# Exercise 4

# Measuring electrical power

## Introduction

The electrical power is one of the basic electrical quantities which can be defined both on DC and on AC. By measuring the electrical power we can determine the efficiency of electrical circuits or the stress of components, and the power measurement is the base of measuring electrical energy or consumption.

The present measurement is governed by the power measurement on different kinds of AC devices and circuits (R-L-C network, incandescent lamp, supply unit of a computer). The R-L-C network can be regarded as the model of a fluorescent lighting, where L is the chuckle, R is e substitute for the fluorescent tube and C is the power factor improving tool. On this model, it is possible to measure in twp different ways the apparent, the effective and the reactive power. By measuring the power of the incandescent lamp, we can learn the characteristic features of a quasi-linear component. The example of the power measurement on the supply of a personal computer illustrates the difficulties connected to the power measurement in case of non-linear wave-forms.

## The object of the measurement exercise

To get practical experiences in addition to the knowledge learned about the measurement of electrical power in the preliminary studies.

## Current measuring tools

### Clamp meter (Amprobe DLC-100)

The working principle of the clamp meter is identical with that of the ring current transformer which is laced on a current rail, where the rail plays the role of the primary winding with one number of turns. The clamp meter differs from such current transformers in the construction of the iron core. While the iron core of a transformer is fix, that of the clamp meter can be opened, and it can be placed around the conductor in which the current flows using the gap on the iron core, than closing it again, the conductor becomes the primary winding of one number of turns. In the secondary winding placed tight on the iron core a current will flow which is proportional to the current of the primary winding corresponding to the equilibrium of the primary and secondary excitation: $N_1 I_1 = N_2 I_2$ (where $N_1 = 1$).

Measuring the current of the secondary winding means indirectly measuring the current of the conductor in question.

The clamp meter is designed for measurements at industrial frequencies, *basically at 50/60 Hz*, but it can also be used in a wider frequency range (40 Hz – 1 kHz) with less accuracy. It was developed first of all to measure small *leakage currents*. Its most sensitive *measuring range is 40 mA* (with a resolution of 10 μA), *its accuracy is ±1% ±3 LSB* (% of the high end of the range: 4 digits display). The accuracy is similar up to the range of 40 A, above this the accuracy is drastically decreasing (e.g. between 80 and 100 A: ±9 % ±10 LSB).

The measuring unit of the clamp meter can also be used independent of the current transformer for measuring *voltage* (0 – 400 V range) and *resistance* (0 – 400 Ω), but in the actual measurement it is used only for measuring current.

**Hall-probe current meter (Hameg HZ-56)**

The sensor of the current meter is a Hall probe, thus it is capable to measure currents from DC up to 100 kHz. The working principle of the Hall probe is based on the phenomenon that if in the semiconductor chip current flows and perpendicular to the plane of the chip magnetic field is acting, then due to the interaction of the field and the moving charge carriers a voltage develops which is proportional to the induction of the magnetic field and it is perpendicular to the direction of the current („Hall voltage"), and measuring this voltage the magnitude of the magnetic induction can be determined. If the magnetic field (induction) is generated by a current, which flows in a conductor, then the induction is proportional to the current, thus placing the Hall probe in this magnetic field, the Hall voltege will be proportional to the current to be measured after all.

The Hall probe current meter contains an electronic circuit (amplifier) which generates in case of 1 A measured current 100 mV output voltage on the output of the instrument (in other words the *conversion factor of the instrument is 100 mV/A*), and by the measurement of this voltage can be determined the value of the current. *The range of the current measurement extends form 0 to ±30 A.* The accuracy on DC: *±1 % ±2 mA (% of the measuring range).* The frequency response is given by the operating instructions of the instrument. In the frequency range from *DC up to 100 kHz* the deviation is *smaller than 0,5 dB*, and from DC up to 100 Hz it is practically negligible, so here the DC accuracy can be regarded valid.

## Special literature, references

[1] The material of the Measurement lectures..

[2] István Zoltán dr.: *Méréstechnika („Measurements"),* Műegyetemi Kiadó, 55029, Bp., 1997.

Calculation of the measurement errors: pp. 20-21.

Measurement of power and energy: pp. 105 - 114.

## Tasks helping the preparation

*Do the following self-contained as preliminary preparation for the measurement at home.*

1. Read thoroughly the chapters listed in paragraph „Special literature".
2. Read and think over the *Measurement tasks*.
3. Answer i.e. solve the Check questions and the Check tasks at the end of this measuring instructions.

