Electric Power Transducers with Networking Capabilities

Peter Ivanov Yakimov and Nikolay Todorov Tuliev

Abstract – **Modern energy systems control faces various challenges caused by the introduction of renewable energy sources and rapidly changing loads. To achieve successful and sustainable control big quantities of information have to be transferred and processed. This establishes the need of universal accurate measuring transducers with rich information capabilities. The paper discusses the structure and the operational possibilities of measuring transducers for networking application.**

Keywords – **Electric power system, Smart transducer, Network**

I. Introduction

Modern energy systems control faces various challenges caused by the introduction of renewable energy sources and rapidly changing loads. This requires the application of innovative approaches in the automation systems aiming energy efficiency increase. Key problems in reaching this goal are intelligent sensor networks development and storage and real time processing of the large amount of data generated by them. Similar to the production technology, production control and monitoring systems have moved away from central operational structures and towards Decentralised Control Systems (DCS) [1]. Industrial processes as well as many modern systems depend on SCADA and DCS systems in order to perform their complex functionality. Typical examples include electric power grids, oil refining plants, pharmaceutical manufacturing, water management systems etc. An advanced trend in the distributed automation systems development for working with great number of sensors and large data arrays is the use of networks and Internet technologies based on Web services (Service Oriented Architectures - SOA) and cloud technology. The building of a smart energy system includes realization of a variety of measuring devices distributed in different locations – at the end customers, at the manufacturers, in the distribution network. These distributed measurements can be done using smart transducers connected in networks which will be able to measure and to process primarily the data but to transmit them to different locations for storage, analysis, accounting and etc. as well. Such networks are from the type IoT (Internet of Things) and WoT (Web of Things). The foundation of Internet of Things (IoT) is the intelligence that embedded processing provides. The IoT is comprised of smart machines interacting and communicating with other machines, objects, environments and infrastructures. As a result, huge volumes of data are being generated, and that data is being processed into useful actions that can "command and control" things to make human lives much easier and safer - and to reduce the human's impact on the environment [2].

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II. Smart Transducers Objectives

Smart Grid is regarded as a system that uses two-way communication and information technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, distribution and consumption to achieve an electric system that is clean, secure, reliable, efficient, and sustainable [3]. The two-way communication, allowing both control and management of the network devices, is becoming even more important.

European Working Group for smart grids defined as intelligent energy networks that can efficiently integrate the behaviour and actions of all connected to them users - producers, consumers and those that do both - in order to ensure economically efficient and sustainable power system with low losses and high quality, security of supply and safety [4].

According to Article 2, paragraph 28 of the Energy Efficiency Directive (2012/27/ES), OJ L 315, 14.11.2012, p1 „smart metering system" or „intelligent metering system" means an electronic system that can measure energy consumption, providing more information than a conventional meter, and can transmit and receive data using a form of electronic communication".

Smart meters and the information they provide are of a great importance for a smart grid to work effectively and efficiently.

Measuring transducers are used everywhere, where measurement of electrical quantities and sending of data or signals to devices is needed for checking and supervising the used energy. They are intended for a permanent monitoring and for conversion of electrical quantities in single and three phase electrical systems. PLCs, PCs, microprocessor control, indicators, alarms units and etc. can be operated by the output signal. The communications interfaces are serial (mostly RS-485) or Ethernet. The analog outputs of the transducers can be used in places where is needed analog output quantities as input into another device [5], [6].

III. Smart Transducers Structure

A smart transducer is the integration of an analog or digital sensor or actuator element, a processing unit, and a communication interface [7]. A smart transducer comprises a hardware or software device consisting of a small compact unit containing a sensor or actuator element, a microcontroller, a communication controller and the associated software from signal conditioning, calibration, diagnostics and communication [8].

