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Smart Transducers Network Development Using PLC as a Gateway

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Abstract – **Development a network of smart power transducers is considered in the present paper. The network control is based on PLC as a gateway. The goal is to investigate the communications abilities of standard devices like PLC for use as a gateway in networks of smart power transducers. Thus the application of PLCs in SCADA systems for control power grids will be enlarged.**

Keywords – **Electric power system, PLC, Transducer network**

I. Introduction

The electric power system (EPS) is a complex which consists of the following subsystems – generation, transmission, distribution and consumption. In every one of them there is a need of transfer specific information. Thus for the generation process like important information is considered the recording key performance and quality of service issues such as scarcity (especially for wind and solar) and generator failures, utilizing the data provided by the market sub-domain to schedule generation and simultaneously provide availability data to the markets and recording the history of device operations and maintenance, and analyze the performance and the life expectancy of devices. The information management part in the transmission subsystem should provide monitoring, information exchange, and control data for operations and control of transmission substations and field devices. This information is generated from widely-deployed measurement and monitoring devices, such as sensors and phasor measurement units [1]. Furthermore, this information should be properly used to manage the operations in the transmission system, including optimizing power flows, improving reliability, and optimizing asset utilization. The task of the distribution subsystem is to deliver the electric energy to the customers. There are performed communications in real time in order to manage the power flows associated with a more dynamic market sub-domain, and hence promptly adjust localized consumption and generation [2]. A large amount of monitoring and control information, including load management and distribution system reliability, should be managed in this subsystem. The consumption is the activity that represents the customers' participation in the electric power system. This is the most important part for which the system is intended. To manage their energy usage, generation, and storage customers need accurate information. It will support the realization of many advanced features, such as remote control, monitoring and control of distributed generation, inhome display of customer usage, automatic reading of meters, and control of new electric devices (e.g. electric vehicles).

To apply a reliable control of all parts of the electric power system new innovative approaches in the automation systems are needed. This will lead to sustainable development of EPS and the energy efficiency increase. Key problem in reaching this goal is intelligent sensor networks development to transfer large amount of data from the system to the dispatch centers for processing and analyzing.

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II. Network Development

One device becomes smart through the integration of embedded processing and the next logical step is remote communication with the smart device [3]. Most of the transducers which are in use in EPS 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 transducers may have several analog outputs. Their number limits the number of the quantities which values can be transmitted. The digital interface gives the transducer the possibility to be included in a network. It is usually serial in order to minimize the number of the wires. The standard is mainly RS-485 or RS-232. There are custom defined interfaces as well. The network can be developed using the well known configurations – star, ring, bus etc. In order to minimize the connections bus topology is suitable and RS-485 has a wide application [4].

The most common used transducers in the electric power system have three phase connection and delta configuration. 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 watt-meters or Aron circuit. The maximal values are 130V and 6A. The data transmitted data buffer contains the values of line voltages (U_{12}, U_{23}), phase currents (I_1, I_3), active power (P), reactive power (Q), frequency (f), ratios of the voltage and current measuring transformers (kU, kI), phase angles of the vectors in relation to U12 (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. All quantities except the active and reactive power are transmitted as unsigned hexadecimal integer. The length is two bytes and the pattern is 0aaaaaaa, 0bbbbbbb. In this case the values of the quantities have the following accuracy: voltage – 0,1V, current – 0,001A, frequency – 0,01Hz, phase angle – 0,1°. The values of the active and reactive power which have different signs in the four quadrants of the complex plane are transmitted as signed hexadecimal integer. The length is two bytes and the pattern is 0±aaaaaa, 0bbbbbbb. The accuracy is 0,1W or 0,1VAr.

A very important part of the network development is to choose the gateway. This is a circuitry used to interconnect networks by converting the protocols of each network to that used by the other. It enables the connection of different network types within the architecture, or provides a means of transportation of data to different network areas for distribution. For application in EPS it has to be small, rugged, reliable device. Thus the goal of the investigation is to use as a gateway a standard device like PLC. They are reliable devices which have a wide application in automation in the industry and in EPS as well. In addition to their main function to handle analog and digital signals in order to control and monitor different devices from the electric power system their communications capabilities will be used to maintain the smart transducers network. The network organisation is shown in Fig. 1.

