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SYSTEM FOR AUTOMATED CALIBRATION OF DIGITAL ELECTRICITY METERS

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Abstract: The developed calibration software for the automated calibration process of digital sampling electricity meters is described. In present, two types of electricity meters, PEM 6711 (Precise Electricity Meter) and single phase electricity meter based on mixed-signal processor TI MSP430FE427 can undergo a fully automated calibration process. Calibration laboratory with the electronic calibration station EKS 05-3, used to calibrate electricity meters, is also described and its function is explained.

Keywords: automated calibration, electronic calibration station, digital electricity meter

1. INTRODUCTION

In digital sampling electricity meters the measurement errors of the analogue input circuits can be simply eliminated in the digital signal processing. Calibration procedure is used to set the parameters of the device and to correct the errors of measurement, [1]. The simplest error correction is only the offset correction, which is done by measuring the value of the input quantity with short-circuited input and storing this value in the memory for use as the correction constant. This error correction is usually accomplished every time the instrument is switched on. To correct the gain error multiplication coefficient must be evaluated. This needs some reference value of the input quantity to be connected to the input and measured by the instrument. The nonlinear characteristic of such an instrument needs more values of the input quantity to be connected to the input and measured by the instrument. In such case, a nonlinear correction function or a table of correction values must be calculated.

In electricity meters, three calibration procedures must be run, [2], [3]: voltage calibration, current calibration and parasitic phase shift correction. The best way is to carry out the calibration process automatically, using a computer. The computer controls a signal source (sets the desired measured values), reads the necessary values from the calibrated and reference instrument in the same instant, calculates the calibration constants and stores them in the memory of the calibrated instrument. Manufacturers of electricity meters usually have such possibility.

The designed instrument, PEM 6711, has an algorithm for the voltage and current calibration using the least squares method. The parasitic phase shift correction is accomplished by shifting the current samples before their multiplication with the corresponding voltage samples to get the measured power value. Calibration equipment used is based on EKS 05-3 electronic calibration station, [4], combined with K2006 precise three-phase comparator, [5], [6], and software developed for control of the calibration process.

2. CALIBRATION LABORATORY

Calibration laboratory for electricity meters is realized as an electronic calibration station EKS 05-3 and consists mainly of parts depicted in Figure 1:

- PEM 6711 – digital 6-phase signal generator combined with 3-phase electricity meter.
- K2006 – precise 3-phase comparator (separate instrument).
- Power transformers and amplifiers for 3-phase voltage and current signals.
- Personal computer with control and calculation software.

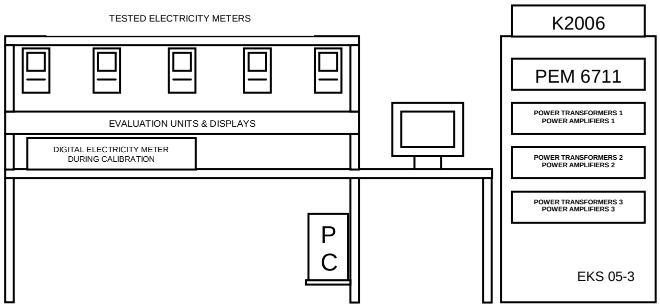

Fig. 1. Schematic drawing of the calibration laboratory with electronic calibration station EKS 05-3.

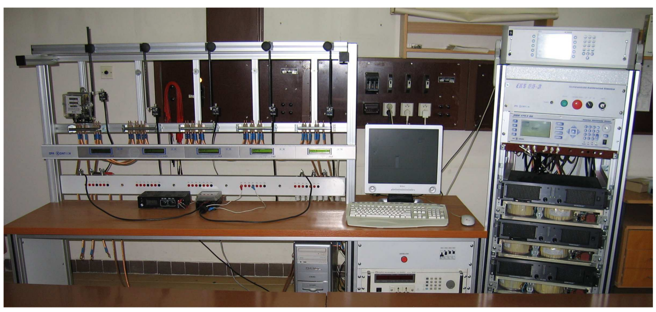

Fig. 2. Photograph of the calibration laboratory with electronic calibration station EKS 05-3.