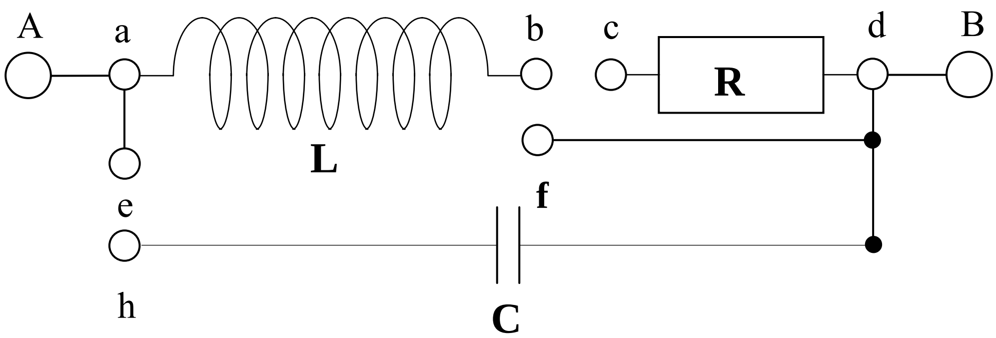
*The preparation can be checked by the leader of the measurement giving oral questions.*

## Applied instruments

| | |
|---|---|
| Oscilloscope | Agilent 54622A |
| Digital multi-meter (6½ digit) | Agilent 33401A |
| Digital multi-meter (3½ digit) | Metex ME-22T |
| Analogue multi-meter | Ganzuniv-3 |
| Electronic power meter | Hameg HM8115 |
| Adjustable AC supply | Metrel MA-4804 |
| Clamp meter | Amprobe DLC-100 |
| Hall-probe current meter | Hameg HZ-56 |

## Devices to be measured

R-L-C network, incandescent lamp, supply unit of a personal computer.




4-1. ábra. The R-L-C network used in the measurement

## Measurement tasks

### 1. Analysis of the related powers of an R-L-C network by measurement and calculation

The device to be measured can be seen on Figure 4-1.

Create the circuit arrangement given by the leader of the measurement by plugging the cables, and measure the current, the voltage, the apparent, effective and reactive power and the power factor of the plugged circuit setting a 50 Hz supply voltage of 40 V effective

1.1. using the electronic power meter,

1.2. using the three voltmeter method.

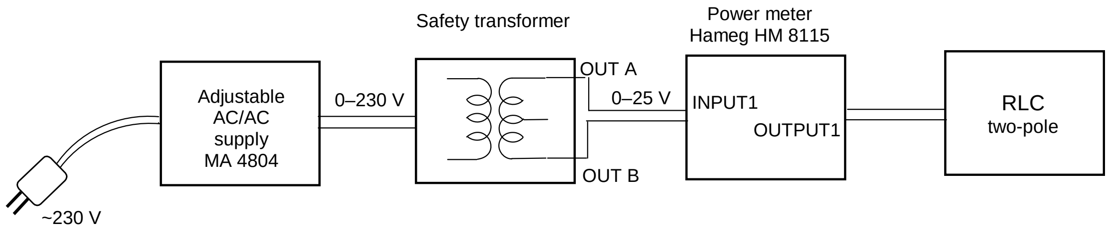



Figure 4-2. Measuring the RLC network using the electronic power meter.