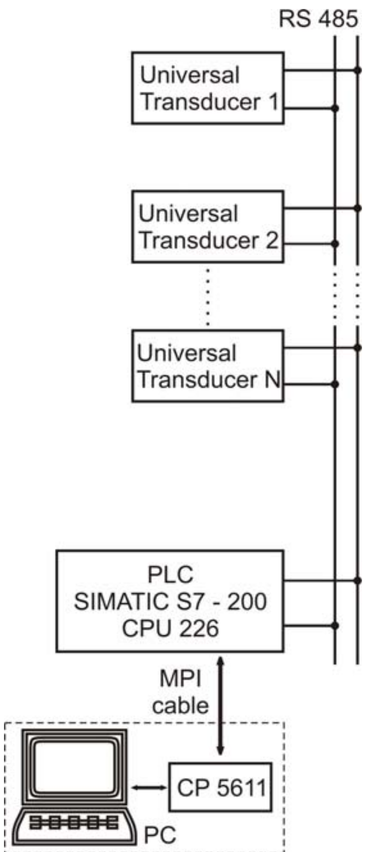

Fig. 1. Smart transducers network organisation

The PLC of Siemens Simatic S7-200 CPU 226 is chosen [5]. It has two ports realizing RS-485 serial interface. Port 0 of Simatic S7-200 CPU 226 is chosen to operate with the transducers network. Port 1 using MPI protocol is intended for connection to the upper level of the SCADA, in this case to a personal computer. It is used as an operator's station in order to observe the information in real time. The collected data can be stored there for post-processing and later visualization. A communication processor module CP 5611 is added to the personal computer which enables it to communicate using MPI protocol.

III. Software Design

During the startup initialization the communication parameters for the Port 1 are set: Micro/WIN → CP5611(MPI) interface and 19200 baud rate. This port is provided for programming the controller and receiving the manipulated data from the transducers, which will be displayed on a PC monitor.

The block diagram of a main PLC program is shown in Fig.2.

