Virtual Three Phase Power Transducer

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Abstract – **In a changing electric industry, monitoring power supply and power quality are critical to ensuring optimal performance of power systems. Key to the success of an effective monitoring system are flexibility, powerful data processing, understandable reports, and easy access to information. This paper describes the development of virtual system for power monitoring and parameter's calculation where the three phase power transducer is interfaced to a computer using serial port. The various electrical parameters can be monitored in graphical user interface which is developed using LabVIEW.**

Keywords – **LabVIEW, Power transducer, Serial communications, Virtual instrumentation,**

I. Introduction

The electric power system is very complex and consists of the following parts – manufacturing, distribution and consumption. The correct control of the system requests a large amount of information for the parameters in different points. There are in use transducers (fig. 1), which measure the values of the main quantities of the three phase electric power system – voltage, current, frequency and calculate the derivatives – active power, reactive power, power factor, active energy and reactive energy [1].

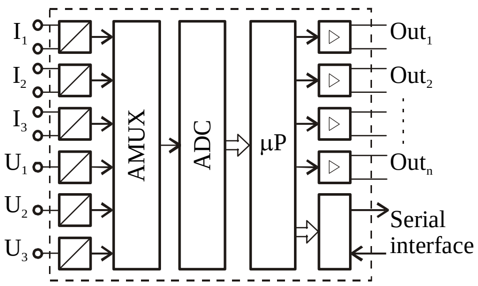

Fig. 1. Block diagram of an universal transducer

Most of the transducers have two types of interface: analog and digital. The output quantities of the analog outputs can be load independent direct current or direct voltage signals. The range of the current outputs may be different - -5mA ÷ +5mA, 0mA ÷ 20mA or 4mA ÷ 20mA. Usually the range of the voltage outputs is 0 ÷ 10V.

The digital interface is usually serial in order to minimize the number of the wires. The standard is mainly RS485 or RS232. There are custom defined interfaces as well.

The transducers may have several analog outputs (fig. 1). Their number limits the number of the quantities which values can be transmitted.

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The digital interface uses only two or three wires but presents the possibility to transmit the values of all parameters of the electric power system. This transfer has higher noise immunity than the analog.

At a given point of the electric power system – power plant, sub-station, there are usually a big number of transducers. It is useful to be included in a computer network. The digital interface makes it possible.

The network can be developed using the well known configurations – star, ring, bus etc. In order to minimize the connections bus topology is suitable.

II. Universal Measuring Transducer

In the Development Laboratory for Semiconductor Circuits Design at Technical University of Sofia have been designed universal transducers for use in the electric power system. They have two-wire instrumental serial interface, which enables development of industrial network (fig. 2) [2]. It is configured using bus topology. In order to connect a standard unit – PC or operator's station to the developed network there must be an adapter to translate the logic levels of the industrial interface in accordance with a standard interface, for example RS232.

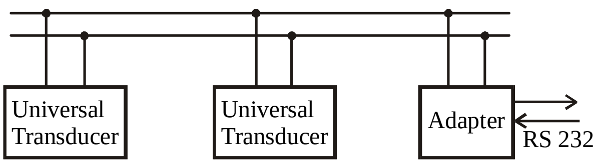

Fig. 2. Universal transducers in an industrial network

The two-wire instrumental serial interface operates with 9600 bit/s baud rate and the communication is reliable when the length of the connection is up to 100m.

The most common used transducers in the electric power system are connected to three phase grids with delta configuration and asynchronous load. This system has three wires. The input variables are the line voltages U_{12} and U_{23} and the phase currents I_1 and I_3. This is known as the method with two wattmeters or Aron circuit. The voltage range is 130V and the current range is 6A.

The high rate of data transfer enables transmission of large amount of information. The data transmitted by the transducer includes the values of line voltages (U_{12}, U_{23}), phase currents (I_1, I_3), active power (P), reactive power (Q), frequency (f), active and reactive energy in four quadrants (ENA+, ENA-, ENRL, ENRC), ratios of the voltage and current measuring transformers (k_U, k_I), phase angles of the vectors in relation to U_{12} (φU_{23}, φI_1, φI_3). The last two bytes contain the checksum (CS) and the value is the sum of the all bytes of the buffer.