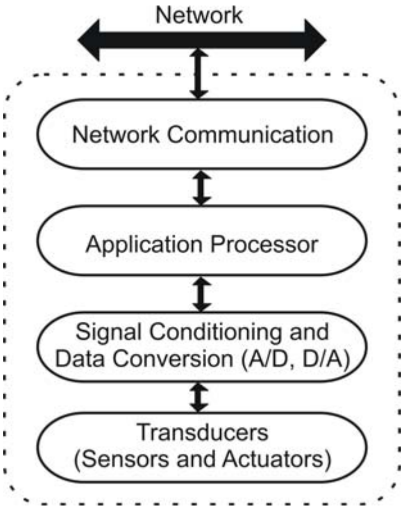

Fig. 1. Smart transducer model

Based on this premise a smart transducer model is shown in Fig. 1. It consists of four parts: transducers (sensors and actuators), signal conditioning and data conversion, application processor, and network communication. The analog output of the sensor is conditioned and scaled (amplified), then converted to a digital format by an A/D converter. The digitized sensor signal is processed by a microprocessor using a digital application control algorithm. The measured or calculated parameters can be passed on the host or monitoring system in a network by means of network communication protocols. In a reverse manner, an actuation command send form a host via the network can be used to control an actuator [9].

IV. NETWORK CONNECTION POSSIBILITIES

The International Electrotechnical Commission (IEC) promotes international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. The standard of IEC 60870 applies to telecontrol equipment and systems with coded bit serial data transmission for monitoring and controlling geographically widespread processes. It defines a telecontrol companion standard that enables interoperability among compatible telecontrol equipment. Nowadays the most often used systems for telecontrol are SCADA. As well as standard SCADA data reporting functions, the IEC 60870-5-101 and IEC 60870-5-104 drivers provide slave file transfer functionality to support remote operations. IEC 60870-5-104 protocol operates over IP interfaces. IEC 60870-5-101 protocol provides the same functionality as IEC 60870-5-104, except 60870-5-101 operates over serial lines.

The mentioned above illustrates that a measuring transducer has to provide a digital interface in order to be included in SCADA system, e.g. to be smart. And this interface must give the transducer networking capabilities. So there are two possibilities – serial and Ethernet interface. Depending on the place of the transducer in SCADA at least one of the pointed interfaces is mandatory but generally most of the smart transducers allow as options the both possibilities. While the Ethernet interface has no alternatives the serial one can be organized using different methods. Therefore that using RS-485 the smart transducers can be connected in parallel and thus to build an industrial network this interface is preferred instead of RS-232. So here will be considered some possibilities to provide the transducers with network communication.

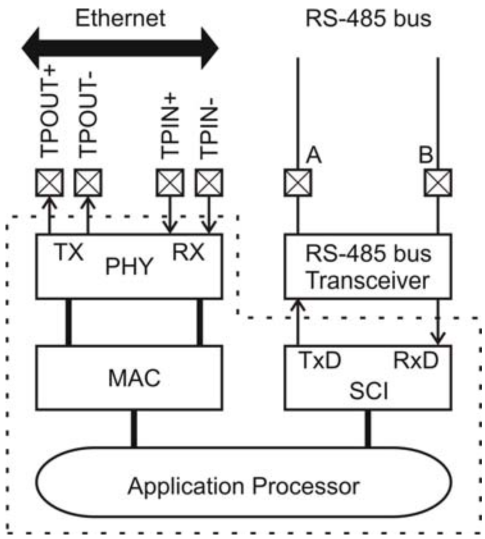

Fig. 2. Smart transducer based on a powerful microcontroller

The first possible model is when the transducer is based on a powerful microcontroller which executes the functions of the application processor and the network communication as it is depicted in Fig. 2. There are various microcontrollers which can be used in this model – for example ARM based microcontrollers LPC1768 of NXP, LM3S6938 of Texas Instruments and etc. They have enough resources to measure the parameters of the power grid – analog-to-digital converters, timer modules, digital inputs and outputs. Also they are supplied with different digital interfaces to maintain the network communications – SPI, I2C, USART and etc. Generically, the USART (Universal Synchronous Asynchronous Receiver Transmitter) is also known as a Serial Communications Interface or SCI. For this example one USART port and an external RS-485 transceiver are used to realize serial communication via RS-485 bus. The Ethernet communication is available too because of the embedded medium access controller (MAC) and physical transceiver (PHY). The system is compact and with low consumption. As disadvantages can be considered difficulties in tasks management which must be had in mind in the software design and also the dependency on only one device which leads to complete failure in case of fault. Nowadays the microcontrollers are reliable enough to minimize the second disadvantage.

