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# WEB-BASED LABORATORY TRAINING ON ELECTRICAL MEASUREMENT SYSTEMS

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**Abstract** – In the educational process of teaching engineers one important part is to bridge the gap between theory (functional principle, model….) and real world (hardware, devices…). By learning e.g. how to use an oscilloscope in a real application the functional principle is accompanied by an evaluation of the measurement results. In our web-based electrical laboratory www.internetlabor.ch the user trains himself how to push the right button on a real oscilloscope by a mouse click via his internet browser. The measured data downloaded subsequently are the product of a real hardware operation based on a real measurement action and not output of a simulation. Web-based instrumentation supports teaching only successfully, if the user understands the basic functional principles of the instruments already to some degree. In addition, the teaching process has to comprise a discussion of the measured data to achieve an understanding of how a reliable measurement result is obtained. Therefore, the electrical internet-laboratory is integrated in a web-based training environment on electrical measurement systems.

Keywords: web-based instrumentation, web-based training, educational laboratory.

## 1. INTRODUCTION

Together with other Swiss partner organizations we intend to build up a knowledge base on science and engineering of metrology under the leadership of the Swiss Federal Institute of Technology ETH - IMRT.[1] At the NTB we are responsible for the sub-project entitled “electrical measurement systems”. (Fig. 1) One part is the development of web-based training on theory and practical application aspects of electrical metrology. Most of the given information’s are based on text and figures well known from text books with simulations and animations added. [2] To understand and analyses electrical circuits the electrical engineer is accustomed to use EDA simulation tools like PSpice also in the field of electrical metrology. Therefore, animations accessible through the web-browser like FLASH are not as important in the training of electrical metrology as they are in other areas of technical training. An effective tool to teach the functional principle of devices e.g. of analog to digital converters is LABVIEW where animations based on “virtual” electrical instruments have been successfully achieved. [3]

It is a well known prerequisite to teach the basics of the functional principle of an instrument before using real hardware in the laboratory. The internet-laboratory [4] completes the web-based training of electrical metrology with a convenient access to real instruments and electrical circuits.

Thus three training steps are necessary:

1) Study the theory and principles of electrical circuits (text, figures, simulations, animations) [2]
2) Exercise of the use of real instruments (web-based electrical laboratory) [4]
3) Documentation and discussion of the measured results (email of the lab report and reply thereon)

## 2. BASICS of NTB INTERNET-LABORATORY

Up to now four types of laboratory tutorials are realized to measure the:

- DC voltage and current on a resistive load
- Frequency response of electrical signal filters
- EMC basic experiments (burst)
- Electrical power quality (three phases)

Thereby the user is able to control several instruments, located at NTB laboratory by interacting via a web-browser:

- DMM digital multi-meter
- Digital oscilloscope
- Waveform generator
- Power supply – voltage source
- Electrical filter – charged capacitor
- EMC burst generator
- Power quality meter

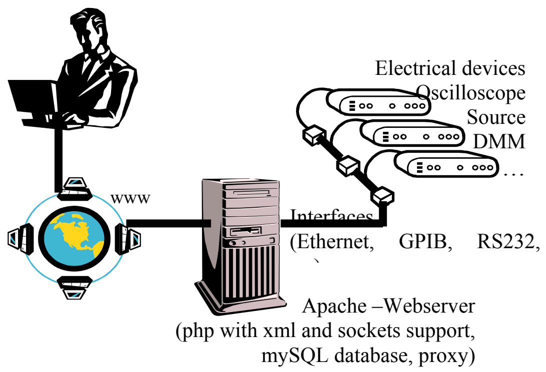



Fig. 1. Concept hard-software NTB internet-laboratory

### *2.1. Concept of the NTB internet laboratory*

To coordinate the different users on the internet and connect them to the appropriate measurement hardware the NTB internet lab uses a central web server and several decentralized interface servers (Fig. 1). Some of the measurement instruments are used in different experimental setups as e.g. the digital oscilloscope. In addition a reservation system was realized using timesharing to prevent conflicts between users on the same instruments at the same time. The solution developed to cope with these problems is illustrated in more detail in Fig. 3.