The communication data buffer is described in Table 1.

TABLE 1. DATA BUFFER DESCRIPTION

Byte number	Value	Format
0	address	HEX - 11xxxxxx
1	command	HEX - 10xxxxxx
2	40 ($28)	HEX - 00101000
3, 4	U_{12}	HEX - 0aaaaaaa, 0bbbbbbb
5, 6	U_{23}	HEX - 0aaaaaaa, 0bbbbbbb
7, 8	I_1	HEX - 0aaaaaaa, 0bbbbbbb
9, 10	I_3	HEX - 0aaaaaaa, 0bbbbbbb
11, 12	P	HEX - 0±aaaaaa, 0bbbbbbb
13, 14	Q	HEX - 0±aaaaaa, 0bbbbbbb
15, 16	f	HEX - 0aaaaaaa, 0bbbbbbb
17, 18, 19, 20	ENA+	BCD
21, 22, 23, 24	ENA-	BCD
25, 26, 27, 28	ENRL	BCD
29, 30, 31, 32	ENRC	BCD
33, 34	k_U	HEX - 0aaaaaaa, 0bbbbbbb
35, 36	k_I	HEX - 0aaaaaaa, 0bbbbbbb
37, 38	φU_{23}	HEX - 0aaaaaaa, 0bbbbbbb
39, 40	φI_1	HEX - 0aaaaaaa, 0bbbbbbb
41, 42	φI_3	HEX - 0aaaaaaa, 0bbbbbbb
43, 44	CS	HEX - 0aaaaaaa, 0bbbbbbb

The value of the first byte is the physical address of the transducer in the network. It is limited to 50.

The next byte contains the value of the command. When it is $82, the transducer transmits the whole buffer.

The third byte always has the value $28.

After that starts the information part of the buffer consisting of the values of the quantities of the electric power system. They are in three formats. In each of them the value of the bytes is limited to $7F. So they are transmitted as ASCII string and could be recognized by standard processing programs.

The first format is unsigned hexadecimal integer. It has length of two bytes and the mode 0aaaaaaa, 0bbbbbbb. Using this format the values of the quantities have the following accuracy: voltage – 0,1V, current – 0,001A, frequency – 0,01Hz, phase angle – 0,1°.

The second format is signed hexadecimal integer. It has length of two bytes and the mode 0±aaaaaa, 0bbbbbbb. This format is used for the values of the active and reactive power which have different signs in the four quadrants of the complex plane. The accuracy is 0,1W or 0,1VAr.

The third format is BCD. It is used for the values of the active and reactive energy. It has length of four bytes. The weight coefficients of the bytes are as follows: 100000Wh for the first byte, 1000Wh for the second, 10Wh for the third and 0,1Wh for the fourth byte.

III. BENEFITS OF VIRTUAL INSTRUMENTATION

With virtual instrumentation, engineers use graphical programming software to create user-defined solutions that meet their specific needs - very different from the proprietary, fixed functionality of traditional instruments. Additionally, virtual instrumentation capitalizes on the ever-increasing performance of personal computers.

Virtual instrumentation has led to a simpler way of looking at measurement systems. Instead of using several stand-alone instruments for multiple measurement types and performing rudimentary analysis by hand, engineers and scientists now can quickly and cheaply create a system equipped with embedded analysis software and a single measurement device that has the capabilities of many instruments. Powerful, off-the-shelf software makes this possible. This software automates the entire process, delivering an easy way to acquire, analyze, and present data from a personal computer without sacrificing performance or functionality [4].

In order to put described three-phase power transducer in virtual level the graphical software environment LabVIEW is selected. This software environment is designed to create test, measurement, and control systems. The package can communicate with hundreds of devices through its built-in knowledge of hardware integration: incorporating ready-to-use libraries for integrating stand-alone instruments, data acquisition devices, motion control and vision products. In addition LabVIEW is also an open development environment that give opportunity continuously to upgrade and improve the developed virtual system [5].

The power transducer and computer platform communicate via two-wire instrumental serial interface. On the other hand programming interface between computer platform and LabVIEW is achieved by Virtual Instrument Software Architecture (VISA).