Another possible model of a smart transducer is when the structure consists of an application processor based on standard microcontroller which is responsible not only for the signal conditioning, data conversion and parameters values calculation but for the serial communication as well. An external Ethernet controller is used to maintain the network communication. The block diagram of such model is shown in Fig. 3.

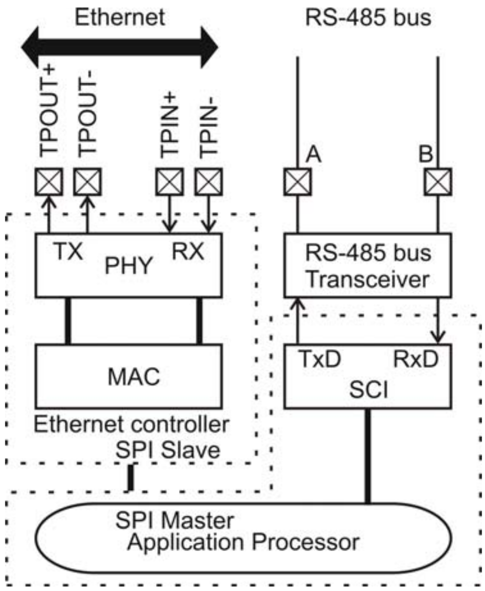

Fig. 3. Smart transducer model using external Ethernet controller

In this example is used external Ethernet controller which transfers information with the application processor using industry standard interfaces – SPI, SCI, I2C. The external controller supports the Ethernet communication. Well known and often used stand-alone Ethernet controllers are ENC28J60 and ENC624J600 of Microchip. Both are IEEE 802.3TM compatible Ethernet controllers fully compatible with 10/100/1000Base-T Networks. They have integrated MAC and 10Base-T physical layer and support one 10Base-T Port with automatic polarity detection and correction. ENC28J60 can communicate with the host microcontroller only via SPI interface with clock speeds up to 20 MHz. It has 8-Kbyte Transmit/Receive packet dual port SRAM. ENC624J600 has 24-Kbyte Transmit/Receive packet buffer SRAM and can communicate with the host microcontroller using 14 Mbit/s SPI interface with enhanced set of opcodes or 8-bit or 16-bit multiplexed or demultiplexed parallel interface. The advantage of the model is that the measurement process and the serial interface are independent from the Ethernet controller. A disadvantage is the delay caused by the communications between the processors. When the data buffer that is transferred is not too big this delay is not significant, especially if the parallel interface is used.

As a new possible model of a smart transducer can be considered the example which is shown in Fig. 4. In this case the application processor deals with the signal conditioning, data conversion, parameters values calculations and the serial communications. It is based on a standard microcontroller with industry standard interfaces – SPI, SCI and etc. The Ethernet communication is assigned to a separate microcontroller with the required capabilities. Representatives of such class microcontrollers are PIC18F97J60 family of Microchip, AX11001/AX11005 of ASIX and etc. The representatives of the PIC18F97J60 family are IEEE 802.3™ compatible Ethernet controllers which are fully compatible with 10/100/1000Base-T Networks. They have 8-Kbyte Transmit/Receive packet buffer SRAM, integrated MAC and 10Base-T physical layer. They support one 10Base-T Port. There are also available SPI, I2C and USART modules. The microcontrollers AX11001/AX11005 are 8-bit pipelined RISC, 100% software compatible with standard 8051/80390. They are fully compatible with 10/100/1000Base-T Networks. 12KB SRAM is dedicated for Ethernet packet buffering. Build in TCP/IP accelerator in hardware improves network transfer throughput. There are SPI, I2C and USART interfaces too. When two microcontrollers work simultaneously the problem with synchronization occurs. One of them must have higher priority and has to initiate the data transfer. As far as the application processor has the leading role in the complex device, it is responsible for the main tasks and is busy more than the communication processor, it has to initiate the data transfer. The advantage is similar like in the previous model. Also the second controller gives more possibilities of the device. The disadvantage caused by the delay needed for the data transfer exists again. It can be overcome using high baud rates in the communications.