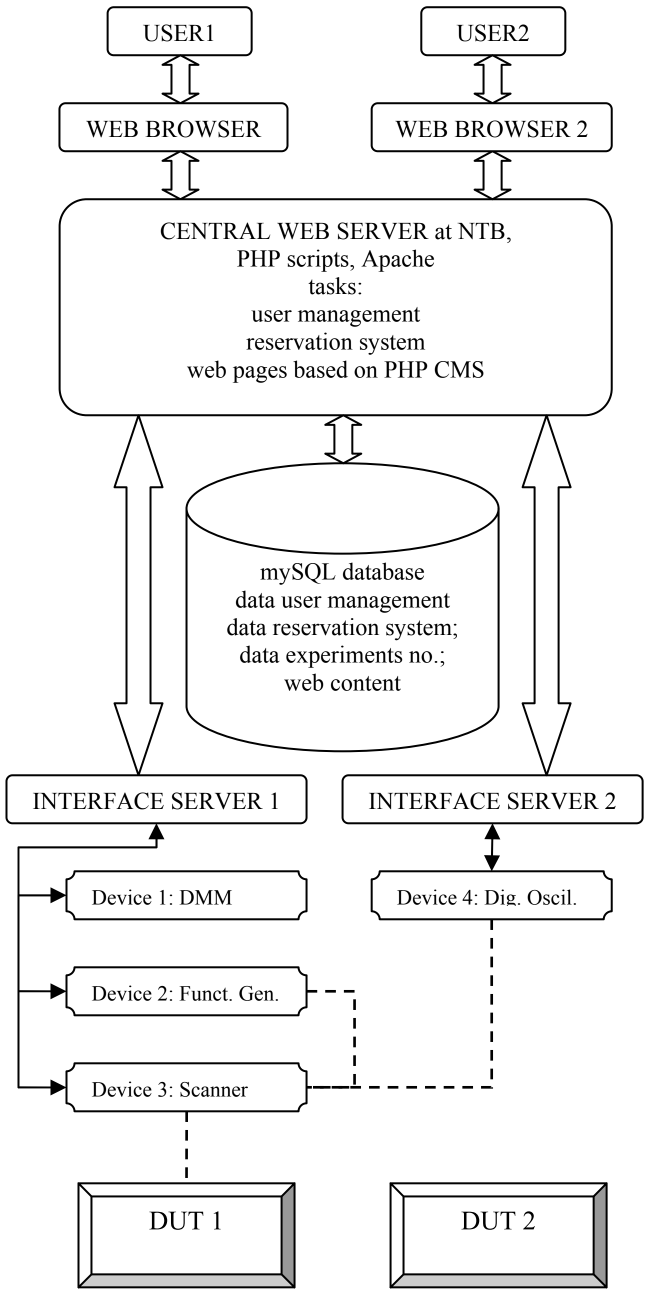



Fig. 2 Communication and data flow at the NTB internet laboratory between the different users and the measurement hardware (e.g. a digital multi-meter DMM). The doted lines indicate the hardware wiring of the device under test DUT.

The functional principles are described for the experimental setup to measure the output signal of a filter as a function of the input generated by the function generator (Fig. 4a). By choosing the experimental setup of the filter, the reservation system of the central web server (Fig. 3) has to check if all devices are ready to use and not occupied by other experiments or users. Each user has to login with his password. The user management system controls this login process. A user entering the NTB internetlab platform for the first time automatically receives a password within seconds. Now the user is able to work with those devices or experimental setups which are ready. In addition the user may book certain devices or experimental setups in advance. All user data, the reservation data and the hardware device data are stored in a small mySQL database. The webpage's are organized on PHP scripts while the information is again found in a content management system by the mySQL database. This concept allows a flexible extension of new devices and experiments.

### *2.2 Control of the hardware of the internet laboratory*

To adjust the frequency of the input signal of the filter experiment, the user simply performs a mouse click in his web browser on the control panel shown in Fig. 3.

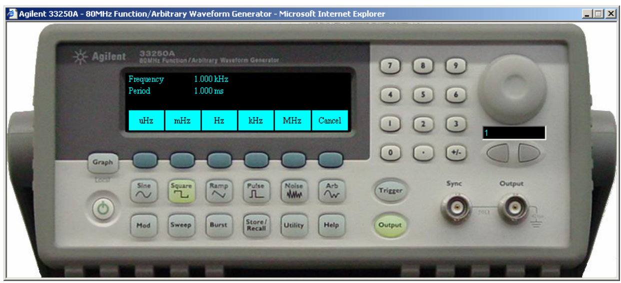


Fig. 3 Control panel of the function generator (Agilent 33250A). All buttons are to be activated by mouse click in the web browser.