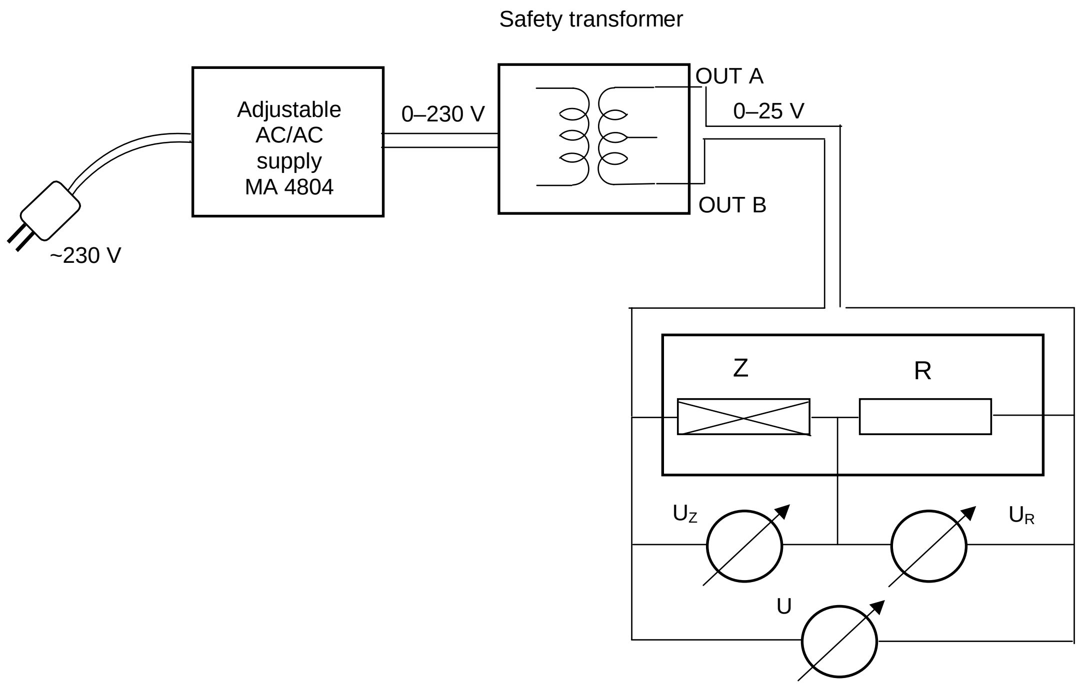



Figure 4-3. Measuring power by three voltmeters

2. **Calculate the error in case of measurement task 1.**

3. **Measure the characteristic of an incandescent lamp with a nominal voltage of 230 V, a nominal power of 40 W at 50 Hz by an electronic power meter while the supply voltage changes from 20 up to 100 % of the nominal voltage in 10 % steps.**

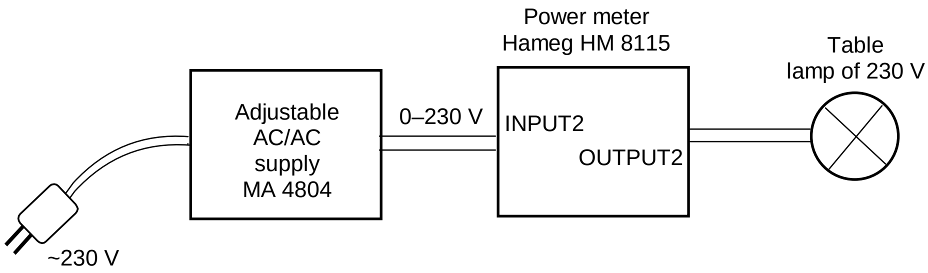



Figure 4-4. Measuring an incandescent lamp.

4. **Plot the effective power, the resistance and the current graphically in case of measurement 3.**

5. **Measure the true r.m.s. value of the current taken by a personal computer configuration and the mains voltage, and give an estimation for the upper power limit of the taken effective power.**

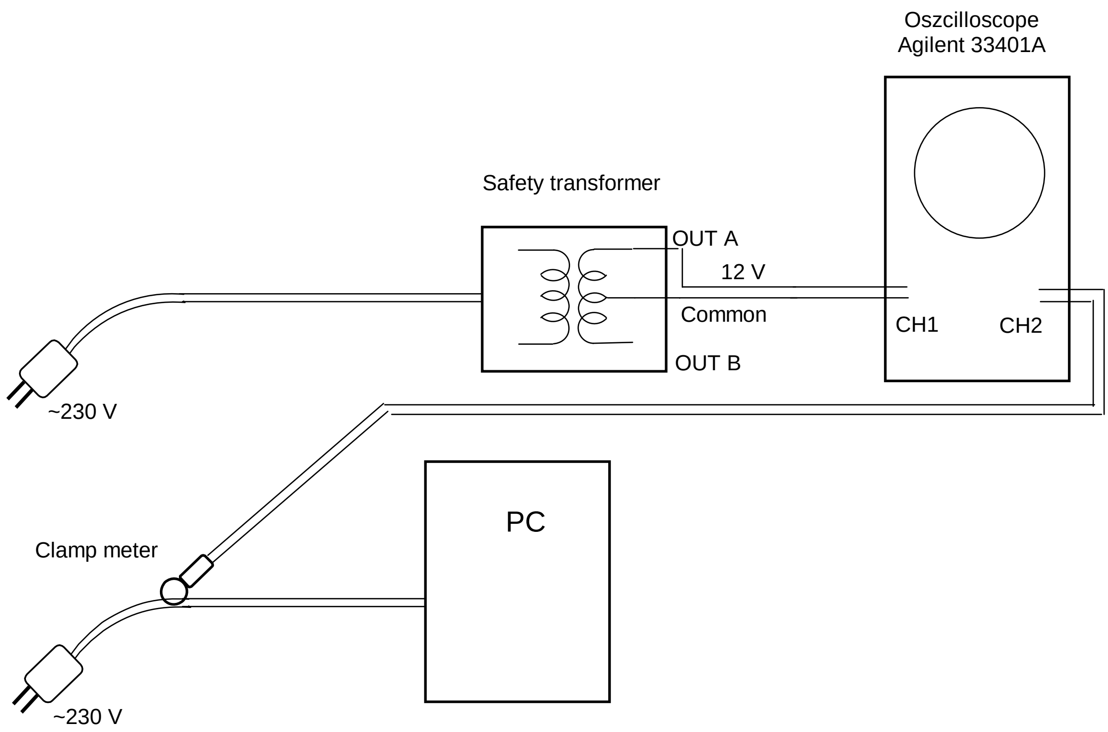



Figure 4-5. Power analysis of a PC.

