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LABORATORY PRACTICUM FOR EDUCATION IN MEASUREMENT

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Abstract − The aim of "Measurement in Electrical Engineering" course, Faculty of Electrical Engineering and Computing in Zagreb, is to give students fundamental knowledge of metrology and measurement of Electrical Quantities. For students, laboratory practicum is good way to understand and to confirm theoretical part of the subject. Also, by real instruments and devices students are practically acquainted with the certain number of procedures and methods for measuring electrical and some non-electrical quantities. Structure, organisation and themes of laboratory exercises are briefly presented in this paper.

Keywords: laboratory practicum, students and measurement.

1. INTRODUCTION

It is very hard to be in trend with measuring technology without fundamental knowledge of it. So, students at the Faculty of Electrical Engineering and Computing (FER) of the University of Zagreb have been listening "Measurement in Electrical Engineering" (MUE) course. This course is common and obligatory for all students in the second year of study and lasts two semesters. About five hundred students attend annually MUE course. Such a big number of students put great demands on the course, which has to be carefully and precisely planned by education staff. Therefore, four professors and eight assistants at the Department for Fundamentals of Electrical Engineering and Measurements participate in the teaching process of the MUE course.

In the MUE course four education parts are included: lecture, preparation for practicum, classroom exercise and the laboratory practice. Thus students have sixty hours of lectures, fourteen hours of preparation for practicum, sixteen hours of classroom exercise and thirty-two hours of laboratory practicum. Lectures are comprised of following themes:

- theory of errors, expression of uncertainty
- electrical measuring instruments
- measuring bridges
- measuring transformers
- electronic measuring devices and systems
- methods for measuring electrical and some non-electrical quantities

Practicum preparation is lectures in which students become familiar with organisation of the laboratory and with laboratory equipment such as:

- measuring resistors, capacitors, inductors
- electrical and electronic sources
- measuring instruments

At laboratory practicum students acquire skills for resolving measurement tasks and improve their theoretical knowledge. Also, they are learning how to make their measurement reports.

2. PRACTICUM

2.1. Accommodation and organisation

The laboratory in which practicum of MUE course is undertaken consists of three spacious rooms. A current group of laboratory exercises are taken place in two parallel connected rooms. The third room are reserved for preceding group of exercise. In the neighbourhood of laboratory there is no sources of electromagnetic, vibration or noise disturbances.

Practicum is contained of sixteen exercise themes, which are divided in the four groups. A group of four themes lasts for four weeks and during that time students performing their laboratory exercises on the basis of predetermined schedule. After those four weeks, a week is needed for setting on new group of themes. At the laboratory, one theme with all necessary equipment and instruction papers is parallely set on three-times. Students are arranged in teams of two persons. So, two students may perform one experiment that means that four students may do one theme of exercise. At the same time, forty eight students may do their tasks in the laboratory.

2.2. Students Task

For efficient and successfully performance of their tasks students have to do following prerequisites:

- attending the lectures
- attending the preparation for practicum
- theoretical preparation of particular theme
- do homework

A week before beginning of laboratory practicum, students receive a paper with questions for homework regarding measuring methods or problems. Usually, there are two to four questions per theme of laboratory exercise. Consequently, each student has to write so called preparation paper of his current laboratory exercise. Preparation paper includes:

- name and identification of student
- name of laboratory exercise
- date
- homework

Without preparation paper students could not proceed with laboratory exercise. In addition, during laboratory exercise student is writing laboratory report. This report should properly, precisely and correctly present the laboratory results and all other appropriate data. In laboratory report following items are included:

- items of preparation paper
- description of methods used in exercise
- measurement results and derived results
- data analyses
- appropriate tables and graphs
- measurement uncertainty
- conclusion

Students have to carefully read experiment instruction paper and have to perform their task in accordance with experiment instructions. Also, their knowledge of current exercise are checked by teaching staff.

2.3. Themes of exercises

As mentioned before practicum is consisted of sixteen exercise themes, which are divided in four groups. Each theme of exercise is consisted from two or three experiments, only one theme is consisted of one experiment. Titles of themes are:

1. *Errors of measurement; Influence quantities*
2. *Basic features of analogue instruments; Influence quantities*
3. *Calibration of voltmeter and ampermeter*
4. *Application extension of moving coil instrument*
5. *Oscilloscopes*
6. *Measuring amplifiers*
7. *Measuring bridges*
8. *Compensators and calibrators*
9. *High voltage testing*
10. *Current transformer errors measurements*
11. *Resistance measurements*
12. *Power measurements*
13. *Measuring converters*
14. *Magnetic measurements*
15. *Calibration of energy meters*
16. *Non-electrical measurements*

Four experiments will be presented in the following text and from this examples, it could be seen scope and object of students' laboratory work.