The NTB web server sends the request to the interface server 1, which passes the information on to the device which changes the output frequency. An interface server can be localized wherever there is an access to the internet. Thus it is possible to integrate different experiments at different locations into the NTB internet laboratory platform. The interface server communicates by RS 232, GPIB, USB or other types of interface standards with the measurement device.

The digital oscilloscope measures the input and output signal at the filter as a function of time. The results are transferred as a picture via the interface server to the web server where they are visualized as content of the "oscilloscope" window. The picture is updated upon a users mouse click. Via the web browsers control panel of the oscilloscope window, the user may also request the data set of the measurement to be stored e.g. in EXCEL-format.

One advantage of this concept is that the user only needs a web browser and is not forced to acquire a license of commercial data acquisition software.

## 3. AUTOMATED INTERNET-LABORATORY

In this part of the internet-laboratory the user requests a set of automated measurement sequences. According to Fig. 3a the voltage drop across the internal resistance of the ampere meter can be measured for different values of load resistance $R_L$ and several supply voltages $U_q$ (start and stop limits are requested). The measured values can be downloaded and used for subsequent calculations e.g. with EXCEL as can be seen in Fig. 4b. The user acts with the objective of testing his/her theoretical understanding of the electrical circuit with real measurement results at several sets of parameters. Two hardware setups in this mode are shown in Chapter 3.1 and 3.2.

### *3.1 Current-voltage measurement - automated sequence*

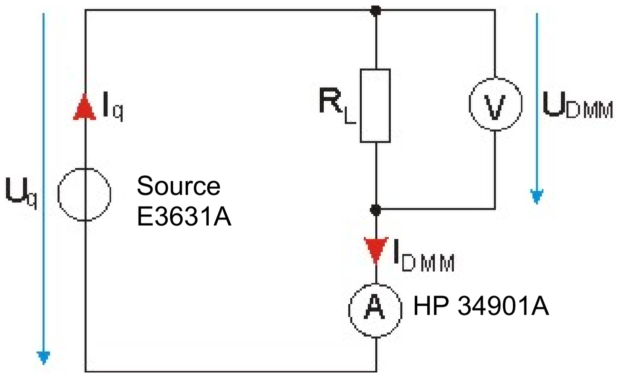
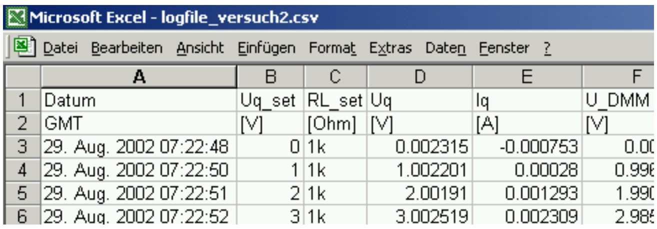



Fig. 4a Schematic diagram to measure load $R_L$. The automatic electric connections are performed by scanner HP34901A 20 – 4x8 with built-in volt and ampere meter.



Microsoft Excel - logfile_versuch2.csv

Datei Bearbeiten Ansicht Einfügen Format Extras Daten Fenster ?

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Datum | Uq_set | RL_set | Uq | Iq | U_DMM |
| 2 | GMT | [V] | [Ohm] | [V] | [A] | [V] |
| 3 | 29. Aug. 2002 07:22:48 | 0 | 1k | 0.002315 | -0.000753 | 0.00 |
| 4 | 29. Aug. 2002 07:22:50 | 1 | 1k | 1.002201 | 0.00028 | 0.99 |
| 5 | 29. Aug. 2002 07:22:51 | 2 | 1k | 2.00191 | 0.001293 | 1.99 |
| 6 | 29. Aug. 2002 07:22:52 | 3 | 1k | 3.002519 | 0.002309 | 2.98 |

Fig. 4b Download of measured values – (Excel csv-format)

### *3.2 Frequency response measurement of a filter by automated measurement sequence*

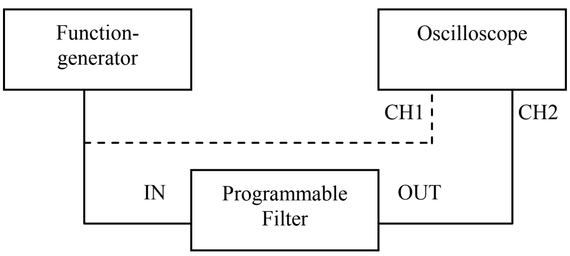



Fig. 5a Block diagram of the filter measurement setup. The input of the filter is given by the controlled function generator whilst the output voltage is measured with the oscilloscope. The filter is realized using the switched capacitor type MAXIM 264.

