

Progress in Education of Electrical Measurements

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Introduction

The dynamic development of computer technology obliges the teaching staff to modify educational processes. It is obvious that at present nearly all students have access to computers and Internet. For this reason, especially in the countries with developed computer technology, distance teaching and learning led by various universities and organizations (IMEKO, IEE, EAEEIE in Europe, IEEE in USA, UICEE in Australia and Asia) is increasing continuously. Looking through the last years publications connected with this problem one can see the great revolution in the educational process [1, 3, 5, 7, 8, 10-15] either for the students who do not have the possibility to take part in real university lectures, or for those who take part in distance learning being audiles. For eye-minded persons it is necessary to print lectures on the websites. For these lectures virtual instruments enabling the performance of different experiments, better explaining the contents, can be very useful. There are also organized distance laboratories offering possibilities to perform practical experiments. Of course they cannot be treated as substitute for real laboratory tasks, which are necessary in engineering education but they can be used as very good tools preparing for practical laboratory jobs. Distance learning through the Internet assures also possibilities to contact the lecturer as well as other students and to discuss problems which seem incomprehensible.

In Poland we do observe certain efforts in development of systems of distance learning [2, 4, 6, 8] but we are far behind many countries in Europe. This situation must be changed and it is high time to ameliorate our educational process and to create new educational tools. This problem can not be solved by single persons but by a specialized council supported by Polish government in cooperation with Polish technical universities and some education centers of EC.

Fundamental solutions

The problem of education of electrical measurements can be solved in following steps:

- Preparation of lectures in the form which can be used directly from the Internet browser. It would be

recommended to provide them with the possibility of different animated experiments clearing up various physical problems. For these reasons virtual instruments are very helpful.

- Preparation of experimental tasks in laboratories in the form of virtual instruments which can be useful as preparation for real laboratory tasks.
- Organized system of distance education with possibilities of contacts and consultations with teaching staff.

At the Gdansk University of Technology it is possible to distinguish several teams interested in the development of distance learning systems and educational tools in the form of virtual instruments [2, 8, 9]. The main problem in creating educational units is to choose the right software. It must be:

- Convenient and rapid in designing new instruments,
- Equipped with intuitive operational interface,
- Convenient for remote measurements and control of different objects.

The virtual instruments must be nice to look at and have great resemblance to actual instruments used in the laboratory.

Practical examples

Several examples of very helpful tools which form the first step in the new system of the electrical measurements education, designed by authors, are presented in this section.

Fig. 1 presents the solution, which enables to examine the time response of the 2nd order transducer in the case of sinusoidal and distorted input signal. The lecturer formulates necessary conditions, which must be fulfilled in order to obtain regular output signal e.g. the proper selection of the natural frequency of the sensor in relation to the frequency of the highest order harmonic component of the input signal. Students very often forget this condition and take into account the frequency of the first harmonic. The misuse of such choice is presented in Fig. 1 and Fig. 2. In the first case (sinusoidal input signal) for the frequency ratio $\eta_1=f_x/f_o=0,9$ (f_x - frequency of measured signal, f_o - natural sensor's frequency) and damping coefficient $\xi=0,2$ the amplitude of

output signal has sinusoidal waveform and is nearly 2,5 time greater than that of the input signal. For the same parameters of the sensor and in the case of distorted input signal the output signal has a rather different form in comparison with the input signal. It is due to the fact that the frequency ratio for third and fifth harmonics is high ($\eta_3=f_3/f_0=2,7$ and $\eta_5=f_5/f_0=4,5$). Therefore third and fifth harmonic are completely suppressed in the output signal which has sinusoidal waveform similar to the output signal shown in Fig. 1.

