

Data Acquisition System for Cold Crucible

Stanislav Jiřinec ¹⁾ and David Rot ²⁾

^{1) 2)} University of West Bohemia, Faculty of Electrical Engineering, Pilsen, Czech Republic,
e-mail: ¹⁾ sjirinec@kee.zcu.cz, ²⁾ rot@kee.zcu.cz

Abstract — The purpose of this article is to introduce the data acquisition system for a cold crucible. The first part describes the induction system, cooling system and components used for the measurement and data collection. The next part is devoted to the program created in the LabVIEW software. It describes the parts of the program used for the CompactRIO chassis and program designed for an industrial PC that is used for visualization and data storage. At the end the main features of the user interface are explained.

Keywords — data acquisition system, LabVIEW, CompactRIO, induction heating, cooling system

I. INTRODUCTION

The aim of this article was to create a HMI and laboratory data acquisition system for measuring electrical and non-electrical values of induction systems with a primary focus on the cold crucible devices. The results obtained by the measuring systems are used for comparing with numerical simulations. In combination with the measuring system and numerical simulation it is possible to make changes leading to higher efficiency of the induction device. The core of the measuring system is created from components from the National Instruments (hardware platform CompactRIO [2] and appropriate measuring cards in combination with the software LabVIEW [5]).

II. MEASURING SYSTEM

The induction system consists of a source Peartec FRQ60, battery bank (capacitors), transformer and inductor. The source is connected to a three phase AC network (3x400 V). Electrical parameters of the source are measured by the industrial power network analyser (multimeter) IME NEMO96HD via current transformers with the ratio 50/5. The source has its own user interface where the basic parameters of the heating system (voltage, current and frequency) can be changed. The communication between the interface and the source is ensured via a serial line. The battery bank is connected to the circuit in series. A water-cooled transformer has the ratio 16:1. The inductor is connected to the secondary side of the transformer by a screw busbar and it is very easy to be replaced. The inductor can be easily changed.

The cooling system consists of two heat exchangers. The first one is used for the source cooling. The second one is used to cool the transformer and inductor. The crucible and load is cooled directly from a water line. It is also possible to connect the crucible and load to the closed cooling circuit. The hydraulic connection is shown in Fig. 1.

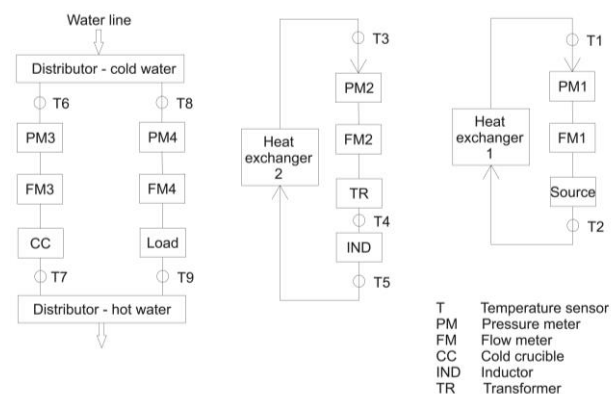


Fig. 1. Hydraulic connection of the cooling system.

The flow meter, temperature sensor and pressure meter are connected to the individual measuring subsystems which can be easily reconnected. The ultrasonic flow meter Kobold DUK [3] equipped with the analog output 4–20mA is used for the flow measurement. The principle of the ultrasonic flow meter is based on the principle of influencing the ultrasonic wave depending on the flow velocity.

The pressure sensor Endress + Hauser [4] which is also equipped with the analog output 4–20 mA is used for the pressure monitoring and detection of any faults. The temperature resistive sensors PT100 are used to measure individual temperatures in the system. All measuring devices are connected to appropriate measuring cards placed to the CompactRIO chassis. The example of one individual measuring subsystem is shown in Fig. 2.

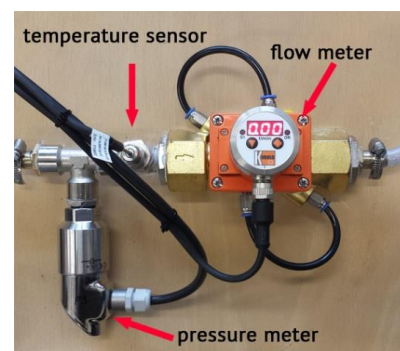


Fig. 2. Individual measuring subsystem.

