Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 89 (2013) 158 – 162

Procedia
Social and Behavioral Sciences

2nd Cyprus International Conference on Educational Research, (CY-ICER 2013)

Energy balance in real electronic RLC circuits By remote experimentation

Lukáš Tkáč[a]*, František Schauer [b]

[a]Trnava University in Trnava, Faculty of Education, Department of Physics, Priemyslená 4, SK-91843, Trnava, Slovak Republic
[b]Tomas Bata University in Zlín, Faculty of Applied Informatics, Department of Electronics and Measurements, CZ-76005 Zlín, Czech Republic

Abstract

Paper presents the elucidation of the charge transport by natural oscillations in real circuits by means of remote experiment with RLC elements in the time domain"Transient phenomena in RLC circuits". Into the circuit are artificially inserted dissipative resistive elements producing damping in a broad rangeenabling both energy balance evaluation, and the determination of all individual circuit parameters. Remote experiment, built on ISES, is free available on URL http://remotelab6.truni.skof the Department of Physics, Faculty of Education, Trnava University in Trnava, Slovakia. The experiment is exploitable in the course on Electromagnetism in all forms of distant form of study.

Selection and/or peer-review under responsibility of Prof. Dr. Huseyin Uzunboylu, Near East University, Faculty of Education, Cyprus
Keywords: Remote experiment, energy, ISES, Integrated e-Learning;

Introduction

Remote experiment (RE) is a new and progressive tool for physics and technical subjects teaching. The experiment in question ("*Transient phenomena in RLC circuits*", http://remotelab6.truni.sk) is designed to teach university or middle school students the basic concepts of electricity. The teaching method we use is Integrated e Learning (INTe-L), which includes ICT technologies for experimentation, demonstrations, analogies, discussion and vocabulary review. It is believed that all modalities should be used as often as possible in order to enable the students to understand the concepts used and to be able to associate the concepts with the appropriate vocabulary. However, electricity is one of the most difficult subject matter for students to grasp, the distant students in particular. For all that the initiative arose to enable the student to grasp this part of physics in an easier way. Our conception is the building of the corresponding remote laboratories and enabling the teachers to introduce new methods, strategies and conceptions of teaching. The paper deals with the problem of physics education of distant students in general and laboratory work in particular. Laboratory work in the first term of physics in technology-oriented universities is sometimes not available and physics education concentrates on lectures and seminars only. Therefore one of the feasible solutions was to introduce the remote experiments (RE) and remote experimentation delivered from e-laboratory. As an example we used the remote experiment "*Transient phenomena in RLC circuits*", (http://remotelab6.truni.sk) and used the energy approach for its explanation.

1. Basics of remote experiment on http://kf.truni.sk/remotelab

For all RE the Internet School Experimental System (ISES) as the physics hardware and WEB CONTROL ISES kit for the client-server Internet communication are used (ISES and WEB CONTROL ISES kit is to be found in

*Corresponding author name. Lukáš Tkáč. Tel.: +421-908-889-399
E-mail address: lukas.tkac@truni.sk

Selection and/or peer-review under responsibility of Prof. Dr. Huseyin Uzunboylu, Near East University, Faculty of Education, Cyprus
doi:10.1016/j.sbspro.2013.08.827

more detail in [3] or http://www.ises.info). Here we give only few relevant details. The ISES is a complex tool for real time data acquisition, processing, displaying and control of experiments. It is an open system consisting of the ISES physical HW and informatics HW. The physical HW is composed of the ISES panel and the set of modules and sensing ISES elements easily interchangeable, their presence and adjusted range are automatically sensed by the computer, with the automatic calibration facility. The ISES panel enables 10 different channels (6 analogue and 2 binary) and capability to use 2 programmable outputs. The informatics hardware is composed of the interface card with A/D-D/A converters and the informatics SW is the controlling program (ISESWIN). The system is equipped with ISES modules as A-meter, V-meter, Ω-meter, thermometer, microphone, deviation sensing unit, adjustable preamplifier, light stop, current booster, relay switch, and many others. ISES in this way provides the physics HW for the easy design of nearly arbitrary hands on experiment from physics, recently from chemistry or biology. In our project of RE for distant students we have concentrated on the Electricity and Magnetism and designed a complete set of remote experiments (Source of DC voltage/Transfer energy in DC circuitshttp://remotelab7.truni.sk, Energy transfer in circuits/Phase in RLC circuits http://remotelab3.truni.sk, Emission of Luminescent diodeshttp://remotelab8.truni.skand Faraday´s law of electromagnetic induction http://remotelab4.truni.sk/faraday.html).Next, we will focus as an example, on one of them, "*Transient phenomena in RLC circuits*", and present the way we use this RE for the energy concept introduction and explanation in the passive electronics. The procedure of the RE exploitation is straightforward, as this students measure real experiments via Internet, using server-client connection and the corresponding web page of the RE and obtain and evaluate the measured data. The enormous advantage of the RE is its availability at any time and any place and the physical background and assignment being a part of the RE as well.