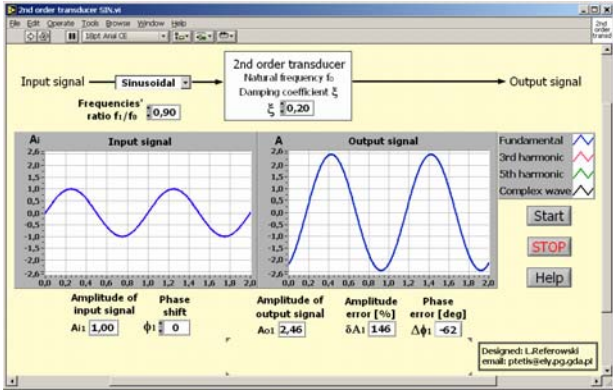


Fig. 1. Time response of the 2nd order transducer in the case of sinusoidal input signal ($\eta_1=f_1/f_0=0,9$, $\xi=0,2$)

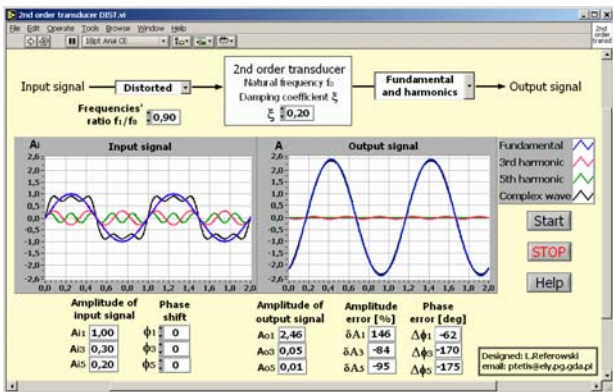


Fig. 2. Time response of the 2nd order transducer in the case of distorted input signal ($\eta_1=0,9$, $\eta_3=f_3/f_0=2,7$, $\eta_5=f_5/f_0=4,5$, $\xi=0,2$)

The basic information concerning properties of the 2nd order transducer present HELP window (Fig. 3) activated by pressing *Help* button on the front panel of described VI. The *Quit* button in the HELP window leads back to the front panel.

The described educational tool makes it possible to choose optional values of sensor's damping coefficient and normalized frequency. It is also possible to see that for previous chosen value of damping coefficient $\xi = 0,2$ and even small value of normalized frequency ratio $\eta=0,3$ the output signal can be rather different from the input signal (Fig. 4). This effect is due to the fact that the natural frequency of the sensor is close to the value of the third harmonic. Therefore there is a great influence of third harmonic in the output signal (amplitude error of the third harmonic is about 150%).

A simple example of the 2nd order transducer with very small value of damping coefficient $\xi=0,003$ in the form of

vibrating reed frequency meter is presented in Fig. 5. This instrument enables to set an arbitrary value of frequency using vertical pointer slide of frequency generator and to read instrument's indication.

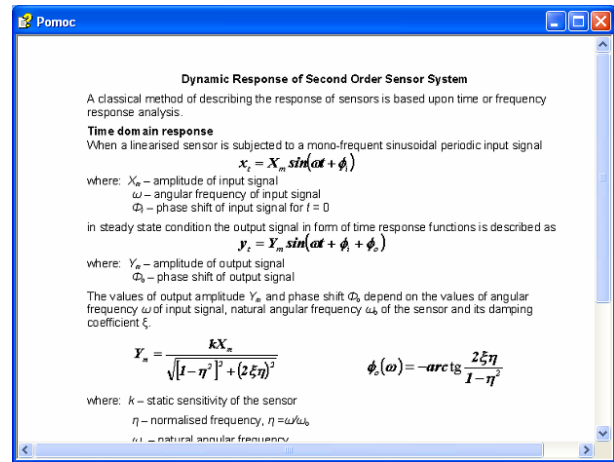


Fig. 3. HELP window with basic information of the 2nd order transducer

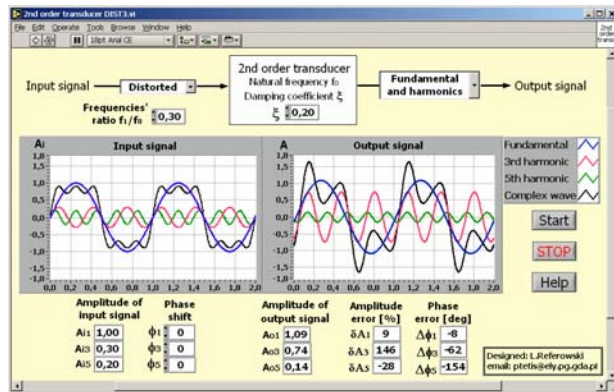


Fig. 4. Time response of the 2nd order transducer in the case of distorted input signal ($\eta_1=0,3$, $\eta_3=0,9$, $\eta_5=1,5$, $\xi=0,2$)

This reed frequency meter can also be used for demonstration the phase response of the second order transducer with damping coefficient $\xi=0,003$ in the proximity of resonant frequency. The output signal in this case abruptly changes phase shift about nearly 180°.