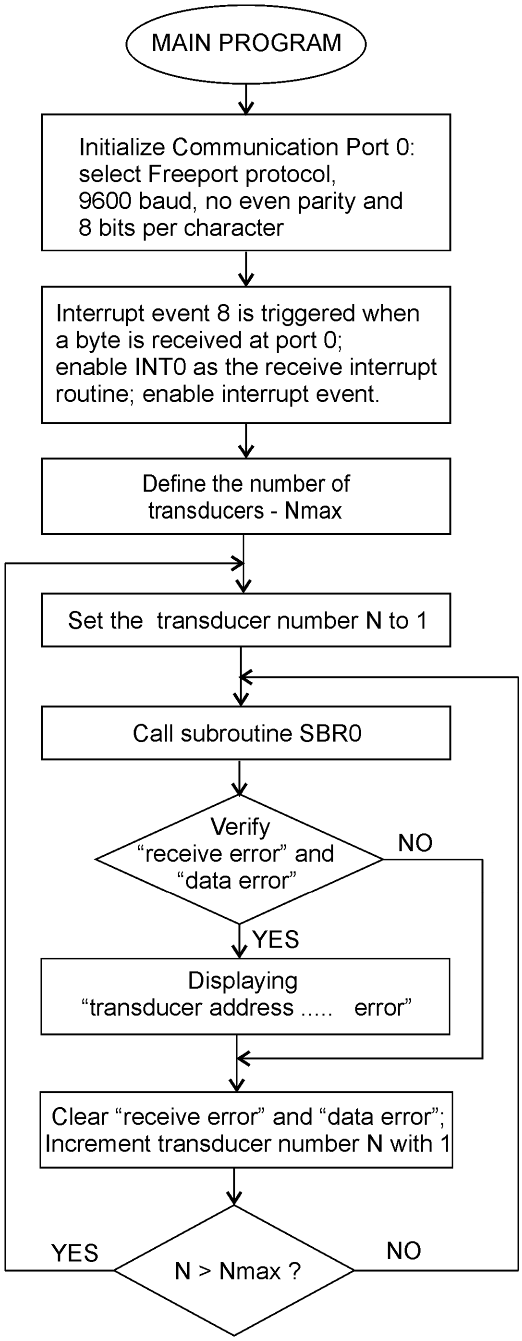

Fig. 2. Block diagram of a main PLC program

For communication port 0 is used Freeport protocol and 9.6 kbaud rate is chosen to correspond to the same value that is used by the transducers.

Interrupt event 8 is attached to interrupt routine INT0 to enable INT0 as the receive interrupt routine. Interrupt event 8 is triggered when a byte is received at port 0. Interrupt events are enabled.

The number of transducers Nmax in the transducers network is defined as the maximum number is 32.

After implementing the subroutine SBR0 are displayed the parameters of the transducers or "error'' signal.

The block diagram of a subroutine SBR0 is shown in Fig.3.

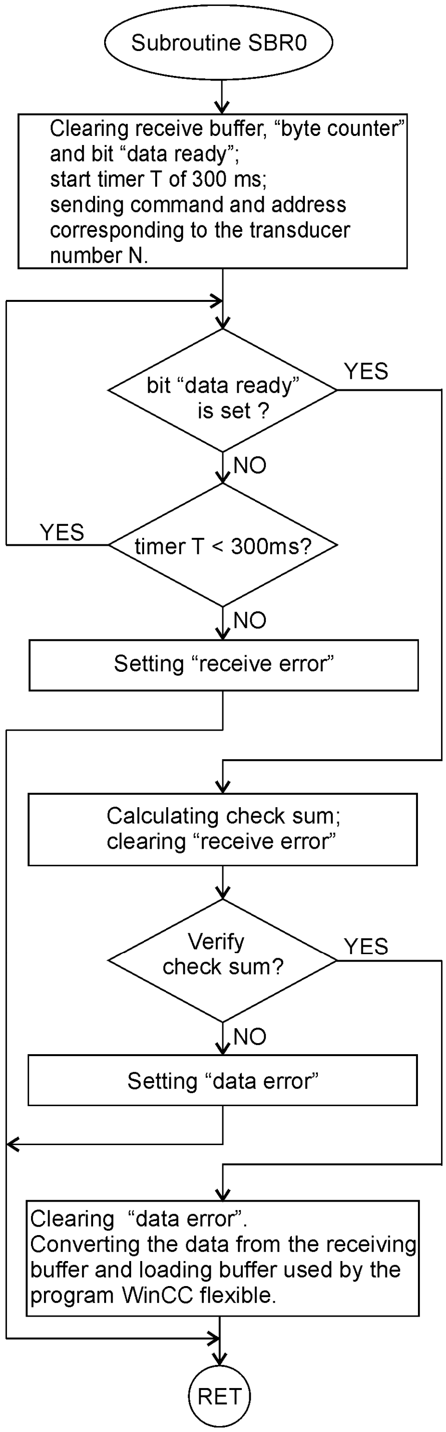

Fig. 3. Block diagram of a subroutine SBR0

In the subroutine is provided a programming timer (On-Delay Timer) representing 300 ms. The timer is starting when command and address corresponding to the transducer with number N are transmitting.

The data are valid if during the time interval from 300 ms the transducer's data are received without "receive error" and "data error".

The measured data except the active and reactive power are received as unsigned hexadecimal integer in two bytes and must be consecutively converted. In order to eliminate unused zeros high byte is multiplied with 256 and low byte is multiplied with 2. Two results are summed and divided by 2.

The equation is:

unsigned integer **K** represented with two bytes

K = ((**high byte**)*256 + (**low byte**)*2) / 2

The values of the active and reactive power which have different signs in the four quadrants of the complex plane are received as signed hexadecimal integer in two bytes.

