical formalism of generalized laws and their consequences. The indispensable quality of this method is the active part the student has to take in the teaching process both in lessons, seminars and laboratory exercises, but also his/her substantially increased activity in form of projects, search for information, presentations etc. [26]

INTe-L contains three main components:

- Remote e-experiments (see 1.1)
- e-simulations
- e-textbook

e-simulations and Easy Java Simulations

The e-simulations and modeling are using both Internet available and homemade Java or Flash applets. They serve for the demonstration and explaining of the observed phenomena and functioning of the concomitant physics laws. Surprisingly, the vast majority of applet simulations do not provide data output, needed for the comparison of real experiments and models. We try to compile for the multipurpose simulation applets providing the data outputs for the support (or contradiction) of the measured data with the model once. [27]

The e-simulations can be home-made in Java or Flash or can be made in specialized programs as the Easy Java Simulations.

Easy Java Simulations (EJS) is a software tool (java code generator) designed for the creation of discrete computer simulations. A discrete computer simulation, or simply a computer simulation, is a computer program that tries to reproduce, for pedagogical or scientific purposes, a natural phenomenon through the visualization of the different states that it can have. Each of these states is described by a set of variables that change in time due to the iteration of a given algorithm. All this means that EJS is a program that helps you create other programs; more precisely, to create scientific simulations.

There exist many programs that help create other programs. What makes EJS different from most other products is that EJS is not designed to make life easier for professional programmers, but has been conceived by science teachers, for science teachers and students. It has been designed to let its user work at a high conceptual level, using a set of simplified tools, and concentrating most of his/her time on the scientific aspects of our

simulation, asking the computer to automatically perform all the other necessary but easily automated tasks. EJS creates Java applications that are platform independent, or applets that can be visualized using any Web browser (and therefore distributed through the Internet), which read data across the net, and which can be controlled using scripts from within web pages. [27] [28]

Figure 25 shows global view of the simulation created in the Easy Java Simulations. The simulation simulates the ball on the spring and renders two plots: actual position in time and change in the overall energy in time.

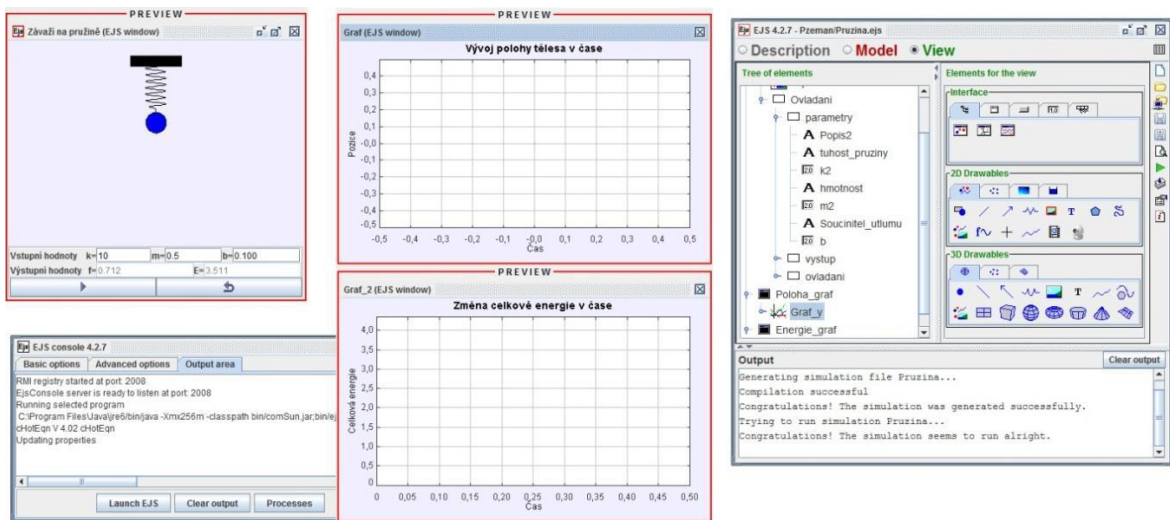


Figure 25 – Global view of the simulation created in the EJS

e-textbook and MOODLE

The e-textbook covering the theory, solved problems and exercises, glossary for quick orientation in the theory covered multiple-choice tests with immediate evaluation of the acquired knowledge. The INTe-L course in Mechanics using LMS (Learning Management System) MOODLE was introduced using the general scheme of INTe-L, i.e. e-remote laboratory (based on ISES), e-simulations and e-textbooks.[26]

Moodle is an Open Source Course Management System (CMS), also known as a Learning Management System (LMS) or a Virtual Learning Environment (VLE). It has become very popular among educators around the world as a tool for creating online dynamic web sites for their students. To work, it needs to be installed on a web server somewhere, either on one of your own computers or one at a web hosting company. [29]

The focus of the Moodle project is always on giving educators the best tools to manage and promote learning, but there are many ways to use Moodle:

- Moodle has features that allow it to scale to very large deployments and hundreds of thousands of students, yet it can also be used for a primary school or an education hobbyist.
- Many institutions use it as their platform to conduct fully online courses, while some use it simply to augment face-to-face courses (known as blended learning).
- Many of our users love to use the activity modules (such as forums, databases and wikis) to build richly collaborative communities of learning around their subject matter (in the social constructionist tradition), while others prefer to use Moodle as a way to deliver content to students (such as standard SCORM packages) and assess learning using assignments or quizzes. [30]

3.3 Project used methods

The EU project plans to use ISES as one of the three technologies to provide capabilities to build remote laboratories. The second technology is CMA and third LINKARE. Every of these systems have different architecture and functionality, the objective of the project is to integrate all systems into virtualized environment – Cloud computing.

Remote laboratory project requirements:

- The measured data has to be stored in centralized storage in predefined format (XML)
- The data should contain measured data from real experiment as well as from virtual experiment

Cloud computing

Cloud computing is a computing paradigm, where a large pool of systems are connected in private or public networks, to provide dynamically scalable infrastructure for application, data and file storage. With the advent of this technology, the cost of computation, application hosting, content storage and delivery is reduced significantly.

Cloud computing is a practical approach to experience direct cost benefits and it has the potential to transform a data center from a capital-intensive set up to a variable priced

environment. The idea of cloud computing is based on a very fundamental principal of 'reusability of IT capabilities'. (Figure 26)

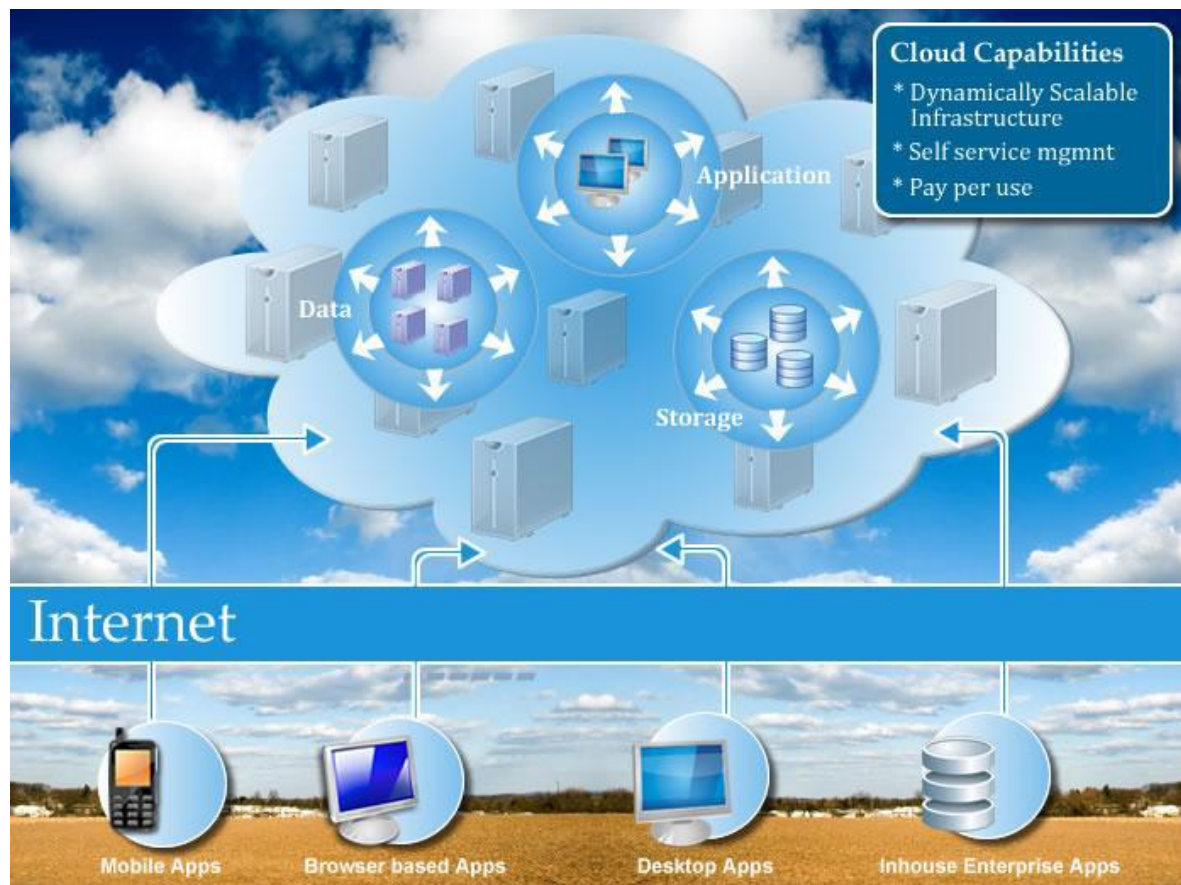


Figure 26 – Conceptual view of cloud computing [31]

Cloud Providers offer services that can be grouped into three categories: Software as a Service (SaaS), Platform as a Service (Paas) and Infrastructure as a Service (Iaas)

Some of the typical benefits are listed below:

- Reduced Cost
- Increased Storage
- Flexibility

The Cloud computing benefits outweigh the drawbacks and the model is worth exploring.

Some common challenges are:

- Data Protection
- Data Recovery and Availability
- Management Capabilities
- Regulatory and Compliance Restrictions

The virtualization is method for cloud computing, the best known virtualization solutions are from Citrix, Microsoft and VMware. [31]

Extensible Markup Language

Extensible Markup Language (XML) is a simple, very flexible text format derived from SGML (ISO 8879). Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the exchange of a wide variety of data on the Web and elsewhere. [32]

With XML, each individual piece of information is "marked up" (a marker shows the meaning of the associated data) with a tag that attaches meaning to the information. The unit of data to which a meaning has been attached is called an "element." An "element" consists of a "start tag", "content," and an "end tag." (Figure 27)

When required, an "attribute" can be described in the start tag of an element, allowing more detailed information to be assigned to the data. (Figure 28)

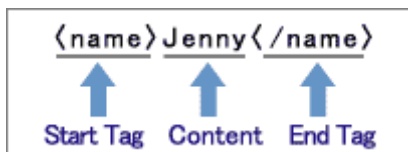


Figure 27 – XML element structure [33]

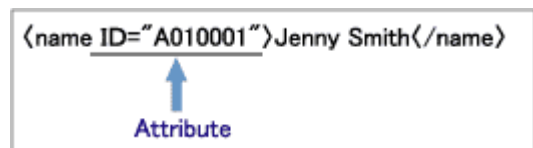


Figure 28 – XML attribute [33]

With XML, a hierarchical element structure can be created by nesting elements. Under the XML specification, one-and only one-XML root element (the outmost element in an XML document) must exist, giving XML a single "tree structure" always having a single root element at the top. A collection of compiled data starting with a root element is called an "XML Document." (Figure 29) [33]

```

XML Document Example
<List>
  <person>
    <department code="A01">education department</department>
    <name ID="A0100001">Jenny Smith</name>
  </person>
  <person>
    <department code="A01">education department</department>
    <name ID="A0100002">Michel Johnson</name>
  </person>
</List>
    
```

Figure 29 – Example of XML Document [33]

II. ANALYSIS

4 ISES WEB CONTROL DATA PROCESSING

The main objective of this thesis is the analysis of ISES WEB CONTROL in terms of data processing and communication with the client. On speaking about the data flow in ISES WEB CONTROL, we generalize this concept on all the data and their processing, storing and transfer, even visualization that serve to achieve the scientific or teaching goals using computer based (remote) experiment and/or complementary simulation of the real world processes. In this sense of generalization we speak about both electronic and even “mental data” for describing the process.

