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Implementation of Internet of Things based solution of universal power transducer (Conference Paper)

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Abstract

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The paper presents a smart power transducer implementation as IoT based solution. The essentials of IoT concept are outlined. The possibilities for application of cloud computing in the electric power system management are discussed. The block diagram of a smart transducer with extended network capabilities is described. The remote user interface is shown. © 2017 IEEE.

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Implementation of Internet of Things based Solution of Universal Power Transducer

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Abstract – **The paper presents a smart power transducer implementation as IoT based solution. The essentials of IoT concept are outlined. The possibilities for application of cloud computing in the electric power system management are discussed. The block diagram of a smart transducer with extended network capabilities is described. The remote user interface is shown.**

Keywords – **Internet of Things, Cloud computing, Smart metering, SCADA**

I. Introduction

Like most of the new concepts, especially in the technical field, Internet of Things has originated at the Massachusetts Institute of Technology (MIT) in the beginning of the 21st century [1]. It is considered not as a brand new process but as an evolutionary one which development has been in progress. The main goal of Internet of Things is to create smart environments for application in different areas of the industry and social life like e-government, e-learning, e-health, e-business, smart homes, smart cities and etc. A significant impact on the evolution of IoT has been given by the strong progress of electronics, computing and telecommunications. On one hand the people have become able to interact with the surrounding world by use of variety of sensors and actuators. In the same time mobile and wearable computing give them the possibility to be connected anywhere and to consume services at any time [2]. The Internet of Things concept represents the integration of various devices like sensors, actuators and etc. to Internet. The term “thing” is related to people, machines, devices, sensors and data [3]. Nowadays the research trends which concern the field of the pervasive and ubiquitous computing consider IoT as the interconnection between things-embedded computing devices and the existing Internet and web infrastructure. Hence, IoT will be able to offer the users improved connectivity of devices, systems, and services in a way that advances machine-to-machine (M2M) communications, and that stimulates the integration of things not only to the Internet (the network), but also to the web (application layer), allowing the development of things-oriented and service-based applications built upon a large number of networked physical elements [4].

There are a lot of definitions for Internet of Things but they have many common points:

- the ubiquitous nature of connectivity;
- the global identification of every thing;
- the ability of each thing to send and receive data across the Internet or across the private network they are connected into [3].

This paper is organized as follows: section 2 presents the essentials of the Internet of Things. The application of the cloud computing and the probable benefits of the introduction of network-based control in the power system are considered in section 3. The IoT based solution of a smart power transducer and the remote interface are described in section 4. The conclusions and the future work are presented in the last section.

II. IoT Concept Essentials

Two basic acts have enabled the IoT development – the first is to define open standards for communication, and the second is to map the traditional IP-based Internet stack to the IoT. The successful communication model of the Web is regarded as a base for the IoT. The idea of an IP-based IoT has been discussed for years and is realized now. The use of the IP protocol for smart object addressing and data exchange will allow the full interoperability and integration of IoT with the existing Internet. The deployment of two important achievements - IPv6 and Cloud computing, has given a significant impact on the fast development of the Internet of Things. IPv6 gives the possibility to assign a communications address to billions of devices. In addition, it makes the management of networks easier because of the auto configuration capabilities and also offers improved security features. Cisco IBSG predicts that there will be 50 billion devices connected to the Internet by 2020 [1]. Cloud computing is already a building block of the Internet and it is expected that the Internet of Things will be the biggest user of Cloud. The IoT applications are comprised of many detectors and services to manage them and are very dynamic, processing data with rapidly changing volumes and rates. Clouds provide a flexible facility to manage this variability. Certainly a Cloud environment can also provide the services for analysis of the data streams often associated with synchronous simulation to support providing the information to the end consumer in an optimal form. The benefits for the business can be found in applications like environmental monitoring, healthcare monitoring and heavy industries monitoring where the high volumes and rates of data need rapid processing to information for perception. Cloud computing, mobile networks development, wearable and smart devices have

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let the wide expansion of IoT. The main features of this expansion are:

• the cloud has developed an infrastructure providing various services – information storage, communications, security, etc.;

• mobile networks have ensured ubiquitous connectivity;

• wearable and smart devices provide the user interface (and a gateway for some devices) to access, manage, and control the things.