2. Technical arranegement and physical background

The experiment "*Transient phenomena in RLC circuits*" is based on the time response to the step voltage, resulting in the RLC circuit free oscillations with variable damping. The schematically arrangement simple is resonant RLC circuits in Figure 1, consisting oft he emf. Source, ISES V-meter and ISES A-meter and discrete RLC elements (C, L and R_L; RC – not depicted). On top of this, the variable damping is introduced by the variable resistors connected in series with the inductor and parallel to the capacitor (R_{1D} and R_{2D}). For creating series and parallel damping resistors, we used the PC controlled relay board (Figure 2) connecting the individual resistors to the circuit.

In Figure1 is the web page with the measured example dependence of the instantaneous voltage u (upper graph) and corresponding current i(lower graph). Left, the live web camera view and the damping resistors adjustment buttons (top right) are visible. The RE provides the data for the processing. The user friendly controls the RE and easy to grasp web page using the control buttons for series/parallel damping resistors adjustment start of the measurement and the data transfer to your computer.

The physical background of the parallel RLC circuit may be started from the energy conservation law, where the original energy from a power source, stored in the capacitor, is stored alternatively in the capacitor electric field and inductor magnetic field and the rest is transformed into the heat. Let us take for the simplicity the case with an ideal capacitor, taking $R_{2D} \rightarrow \infty$. The instantaneous power equation then reads

$$\frac{d}{dt}\left(E_C + E_L + E_{heat}\right) = 0, \tag{1}$$

whereE_C , E_L and $E_{heat}$is the instantaneous energy stored in the capacitor, the inductor and the dissipated heat, respectively. We may express the energies using the instantaneous values of charge q and current i and obtain the energy balance equation of the RLC circuit

$$-\frac{d}{dt}\left(\frac{1}{2}\frac{q^2}{C} + \frac{1}{2}Li^2\right) = Ri^2 \tag{2}$$

This equation is basic for the explanation of the energy flow in the RLC circuit.

After small rearrangement, using II. Kirchhoff′slaw and

$$u = u_C = \frac{1}{C}\int i dt, u_L = L\frac{di}{dt}, u_R = iR, \tag{3}$$

We obtain the corresponding differential equation for the voltage on the circuit ($u = u_C$)

$$\frac{\mathrm{d}^2 u}{\mathrm{d}t^2} + 2b\frac{\mathrm{d}u}{\mathrm{d}t} + \omega_0^2 u = 0\,, \tag{4}$$

With the solution:

$$u = U_0 e^{-bt} \sin(\omega_0 t) \tag{5}$$

Where the damping

$$2b = \frac{R_1}{L}, \tag{6}$$

And

$$R_1 = R_{1D} + R_L. \tag{7}$$

The frequency of the natural oscillations is

$$\omega_0^2 = \left(\frac{1}{LC}\right)\cdot. \tag{8}$$

In a general case of $R_1 = R_{1D} + R_L$, $R_2 = R_{2D}$, we find the solution

$$2b = \frac{1}{R_2 C} + \frac{R_1}{L}, \tag{9}$$

and

$$\omega_0^2 = \left(\frac{1}{LC}\right)\cdot\left(1 + \frac{R_1}{R_2}\right), \tag{10}$$

(See [4]).

Also important information is carrying the phase shift φ of the current across the resistive load R_{1D} with respect to the voltage

$$i = I_o e^{-bt} \sin(\omega_o t + \varphi), \tag{11}$$

as depicted in the Figure 3.

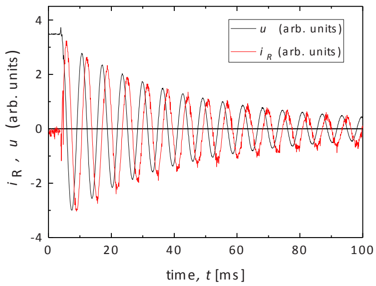

Figure 1.Phase relationship between current i_R (red) and voltage*u* (black) in the measured circuits

2.1. Results of students work

The example of the student´s work is in Figure 2 and Figure 3, where the measured effect of the serial (R_{1D}) and parallel (R_{2D}) resistances on the damping coefficient b is plotted. The assignment for the students is to find from those dependences the value of the components L,C andR_L of the circuit, using eq. (9).