First I want to describe contemporary approach to this problem, and then I will focus on a new proposal to this important problem in connection with ISES WEB CONTROL new solution.

4.1 Data processing – present approach

The present data processing approach is based on five steps of ISES WEB CONTROL data acquisition during measurements (Figure 30). This diagram describes a standard procedure which has to undergo a client who wants to measure any of the experiments based on the ISES WEB CONTROL system.

The client has to master first the corresponding theory, to gain awareness of all possible useful and destructive phenomena that may occur during the measurement and data collection and realize all the assumptions for experiment. Study materials are typically in printed form or as e-textbooks saved in the centralized file system.

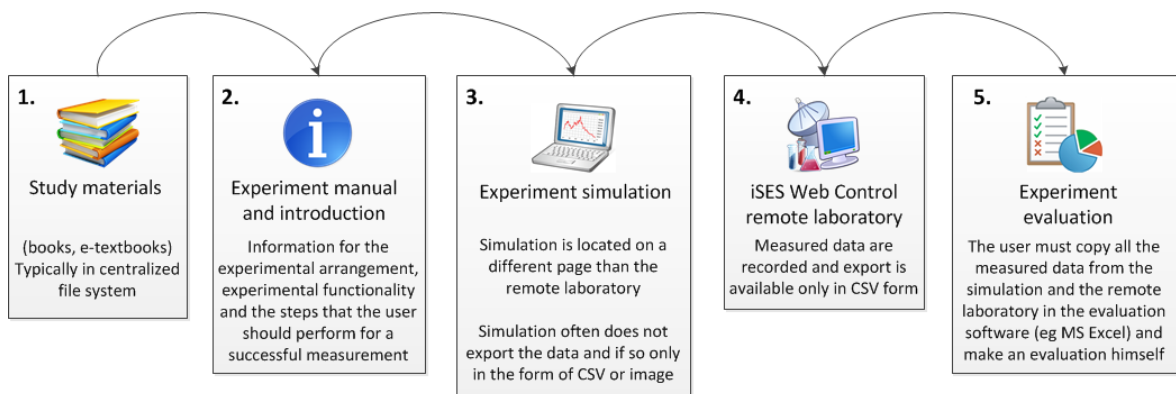


Figure 30 – Five steps of the contemporary ISES WEB CONTROL measurements

Before measurement the client should read experiment manual as well as experiment introduction that provides to him required information for successful measurement. The experiment manual has to give the assignment that provides the task description and goals to be achieved in an exploratory manner (not speaking about “recipe” assignments given in fixed and numbered steps that preclude the explorative way of problem solving). The concomitant simulation to the observed phenomenon is usually located on an URL address and displayed on an independent to the remote laboratory web page. Therefore, the client must work separately with simulation. Often the data export from simulation is missing and client must copy graphs as an image. Rarely client can export data in CSV format.

The fourth step is to connect to ISES Virtual Measure Client and run an experiment from remote laboratory. Figure 31 shows the flowchart that describes steps the client executes when using the remote experiment for the measurement.

The last step (Figure 30) is to evaluate the gathered measured data using any data processing software, which integrates the data from both simulation and experiment. Typically, the client plots the graphs of measured and simulated quantities in question, which are then used for the comparison of real data and data given by the theory and serve for the discussion of achieved results in measurements report.

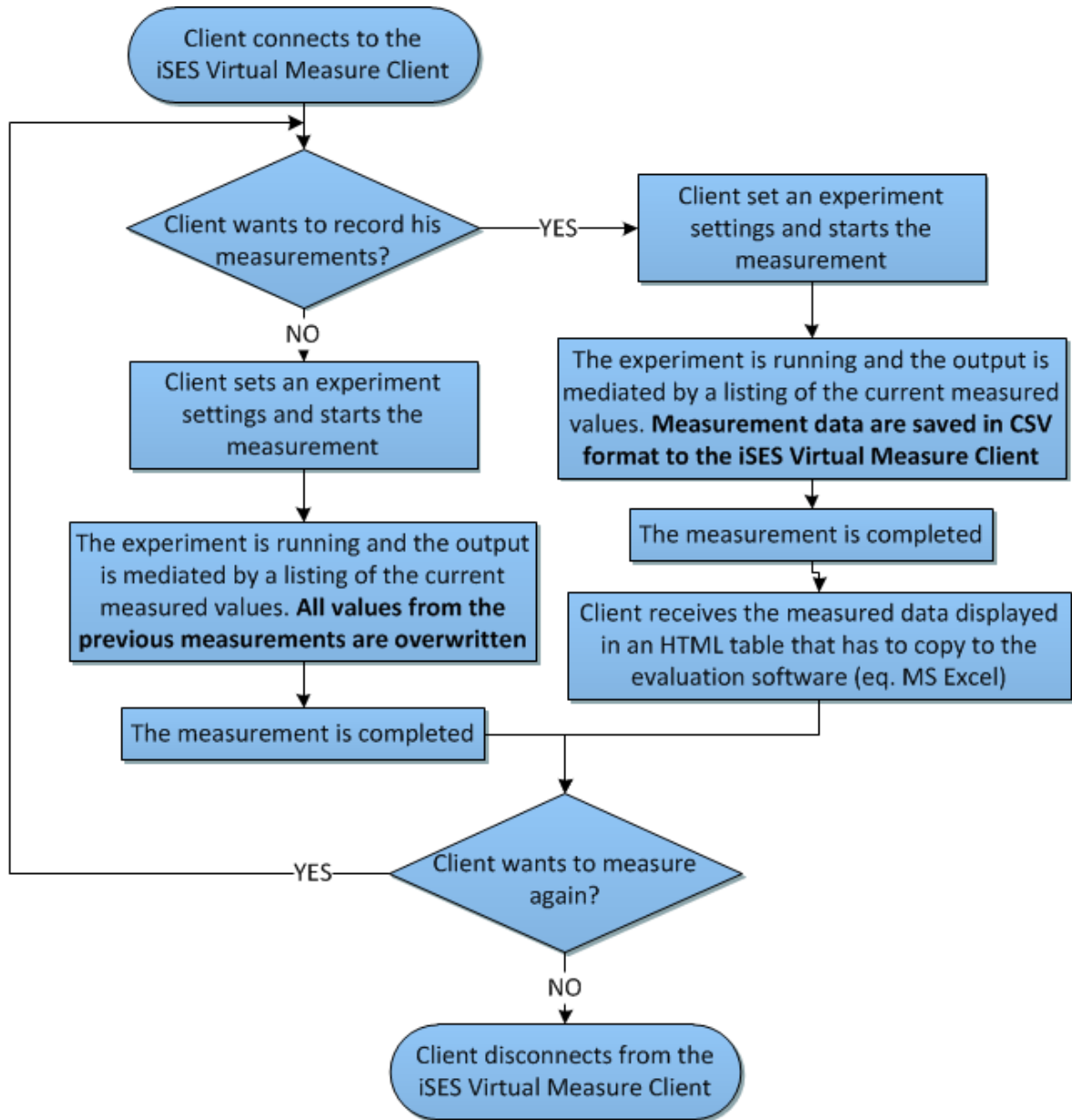


Figure 31 – ISES Virtual Measure Client client measurement flowchart

Figure 32 shows ISES WEB CONTROL old data processing concept. Experiment is connected via ISES Hardware and modules to the MeasureServer. The MeasureServer sends the measured data to the client and receives control commands from the client both via his/her web page controls. ISES Virtual Measure Client communicates using socket communication with the MeasureServer and provides client-server communication. ISES Virtual Measure Client is the only component that communicates with user. The measured data is stored in ISES Virtual Measure Client temporary memory. The temporary memory holds measured data for actual client. If MeasureServer logging function is enabled, the data is stored in TXT file in the server file system. Data to be exported from the

MeasureServer is withdrawn from the temporary memory or MeasureServer log file and displayed in the HTML format table from which the client copies them to the any evaluation software.

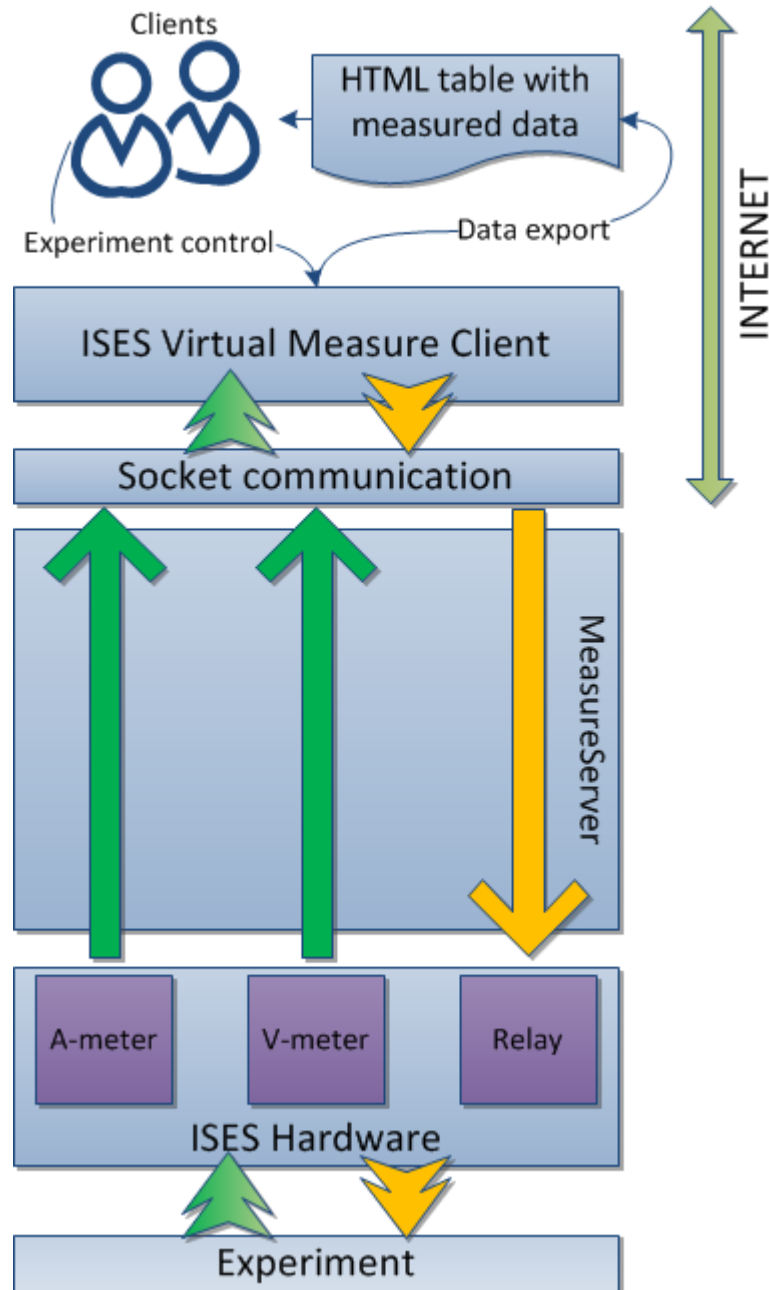


Figure 32 – Old data schematic description of the processing concept

4.2 Data processing – new approach

The old concept has a few drawbacks. First, every step (of Figure 30) is located on different web server and the client must switch between different web pages using corresponding URL addresses. Second the simulation often does not support data export

and is partially different (data format, graph style, data transfer etc.) from the measured experiment. Finally the data export is only via HTML table in CSV format and the client must copy it first to process it for the evaluation. The new approach for data processing focuses on the experiment and corresponding simulation integration and their simultaneous partial evaluation.