2.3.1. Calibration of voltmeter

In this experiment, voltmeter ranges are expanded by serial added resistors. After that, the same voltmeter with new ranges are calibrated by voltmeter with higher accuracy.

At the beginning of experiment, students have to calculate value of resistors for new ranges of the voltmeter. Basic range of analogue voltmeter is 10 mV and this range should be expanded on 50 mV, 100 mV and 200 mV. After calculation has been done, students have to pick up adequate resistors from set of various resistors and construct voltmeter V_1. Then, they have to connect the circuit for calibration of voltmeter V_1 with voltmeter V_2, Fig. 1. Elements of this circuit are: DC source V_S – 6V, potentiometers R = 600 Ω and R_1 = 1k Ω, analogue voltmeters V_1 and V_2 – 60 mV, 120 mV, 300 mV ranges. After connection has been done, they have to call teacher for connection checking. If connection is good, they could proceed with measurement.

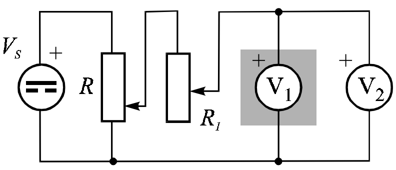

Fig. 1. Calibration of voltmeter.

Calibration points are specified in Table 1. When measurement is finished, students have to calculate errors and estimate measurement uncertainties for each calibration point. Also, they have to draw correction graph as function of voltmeter V_1 reading on 50 mV range.

Table 1. Calibration points

V_1 range	V_1 reading	V_2 reading	absolute error
50 mV	5,0 mV		
50 mV	10,0 mV		
50 mV	15,0 mV		
50 mV	20,0 mV		
50 mV	25,0 mV		
50 mV	30,0 mV		
50 mV	35,0 mV		
50 mV	40,0 mV		
50 mV	45,0 mV		
50 mV	50,0 mV		
100 mV	100,0 mV		
200 mV	200,0 mV		

2.3.2. Schering's bridge

Bridge according to Schering are often used for measuring capacitance C and dissipation factor tan δ.

Students in this experiment have to connect Schering bridge Fig. 2a). Then, they have to get teacher's confirmation of connection. In further step, they need to measure capacitance C_x and dissipation factors tan δ of two samples of insulation materials. These samples of insulation

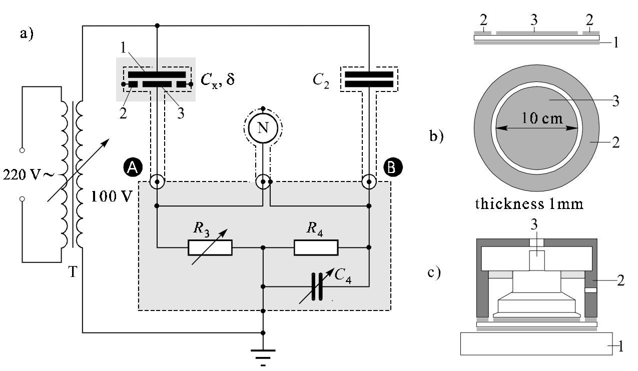

Fig. 2. a) Schering bridge b) sample of insulation material c) connection device

materials are vitroplast and pertinax. Both sides of samples are painted with conductive graphite coat to form electrodes (1, 2 and 3) of measured capacitors C_x, Fig. 2b). Capacitor C_x is connected to the bridge with device specially built for this purpose, Fig. 2c). Also, students have to calculate relative dielectric constants ε_r of both samples from measured capacitance (C_{vit} and C_{pert}) and their dimensions (Fig. 2b). At the end of experiment, they have to give conclusion regarding improvement of bridge accuracy and uncertainty.

2.3.3. Current transformer error measurement

Measuring current transformers have two components of errors, phase and ratio errors. Students task is to apply method according to Hohle in measuring error components of current transformer under test X, Fig 3. In this method, standard transformer N is connected in serial with transformer X. Standard transformer N has much better accuracy then transformer X. Same current I_1 flows through primary windings of both transformers. Difference of secondary currents (I_{2X} - I_{2N}) is equivalent to current errors of transformer under test X. Voltage drop on resistor R is caused by current errors and that drop is compensated with voltage drop on potentiometers R_3 and R''. Voltage drop on potentiometer R_3 is in phase with secondary current I_{2N} of standard transformer. While, voltage drop on potentiometer R'' is 90 degree out of phase with secondary current I_{2N}. It is possible to calculate current error from values of compensation elements.