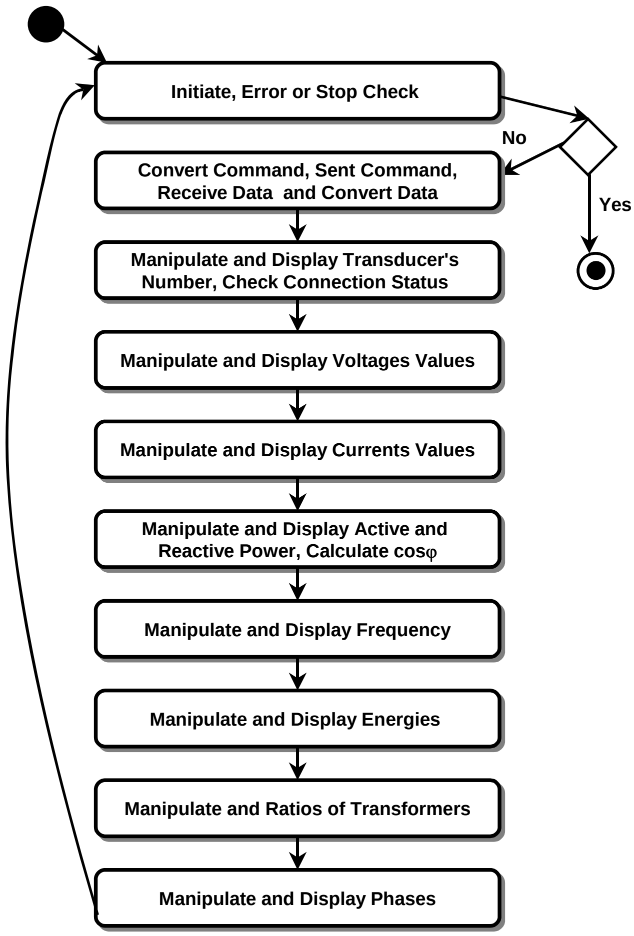

Fig. 3. Software design of the virtual system.

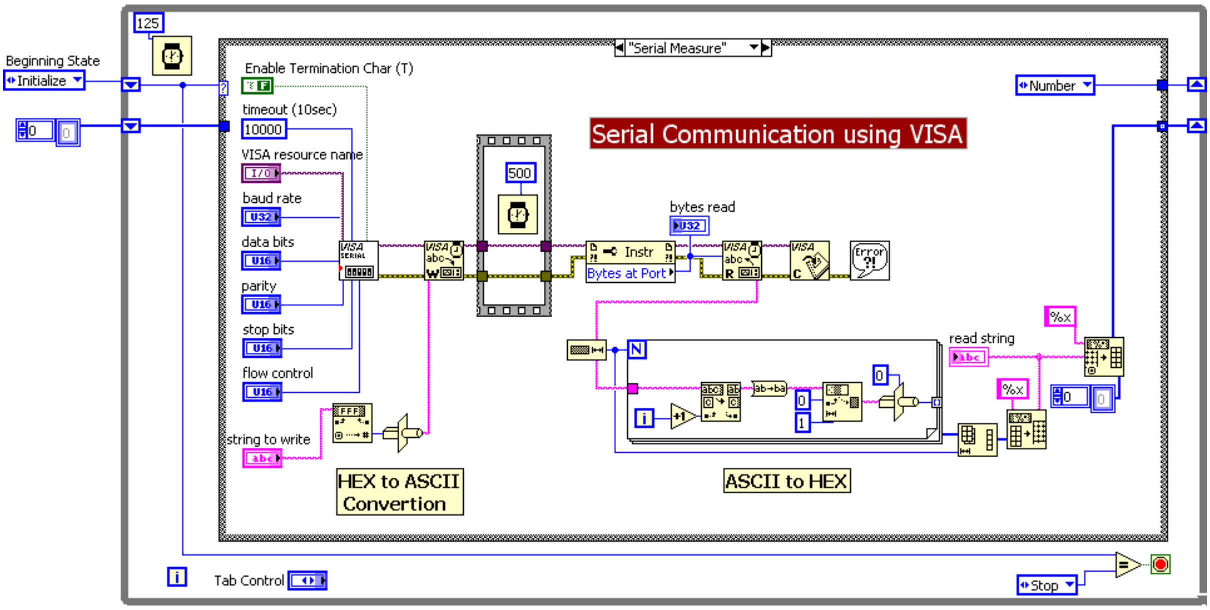

Fig. 4. Graphical programming code of developed virtual three phase power transducer.