## Check questions

1. How to calculate the momentary power?
2. What is the meaning of the positive or negative sign of a DC power according to convention.
3. In an AC circuit the effective (r.m.s.) value of the voltage and the current measured on a two-pole is V and I respectively. The phase angle between the voltage and the current is $\varphi$ (the voltage leads to the current if $\varphi$ is positive). How to calculate the effective, the reactive and the apparent power of the two-pole? How do these quantities change if the sign of $\varphi$ reverses?
4. How do we define the effective and the reactive power if the wave-form is not sinusoidal but it is periodical? (denote the DC components of the voltage and the current $V_0$ and $I_0$ respectively, $V_i$ and $I_i$ the effective value of the i-th over-harmonic of the voltage, i.e. the current and $\varphi_i$ the phase angle between these over-harmonics /i = 1 belongs to the fundamental harmonic and the voltage leads to the current if $\varphi_i$ is positive/).
5. How do you calculate the effective power in a circuit where the wave-form of the voltage is sinusoidal, but that of the current – due to the non-linearity of the circuit – is not sinusoidal but the period times are identical?
6. What is the definition of the electrical energy (work, consumption)?
7. What kind of possibilities do you know for the multiplication of two electrical quantities?
8. Describe the principle of the electromechanical, the quadrature and the digital multiplier.
9. Describe the method of the three voltmeter effective power measurement.
10. How do you determine the relative error of the three voltmeter effective power measurement method if the systematic error of the voltage measurements is known (there is no accidental error of the measurements)?
11. Describe the principle of the electronic power meter.
12. Describe the principle of the power analyser.

## Check tasks

1. Draw an AC generator of known frequency, source voltage and internal impedance. Connect a load impedance composed of an inductance and a series resistance to it. Take the positive direction of the voltage and the current as you like and write the relationships for the calculation of the current, the voltage on the terminals of the generator and the power respectively.
2. See task 1. Plot the time functions of the voltage, the current and the power for an interval of one period time if
   - a.) the value of the inductance is zero,
   - b.) the value of the resistance is zero,
   - c.) if the inductance is substituted by a capacitance and the resistance is zero.

3. Draw the voltage and the current on a phasor diagram in the above cases.

4. Suppose that the internal impedance of a 50 Hz voltage generator is zero, the source voltage is 110 V and in the load impedance the inductance has a value of 1.2 H and the value of the series resistance is 40 ohm. What are the effective value and the phase angle of the current? How much are the real and the imaginary components of the current? What is the value of the dissipated loss in the impedance? How much are the reactive and the apparent powers?

5. See task 3. What should be the value of an additional resistance connected series to the load impedance to get a phase angle of 45° between the terminal voltage and the current?

6. See task 4. Denote the resulting load impedance by $Z_E$. What are the effective value and the phase angle of the current? How much are the real and the imaginary components of the current? What is the value of the dissipated loss in the load impedance?

7. Draw the phasor diagram of the current and the voltage according to task 5.

8. What should be the value of the phase improving capacitance connected parallel to the $Z_E$ impedance to get a phase angle of 0° between the terminal voltage and the current? It is given that the loss factor of the capacitance is less than $10^{-4}$. In this case, how much is the absolute value and the phase angle of the resulting impedance? How much is the loss in the capacitance?

9. Study the manual of the electronic power meter of Hameg, type HM 8115. Analyse whether this instrument can be used to measure the terminal voltage, the current and the power of the networks according to tasks 4 and 5. If yes, draw the connection arrangement. Think over the way of use of the instrument. Summarize the elementary steps from the drawing of the connection arrangement till the determination of the final result and the measurement uncertainty. (An elementary step is e.g. the formation of the cabling according to the connection diagram, the switch on, the setting of an operation point, taking and recording the readings etc.).

10. Analyse whether it is possible to measure the terminal voltage the current and the power of the networks according to tasks 4 and 5 by using the Agilent digital multi-meter in a three voltmeter arrangement. If yes, draw the connection arrangement. Think over the way of use of the instrument. Summarize the elementary steps from the drawing of the

connection arrangement till the determination of the final result and the measurement uncertainty.

11. Analyse whether it is possible to measure the terminal voltage the current and the power of the networks according to tasks 4 and 6 by using the Agilent digital oscilloscope, type 54622A. If yes, draw the connection arrangement. Think over the way of use of the instrument. Summarize the elementary steps from the drawing of the connection arrangement till the determination of the final result and the measurement uncertainty.

12. You are given an incandescent lamp with a nominal voltage of 230 V and a nominal power of 100 W. How much is its nominal resistance? Give an estimation for its cold resistance.