PEM 6711, [2], is a precise digital electricity meter combined with a 3-phase signal generator. This instrument is used in the electronic calibration station as a reference standard for measurement and generation of the 3-phase test signals (voltages and currents) with sufficient accuracy. It is possible to set the desired phase shifts between the phase voltages and also between the corresponding phase voltage and current. Measuring function of the device makes it possible to stabilize the amplitudes of the generated signals. The accuracy of this electricity meter is 0.05% and it supports the RS-232 interface control protocol.

K2006 is a precise three-phase comparator developed for calibration laboratory and test use. It is used as a standard meter for precise measurement of calibration values and error calculations based on frequency outputs (if necessary). It can also display the time and phase diagrams for quick orientation in the positions of the generated signals and to calculate and display the frequency spectra of the generated signals. The basic accuracy of the comparator is 0.01 % and the communication via RS-232 interface is also included in its software.

Three double-channel power amplifiers amplify analogue signals from the test signal generator PEM 6711. Amplified 3-phase signals used as the test voltages and currents are led into the three pairs of toroid voltage and current power transformers, respectively. The transformers enable to get such values of voltages and currents which are impossible to obtain directly from the outputs of the amplifiers. These transformers contain secondary windings with a few taps to enable to create different combinations of voltage and current values which are switched to the output by a set of relays controlled via RS-485 interface.

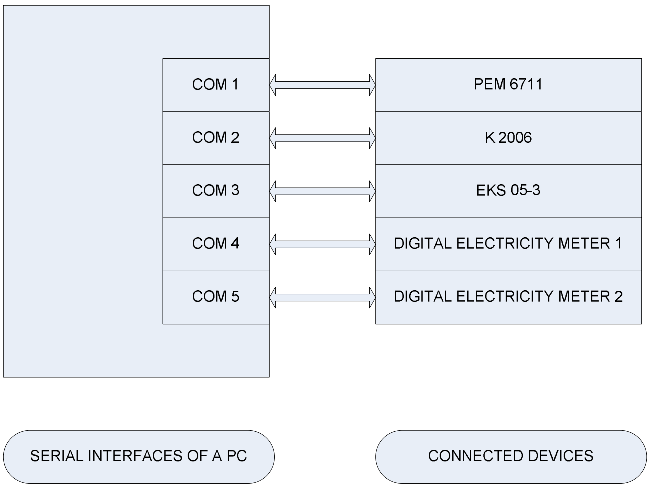

Fig. 3. Connection of the devices to the master PC.

The developed software called Station in the PC controls the whole calibration laboratory via multiple RS interfaces. It is used to control the PEM 6711 in the station, a set of power transformers' relays, an external digital electricity meter being calibrated and the K2006 comparator.

3. CALIBRATION SOFTWARE

The software Station is designed to run under Microsoft Windows operating systems. It was realized in C++ programming language, using Borland C++ Builder 6 and the communication of the program via serial port is covered by a C++ Builder's component ComPort. The most useful function of the program Station is to control the automated calibration process of an external electricity meter based on the K2006 comparator. Program Station enables to calibrate multiple PEM 6711 devices at the same time and what is more, it is capable to perform an automated measurement also on different digital electricity meters supporting communication via RS-232 interface, e.g. on a new developed digital single phase electricity meter with MSP430FE427, a mixed signal processor of Texas Instruments.

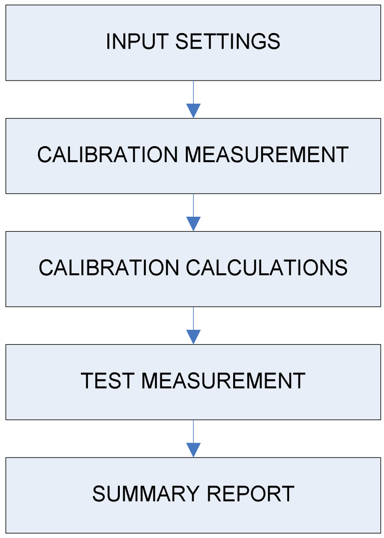

Fig. 4. Steps of the automated calibration process.

The automated process of calibration of an electricity meter is realized in five steps. The first one, the input settings, means at the top level to define the calibration sequence e.g. a sequence of measuring protocols. Each of them is a structured text file that contains necessary information for the calibration or test measurement of one electrical quantity (voltage, current, phase shift). It consists mainly of a suite of test points for the measure of each measuring range of the electricity meter.