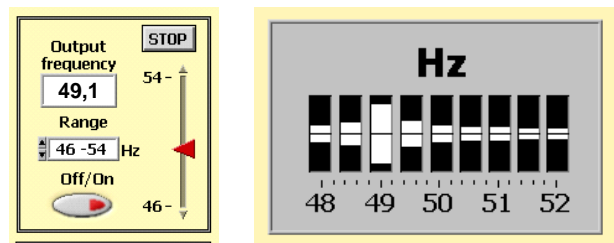


Fig. 5. Vibrating reed frequency meter as 2nd order transducer with damping coefficient $\xi=0,003$

To show this effect the indicator of frequency meter is illuminated by a stroboscopic tube controlled by measured frequency. When the moment of flashes is good adjusted the reeds with natural frequency below the value of

measured frequency (equals to the frequency of flickers) are in opposite position to the reeds with natural frequency above this value (Fig. 6).

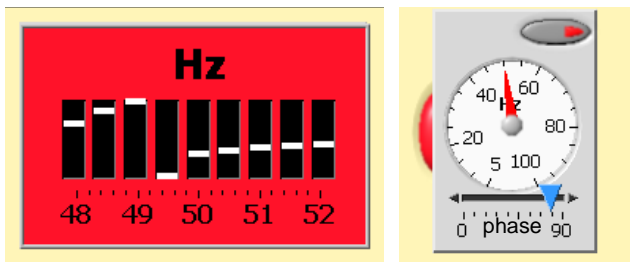


Fig. 6. Demonstration of phase response of second order transducer with damping coefficient $\xi=0,003$

The principle of digital frequency measurements is illustrated by virtual instrument shown in Fig. 7. The frequency to be measured is adjusted by the knob *Frequency generator* after activation *on/off* button. The time of successive measurement is chosen by the selector *Time of measurement* (0.1, 1 and 10 s).

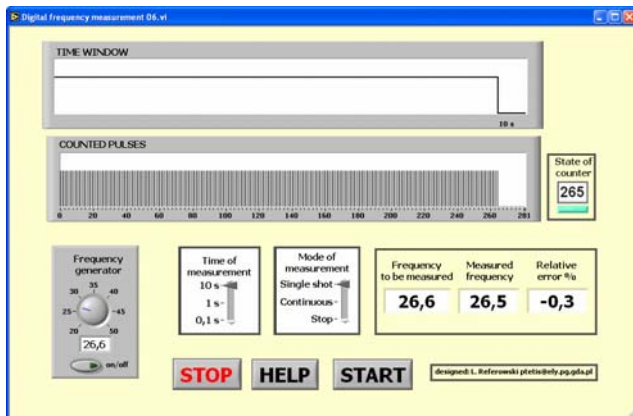


Fig. 7. Digital frequency measurement in time window 10 s

Comparing the results of measurements for different values of time it is easy to understand that the number of counted pulses determines the precision of measurements. The longer is the time of counting pulses the higher the precision of measurement e.g. for frequency 26,6 Hz the result of measurement is 26,5 Hz for time window 10 s (Fig. 7) and 20 Hz for 0,1 s (Fig. 8). However it is necessary to underline that the results of digital measurement present always the measurement's mean value in the time window of counted pulses from clock generator. It is possible to measure frequency in single shot mode or in continuous mode using *Mode of measurement* button. *Help* button opens window with context description of digital frequency measurement.