Firstly, students need to calculate nominal load Z_X from data markings of transformer X. Resistance of R4 should be adjusted on calculated load value Z_X by Wheatstone bridge.

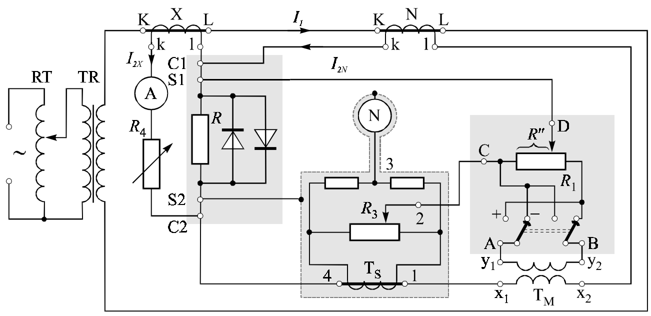

Fig. 3. Hohle method for measuring transformer errors

Then, they have to connect the measuring circuit according to Fig. 3. Voltage on regulation auto-transformer RT should be adjusted on 0 V. After connection has been made, they have to call teacher for checking of connection and R_4 calculation. Consequently, they could turn on regulation auto-transformer RT and start to increase regulation voltage until the current in secondary circuit reach nominal value of 5 A. In that case, students should compensate voltage drop on R with potentiometers R_3 and R'' and calculate the error. In addition, students should repeat the measurement of the current error R_4 at secondary current nominal value of 5 A with short-circuit load resistor.

2.3.4. Calibration of energy meters with "artificial" load

The point of this experiment is to give basic knowledge of induction energy meters calibration. Induction energy meter is calibrated with wattmeter and stop-watch, Fig. 4. Two AC sources are necessary for this calibration. One source supplies connected serially current coils of energy meter and wattmeter. The second source supplies connected parallel potential coils of energy meter and wattmeter. Thus, easy adjustment of voltage, current and power factor cos ϕ is achieved and there is low consumption of energy during calibration. Reading W_e of energy meter, for n turns of its rotating plate, is calculated from energy meter constant c=1500 turns/kWh. Calibration energy W_r is calculated from time t needed for n turns of energy meter rotating plate and reading power P of wattmeter.

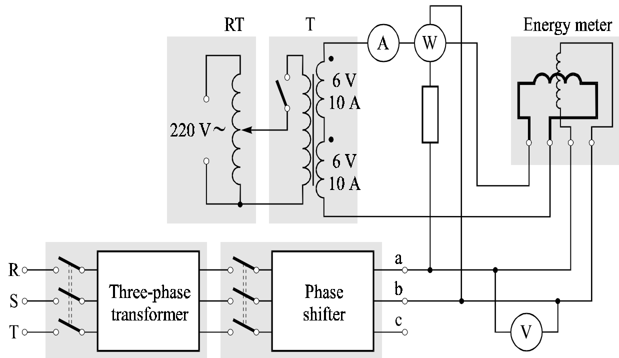

Fig. 4. Calibration of energy meter

Table 2. Calibration points for various currents

I [A]	2	3	4	5	6	7	8	9	10
V	230 Volts								
$cos\phi$	1,0								
P [W]									
n	10 turns								
t [s]									
W_e [Ws]	24000								
W_r [Ws]									
error(%)									

On the beginning, students have to connect calibration circuit, Fig. 4. After the circuit is checked, they adjust the current I on 2 A with regulation transformer T. Then, they set voltage V on 230 V and cos ϕ =1, with three-phase transformer and phase-shifter. In the first part of experiment, students measure energy consumption W_e and W_r for various values of current I, Table 2. Calibration points of the second part of experiment are shown in table 3. In that part, students measure energy consumption W_e and W_r for various values of power factors cos ϕ. After measurements have been done, students need to draw diagrams which represent energy meter errors as function of current e=f(I) and as function of power factor e=f(cos ϕ). They also have to comment the character of errors depending on the current I and the power factor cosϕ.

Table 3. Calibration points for various power factors

I	10 Amperes			
V	230 Volts			
cos.	0,8	0,7	0,6	0,5
P [W]				
n	10 turns			
t [s]				
W_e [Ws]	24000			
$W_{R.}$ [Ws]				
error(%)				

3. CONCLUSIONS

Attending the MUE course, students have been systematically and thoroughly getting fundamental knowledge of metrology and measurement of Electrical Quantities. Theoretical and practical parts of MUE course are connected through laboratory practicum, in which, students are getting experience of laboratory structure, organisation and work. They are practically acquainted with the some procedures and methods for electrical measurements. So students who finish laboratory practice and pass final exams are basically educated and trained for simple start of working in testing laboratory.

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