Proposal for the new data processing concept

The requirements for the new concept of data transfer and processing are based on the solution and removing of the above-mentioned drawbacks of the old concept, the EU call requirements and our long-term experience

- The system should integrate data from simulation and real experiment,
- ISES WEB CONTROL data export should be in two formats; CSV and XML,
- Data export in XML should be in according to the EU project standardization,
- Simulation, remote experiment and experiment evaluation should be running on the same server,
- The system should provide experiment login and steps statistics,
- Integration with remote experiments with collaborative features and into any Learning Management System (LMS), e.g. MOODLE. ,

The new concept of data processing transforms five steps of the ISES WEB CONTROL measurement (as depicted in Figure 30) into three steps of the ISES WEB CONTROL measurement (as depicted in Figure 33).

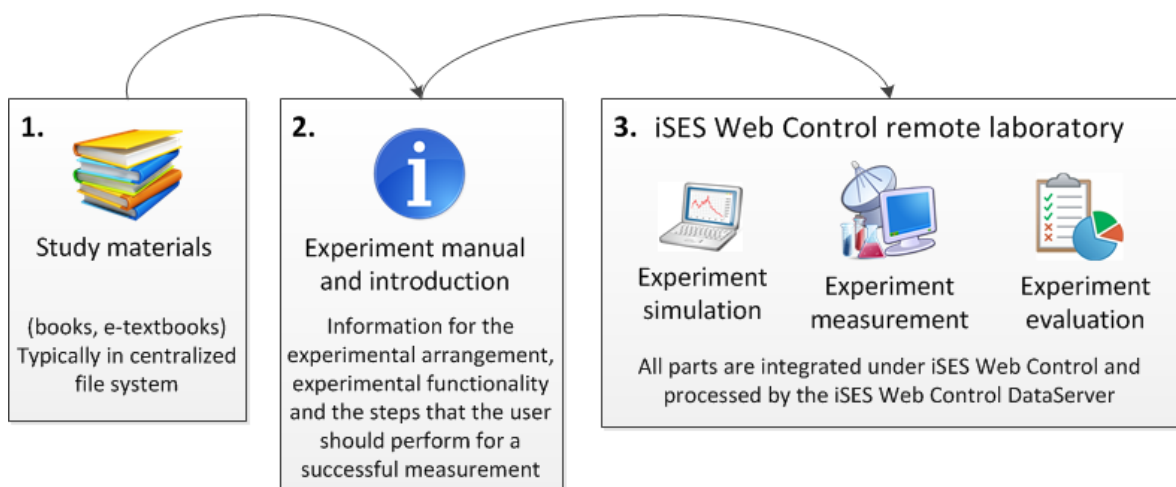


Figure 33 – Three steps of the ISES WEB CONTROL measurement

The real remote experiment and the simulation run under ISES WEB CONTROL system, and the system also integrates the corresponding data (measured and simulated) and makes their partial evaluation. By the partial evaluation we talk the averaging, filtering, noise removing, zero suppression etc., not touching the problem of physics behind the problem.

My general proposal for the new data processing concept for the ISES WEB CONTROL is presented on the Figure 34. Let me explain its basic features. Left part of the block diagram is identical to the old data processing concept (Figure 32) besides the measured data export. In the center of the diagram is the new server – DataServer. The DataServer has two parts: server desktop part and server web part. DataServer server desktop part creates socket communication layer that is used to gather measured data from ISES Virtual Measure Client along with the data from the simulation. The simulation must support socket communication in order to gather data by DataServer. This means that we can use any simulation if we ensure the simulation is able to send measured data via socket communication. DataServer stores the received data in two formats: CSV and XML. CSV format is used for graph plotting, when the experiment will collect a very large number of data in short time, DataServer filters the data for faster graph plotting and XML for unfiltered data storage.

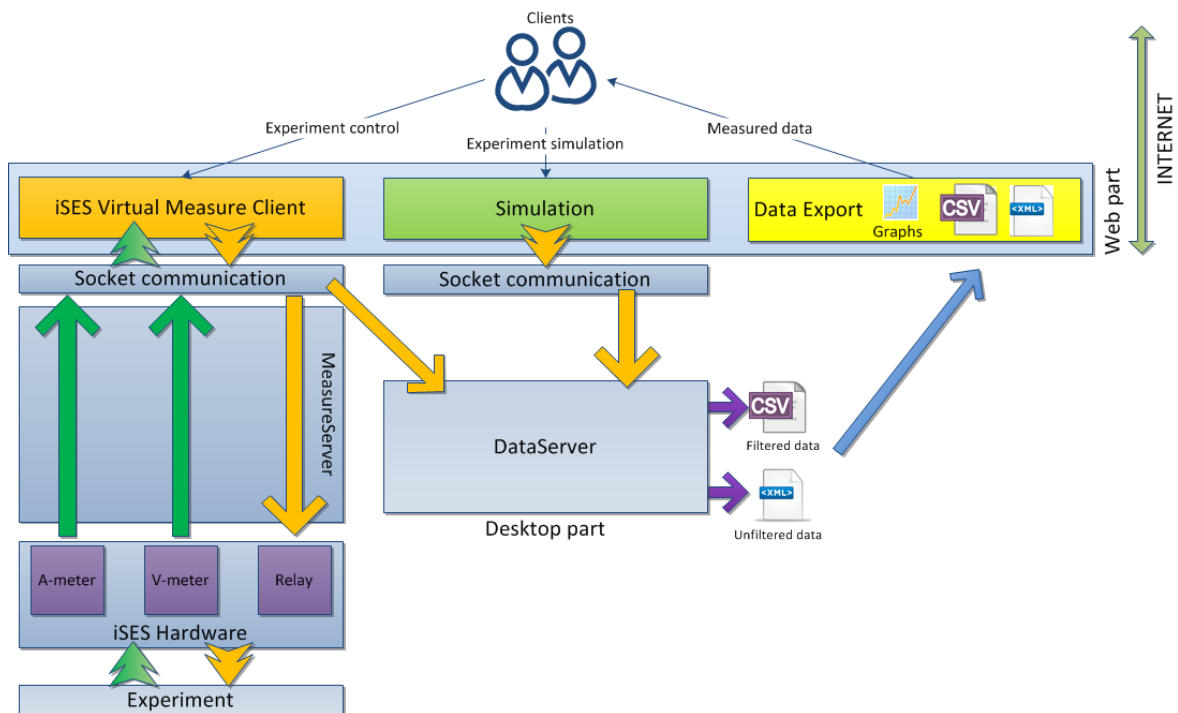


Figure 34 – Proposal for the new data processing concept

The DataServer server web part is client-side part of the system that integrates ISES Virtual Measure Client, simulation and Data Export. Data Export is part of the DataServer for presenting measured data and measurements partial data evaluation. Client receives his/her measured data from experiment and simulation as well as ability to plot graphs from his/her measured data. After the measurement, all data files are available to download in the Data Export part and ready for additional evaluation on the client's computer.

The new system for data processing, storing and evaluation required new additional parts to the existing ISES WEB CONTROL SW, so before creating the first proposal I had to evaluate the available techniques and programming languages used in the system ISES WEB CONTROL kit.

The choice of programming language for the server desktop part (DataServer) was straightforward. ISES Virtual Measure Client is completely programmed in Java and thus the easy combination of DataServer and ISES Virtual Measure Client was achieved. The second option was the choice of programming language C++ because in this language MeasureServer, ImageServer and HTTPRelayServer are programmed. I skipped this choice as complicated and not as flexible as Java was.

The programming language for the server web part (integration of ISES Virtual Measure Client, simulation and Data Export) was not so straightforward decision. The main decision was between PHP and Java language. I had three options for how to program this part. Every technique is common programmer procedure which needs to be adapted to a specific solution.

- **Java Servlet** – Java Servlet is a Java-based server side web technology. It serves a client request and receives a response from the server. Servlet is a Java class in Java EE that conforms to the Java Servlet API, a protocol by which a Java class may respond to requests. Servlets are most often used with the HTTP protocol.
- **PHP/Java Bridge** – The PHP/Java Bridge is an implementation of a streaming, XML-based network protocol, which can be used to connect a native script engine for example PHP, Scheme or Python, with a Java virtual machine.
- **PHP-Java socket communication** – A socket is one end-point of a two-way communication link between two programs running on the network. PHP represents web part, Java desktop part.

Java Servlet would be in my opinion the best choice because it is a powerful technology that could integrate every part of the ISES WEB CONTROL in one robust system. Unfortunately I have no experience programming in Java EE and with Java Servlets. That is why I did not choose this solution.

The PHP/Java Bridge would be the second best solution after Java Servlet. However, after prolonged testing the system did not work as expected, especially because of the web server incompatibility. ISES Virtual Measure Client runs on the Nginx web server, unfortunately Nginx is not supported by this technology. However, ISES Virtual Measure Client stability was a major and it was not possible to use another web server. Nginx is only web server that provides sufficient stability.

The last possibility was implementation PHP-Java socket communication. Server desktop part runs as a socket listener. Web part sends predefined messages that server processes.

The detailed architecture and functionality is described later in this sub-chapter and implementation of this new data processing concept is described in chapter 4.3.

ISES WEB CONTROLDataServer

As mentioned above the ISES WEB CONTROL DataServer is data processing server for ISES WEB CONTROL. The main objective of this server is integration of measured data from simulation and experiment with partial evaluation. The server is divided into two parts; server desktop part and server web part. Figure 35 presents DataServer architecture.



Figure 35 – DataServer architecture

The web part integrates ISES Virtual Measure Client, experiment simulation programmed in Easy Java Simulations environment [27] and Data export. As mentioned in chapter 2.3 the ISES Virtual Measure Client is composed of the Java Applets. EJS simulation is also provided via Java Applet. An applet is a program written in the Java programming language that can be included in an HTML page, much in the same way an image is included in a HTML page. When we use a Java technology-enabled browser to view a page that contains an applet, the applet's code is transferred to client's system and executed by the browser's Java Virtual Machine (JVM). This means an applet is running on client's computer therefore it cannot communicate directly with the server only via socket communication or via Java Servlet.

I have implemented socket communication extension to the ISES Virtual Measure Client for connectivity to the DataServer. As a simulation we can use any EJS based simulation that needs little adjustment only. We must add socket communication extension to the existing EJS simulation (see 4.3). ISES Virtual Measure Client function is extended to assigning unique client ID using PHP session ID. The Data Export unit is output of the system to the client. This part provides capability to download measured data and provides partial evaluation using pChart2. pChart2 is a PHP library that can create anti-aliased charts or pictures directly from web server. pChart2 has the ability to render graphs from clients measured data on demand or in real time.