The problem of digitising or counting error δ_c , which occurs during digital measurements, presents Fig. 9. This error is caused by the lack of synchronisation between the instants when the gate is opened or is closed and the appearance of the first and the last of counted pulse. As it is seen the number of counted pulses varies from 7 to 8 in successive measurements and depends on the instant of appearing the first gating signal chosen by the ring *Delay*.

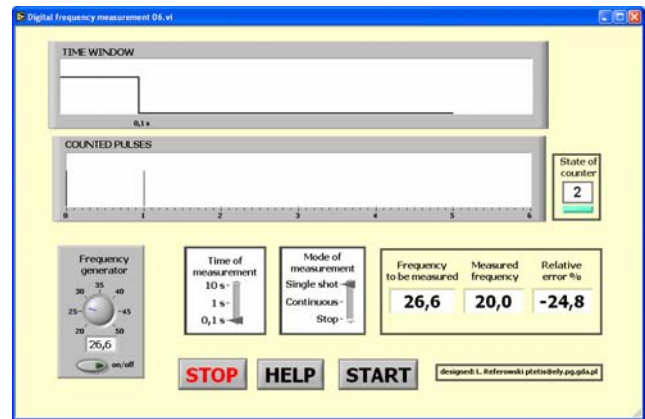


Fig. 8. Digital frequency measurement in time window 0.1 s

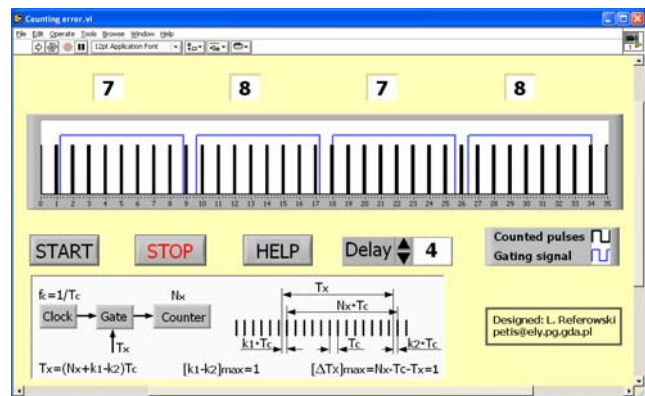


Fig. 9. Digitising or counting error

Fig. 10 presents a virtual instrument which is used during the lectures and as training instrument for laboratory tasks concerning dynamic signal analysis. This VIRTUAL INSTRUMENT enables signal's simulation and its measurement and analysis. Input signal consists of two components. It is possible to set their amplitudes, frequencies and phase shift as well as to change noise level. One can determine a sampling frequency and number of samples. In the analysing process it is possible to choose strictly defined filter (low-pass, high-pass, band-pass, or band-elimination filter), its order and also low and high cut-off frequency.

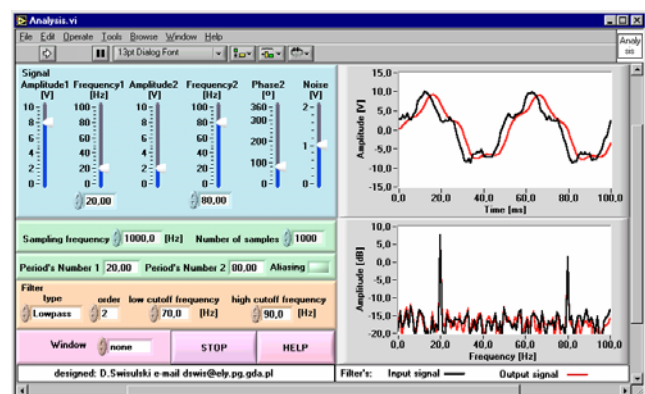


Fig. 10. Virtual instrument for studying dynamic signal analysis

Filter's input and output signal versus time and frequency spectra of input and output signal are presented on the monitor. It is also possible to select Window function (Hanning or Hamming) in order to reduce the leakage in the frequency domain spectrum (Fig. 11).