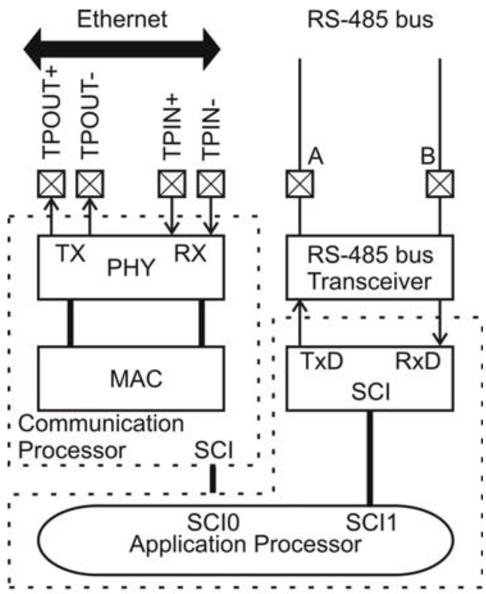

Fig. 4. Smart transducer model using a communication processor

The RS-485 standard is ideal for multi-drop applications and for long-distance interfaces. RS-485 allows up to 32 drivers and 32 receivers to be connected to a data bus, making it an ideal choice for multi-drop applications. Because it is a differential interface, data is virtually immune to noise in the transmission line. That's why it is recommended for energy meter networks, industrial automation and building automation networks. The modern representatives of the RS-485 transceivers are low-power and fast like SP485E of Exar, SN65HVD3082E and etc. of Texas Instruments.

V. SMART TRANSDUCER DEVELOPMENT

On this phase of the project the third model for smart transducer development is chosen and its block diagram is shown in Fig. 5. Based on the previous experience as application processor is used the microcontroller of Freescale MC9S12A32 [10].

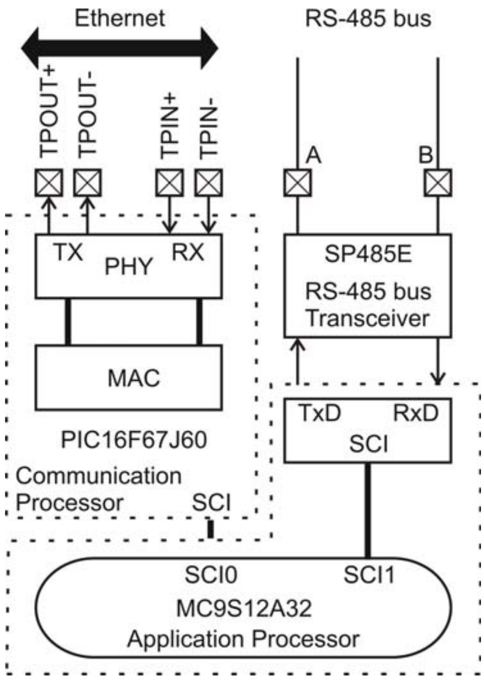

Fig. 5. Smart transducer project development

The communication capabilities are improved by adding a special module which provides standard serial and Ethernet interfaces. As RS-485 transceiver is chosen SP485E and it is connected to one of the available SCI ports. The other one is intended for connection to the communication processor. For this purpose is used PIC18F67J60. Its function is to maintain the Ethernet communications. The serial interfaces operate with 9600 bit/s baud rate. The data buffer which is sent by the application processor is 45 or 55 bytes long according to the concrete purpose of the transducer (Delta or Wye connection).

VI. CONCLUSION

In this paper the objectives, functions and possibilities of the smart transducers are considered. Three models of smart transducer structure are proposed and discussed. For each of them the basic components of the main blocks are proposed. At least two possibilities for choice are presented. On the current phase of the project a smart transducer proposal is developed. Its possibilities are investigated. On the next phase of the project another model might be investigated in order to compare the possibilities of each. The proposed transducers are intended for Internet based SCADA system development.

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