**Katarzyna Peplińska-Matysiak**
**Sebastian Pecolt**
**Tomasz Krzyżyński**
Wydział Technologii i Edukacji
Katedra Mechatroniki i Mechaniki Stosowanej
Politechnika Koszalińska

# Experimental set - up to research inductive heating of domestic hot water

**Key words:** inductive, domestic hot water, heating systems, temperature sensors

## Introduction

Electric heaters made of a resistive material, which is insulated from the heated water, are often used to heat domestic water in closed tanks.

Induction heating is another solution for heating water. It is the process of heating an electrically conducting object by electromagnetic induction. Many parameters i.e. heater power, heat exchanger surface, mixing water process have influence on the heating process.

To properly investigate the efficiency of the developed heating system it is necessary to monitor important parameters in the whole system, such us input power, power factor and the temperature of heated water.

## 1. Experimental set - up

Experimental set-up (Fig. 1) consists of three major parts: water tank, heating system and data acquisition system. The aim of the research is to measure real power and temperature of water filling the tank during the measuring process.

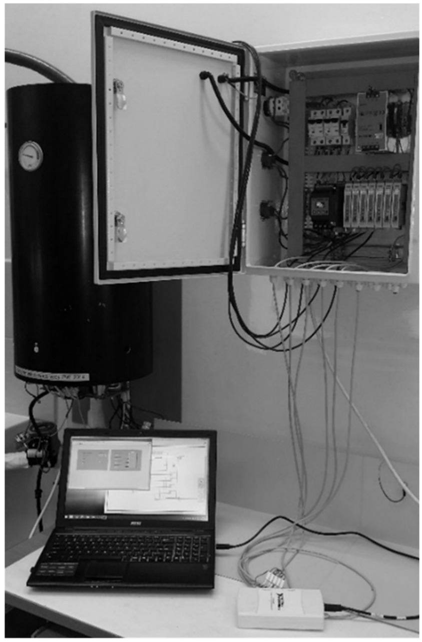

**Fig. 1.** Experimental set-up to research inductive heating of domestic hot water

## 2. Measurement system

Data acquisition system is based on National Instruments components and Labview applications. Signals from temperature sensor (Fig. 3) and 1-phase power network meter (Fig. 5) after processing by transducers go to Bus - Powered M Series Multifunction DAQ (Fig. 7).

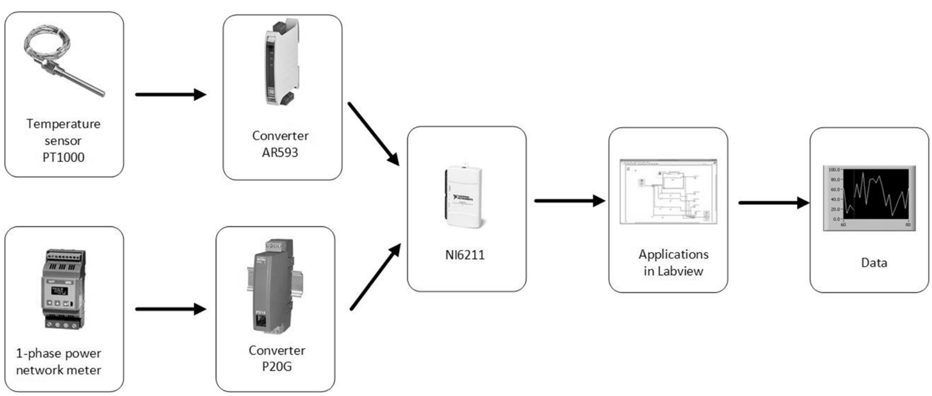


**Fig. 2.** Measuring system for acquisition data

Temperature sensors are located in different positions of the tank. This setup provides more precise readings while water is stirred by a pump and an overview of the temperature sensors when the water is not stirred.

The capacity of the tank is equal to 50 liters. The volume of 48.5 liters is used for this research due to the fact that the heated water is in an open configuration i.e. open-vented non pressurised system and to prevent leakage of water from the upper hole of tank due to thermal expansion of water so it was decided to reduce the amount of water to a safe level.

Two coils (9,10) are used as the heating elements and they are located between the water tank and the case (11). Electrical system (4) is located under the tank. IGBT transistors and bridge rectifier (13) are directly attached to the tank for better heating efficiency. The thermostat (8) is used for disconnecting the system when the temperature of water is equal to 70 degrees. Cold water flows on intake (6). Warm water is channeled by exhaust (14).