The server desktop part is composed of three parts:

- **Communication module** – Communication module is multi-threaded socket server that listens on predefined TCP port (default is 7777). Transforms messages from ISES Virtual Measure Client and EJS simulation for further processing done by DataServer core.
- **DataServer core** – DataServer core provides data processing abilities, send measured data to the Export module for further processing, handles client log and GUI (Figure 36) of the server. Sample config file is shown in Figure 37 and sample client log on Figure 38.
- **Export module**–Export module saves unfiltered data do the XML file. If filtration is enabled, export module filters data in at a specified rate (1:1, 1:2 etc.). As an example 1:2 means measured data in one time unit is saved, measured data in two time units are deleted. Filter function is used when measuring a large number of data in a short time for faster graphs plotting.

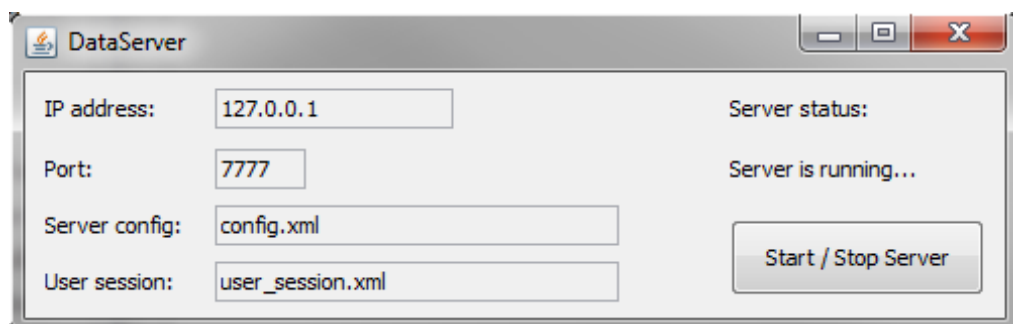


Figure 36 – Dataserver GUI

```
<?xml version="1.0"?>
<DataServer>
  <config name="ipaddress" value="127.0.0.1"/>
  <config name="port" value="7777"/>
  <config name="userlog" value="user_log.xml"/>
  <config name="filter" value="true"/>
</DataServer>
```

Figure 37 – Sample config file

```
<?xml version="1.0"?>
<Measurement>
  <session id="ibdi6l58d2v3028hran0obp136" entry_time="25/4/2012-00:23:48"/>
  <session id="7am9vnfrghs57lrv37u3380uo0" entry_time="25/4/2012-11:56:10"/>
  <session id="d584g1e20w3s54851ddfe205s5" entry_time="13/5/2012-22:43:37"/>
  <session id="kdg10f156e05d4x8s915fr7e3d" entry_time="13/5/2012-23:37:58"/>
  <session id="a4e81f2dfg6r9dfgsew1f2fg0a" entry_time="16/5/2012-02:19:08"/>
</Measurement>
```

Figure 38 – Sample client log

The Export module processes filtered and unfiltered data as mentioned above. The filtered data represents one CSV file is one measurement. The unfiltered data are represented in a XML file. This XML file collects data from all measurement. This means one session ID, one XML data file. The structure of unfiltered XML file is shown on Figure 39.

```
<?xml version="1.0"?>
<Measurement>
  <session id="PHP session ID" entry_time="dd/mm/yyyy-hh:mm:ss"/>
</Measurement>
<Simulation>
  <s x="value1" y="value2"/>
</Simulation>
<Experiment>
  <e x="value1" y="value2"/>
</Experiment>
```

Figure 39 – Structure of the unfiltered XML data file

Figure 40 shows flowchart that describes steps that the client takes using new arrangement of new data processing concept measurements. The flowchart describes steps taken by the client along with steps done by the ISES Virtual Measure Client and DataServer. Chapter 4.3 describes the deployment of the proposed solution using experiment “Transients in RLC circuits“ as an illustrative example.

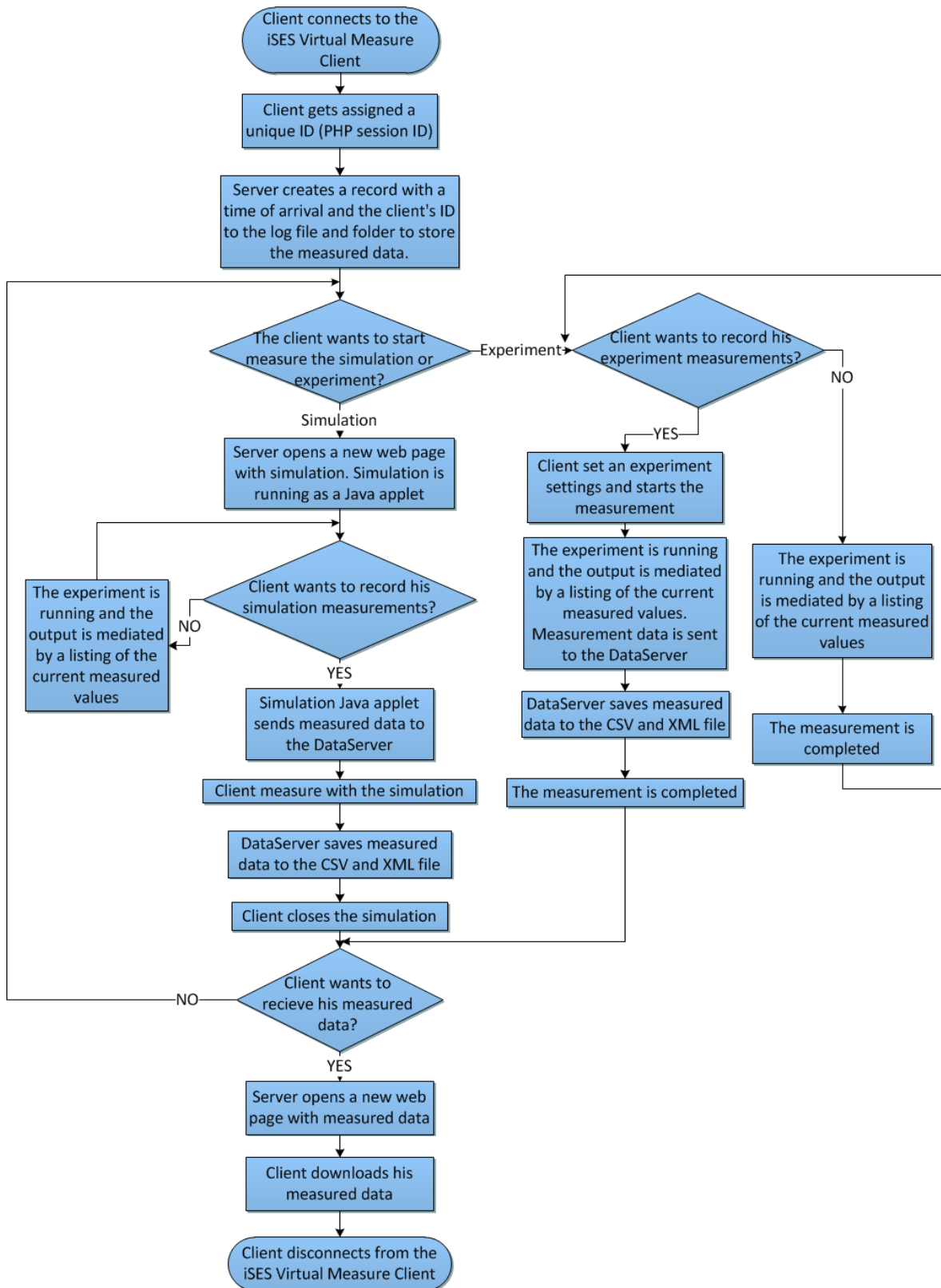


Figure 40 – ISES Virtual Measure Client new data processing concept flowchart

4.3 Implementation of the new data processing concept

To verify the functionality of an experiment, I chose “Transients in RLC circuit” experiment that runs in TBU FAI remote experiments laboratory (see 2.4). Figure 41 shows the server screen with running MeasureServer, ImageServer and DataServer. The server runs Nginx web server version 1.0.1.14.

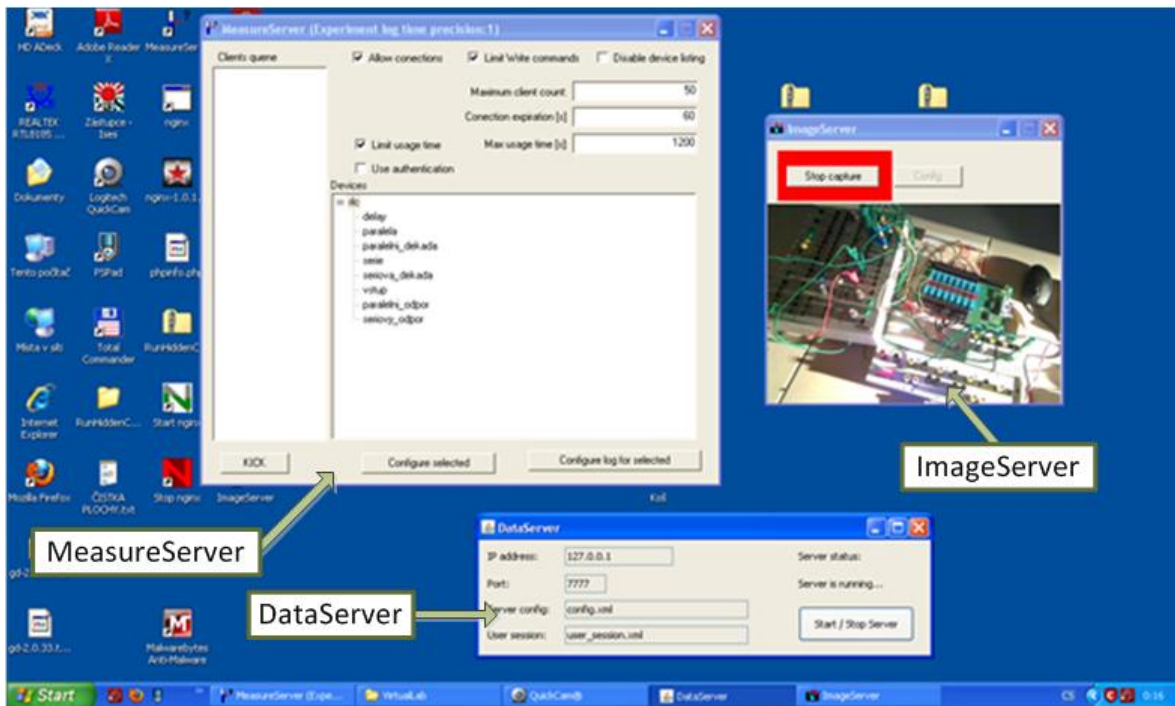


Figure 41 – The server screen with running MeasureServer, ImageServer and DataServer

When client connects to the webpage with running ISES Virtual Measure Client, the DataServer extension is presented to him (Figure 42). Extension informs client of his session ID and provides ability to open simulation or receive his measure data. Refer to the Appendix PII for full screens of every part of DataServer web part.