VISA is a widely used application programming interface in the test and measurement industry for communicating with instruments from a computer platform. VISA is an industry standard for configuring, programming, and troubleshooting instrumentation systems comprising GPIB, VXI, PXI, Serial, Ethernet, and USB interfaces. In addition the VISA library has standardized the presentation of its operations over several software reuse mechanisms, including through a C API exposed from Windows DLL, visa32.dll and over the Microsoft COM technology.

IV. Software Design

As base software design pattern for presented development, the most highly utilized LabVIEW design patterns - classical state machine is selected [5].

By definition a finite state machine is model of behavior composed of finite number of states, transitions between those states, and actions. The classical state machine is made up of entry, exit, input, and transition actions. This abstract machine defines a finite set of conditions of existence, a set of behaviors or actions performed in each of those states, and a set of events which cause changes in states according to a finite and well-defined rule set.

The sequence of states that must be executed in order to achieve and visualize required data are shown in Fig. 3. As can be seen after initiation and error or stop checking the communication between transducer and software is accomplished. Following states manipulate and display the acquired data.

There are many variations of State machine implementation in LabVIEW. Most of them consist of a *Case structure* within a *While Loop*, with a *Shift register* wired to the case selector terminal. Each case of the *Case structure* contains a subdiagram corresponding to a state of the application. The case selector is an integer, string, or enumerated data type identifying the states. The Shift register construct passes the next state selection from a previous case to the selector terminal in the next loop iteration. In a typical application, the state selection is determined by an event on the user interface, by a step in a sequential test or measurement routine, or from the result of a previous state.

All of mentioned software component can be seen in Fig.4. Subdiagram corresponding of serial communication is shown as illustration of developed software. Before sending command calling serial VISA drivers, hexadecimal (HEX) string to ASCII conversion must be implemented. Similarly the measured data are received in ASCII code and must be consecutively converted to HEX string and to array of digits in order to be manipulated. According data buffer submitted in Table 1 for three formats, three type of manipulation is needed. First one is manipulation of unsigned integer represented with two bytes (voltages, currents, phases and ratio of transformers from Table 1). The graphical programming code of developed subVI, that make such conversion is shown in Fig.5.

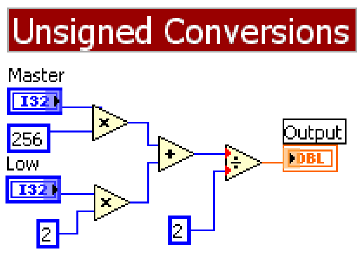

Fig. 5. Conversion of unsigned two byte integer.

In order to eliminate unused zeros master byte is multiplied with 256 and low byte is multiplied with 2. Two results is summed and divided in 2. Similar LabVIEW programming code is developed for second and third type of manipulation for signed two byte integer and for four bytes in binary decimal code.

The front panels or so called user interfaces of developed virtual system for primary and secondary power parameters are shown in Fig. 6 and Fig.7 respectively.

As can be seen all of parameters from Table 1 is visualized in corresponding dimensions. Additionally power factor (cosφ) is calculated and displayed.