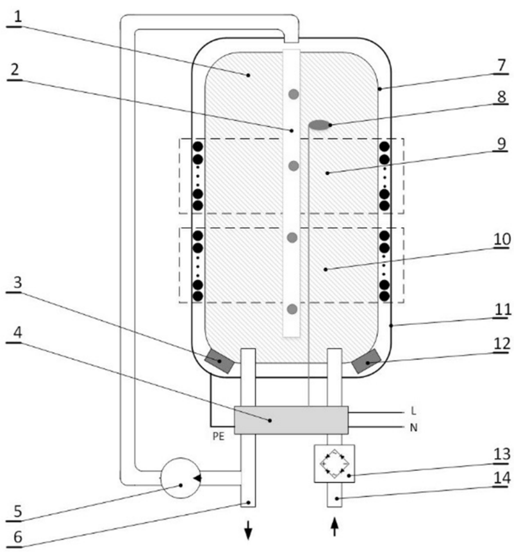


**Fig. 3.** Water tank with heating system and temperature sensors

## 2.1. Measuring equipment

**Temperature sensors** (Fig. 3) used in measuring system have 4-core cables PT1000 which have 1/3B class of tolerance (EN 60751). The measuring range is from -30°C to 100°C. Temperature factor is 3850 ppm/K.

**Fig. 4.** Temperature sensor TT4- PT1000X – 255 – PL

Apar's **universal transduces AR593** (Fig. 4) is used to convert the signal from temperature sensor. The converter has two independent outputs i.e. the current output - 0/4 ÷20mA and the voltage output - 0/2 ÷ 10V. Scope of processing, input type, and other parameters configured with programmer from PC[2].

**Fig. 5.** Universal transducer AR593

**1 – phase network meter N27P** with graphical display can measure direct or indirect several network parameters i.e. phase voltage, current, active, reactive and apparent power, active power factor. Meter has universal measuring input 1/5 A 100/400 VA.C. or 32/63 A, 100/400 V A.C. and outputs RS-485 interface with MODBUS protocol, relays (numbers of delays is depending on version) and analog. It is direct measurement (up to 63A) [1].


**Fig. 6.** 1 –phase power network meter N27P

Source: [1]

**Separator P20G** is used to convert signal from 1 – phase power network meter. It has one current input and two outputs i.e. current output -20÷ 20 mA and voltage output -10 ÷ 10V). It is possible to recalibrate the analog output according to the output individual characteristic, change input and output type by PD14 programmer. Accuracy class 0,2.


**Fig. 7.** Separator P20G

Souce: [1]

Bus - Powered M Series Multifunction DAQ - The National Instruments USB – 6211 (Fig. 7) is used to acquire data from sensors. It has 16 analog inputs, 2 analog outputs and 4 digital inputs. Analog inputs measure with 16 bits resolution in maximum range -10 V to 10V with accuracy 2,69mV and sensitivity 91,6 μV (minimum range in -200mV to 200mV with accuracy 0,088 and sensitivity 4,8μV). Analog outputs are with resolution 16 bits in maximum range -10V to 10V with accuracy 3,512mV. Digital input and output are sinking sourcing type. Digital input is measuring in maximum range 0V to 5.25V. Digital output is in maximum range 0V to 3,8V.


**Fig. 8.** Bus Powered M Series - NI 6211

Source: [3]

## 2.2. Acquisition system in LabVIEW

Dedicated application in LabView was created (Fig. 8) for measuring system. On the front panel there are two sections: one is for parameters from 1 –phase network meter N27P, the other is for temperature from temperature sensors PT1000.

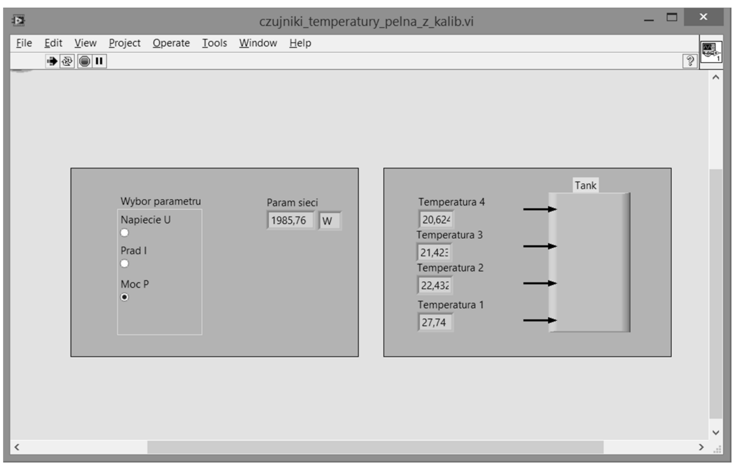


**Fig. 9.** Front panel of application for data acquisition

When one of the parameters i.e. Voltage (U), Current (I), Real power (P) is chosen data from sensor is processed to correct range (Fig. 9) in case statement.