• the Internet means this new infrastructure is accessible anywhere and at any time.

The result of the expansion is the incredible increase of the amount of data available for processing. This, together with the ability of Internet to exchange this data, will allow people to improve the services in most of the fields even further.

The most common cases for the application of Internet of Things are:

• general remote monitoring and control;

• asset tracking;

• process control and automation;

• resource allocation and optimization;

• decision optimization [5].

The common requirements to all of the mentioned above cases include:

• presence of sensing nodes for data collection;

• presence of local embedded processing nodes;

• presence of connectivity nodes for cable and/or wireless communication;

• presence of software for enabling new classes of services;

• presence of remote embedded processing nodes;

• security of information across the signal path [5].

The Internet of Things architecture is organized in layers and it is used to abstract and automate the integration of objects, and to provide smart service solutions to applications. The systems architecture can be divided into three layers [6], perception, transportation, and application, as shown in Fig. 1. The perception layer is responsible for the recognition and control of field devices, and also for the collection of the data provided by these devices. The transportation layer provides the elements of the perception layer with ubiquitous network access.

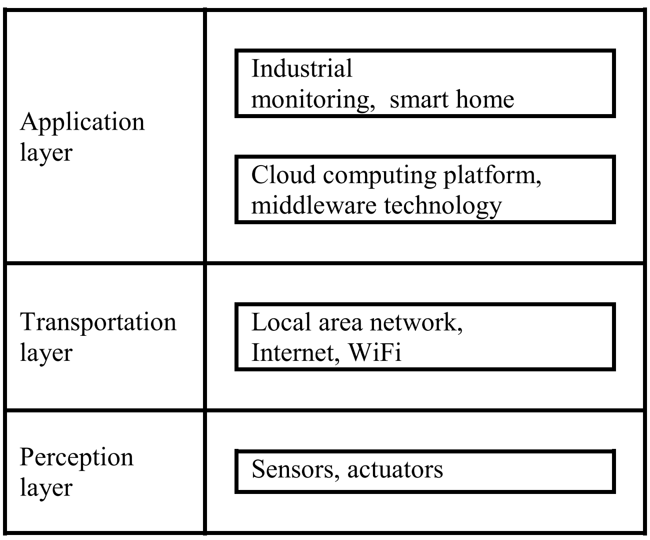


Fig. 1. IoT systems architecture

The application layer concerns the domains where IoT applications can be developed. It is responsible to support the services provision, and in the same time for the realization of intelligent computation and logical resources allocation also. High-level system layers, like the application layer, are comprised of IoT applications and a middleware system, which simplifies the development of applications by supporting services to cope with the interoperability requirement among heterogeneous devices [7].

Internet of Things also can be considered as a network of networks. The Internet is the physical layer or network which is composed of switches, routers, and other communication equipment. Its basic function is to ensure quick, reliable, and secure transport of information from one point to another. The Web itself is an application layer which operates on top of the Internet. Its primary responsibility is to provide an interface which makes usable the information that flows across the Internet [1]. Now it can be supposed that the IoT will be a network of heterogeneous, interconnected devices that will form the infrastructure for the so-called Web of Things (WoT) [2].

III. Expected Benefits from the Introduction of IoT and Cloud Computing in the Power System Control

The European Commission has set the Renewable Energy Directive, which establishes a common policy for the countries in the European Union (EU) for the promotion of renewable energy sources (RESs). The main goals are to achieve a 20% reduction in greenhouse gas emissions, 20% renewable energy consumption, and a 20% reduction in energy consumption by 2020 (compared to the levels in 1990).