The equations used to convert data are:

- if the sign is plus:

positive signed integer **K** represented with two bytes

K = (**high byte**)*256 + (**low byte**)*2

- if the sign is minus:

negative signed integer **K** represented with two bytes

K = 16384 - ((**high byte**)*256 + (**low byte**)*2)

Ready data for visualization are stored into a buffer and are intended for the program WinCC flexible.

Interrupt routine INT0 is shown in Fig. 4.

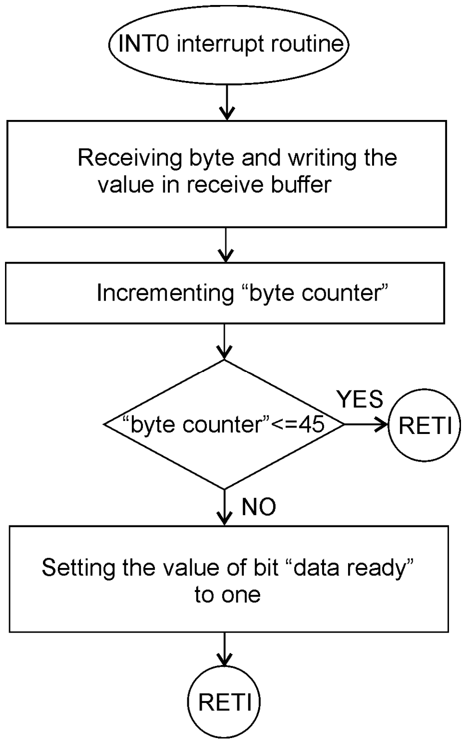

Fig. 4. Block diagram of an interrupt routine.

When a byte is received at port 0, the interrupt routine is executed. Received byte is stored in receive buffer and "byte counter" is incremented by 1. If all of the bytes have been received, the bit "data ready" is set to 1.