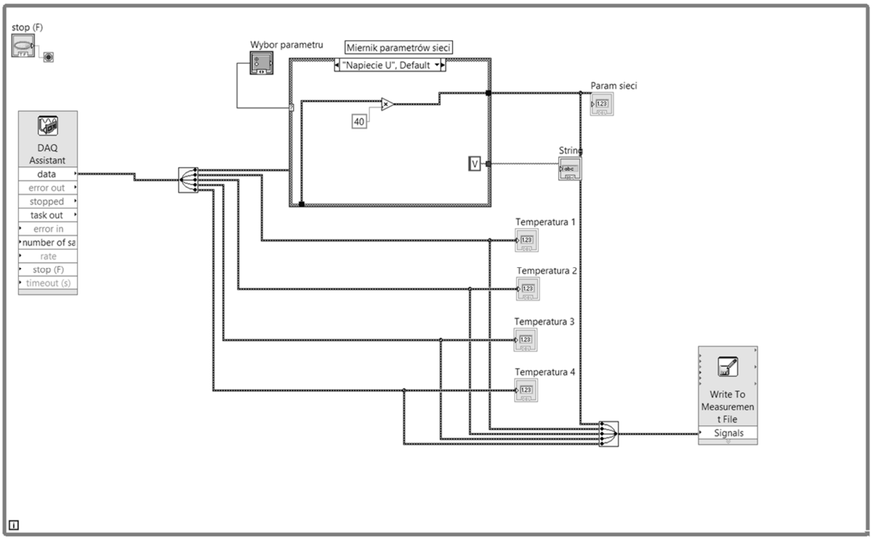


**Fig. 10.** Project of application in LabView environment

The signal from temperature sensors is not processed because all sensors were calibrated within range at 0 to 100 degrees in closed tank. Measured temperature is displayed directly on the screen. Temperature from calibrated sensors was compared to standard sensors.

## 3. Experimental results

Research was conducted in two setups:

– water stirred by pump,
– not stirred water.

Each approach took approximately 1,5h.

Samples were measured with 100Hz frequency. Real power [W] was chosen from 1 – phase network parameters. Data of temperature and real power were presented below on graphs.

Temperature sensors were located in water tank in order from the bottom *Temperatura 1*, *Temperatura 2*, *Temperatura 3* and *Temperatura 4*. Measured signal was presented on the figure (Fig. 8). Temperatures in the second variant where water was not stirred show visible differences (Fig. 10). The highest temperature is from sensor *Temperatura 4*, and the lowest from sensor *Temperatura 1.*

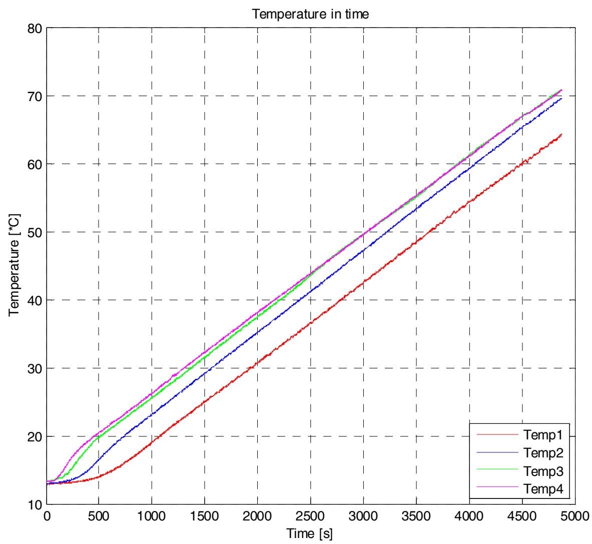


**Fig. 11.** Temperature in process without stirring water by pump

In the process with water stirring (Fig. 11) differences between temperatures are smaller and all of sensors presented almost the same temperature.