This directive sets requirements to the consumers and utility suppliers to implement smart metering units to monitor the power consumption. The consumers will be forced to use the home appliances in low tariffs periods. Furthermore, the increasing availability and usage of smart devices in homes promises future integration in the Internet of Things of intelligent homes. This fact lets the residential electrical power systems to work in cooperation with smart devices in order to achieve smarter, more effective, more sustainable, and cleaner energy systems [8]. For the industrial consumers it is very important to plan the energy delivery quantities and periods of use aiming low prices. The implementation of IoT networks might contribute for significant energy savings. By collecting and monitoring consumption patterns, it is easier to adjust the electricity demand and generation, especially when using RESs such as PV and wind because their generation depends on the weather and it is difficult to be predicted.

In the beginning the Internet of Things networks implementation was intended to connect industrial equipment. Nowadays its application has been expanded to connect everything from industrial equipment to everyday objects. The range of items includes from gas turbines to automobiles to utility meters. The modern application of IoT networks for industrial and home automation means that every device can be connected to energy-management system (EMS) and to provide information to the consumer. Consumers will be aware of their consumption, and, therefore, they can adjust their behavior to reduce the energy bills because a significant reduction in consumption can be achieved when the user is aware of the cost of the energy that is being consumed [9].

The complexity and the geographical distribution are two important characteristics of the electric power system. The energy-management system is responsible to assure sustainable, effective and safety operation. Increasing transmission capacity is essential to meet an increased demand of electricity, integration of renewable generation and etc. The first approach to satisfy the need for the most economical ways for transferring the bulk power along a desired path might be by building new transmission lines, but it is a long and expensive process. Alternately, to increase the available transfer capacity of the existing transmission lines with the introduction of a smart metering infrastructure including power flow controllers and development of IoT networks may contribute not only to the costs reduction but to the improved operation regarding the reliability and the sustainability. One of the important problems in this area is caused by the different equipment, devices and software from different suppliers which are installed. All these elements must be connected in a proper way so that the entire system can operate reliably. Another problem concerns the system functionality. The electric power system includes different levels (such as generation, transmission, distribution and consumption) and its proper structure can be seen in the way it assures interoperability of control functions on all its component levels. In the last years, new sensors and devices with Internet connectivity and abilities to provide real-time information and access have appeared. The importance of the topic is proved by many research articles in the technical literature which describe the benefits of a sensor-based distributed computing infrastructure [3].

The main requirements for the next-generation SCADA-based applications that can be intended for monitoring and control in the electric power system are [3]:

• real-time;

• scalability;

• connectivity – to allow sensors connectivity to enterprise IT systems;

• support for dynamic environments;

• security.

An Internet of Things oriented solution must take into account all these aspects. Also, it must ensure the autonomy of a various IoT objects and resources, such as sensors, smart devices, sensor networks, etc. Monitoring and control systems in the energy field use the following types of devices:

• dispersed devices – which are spread over a wide area;

• concentrated devices – which are close to each other (e.g. in substations).

These devices can be fixed or mobile. The fixed devices (being in fixed locations) might use cable or wireless Internet connection. The mobile devices can be wirelessly connected to the Internet (e.g., by mobile phone). When the thing itself is connected to the Internet, it is in active mode and is able to send real-time information to the IoT. By now, there are many devices and sensors which are used in the power system monitoring and control, which are not connected to the Internet. These devices could be connected as things to the Internet of Things in a passive mode through the concentrated devices (gateways or mediators) that support sub-networks and are connected to the Internet [10]. In the passive mode, a thing is not connected to the Internet, but can be uniquely identified through the gateway which maintains the network of smart units.

IV. IoT based Power Transducer Description

The block diagram of such transducer is shown in Fig. 2, and the view of the remote HMI – in Fig. 3. The structure is divided into two parts, namely Application processor and Communication processor. Both parts are developed using standard microcontrollers and the data transfer between them is serial using UART. This is a further development of a universal power transducer [11].

The Application processor accepts the input signals and it is connected to the grid by measuring transformers with ratios kV and kI. The main quantities of the three phase power grid – voltage, current, frequency and phase angles are measured, and the derivatives – apparent, active and reactive power, and power factor are calculated. The rated input values are 57,7 V and 5 A and they are standard for the measurement and control systems in the objects of the power grid – power plants, substations and etc.