The power network analyser is connected to the CompactRIO chassis via ModBUS RTU (RS485). The whole system is further complemented by an optical

pyrometer Kleiber 273c. The optical pyrometer is also equipped with an analog output (0–20 mA). To measure the surface temperature the infrared camera FLIR T335 is used.

The hardware platform (chassis) CompactRIO is used for the collection and processing of the measured data. The LabVIEW software is installed on an industrial PC. The CompactRIO, power supplies and circuit breakers are installed in the rack to achieve a higher robustness of the system.

The whole induction and measuring system is shown in Fig. 3.

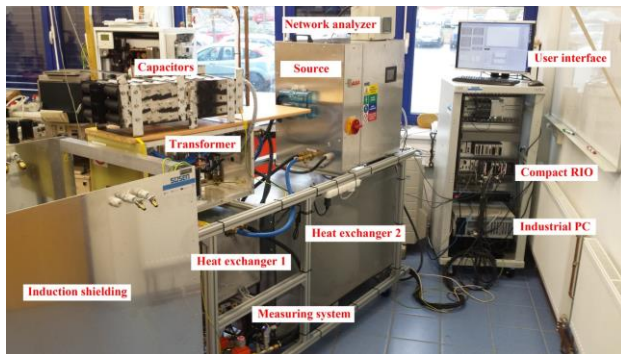


Fig. 3. Induction and measuring system.

III. STRUCTURE OF THE CREATED PROGRAM

The program for the data acquisition is created in the LabVIEW software from the company National Instruments. The project consists of two parts. The first part is uploaded in the industrial PC and provides the user interface and data storage. The second part is uploaded to the remote interface CompactRIO. The main task of this program is to collect and process the measured data, and to communicate with industrial PC.

IV. PROGRAM CREATED FOR COMPACTRIO

The created program for the CompactRIO consists of six parallel loops:

- Multimeter ModBUS
- RSI Low Speed
- UI Command Loop
- Message Handling Loop
- Watchdog Loop
- System Health and Monitoring Loop

The UI Command Loop receives messages from the user interface. The Message Handling Loop handles all messages coming from all the other loops, and itself. The Watchdog Loop sends periodical messages to ensure the system remains responsive. The System Health and Monitoring Loop sends diagnostic information and monitoring data to the user interface.

The queues are used for passing data between parallel loops. The queue is created and initialized by a message entered into the queue. The message is sent to the parallel loops and is separated from the queue for further processing. If an output of one parallel loop is used in

another loop, the data are inserted to the end of the queue. The queue works in a FIFO (first in, first out) manner.

The initialization of the basic parameters is performed by the sequential structure Fig. 4. In the structure parameters of the ModBUS RTU (RS485) communication with power network analyser (COM port, ID, baud rate and parity) can be modified. The name of all measured values, units, upper and lower limits can be also changed.

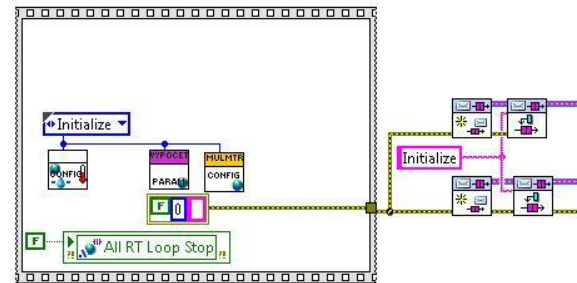


Fig. 4. Initialization sequence structure.

A. Multimeter ModBUS Loop

This loop receives data from the power network analyser using the ModBUS RTU (RS485). The loop contains the conditional structure which controls the steps of the loop. The first step is initialization, after that the connection with the power network analyser is established. The conditional structure enters the state of reading parameters. The starting address of register and number of elements for reading is inserted in this state. Some values are composed of multiple words or contain sign, which is transmitted in a separate register. It is therefore necessary to build the value from words, add signs and convert the value to the base unit specified in the initialization. The next step is assigning the values to names, units and limits. Global variables provide data exchange with the user interface. The last part of the conditional structure provides the termination of the connection. The sampling period is 1s (limited by ModBUS RTU).