This includes the following settings for each test point:

- voltages for the selected phases,
- currents for the selected phases,
- phase shifts between voltages and currents for the selected phases,
- number of measurements,
- time spacing between measurements.

It is also necessary to:

- select measured quantities to be saved into a file (voltages, currents, powers),
- input the name of the directory for the results files to be saved to.

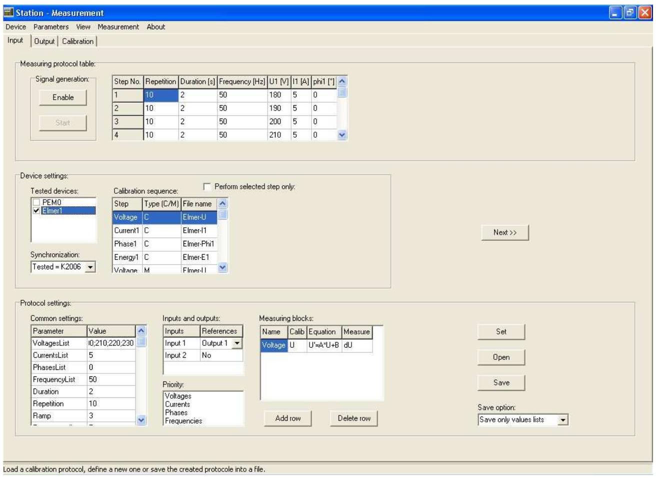

Fig. 5. Screen shot of the program Station – input settings.

Once this setting is complete, the second step can start. An automated calibration measurement is performed. Measured values originating in each calibrated device together with reference values coming from K2006 device are written into a result text file in a tabular form during the automated measurement. As soon as new values are gathered, the program displays them in the grids of the screen and relative errors are calculated and graphically displayed for each tested device, too. The user is informed also about the progress of automated measurement by displaying of the number of the current measure point, the time elapsed from the beginning of the measurement and the time estimation of the total duration of the measurement.

When the measurement is done, the third step of the calibration is realized. It means to process the measured values and finally to calculate calibration constants for each measuring range of a tested device and to write them into device's memory via RS-232 serial link. Well-arranged tabular format of the results file allows easily importing it into Microsoft Excel and exploiting its powerful functions to achieve further processing of measured values.

The next step consists in carrying out test measurements to achieve error characteristics of the given device after calibration. This measurement is performed exactly the same way as the calibration measurement.

After all test measurements are done a summary report is prepared. It includes the results of all test measurements in a structured format and serves as a basis for the calibration certificate of the calibrated digital electricity meter.

4. COMMUNICATION AND AUTOMATION

Communication between PC and a device via the serial link is based on commands composed of strings of bytes. Although the formats of these strings are specific for each device, all of them have some common characteristics. Some parts of the strings are constant and their bytes correspond to readable ASCII characters, however other constant parts are unreadable. Other parts of the strings are variable and may contain known or unknown number of bytes.

There are three types of strings for each command:

- string of request sent from the PC to the device
- string of response sent from the device to the PC
- string messaging error sent from the device to the PC

We found a solution how to write all these strings in a new common format, which uses some characteristic strings to write all variable and unreadable parts. This solution permits to save new common format strings into a configuration text file for each of the devices that communicate with the PC. Those parts that consist of readable characters keep their format.

Characterisic strings for the unreadable characters:
|\ddd| – 1 byte in decimal
|\0xhh| – 1 byte in hexadecimal

Characterisic strings for the variable parts of the string:
|#*n*| – a string of n-bytes, n is a number
|#?| – a string of unknown number of bytes
|&O*i*| – in the response of the device, there is expected the same string as the string in place of the i‘s characteristic string |#n| alebo |#?| in the corresponding request from the PC

These files are loaded into the program Station and then it is able to generate the final byte string replacing all the general characteristic strings by concrete ones. Program can also validate the response coming from the device by comparing it to the appropriate format string and to read out any necessary value from the string.