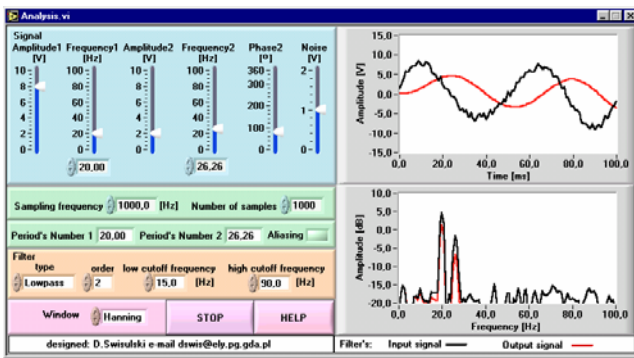


Fig. 11. Dynamic signal analysis using Hanning Window

Using this VI the students have possibilities to go into the matter of:

- Aliasing effect

When the sampling frequency f_s is lower than double the value of signal's frequency f an alias error may occur e.g. if $0,5f_s < f < f_s$ then the value of measured frequency will be determined as $f_s \cdot f$ instead of f .

- Leakage effect

A leakage error occurs when the number of periods in the sampling signal is not integer e.g. if (N/f_s) is integer, (where N is number of samples), then in the frequency characteristic there will be only single spectral line with the frequency f . If this condition is not fulfilled there will be spectral line broadening as the result of leakage effect.

- Signal filtering

Changing the type of filter and its cut-off frequency

for different parameters of input signal it is possible to observe this signal in the time domain and its spectrum before and after the filter, e.g. tracing filtration of unwanted component or separation of the component with useful information.

- Window functions

It is possible to observe Window functions used to reduce the leakage error in the frequency domain spectrum. If in measuring signal there are two components with near-values of frequency but greatly different amplitudes then, in the frequency spectrum, it is possible to see the component with smaller amplitude only after windowing.

Virtual laboratory stands are very useful for students, and they enable to practice at home the measurements technique. They are equipped with virtual instruments similar to these used in the university laboratory. The virtual stand in Fig. 12 presents principle of temperature measurements using a platinum resistance thermometer Pt100/138,5 and a thermocouple J (iron-constantan). They measure the temperature of liquid in the tank equipped with an electrical heater controlled by *on/off* switch.

The resistance of platinum thermometer is measured by Wheatstone bridge. The bridge is balanced by adjustment 5-decade resistor after choosing the right values of ratio resistance. The *key* switch activates the galvanometer. The switch *Sensitivity* changes the galvanometer's sensitivity from *low* to *high* level.

The thermo-electric EMF of the thermocouple is measured by means of technical potentiometer, which is fed by an internal dry cell. The proper value of feeding current is adjusted with the help of internal standard Weston cell (*Mode switch* in position E_n). The feeding current is controlled using knobs *coarse* and *fine*. The measurement of the thermo-electric EMF of thermocouple is realised with mode switch in position *Ex*. The adjusted values of decade resistor at the balance state of the