B. RSI Low Speed

The next part of the program contains a loop for reading values from the measuring cards installed in slots of the CompactRIO chassis. In our application 3 cards for the temperature measurement (NI 9217) and 1 analog card ± 20 mA (NI 9203) were used. The sampling period is 250 ms. This value can be modified in the program. The measured values are scaled, cooling power is calculated and upper and lower limits are checked. The data are written to the global variable.

V. PROGRAM CREATED FOR PC

This part of the program creates the user interface. The user can change parameters of communication, names and limits of the measured values and set path for the data storage. The program is divided into three parts:

- Event Handling Loop
- UI Message Loop
- Monitoring Loop

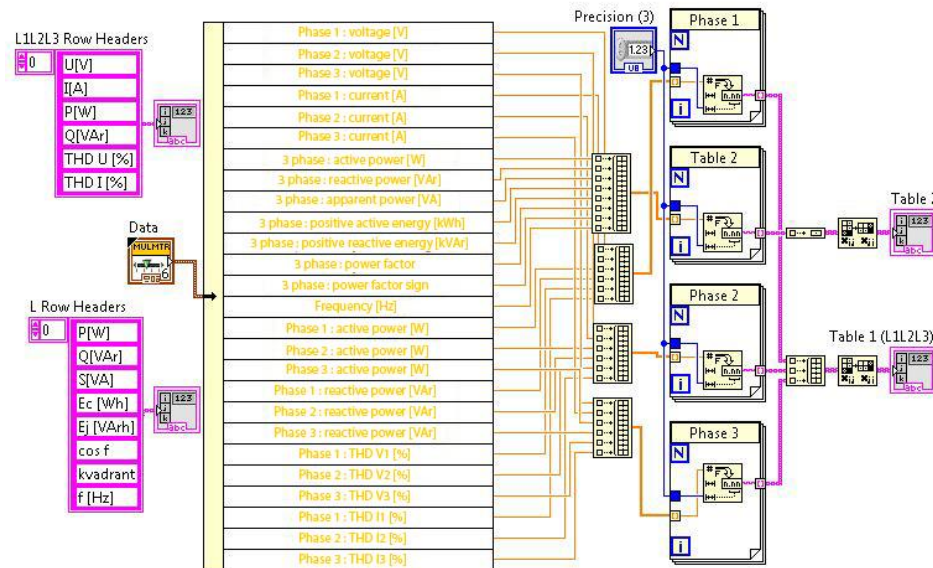


Fig. 5. Part of the Monitoring Loop.

The queues are also used for data exchange between the loops. The program uses global variables for the data exchange between the PC and CompactRIO. This communication is performed via Ethernet.

The Event Handling Loop handles all events from the user interface like modification of the parameters, setting values shown in the chart, setting the path for data storage, etc. Received events are transmitted to the UI Message Loop.

The UI Message Loop handles all messages coming from the Event Handling Loop, itself, and the Monitoring Loop. Changed parameters are written to the global value and data are transmitted to the CompactRIO. It is also used to establish the communication between the PC and CompactRIO.

A. Monitoring Loop

The data from global variables are received, processed for visualization in the user interface and stored in the PC hard disc. Fig. 5 shows part of the program used for dividing data from the global variable (data from the power network analyser) into the measured values. The measured values are compiled in two tables. The first table shows values of the voltage, current, power and total harmonic distortion in each phase. The second table shows values of the total power, energy, frequency and power factor. The row headers of the tables can be seen on the left side of Fig. 5.

The global variables are also used for reading data from the CompactRIO (appropriate measuring cards). The program in PC receives the measuring values, upper and lower alarms. The names and units of the measured values are assigned to the measuring values. The data are divided into individual tables according to the cooling loops (crucible, source, load, transformer + inductor). The inlet and outlet temperatures, pressure, flow rate and cooling power are displayed.

These measured values can be also graphically displayed on the user interface. All values are displayed in

one graph and the user can choose which values should be displayed.

All measured values can be saved to a file in TDMS format which can be easily opened in the Microsoft Excel. The program creates a file on the hard disc and leaves it open for a further data storage. The storage is indicated by the light on the user interface. At the end of the writing the file is closed. This part of the program is shown in Fig. 6.