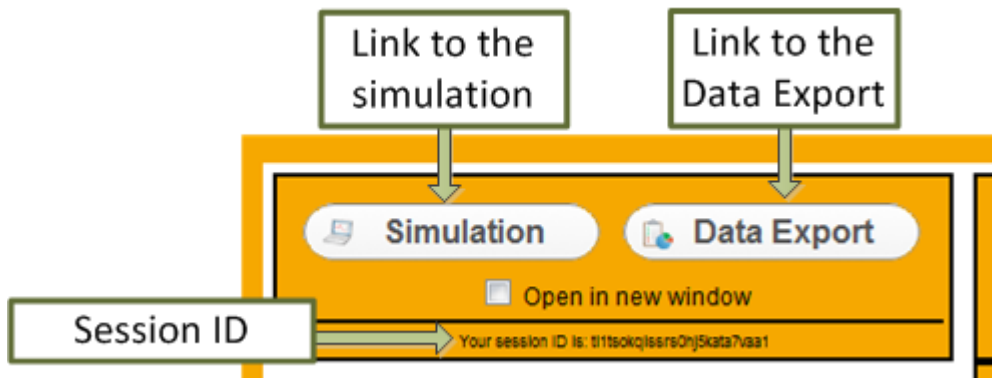


Figure 42 – ISES Virtual Measure Client with DataServer extension

When client clicks “Simulation” button, he/she will be redirected to the web page with EJS Simulation (Figure 43). Client also has option to open Simulation or Data Export in new window by checking the check box “Open in new window”. Simulation will send client’s data after enabling data transfer. To do this client needs to click “Start sending” button in the simulation. To stop, client needs to click “Stop sending” button in the simulation. For details about EJS adjustment see EJS modification later in this chapter.

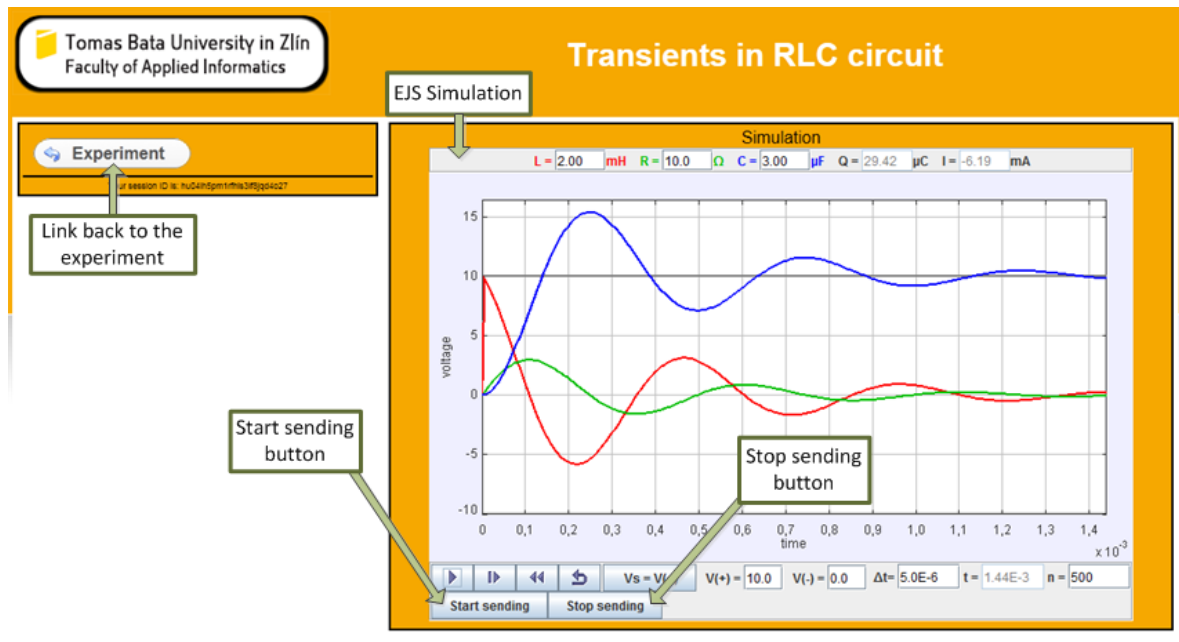


Figure 43 – Web page with EJS simulation

When simulation measurement is completed, client closes the simulation web page and returns to the ISES Virtual Measure Client. Measurement is exactly the same as in the previous version without DataServer. The data are automatically sent to the DataServer for processing.

DataServer creates folder on the server according to the client’s session ID (Figure 44). Every folder contains measured data in CSV and XML, eventuality PNG with rendered graphs. In the example experiment server creates one CSV file for every rendered graph. This means if client done three measurements with simulation and two with experiment, the folder will have five CSV files. The XML file contains all measured data from experiment and simulation.

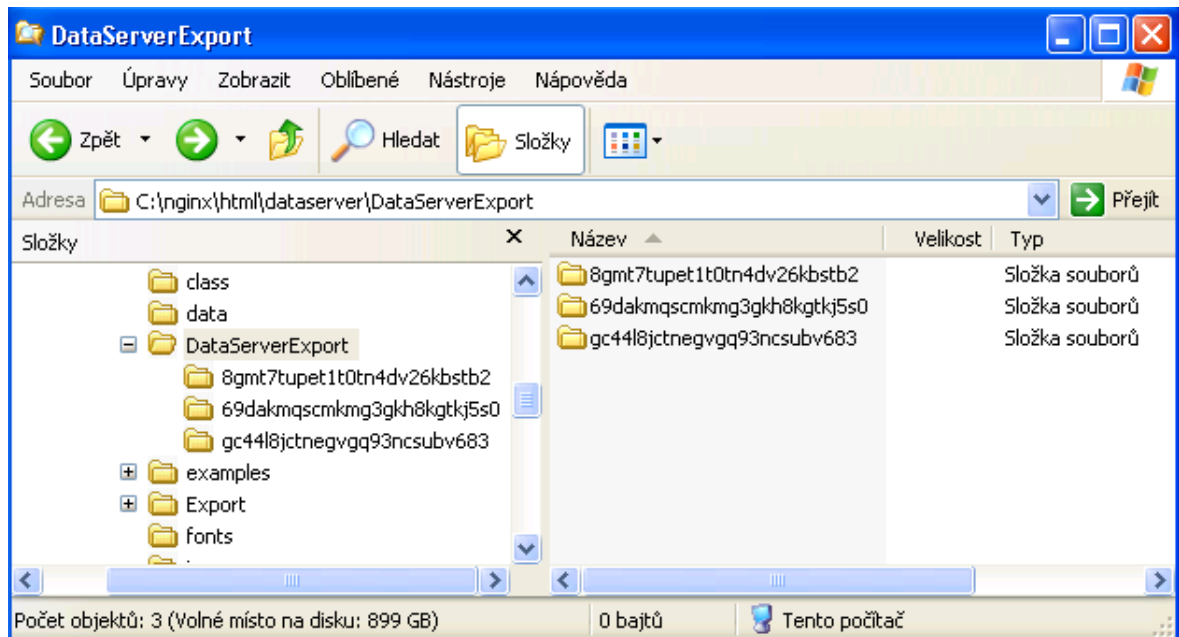


Figure 44 – Folders with measured data

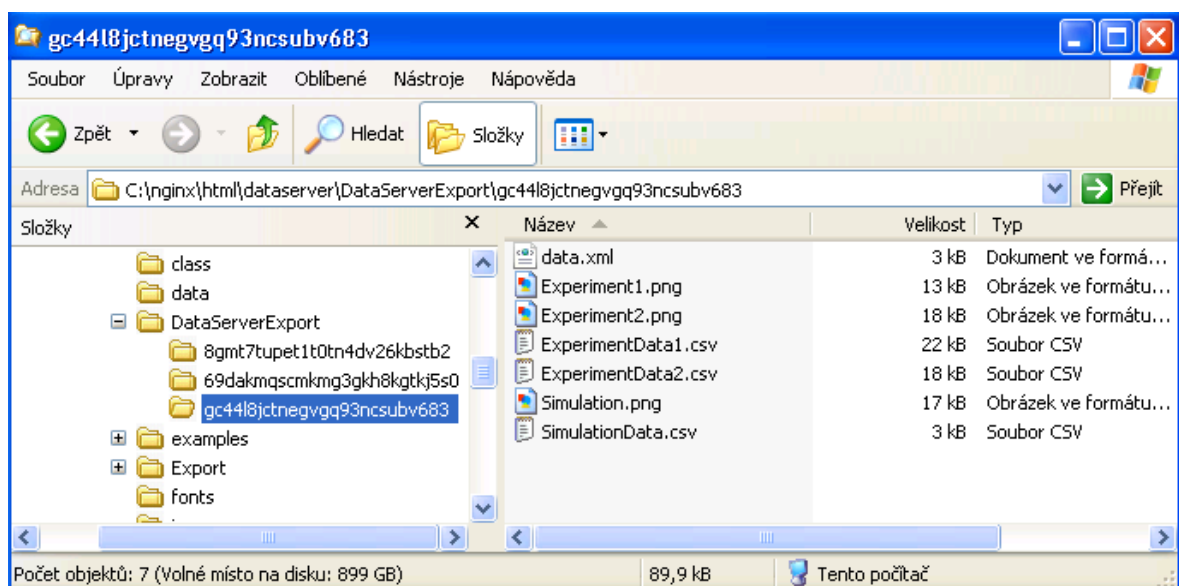


Figure 45 – Folder with measured data in CSV, XML and rendered graphs in PNG

When measurement from experiment and simulation is completed, the client can open Data Export (Figure 46) from the web part navigation (Figure 42). Data export delivers measured data in CSV and XML to download. If client wants to render graphs he can click the “render graphs” button. Rendering takes time. When rendering is completed, the client can download rendered graphs as well as measured data.

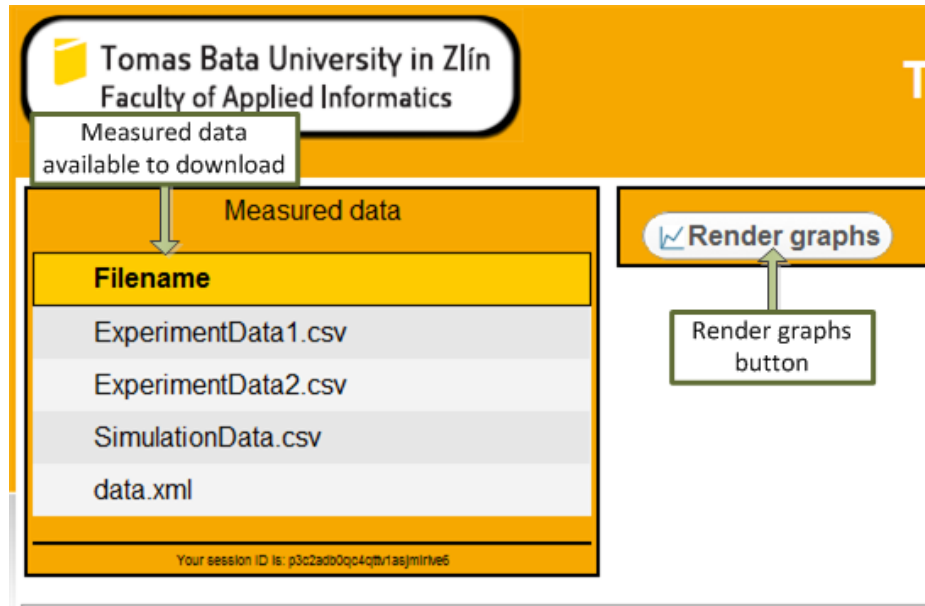


Figure 46 – Web page with exported data

EJS modification

As a simulation we can use and EJS based simulation that we can modify. 99% of the EJS simulations are editable, but the author does may/may not allow further editing.