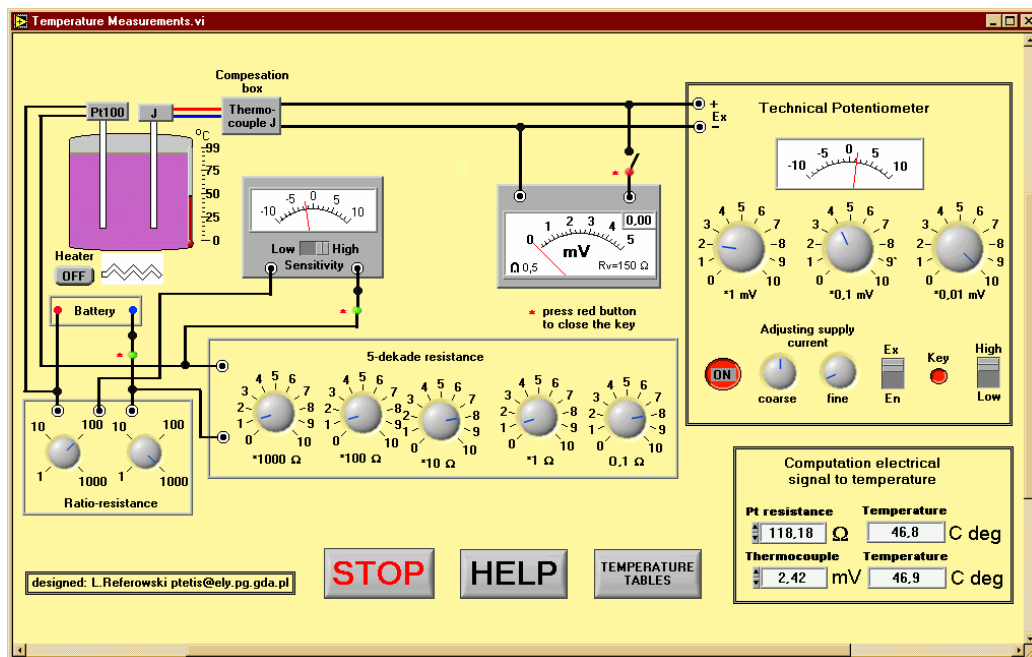


Fig. 12. Virtual stand for temperature measurements using Pt100 resistor and J thermo-couple

potentiometer determines the value of measured thermo-electric EMF in mV. The compensation box with compensation circuit between thermocouple and potentiometer compensates the influences of ambient temperature giving right value of signal for ambient temperature 0 C deg.

The influence of the output resistance of the measuring circuit on the value of measuring signal is can be shown by switching a voltmeter into the thermocouple circuit. Te value of output signal diminishes. The right value of signal can be calculated knowing the resistances of voltmeter (150 Ω) and thermocouple with leads (2 Ω).

The values of measured resistance and thermo-electric EMF are transformed into temperature with the help of standard temperature tables $R_{\theta}=f(\theta)$ and $E_{\theta,\theta_0}=f(\theta-\theta_0)$ activated by *TEMPERATURE TABLES* switch. It is also possible to make this calculations using *Computation of electrical signal to temperature* circuit. The *HELP* button activates window with fundamental information of measuring circuits and measuring procedure.

The virtual measuring instruments cannot be spoiled by overloading and misfortune manipulation. However it is necessary to accustom students at the training stands for proper manipulations of measuring circuits. Therefore in the case of excessive galvanometer's overloading an instrument disappears covered by an inscription "You have damaged galvanometer" (Fig. 13).



Fig. 13. Information about excessive galvanometer's overloading

Another example of virtual laboratory stand used for strain measurements by means of strain gauges is presented in the Fig 14. It is possible to adjust the dimension of the tested beam, its Young's modulus and Poisson constant

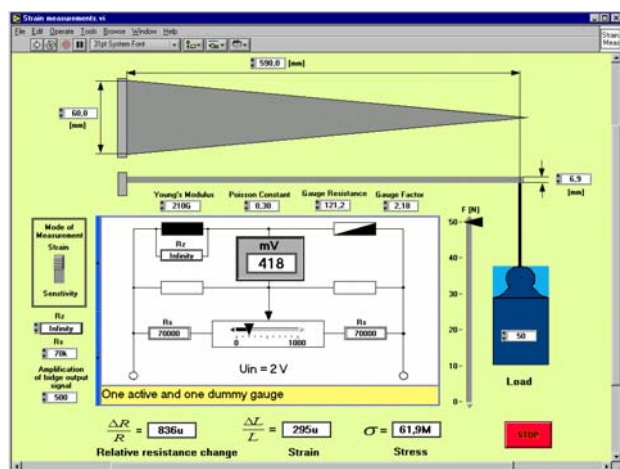


Fig 14. Stand for strain measurements

At the beginning of measuring session it is necessary to choose the measuring bridge connection: and to balance

the bridge with the help of trimming potentiometer. It can be choose the quarter bridge with one active gauge, the half bridge with one active and one dummy gauge, the full bridge with two active and two dummy gauges or the full bridge with four active gauges. In the last case the sensitivity of measuring circuit is 4 times greater than in the case of quarter bridge.