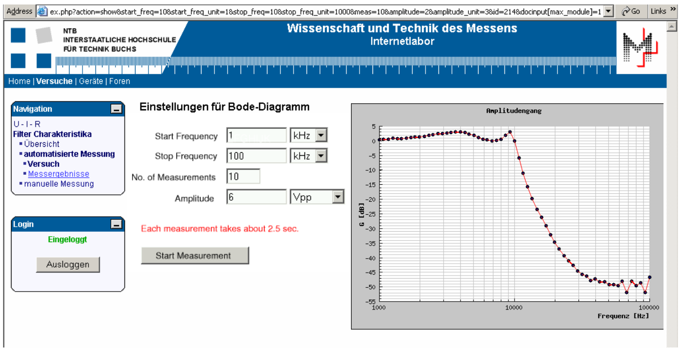



Fig. 5B. To the left hand side of the graph the input parameters as chosen by the user are given for an automated frequency-response measurement. The resulting frequency response is also shown.

## 4. CONTROL EACH INSTRUMENT

The aim of the user is to control all functions via the buttons of the used instruments in this second part of the internet-laboratory. Thus the user can exercise the operation of e.g. the oscilloscope in the same manner as in a real laboratory. The instrument function is activated by a mouse click on a picture of the instrument. Fig. 6 shows the three relevant windows to measure the step-response of a filter, the function generator window (bottom right), control panel (bottom left) and the screen output of the oscilloscope (in the top of Fig. 6). Approximately 3 seconds after the mouse click the oscilloscope output screen will be updated.

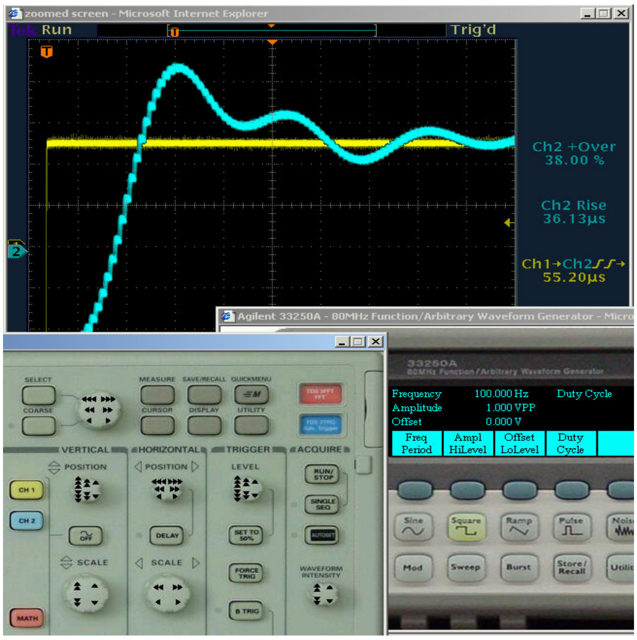



Fig. 6 Three interactive windows to control the oscilloscope, TDS3012B Tektronix and the function generator 33250A Agilent

## 5. OTHER EXPERIMENTAL SETUPS

In addition to the basic laboratory experiments mentioned in the chapter before, the NTB internet laboratory also has access to more complex experimental setups like the control of a power meter and an EMC experimental setup with the use of a burst generator.

### *5.1 Power meter and power quality analyzer*

The commercial power quality analyzer Hioki 3196 serves to investigate the relevant quality figures of a grid like, transient over voltage, the voltage dip, and the current and power transient values. In addition, the phase damages of the 3-phase supply voltage are measured in real time and visualized graphically (Fig. 7a). With the power meter the harmonic distortion up to 50th order is measured (Fig. 7b).

This multi-functional power instrument is suited to test and train the understanding on 3-phase supply grids, their vector display and the harmonic distortion under real conditions. The control of the instrument via a web browser is supported. Thus the HIOKI 3196 was easily integrated into the NTB internet laboratory platform.

As mentioned in chapter 1 the knowledge on the theory and the definitions of the relevant figures have to be the step ahead of the mouse click. It is therefore recommended that users first check the link to the web based knowledge base on electrical measurement [4] in order to check their knowledge on electrical measurements in power electronics.