The EJS modification is simple; first we need to add three mandatory variables (Table 2). Figure 47 shows variable setting in EJS environment. Variable **importSocket** imports Java library that provides socket communication capabilities. **Address** variable is IP address of the DataServer and **port** variable is TCP port on which DataServer listens. The **send** and **stop** are state variables I used them because of GUI of the simulation; for server connect extensions they are not mandatory.

Table 2 – EJS variables setting

Name	Initial value	Type
importSocket	<i>blank</i>	Java.net.Socket
address	Address of the DataServer	String
port	TCP port; DataServer communicates on port 7777 in default settings.	int
send	false ; not mandatory variable, only used as a state variable in experiment GUI	Boolean
stop	true ; not mandatory variable, only used as a state variable in experiment GUI	Boolean

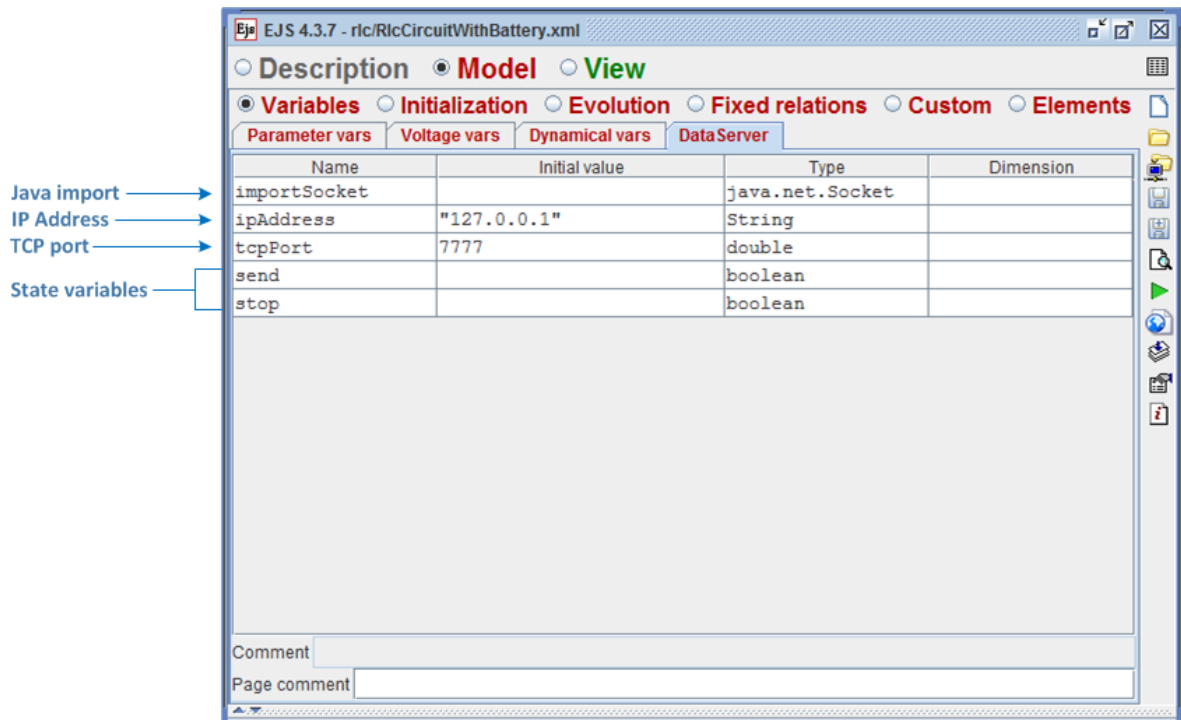


Figure 47 – EJS variables setting

The next step is adding the server connection extension. The extension is Java function which connects to the DataServer and sends measured data. To add this extensions we need to switch to Custom pane in EJS environment and import code presented in Figure 48 (or refer to the Appendix PIII).

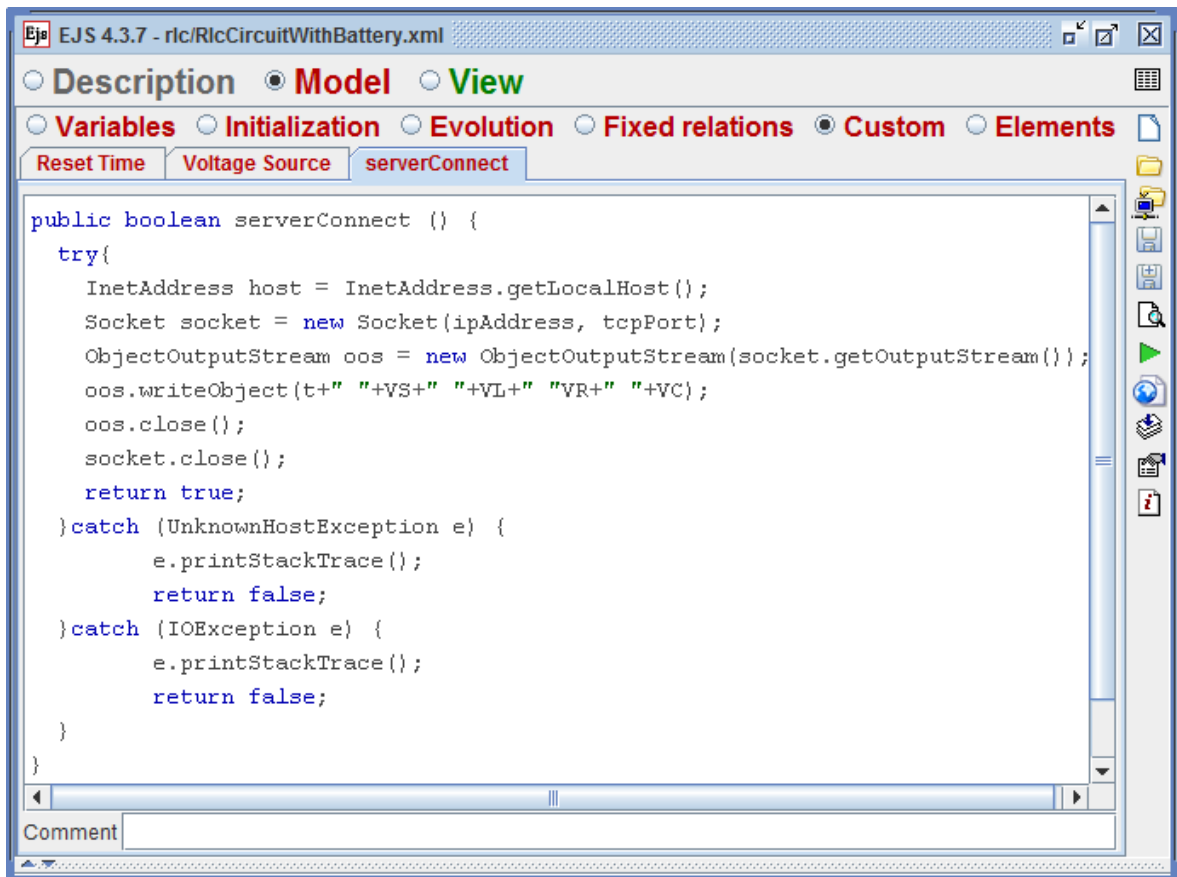


Figure 48 – EJS server connection

The last step is to set up graphical environment for server connection capability. This means we need to add control object (eq. button) that enables connection to the server. Figure 49 shows steps that we need to take to add control buttons to the simulation. First select button from the elements list (1), add the button to the tree of elements (2), the button will appear in the GUI preview. Double click on the button in the tree of elements to open properties windows and set **Text** and **Action** property. In this case **Text** value is start sending and **Action** value is send = true;. Repeat the procedure to add stop sending button, only Action value set to send = false;.

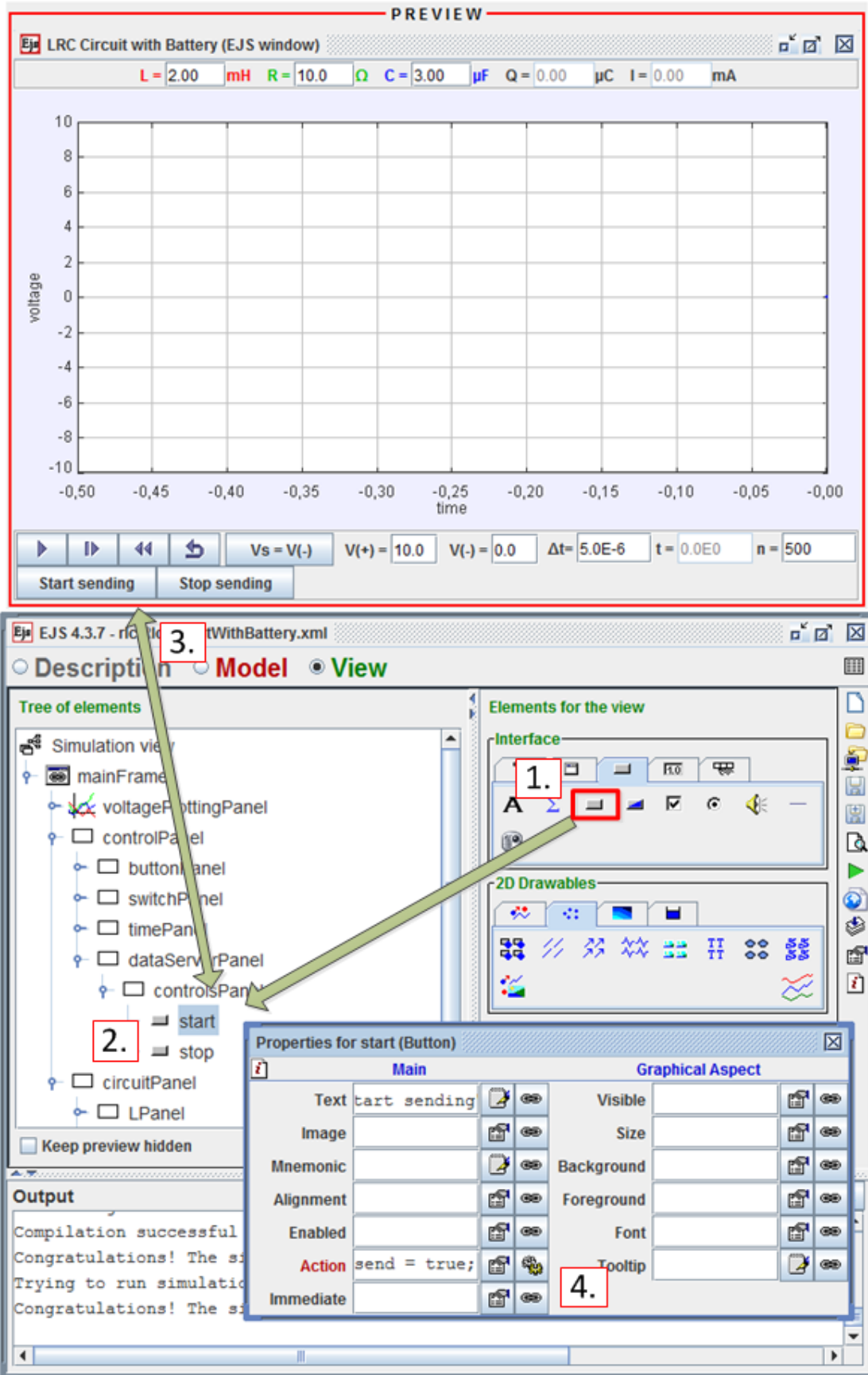


Figure 49 – EJS GUI adjustment

5 PROPOSAL FOR THENEXT STPIN DEVELOPMENT PHASE OF ISES WEB CONTROL DATASERVER

This chapter summarizes the achieved objectives, assesses the DataServer functionality and also contains a proposal for further development of the ISES Web Control in the areas of data processing, integration with the LMS and collaborative systems

5.1 Assessment of functionality of the first version of the DataServer

Requirements of the new proposal were set out in Chapter 4.2. Proposed system integrates measurement data from the simulation and remote experiment. Collecting data from ISES Virtual Measure Client is not perfectly solved, because there is duplication of data sending. MeasureServer sends measured data to the client, ISES Virtual Measure Client, which runs on the client at the JVM (because it is a Java applet); sends data back to the server for processing (to DataServer). This problem is due MeasureServer architecture that does not allow sending measured data to another server application.