Then it is possible to determine the sensitivity of the bridge switching on the shunt resistor R_z and reading the value of the output voltage. Afterwards are performed the strain measurements for different values of load. It is possible to compare the sensitivity of different bridge connections and to match the amplification of output voltage in such manner that the values of millivoltmeter's indication correspond strictly to the value of measured strain.

Conclusions

Teaching and learning virtual instruments created by our team have had very positive influence on educational process of electrical measurements and instrumentations.

The lectures including demonstration of virtual instruments are:

- More interesting from the students' point of view,
- More comprehensible because many theorems are accompanied at once by experiments which makes it easier to keep them in mind.

Moreover:

- Possibility of using demonstration virtual instruments at home creates better understanding of the lectures and better preparation for final exams.

Laboratory virtual instruments used as training instruments or training stands offer to students:

- Possibility of good preparations for laboratory tasks in the university laboratories,
- Possibility to foresee any problem which can occur during the measuring session,
- Skill in manipulating of complicated instruments, which is a very important advantage for the students in their first contact with measuring instruments and measuring circuits.

References

1. **Graf F., Hausding M.** An Open Framework for Monitoring Learning Success in WWW-based Training // 10th EAEEIE Conference, Napoli (I), 1999, Litografia Libero Nicola. - P. 21-24.
2. **Gwoździńska A., Kaczmarek J.** Methods and Tools for Virtual University Design // 12th EAEEIE Conference, Nancy (F), 2001, Université Henri Poincaré. ISBN 2-9519740-0-7, Paper 109. - P.1-6.
3. **Halaj M., Kurekova E., Gabko P.** Multimedia Tools for Education in Measurement and Metrology // Symposium "Virtual and Real Tools for Education in Measurement", Twente (NL), 2001, P. Regtien (Ed), University of Twente. ISBN 90.365.1664.1. - P. 3-13.
4. **Hetman A., Korczynski M. J.** Teaching Digital Signal Processing in Quality Engineering Laboratory // 1st Virtual Workshop on Tools for Education in measurement, Tampere (FIN), 2001, Tampere University of Technology, ISBN 952-5183-17-3. - P. 25-30.

5. **Hofmann D.** Measurement, Instrumentation & Test Management MTM, a Newcomer to Education & Training // Symposium "Virtual and Real Tools for Education in Measurement" Twente (NL), 2001, P. Regtien (Ed), University of Twente. ISBN 90.365.1664.1. - P.15-22.
6. **Korczyński M. J., Gozdur R.** Virtual Instrumentation – a Key for Teaching Metrology and Quality Engineering // 1st Virtual Workshop on Tools for Education in measurement, Tampere (FIN), 2001, Tampere University of Technology, ISBN 952-5183-17-3. - P. 48-52.
7. **Platil A., Smidr R.** WWW System for Modular Courses on Modern Sensor // Symposium "Virtual and Real Tools for Education in Measurement" Twente (NL), 2001, P. Regtien (Ed), University of Twente, ISBN 90.365.1664.1. - P. 111-114.
8. **Referowski L., Roskosz R., Swisulski D.** Transmission of Measurements' Results using DataSocket Technology // 12th EAEEIE Conference, Nancy (F), 2001, Université Henri Poincaré. ISBN 2-9519740-0-7, Paper 146. - P. 1-6.
9. **Referowski L., Roskosz R., Swisulski D.** Virtual Instruments in the Program of the Electrical Measurements Chair (TUG) // Symposium "Virtual and Real Tools for Education in Measurement", Twente (NL), 2001, P. Regtien (ed), University of Twente, ISBN 90.365.1664.1, P.103-110.
10. **Referowski L.** CD-ROM Aid for Electrical Measurement Laboratory // XVI IMEKO World Congress, Wien (A), 2000, M. N. Durakbasa, A. Afjeji-Sadat, P.H. Osana (eds) Austrian Society for Measurement and Automation
11. **Robert M., Conrard D., Gend P.** Teaching of Electrical and Information Engineering with Help of Internet, The INEIT-MUCON Socrates Project // 10th EAEEIE Conference, Capri (I), 1999, Napoli, Litografia Libero Nicola. - P. 5-9.
12. **Schmid D.** Virtual Control Laboratories and Remote Experimentation in Control Engineering // 11th EAEEIE Conference, Ulm (D), 2000, M. W. Hoffman (ed), Abteilung Mikrowellentechnik der Universität Ulm. ISBN 3 00 005965 2. - P. 213-218.
13. **Thiriet J. M.** Curricula Reachable via Internet for Teaching Intelligent Instruments and Signal Processing, 11th EAEEIE Conference // Ulm (D), 2000, M. W. Hoffman (ed), Abteilung Mikrowellentechnik der Universität Ulm. ISBN 3 00 005965 2. - P. 250-254.
14. **Referowski L., Roskosz R., Świsulski D.** Virtual Models of Analog-Digital Converters in Education of Electrical Measurements and Instrumentation // Int. Conference on Education and Information Systems EISTA'04, July 21-25, 2004, Orlando (USA). - Vol. 1. - P. 61-66.
15. **Świsulski D., Referowski L.** Effective education of metrology basing on example of position measurements with incremental encoder // 16th EAEEIE Annual Conference on Innovation in Education for Electrical and Information Engineering, Lappeenranta, (FIN) 6th-8th June 2005. - P. 1-6.