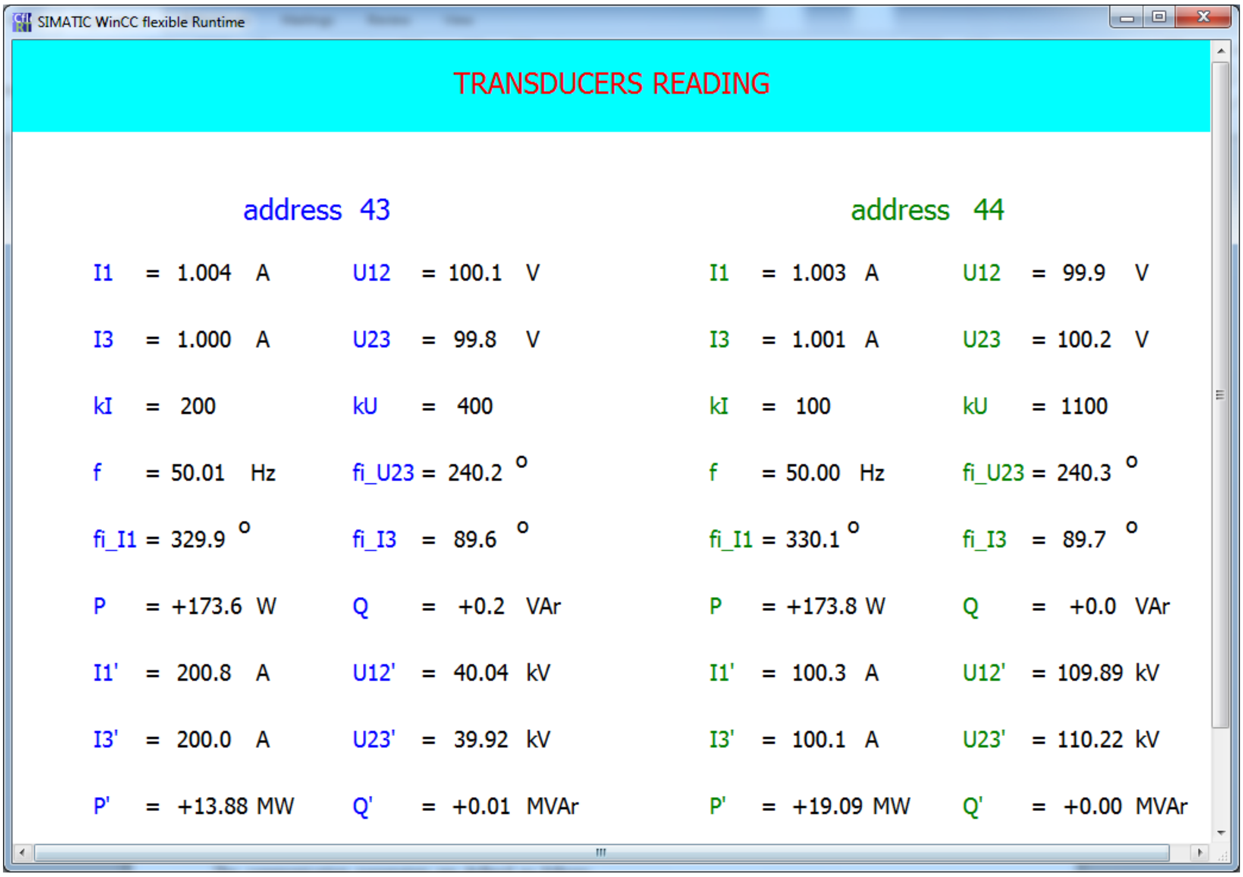

Fig.5. Front panel of two power transducers connected to smart transducers network

The SIMATIC WinCC flexible 2008 programming package is used for visualization of power transducers data. The communication parameters are defined as follows: personal computer as HMI - address 1, interface MPI/DP, baud rate 19200, network profile MPI and communication station SIMATIC S7 200 as a gateway - address 2.

The data of two power transducers with addresses 43 and 44 in transducers network are shown in Fig. 5.

The appropriate tags are developed that give the relationship between the displayed value and the relevant data stored into the buffer for visualization in the PLC memory. The project is starting in runtime mode. The buffer for visualization is updated every second.

IV. Conclusion

A system based on PLC as a gateway in a network of smart power transducers for parameters calculation and monitoring of three-phase power grids is developed and considered in the present paper. The system can capture the signals from the power grid and display the values of active power, reactive power, frequency, voltages and currents, active and reactive energy in four quadrants, phase angles, ratio of transformers and etc. The system can process data of up to 32 power transducers connected via industrial network using standard serial interface RS-485. The functionality of PLCs as components in the automation in EPS is widened. To their main control functions are added the obligations for smart sensors network management. The presented results will be used in further investigation of more complex systems for electric power management.

Acknowledgements

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References

[1] X. Fang, S. Misra, G. Xue, and D. Yang. *Smart grid - the new and improved power grid: A survey*. IEEE Communications surveys and tutorial (Digital Object Identifier: 10.1109/SURV.2011.101911.00087).

[2] National Institute of Standards and Technology. NIST framework and roadmap for smart grid interoperability standards, release 1.0, Available: http://www.nist.gov/public_affairs/ releases/upload/smartgrid_interoperability_final.pdf. January 2010.

[3] White paper. *What the Internet of Things (IoT) Needs to Become a Reality*. Freescale and ARM. Available: http://www.freescale.com/files/32bit/doc/white_paper/ INTOTHNGSWP.pdf

[4] Yakimov, P., Ovcharov, S., Tuliev, N., and Stanchev, A. (2005). *Possibilities for remote reading of electric power system parameters*, Proceedings of XL International Scientific Conference on Information, Communication and Energy Systems and Technologies, June 29-July 01, 2005, Nish, Serbia and Montenegro, Vol. 1, pp.50-51, ISBN 86-85195-24-1.

[5] http://www.automation.siemens.com/doconweb/pdf/ SINUMERIK_SINAMICS_04_2009_E/S7200SH.pdf?p=1.