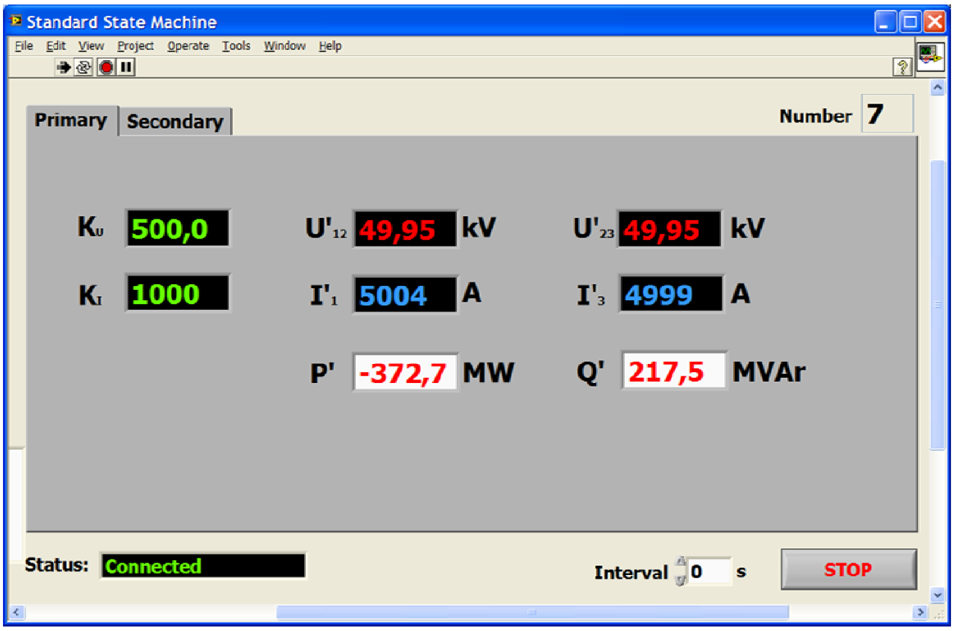

Fig. 6. Front panel for primary power parameters.

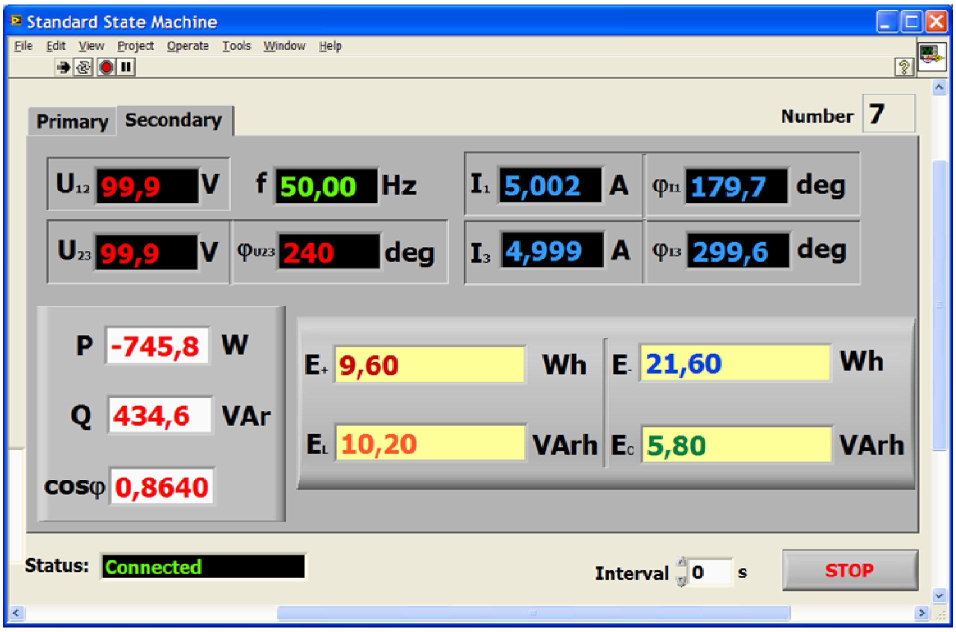

Fig. 7. Front panel for secondary power parameters.

Switching between primary and secondary parameters is accomplished by tab in upper left corner. In upper right corner the number of corresponding power transducer is indicated (up to 10 transducers can be used simultaneously). In left bottom corner the status of connection between transducers and personal computer is shown.

V. CONCLUSION

A virtual system for monitoring and parameters' calculation of three-phase power line is developed and considered in present paper. The system can capture the signals from the power line and display the value of active power, reactive power, frequency, voltages and currents, active and reactive energy in four quadrants, phase angles, ratio of transformers etc. The system can be easy adapted for data collection where the user can set the frequency of data collection and it can be restored. The presented results will be used in further investigation of more complex systems for electric power management.

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