Commands that it is necessary to execute in order to perform automated measurement correctly may be suitably grouped together into a common block. All commands of the block, called command steps, are executed consecutively. As soon as the program validates the response of a device, sends the next command in the block. Most important blocks for the automated process are the following:

Block Range & Output:

- sets the correct voltage and current measure ranges in all measuring devices and appropriate taps of the transformers secondary windings to the output according to the signal parameters
- sets the parameters of the generator for the output signal (voltages, currents, phase shifts)

Block Measure:

- reads necessary values from measuring instruments

Block Calib:

- sets the selected voltage and current measure ranges in the calibrated device
- writes the calculated calibration constants into the calibrated device

Block Start & Delay:

- launches the signal generation to the output and delays the execution of the next block

Block Stop:

- ceases the signal generation to the output

Program Station controls the setting and execution of these blocks of commands. Blocks Begin, Range & Output, Start & Delay, Stop and Measure are set at the beginning of each measuring protocol. The pointer is set to the first measuring point of the appropriate protocol. Blocks Begin, Range & Output and Start & Delay are executed in sequence, respectively. The last of them triggers the generation of the signal to the output and let the program wait till the amplitude of the output signal is constant. Next, the timer starts, which is responsible of executing the block Measure periodically, with a preset period. When the block Measure is executed for the last time, which is limited by the value of measurements in the current measuring point in the measuring protocol, the Stop block halts the signal generation. The next measuring point takes its turn. Program sets the block Range & Output with new values and executes the commands within. The setting and execution of the blocks is the same for each measuring point. If all measurements for the current measuring protocol are completed program station performs data processing with gathered values. In case of calibration measurement Calib block is set up and its commands are executed. This process is performed until all measuring protocols are completed. This process is shown in flowchart Figure 6.

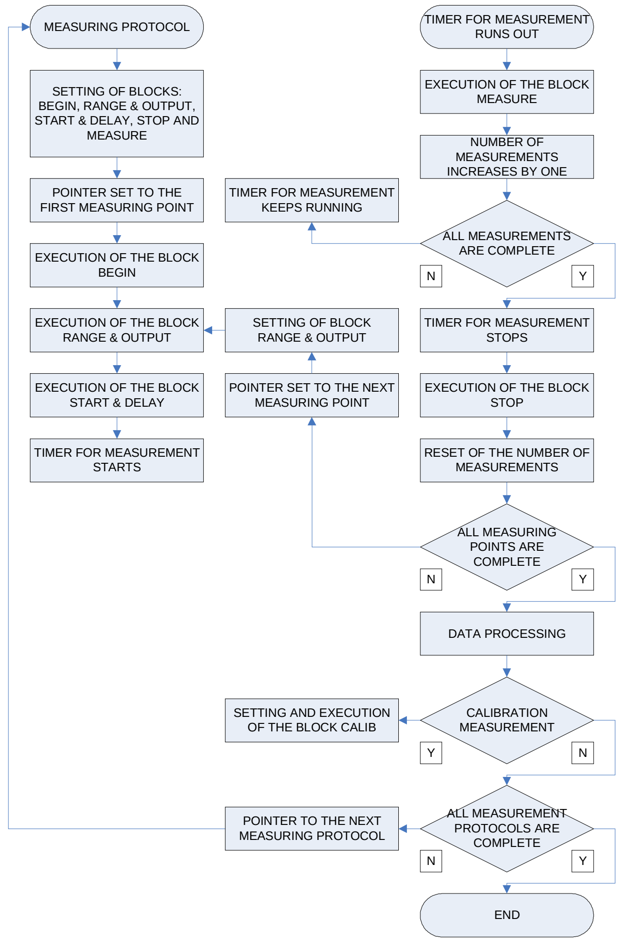

Fig. 6. Flowchart of the program Station – automated measurement.

5. CONCLUSION

Electronic calibration station EKS 05-3, used to calibrate different kinds of electricity meters, is described and its function is briefly explained. It consists of the PEM 6711 digital sampling electricity meter, three dual-channel power amplifiers, a set of voltage and current transformers, an equipment for error evaluation and display, a personal computer with control and calculation software and the K2006 precise three-phase comparator. The developed calibration software named Station for the calibration of the designed and constructed PEM 6711 digital sampling electricity meter and also another one based on MSP430FE427 processor is also described.

Using the program Station, an automated calibration of mentioned electricity meters can be performed. No consuming process of manual collecting of measured values is needed and computer controlled calibration laboratory provides error-free and accelerated calibration process.

ACKNOWLEDGMENTS

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