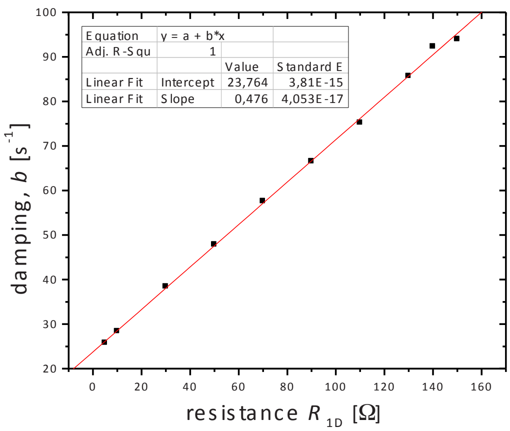

Figure 2. Dependence of the damping$b$on the inserted resistance R_{1D},and the linear fit; the slope gives $1/2L$

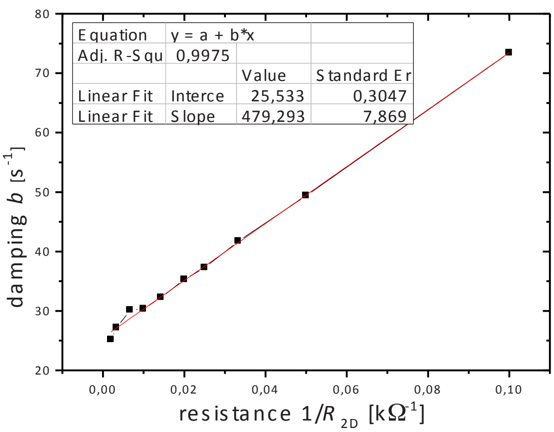

Figure 3. Dependence of the damping$b$on the inserted resistance R_{2D}, and the linear fit; the slope gives $1/2C$

Table 1. Resultant values ofdiscreteRLC elements

Inductance of the inductor L	L= 0,476 H
Resistance of the inductorR_L	R_L=49,65 Ω
Capacitance of the capacitor C	C=1,01 μF

3. Conclusion

The globally accessible remote experiments serve as the powerful tool for the teaching and study of the Electricity and Magnetism phenomena in circuits.These experiments potentially play an important role in the gaining of interest, motivation and individual involvement in pedagogical process using remote experiments covering various areas of Natural sciences, entering lectures, seminaries, laboratory exercises, project work, examinations and self study. As a help for teachers and students in this respect we have built the 1st Slovak Internet Natural Sciences Remote e-Laboratory (INRe-L) with basic experiments from Environment, Mechanics, Chemistry and Electricity and Electromagnetism [5].Experiments in Electricitywere designed in order to cover the syllabi of predominantly distant students.

In the remote experiment *“Transient phenomena in RLC circuits”* we try to show the students, starting from the energy concepts, how the law of energy conservation works in real passive RLC circuits, variable dissipative elements including. The measurements of the responses in the time domain enable an easy measurement of the damping and its evaluation in a broad range gives information on the elements of the RLC circuit.

We may conclude with our own experience that RE starts to be an indispensable tool both for the individual work of students, but also as an important motivating and inspiring tool for lectures, seminars and project work and with advantage used for the examination purposes.

Acknowledgements

The project was partially supported by KEGA “Energy as a Category in Science Education via remote experiments and Integrated e-Learning” No 011TTU-4/2012.

References

Cooper, M. (2005). Remote laboratories in teaching and learning – issues impinging on widespread adoption in science and engineering education. *iJOE International Journal of Online Engineering*, Vol. 1, No. 1, 2005, ISSN: 1861-2121.

Schauer, F., Ožvoldová, M., &Lustig, F. (2009). Integrated e-Learning – New Strategy of Cognition of Real World in Teaching Physics. *Innovations 2009* (USA), World Innovations in Engineering Education and Research iNEER Special Volume 2009.chapter 11, pp. 119-135, ISBN 978-0-9741252-9-9.

Schauer, F., Lustig, F., Dvořák,J., &Ožvoldová, M. (2008). An easy-to-build remote laboratory with data transfer using the Internet School Experimental System. *European Journal of Physics*, Vol. 29, No. 4, July 2008, pp. 753-765.

Patil, M., B. (2012).*RLCCircuits (with DC sources)*.(website): http://www.ee.iitb.ac.in/~sequel/ee101/ee101_rlc_1.pdf.Accessed October 20, 2012.

Ožvoldová, M., Schauer, F., Čerňanský, P., Gerhátová,Ž.,Tkáč., L., &Beňo, M. (2010). 1st Slovak Internet Natural Sciences Remote e-Laboratory (INRe-L). *Proceedings of the conference REV2010 - Remote Engineering & Virtual Instrumentation.* June 29 – July 2, 2010, Stockholm, ed. Michael E. Auer, GoranKarlsson. Wien – Austria, InternationalassociationofOnlineEngineering. pp. 313 – 319, ISBN 978-3-89958-540-7