DataServer saves measured data in two formats, CSV and XML. The XML is not according to the EU because no systematized pattern has been released yet. The structure of XML is easy to accommodate to any requirement. The main disadvantage of the XML is that XML always requires a processing application that can handle predefined XML format. Along with this disadvantage is the need to mention the need for suitable choice of algorithm that will process the XML files. It is necessary to take account of processing speed and size of the generated files. Every part of the system (Simulation, remote experiment and experiment evaluation) is running on the same server. The speed of the rendering engine (pChart) is a bit slow, more adjustment in suitable.

The Easy Java Simulation connection extension works fine but for easier usage it should be integrated as an EJS Element. EJS Elements are packs that provide additional functionality and are easily addable to any simulation.

The DataServer is now adapted to the “Transients in RLC circuit” experiment. The proposed concept verifies the correctness of data processing solutions, further development should be directed to the universality of the DataServer. Integration with LMS and collaboration system were not implemented. Proposal for further development of the DataServer is described in the next chapter; proposal is based on achievements and placed on the system needs and client’s needs.

5.2 ISES Web Control DataServer second version proposal

The proposal for the second version of the DataServer provides following functionality, based on the results analysis of the first version:

- DataServer should be universal in order to deploy to any experiment running on the system ISES Web Control.
- Data traffic should be minimized. Data gathering from the experiment should be on the server. The DataServer’s extension Data gatherer will provide this functionality.
- DataServer should be able to export data to the data storage in cloud.

Figure 50 shows proposal for the second version of the DataServer. Left part of this block diagram is the same as previews. The center part is different, DataServer has new component – Data gatherer. Data gatherer provides bridge between MeasureServer and DataServer and receives measured data directly from the MeasureServer.

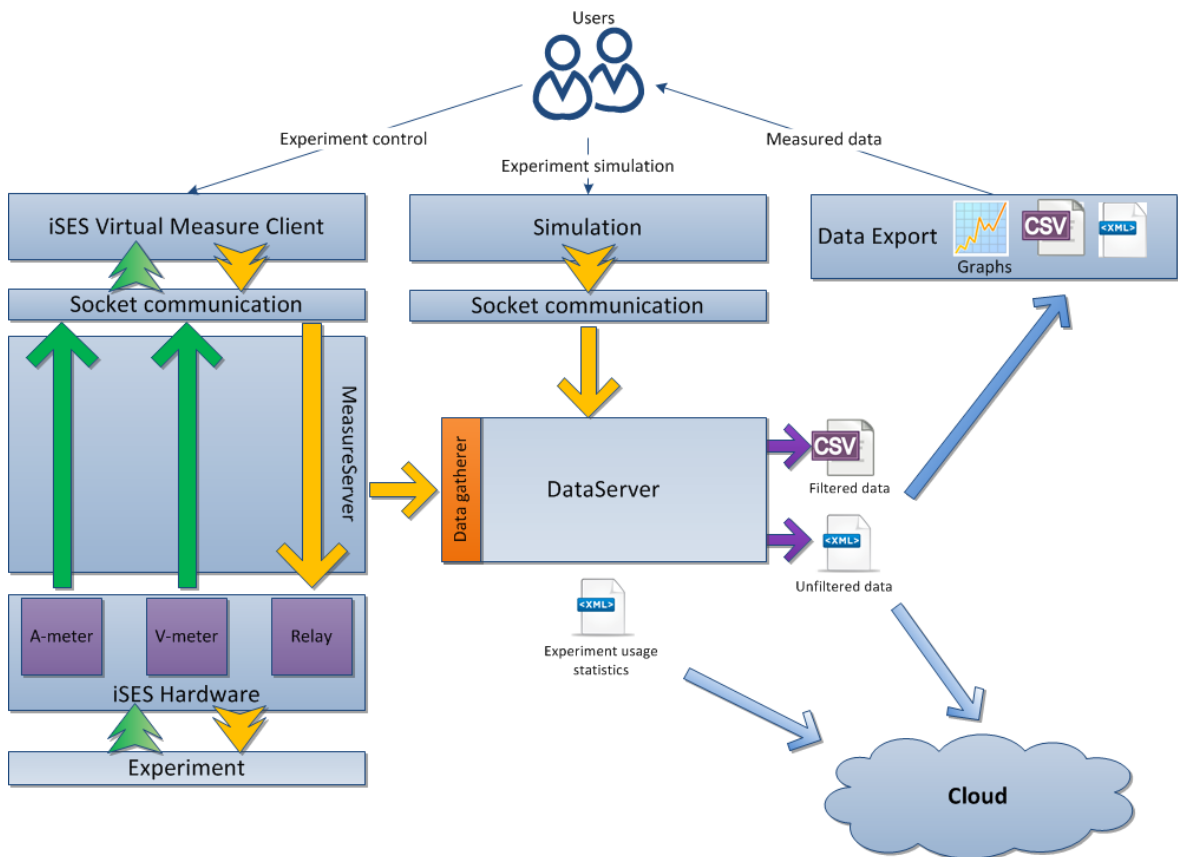


Figure 50 – ISES Web Control DataServer second version proposal

DataServer also provides functionality for export to the virtualized data storage which is shown in the right-bottom corner of the diagram. The Data export part provides additional options for working with measured data.

5.3 ISES Web Control integration to the Learning Management System

The main objective of the second development phase is integration to the LMS. As a Learning Management System in this proposal I choose MOODLE because it is widely used at TBU in Zlín where ISES is used as a technology for remote experiments.

The new concept integrates study materials, experiment manual, introduction and assignment under MOODLE. Figure 51 shows data diagram of the ISES Web Control integration to the LMS. User first study materials and experiment manual located on the MOODLE. As soon as he is familiar with all possible phenomena and experiment structure, he can proceed to the Entry knowledge examination.

Entry knowledge examination could be provided in two forms:

- **Moodle test engine** – Moodle is able to create tests from predefined questions bank. The results are saved in the Moodle to evaluate the performance of students. The problem is with export to third party software. Export to other software is not possible without interfering with the Moodle.
- **ISES Web Control examination module** – Examination module is Java Applet that can be easily imported to the Moodle page. The module can receive client information from the Moodle and send information to the DataServer.

When client passes entry knowledge test, he will be redirected to the experiment for measurement. The measurement procedure is the same as in first version of the DataServer.

The DataServer's Export module provides export to the virtualized cloud and to the Data Export as in the first version of the DataServer. Export module should be able to send measured data back to the Moodle for further evaluation and storage.

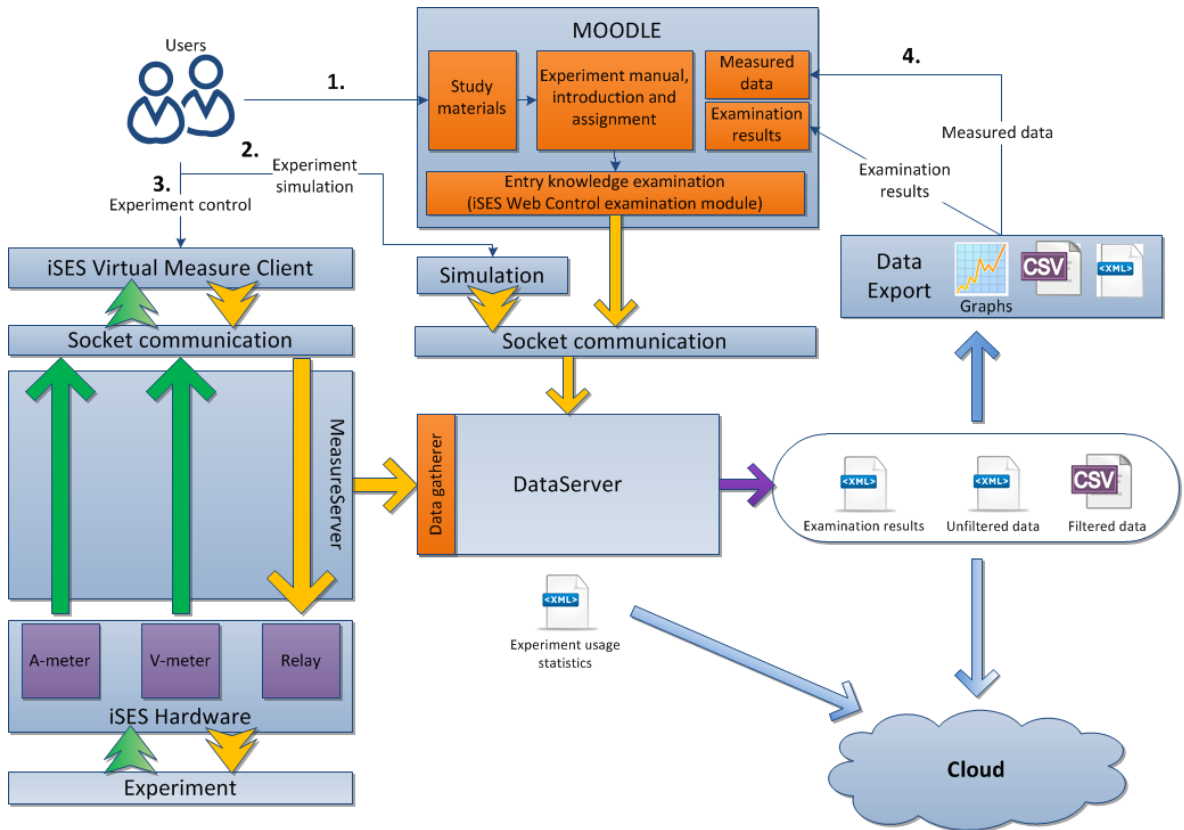


Figure 51 – Proposal for integration ISES Web Control with Moodle

This new concept transforms the three steps of the ISES Web Control measurement (Figure 34) into two steps of the ISES Web Control measurement (Figure 52). After this transformation the usage of ISES Web Control would be very easy, flexible, intelligent and robust.