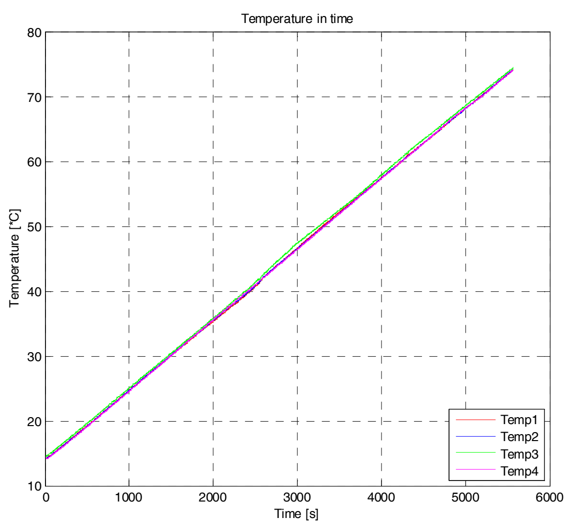


**Fig. 12.** Temperature in process with stirring water by pump

Power consumption during the research grew up to the moment when the thermostat disconected from the heating system. Process without water stirring (Fig. 12) spanned less than that of the process with the water stirring (Fig. 13), because water temperature on the top layer in tank was adegnate enough to allow the disconection of the system by the thermostat.

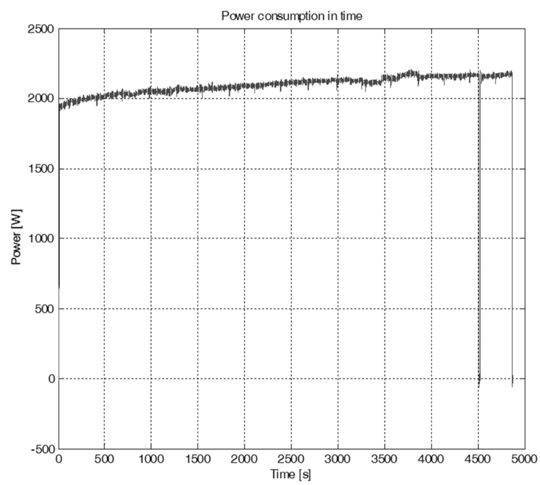


**Fig. 13.** Power consumption in process without stirring water by pump

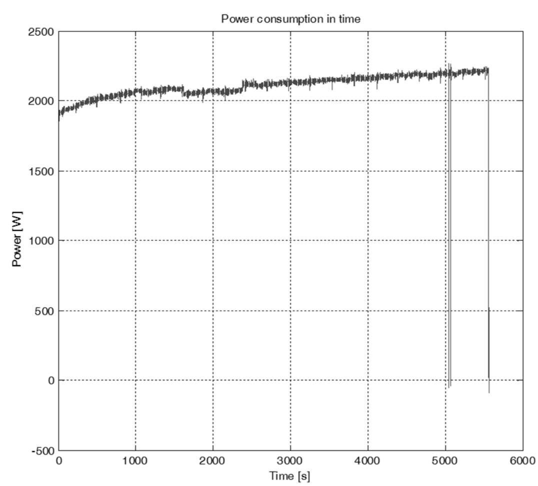


**Fig. 14.** Power consumption in process with stirring water by pump

In the Fig. 12 and Fig.13 in the final stage of collection data can be observed a short duration in reduction to zero level power consumption before the final off. This is due to the use of mechanical thermostat vibration contacts at specific temperature.

## 4. Conclusions

The measuring system for the experimental set-up provides the ability for automatic data collection of several parameters of the process. Temperature sensors used in the process are calibrated and provide accurate measurements. By applying four temperature sensors inside the tank, there is a possibility to measure the layers of temperature in heated water. The measuring system allows for future comparative efficiency study of conventional heating system with inductive heating domestic hot water.

## References

1. Lumel [online], http://www.lumel.com.pl/, Available at 06.03.2016
2. Apar [online], http://www.apar.pl/, Available at 06.03.2016
3. National Instruments [online], http://www.ni.com, Available at 04.11.2015

## Abstract

The article discusses experimental set – up to research inductive heating of domestic hot water. The article presents parts which contain test stand include: water tank, measuring, heating and acquisition systems. Each part is described with important parameters. The paper further presents result of research in two setups – with the stirring of water by pump and without the stirring of water.

## Streszczenie

Artykuł przedstawia stanowisko pomiarowe do badania indukcyjnego podgrzewacza wody użytkowej o pojemności 50 litrów. Szczegółowo opisano elementy stanowiska pomiarowego do automatycznej akwizycji danych wraz z aplikacją zbudowaną w LabView. Omówiono parametry zastosowanych czujników i przetworników. W drugiej części artykułu przedstawiono wyniki badań zebrane na stanowisku badawczym podczas dwóch procesów – z mieszaniem wody w zbiorniku w obiegu zamkniętym i bez mieszania wody, dzięki czemu można było zaobserwować uwarstwienie temperaturowe wody w bojlerze.