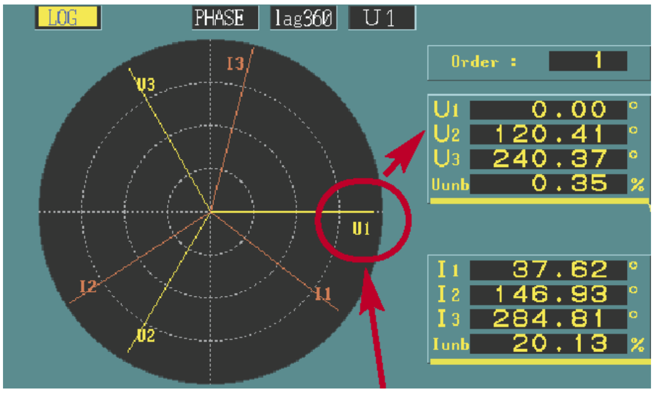



Fig. 7a Web browser display of the energy meter in vector mode.

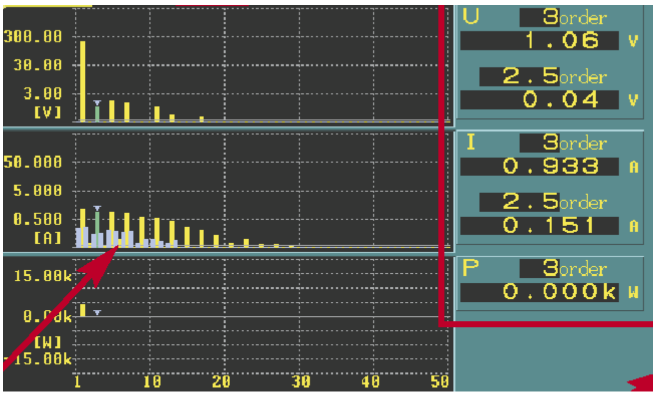



Fig. 7b Web browser display of the energy meter harmonics mode.

### *5.1 EMC response with burst generator*

A further experiment deals with the influence of the EMC burst produced by Schaffner's NSG 3025 generator [5] coupled on the DC supply of a digital circuit (Fig. 8). A major limitation of the internet laboratory in comparison to real laboratory measurement occurs when measuring the transient burst voltages. Depending of the mechanical position of the oscilloscopes probe and the wiring dielectric currents arise which cannot easily be mimicked by switching the scanner to the oscilloscopes input channel.

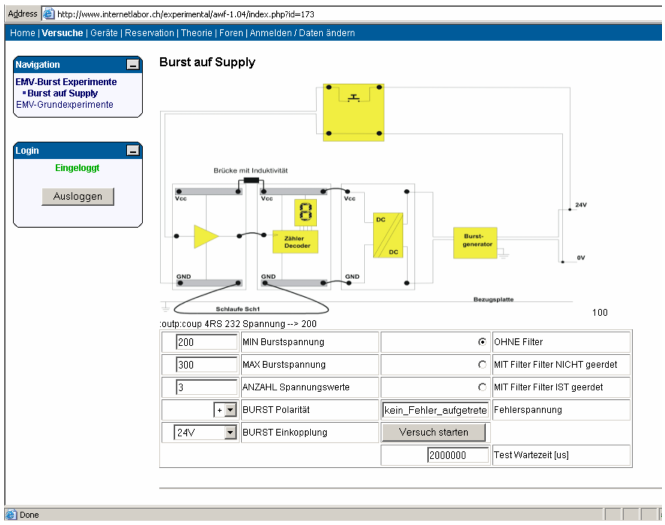



Fig. 8 Schematic diagram of EMC burst on DC supply experiment.

## 6. CONCLUSION

One trend in electrical instrumentation is to find measurement equipment like oscilloscope and power quality meter on the market which can be completely controlled using a web browser. The application behind these devices is in the field of remote control of processes and systems via internet. At the NTB internet laboratory we use such web based devices to give the user the opportunity to practice the control of complex equipment. Training on real measurement equipment is very helpful to test the theoretical understanding of measuring the electrical current, voltage and power.

The internet laboratory cannot replace a hands-on contact to the measurement object and equipment, nor can it substitute personal advice from a teacher in the real laboratory. However, the internet laboratory is a suitable means to prepare students to make reliable measurement close to real life.

## REFERENCES

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[4] NTB web-based electrical laboratory http://www.internetlabor.ch/

[5] http://www.schaffner.ch

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