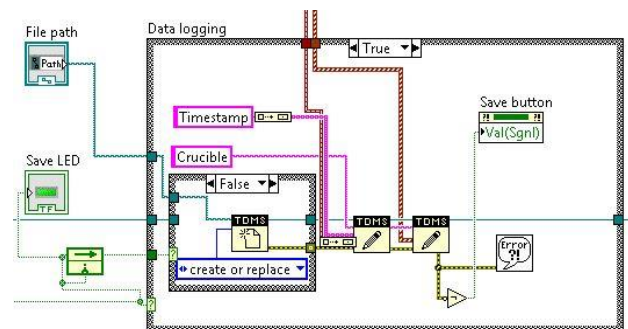


Fig. 6. Block diagram for data storage.

VI. USER INTERFACE

The user interface (Fig. 7) has been created with regard to the clarity of the measuring system. The user interface consists of four windows. The most important measured parameters of the induction system are shown in the upper left corner. There are shown the flow rate, pressure, temperatures and calculated cooling power. The parameters are divided into six tables according to the cooling loop.

The electrical parameters measured by the power network analyser are situated in the table in the lower left corner. All measured values can be displayed in the graph. The user can choose which values have to be currently charted.

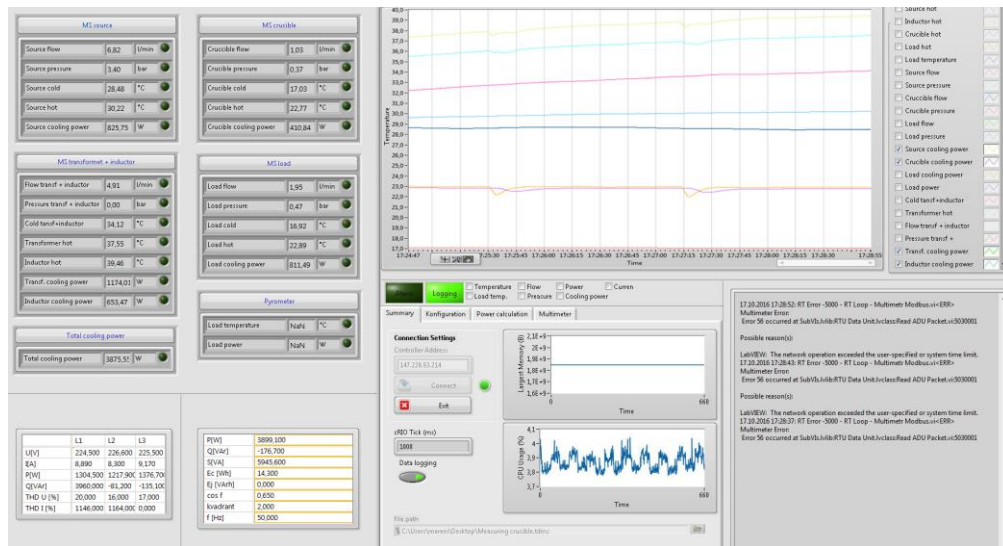


Fig. 7. User interface (example: measuring on simplified model of the cold crucible).

The configuration window and the window for error messages are situated below the graph. The configuration window is useful for setting the IP address of the CompactRIO or for set up of the communication with the power network analyser. The configuration window is used to select path for the data storage and to enable and disable recording of the measured values. It is also possible to modify the names of the measured variables, units, allowable limits and alarms. Communication problems with the power network analyser and values which are out of the permitted range are shown in the error window.

VII. CONCLUSION

The result of this project is a versatile, modular, scalable and customizable system for measuring electrical and non-electrical quantities and power losses in different parts of the induction system. We experienced many difficulties during implementation. All problems were debugged and system can be put into full operation. The system helps us during verification of numerical models on the induction devices and allows us to make changes which will lead to a higher efficiency of the system. The obtained data are absolutely crucial for verification of the numerical models. The developed measuring system in combination with numerical models creates a powerful tool that allows us to investigate influence of the individual construction parts of the cold crucible to the efficiency of the induction system.

The ten values of temperature (nine temperature sensors and temperature of pyrometer) and four values of pressure and flow are measured and stored four times per second. The electrical values are stored one time per second. This time is absolutely sufficient for this application. The measurement is always performed to a steady state which

occurs within a few minutes from the beginning of measurement.

In the next step we want to use CompactRIO to control the medium-frequency source where the real time device is necessary. We are going to use card with update rate 7 μ s.

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