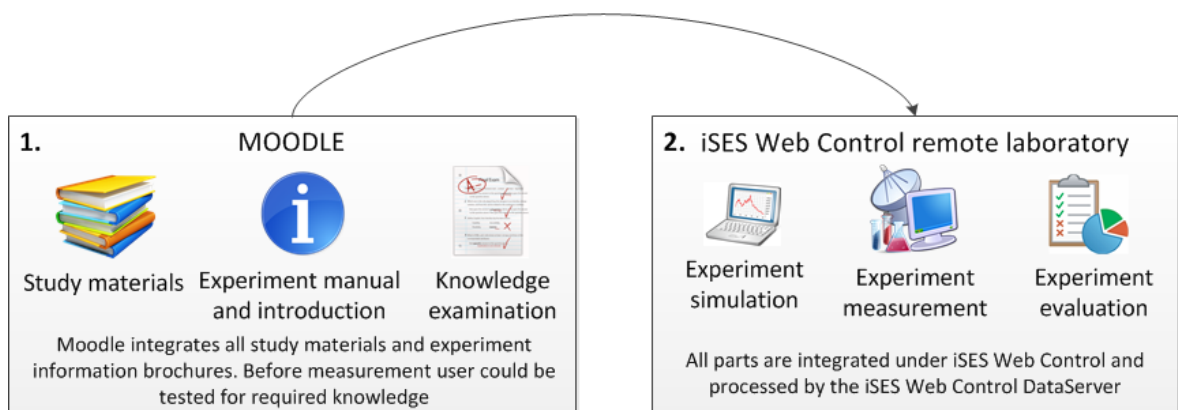


Figure 52 – Two steps of the ISES Web Control measurement

CONCLUSIONS

The thesis focuses on data processing system ISES; it describes the system throughout the ISES concept in terms of communication between the individual parts, data processing and communication with the client. Development of methodology INTe-L brought new needs that the system must provide remote experiments.

The thesis proposes a new concept of data processing system which provides integration of measured data from simulation and experiment. I verified this concept in the selected experiment. The thesis is also a proposal for further development of the system, especially in the area of data export into virtualized cloud and integration into Learning Management Systems.

The output of this thesis is prepared for testing and subsequent publication in a ICT journal.

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LIST OF ABBREVIATIONS

ADDA	Analog-Digital Digital-Analog
CMA	Centre for Microcomputer Applications
CMS	Course Management System
CSV	Comma Separated Values
EDA	Electronic Design Automation
EJS	Easy Java Simulations
FAI	Faculty of Applied Informatics
FPGA	Field-programmable gate array
GPIB	General Purpose Interface Bus).
GUI	Graphical User Interface
HTML	Hyper Text Markup Language
INTe-L	Integrated e-Learning
ISES	internet School Experimental System
ISO	International Organization for Standardization
Java EE	Java Enterprise Edition
JVM	Java Virtual Machine
LABI	Laboratories of integrated automation
LMS	Learning Management System
MOODLE	Modular Object-Oriented Dynamic Learning Environment.
MS	Microsoft
OLE	Object Linking and Embedding
PCI	Peripheral Controller Interface
PHP	Hypertext Preprocessor
SCORM	Sharable Content Object Reference Model

SGML	Standard Generalized Markup Language
SW	Software
TBU	Tomas Bata University
TCP	Transmission Control Protocol
TTL	Transistor-Transistor Logic
UDP	User Datagram Protocol
USB	Universal Serial Bus
VLAM	Virtual Laboratory of Microprocessor Technology Application
VLE	Virtual Learning Environment
XML	Extensible Markup Language

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Appendix P II: Screens of the DataServer web part

Appendix P III: EJS DataServer extension

Appendix P IV: DVD-ROM contains ISES Virtual Measure Server, DataServer, and EJS source codes

APPENDIX P I: ISES VIRTUAL MEASURE CLIENT EXAMPLE

SOURCE CODES

(0.) ConnectionHub java applet

```
<applet      codebase="/"      archive="virtuallabmeasureclient.jar"      name="hub"
code=virtuallabmeasureclient.hub.basic.connectionhub.class width=325 height=18>
<param name=server_ip value= "195.178.94.141">
<param name=http_server_url value="http://195.178.94.141">
<param name=server_port value= "8899">
<param name=authentication_code value= "">
<param name=use_random value= "1">
<param name=read_only value= "0">
<param name=control_timeout value= "1200">
<param name=expected_initialized_applet_count value="34">
<param name=terminate_timeout value= "300">
<param name=state_uninit value= "Neinicializováno">
<param name=state_connected value= "Připojeno">
<param name=state_closed value= "Spojení ukončeno">
<param name=state_io_error value= "Chyba komunikace">
<param name=state_error value= "Chyba programu">
<param name=state_security_error value= "Nedostatečná práva">
<param name=state_timeout value= "Vypršel timeout">
</applet>
```

(1.) SingleValue java applet

```
<applet  codebase="/"  archive="virtuallabmeasureclient.jar"  code=virtuallabmeasure
client.hub.modules.singlevalue.class width=100 height=20>
<param name=hub_name value="hub">
<param name=refresh value="300">
<param name=description value="Ohm">
<param name=device_name value="rlc_serie">
<param name=fractional_digit_count value="0">
<param name=s_min value="0.0">
<param name=s_max value="160">
<param name=d_min value="0.0">
<param name=d_max value="160">
</applet>
```

(2.) ValueSend java applet

```
<applet codebase="/" archive="virtuallabmeasureclient.jar" code="virtuallabmeasureclient.hub.modules.valuesend.class width=41 height=23">
<param name=hub_name value="hub">
<param name=device_name value="rlc_seriovy_odpor">
<param name=description value="0">
<param name=value value="0">
<param name=refresh value="100">
</applet>
```

(3.) ExperimentGraph java applet

```
<applet codebase="/" archive="virtuallabmeasureclient.jar" code="virtuallabmeasureclient.hub.modules.experimentgraph2.class width=760 height=430">
<param name=window_width value="750">
<param name=window_height value="300">
<param name=hub_name value="hub">
<param name=event_id value="2" >
<param name=reset_event value="1" >
<param name=storage_index value="2">
<param name=maximal_sample_count value="500000">
<param name=drop_sample_count_start value="1">
<param name=explicit_minimum_y value="-5">
<param name=explicit_maximum_y value="5">
<param name=explicit_minimum_x value="0">
<param name=explicit_maximum_x value="0.05">
<param name=device_count value="1">
<param name=device_name_1 value="burst_0">
<param name=s_min_1 value="34">
<param name=s_max_1 value="4095">
<param name=d_min_1 value="-5">
<param name=d_max_1 value="5">
<param name=color_1 value="0000ff">
<param name=fractional_digit_count_1 value="3">
<param name=display_fractional_digit_count_x value="3">
<param name=positive_only value="0">
<param name=axis_display_mode value="1">
<param name=values_description value="N|a|p|e|t|i|[V]">
<param name=time_description value="Cas [s]">
<param name=step_x value="0.005">
<param name=step_x_big value="0.025">
<param name=step_y value="0.25">
<param name=step_y_big value="1">
</applet>
```

(4.) ExperimentList java applet

```
<applet codebase="/" archive="virtuallabmeasureclient.jar" code=virtuallabmeasureclient.  
hub.modules.experimentlist.class MAYSCRIPT width=0 height=0>  
<param name=hub_name value="hub">  
<param name=device_count value="1">  
<param name=device_name_1 value="burst_0">  
<param name=event_id value="4">  
<param name=storage_index value="2">  
<param name=s_min_1 value="34">  
<param name=s_max_1 value="4095">  
<param name=d_min_1 value="-5">  
<param name=d_max_1 value="5">  
<param name=maximal_sample_count value="50000">  
<param name=data_start value="DataStartTable1">  
<param name=data_add value="DataAdd1">  
<param name=data_end value="DataEnd1">  
</applet>
```

APPENDIX P II: SCREENS OF THE DATASERVER WEB PART

Link to the simulation

Univerzita
Zlín

Link to the Data Export

Transients in RLC circuit

ISES Virtual Measure Client

Simulation Data Export

Open in new window

Session ID: Your session ID is: 3022a090c0d6f9a19m6e8

View of the experiment:


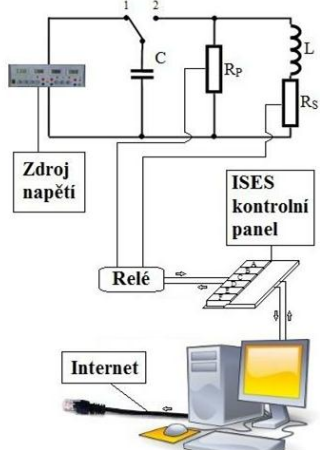


Schéma experimentu



Serial resistor decade

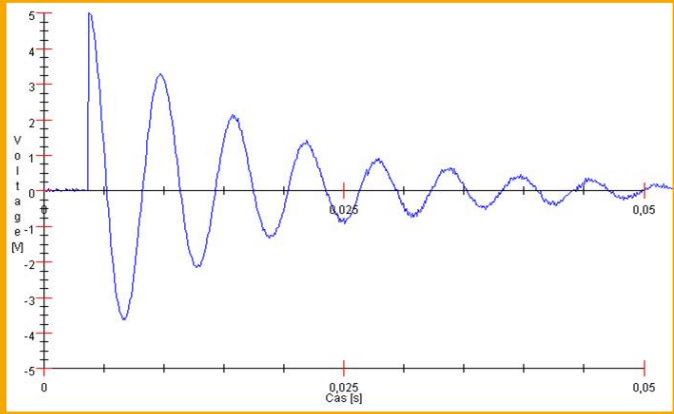
0 Ohm 0 5 10 30 50 70 90 110 130 140 150

Parallel resistor decade


100 kOhm INF. 500 300 150 100 70 50 40 30 20 10


start

Voltage



Current



 Tomas Bata University in Zlín
Faculty of Applied Informatics

Transients in RLC circuit

Experiment

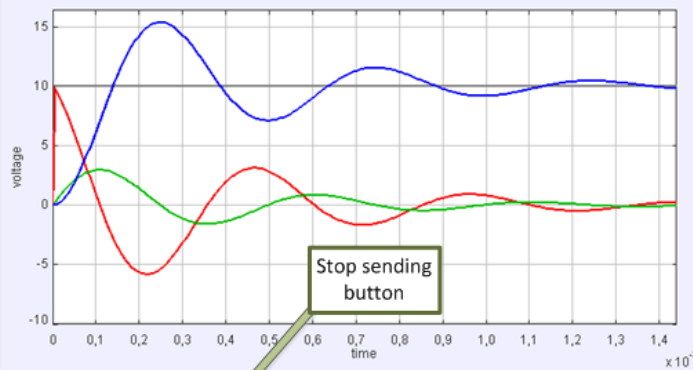
Link back to the experiment

Start sending button

EJS Simulation

Simulation

L = 2.00 mH R = 10.0 Ω C = 3.00 μF Q = 29.42 I = -6.19 mA



V(+)=10.0 V(-)=0.0 Δt=5.0E-6 t=1.44E-3 n=500

Start sending Stop sending

Stop sending button

Measured data
available to download

Measured data

Filename

- ExperimentData1.csv
- ExperimentData2.csv
- SimulationData.csv
- data.xml

Your session ID is: p3c2ad0c4c2b1a1a1m1ue6

Render graphs

Render graphs
button

APPENDIX P III: EJS DATASERVER EXTENSION

```
publicbooleanserverConnect () {  
  
    try{  
  
        InetAddress host = InetAddress.getLocalHost();  
  
        Socket socket = new Socket(ipAddress, tcpPort);  
  
        ObjectOutputStream oos = new ObjectOutputStream(socket.getOutputStream());  
  
        oos.writeObject(t+" "+VS+" "+VL+" "+VR+" "+VC);  
  
        oos.close();  
  
        socket.close();  
  
        return true;  
  
    }catch (UnknownHostException e) {  
  
        e.printStackTrace();  
  
        return false;  
  
    }catch (IOException e) {  
  
        e.printStackTrace();  
  
        return false;  
  
    }  
  
}
```