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L. Referowski, D. Swisulski. Progress in Education of Electrical Measurements // Electronics and Electrical Engineering – Kaunas: Technologija, 2006. – No 3(67) – P. 25 – 30.

In the paper the authors present the possibilities of preparing modern, educational tools which, in the form of virtual instruments, are very helpful for educational process concerning electrical measurements. These dynamic instruments make it possible to use during the lectures some demonstrations which better explain the presented theory of electrical measurements, especially when some kinds of phenomena are shown in a slow-down time scale. Another group of virtual instruments make it possible to simulate measuring sessions realized later in the university laboratory. The third group explains the idea of remote measurements with help of modern technologies. These measurements are realized on different industrial objects. The paper presents several solutions of educational virtual instruments designed by the team of Gdansk University of Technology using the software LabVIEW of National Instruments. Ill. 14, bibl. 15 (in English; summaries in English, Russian and Lithuanian).

Л. Реферовский, Д. Свисульский. Прогресс в области изучения электрических измерений // Электроника и электротехника. – Каунас: Технология, 2006. – № 3(67). – С. 25 – 30.

Авторы представляют возможность приготовления современных научных инструментов („виртуальных инструментов“ ВИ), которых будет возможно использовать в изучении теории по электрическим измерениям. Такие динамические инструменты дают возможность во время доклада объяснить теорию электрических измерений. Это очень удобно, если действительный процесс очень скорый и надо его указать в медленном режиме. Вторая группа виртуальных инструментов дает возможность симуляции, которые потом студенты проверяют в современной лаборатории. Следующая группа ВИ объясняет принципы дистанционных измерений с помощью современных технологий. Такие измерения можно делать для разных промышленных объектов. Статья представляет несколько решений ВИ, которых проекты сделала команда Гданской Политехники, используя программу LabVIEW фирмы National Instruments. Ил. 14, библи. 15 (на английском языке; рефераты на английском, русском и литовском яз.).

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Aprašomos galimybės paruošti modernius mokymo įrankius, kurie, pateikiami virtualių instrumentų forma, yra labai naudingi elektrinių matavimų paskaitose. Šiais dinaminiais instrumentais paskaitų metu galima taip pateikti medžiagą, kad būtų galima geriau išdėstyti elektrinių matavimų teoriją, ypač tais atvejais, kai tam tikrų rūšių reiškiniai demonstruojami sulėtinto laiko skalėje. Kita virtualių instrumentų grupė leidžia modeliuoti realius matavimus, kurie vėliau bus atliekami universiteto laboratorijose. Trečioji grupė skirta paaiškinti nuotolinių matavimų sąvoką panaudojant modernias technologijas. Šie matavimai atliekami įvairiuose pramonės objektuose. Straipsnyje pateikiami keli mokomųjų virtualių instrumentų variantai, sukurti Gdanskio technologijos universitete, pritaikant firmos National Instruments programinę įrangą LabVIEW. Il. 14, bibl. 15 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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