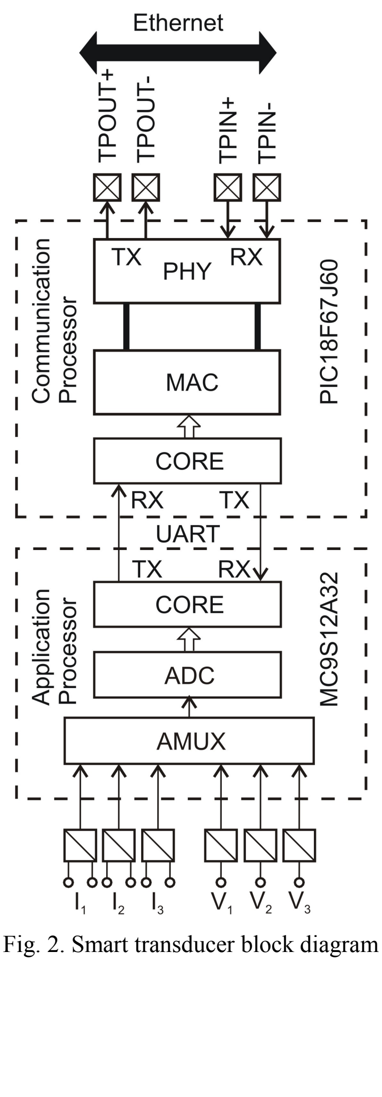
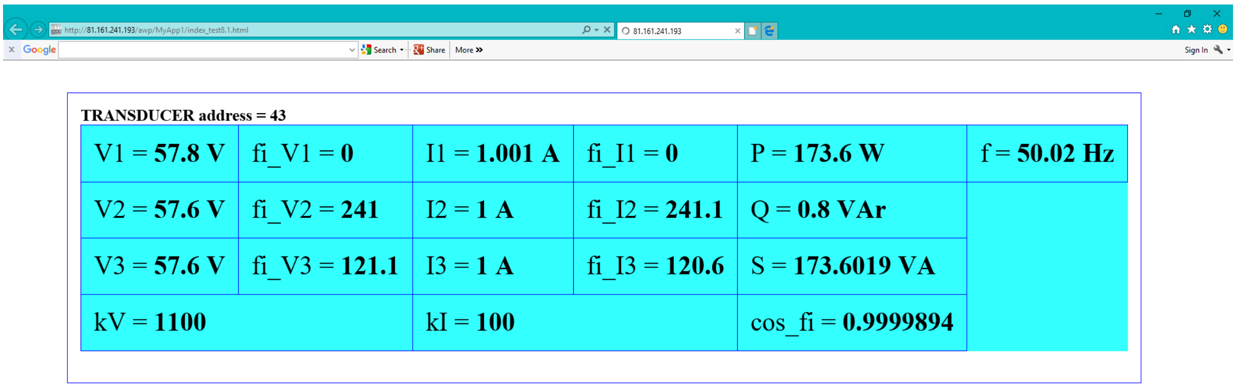


Fig. 2. Smart transducer block diagram



TRANSDUCER address = 43

V1 = **57.8 V**	fi_V1 = **0**	I1 = **1.001 A**	fi_I1 = **0**	P = **173.6 W**	f = **50.02 Hz**
V2 = **57.6 V**	fi_V2 = **241**	I2 = **1 A**	fi_I2 = **241.1**	Q = **0.8 VAr**	
V3 = **57.6 V**	fi_V3 = **121.1**	I3 = **1 A**	fi_I3 = **120.6**	S = **173.6019 VA**	
kV = **1100**		kI = **100**		cos_fi = **0.9999894**	

Fig. 3. Remote user interface

The inputs of the transducer have the flexibility to be adjusted to different rated values. For example the voltage dividers can be set for 230V and the transducer will be able for direct connection in industrial and home supply systems.

The communication processor is responsible for the networking applications and it supports the remote user interface. It is fully compatible with 10/100/1000Base-T Networks. The implementation of networking capabilities makes the transducer possible for inclusion in Internet of Things networks.

V. CONCLUSION

In this paper the main features of the IoT concept are explained. The expected benefits from the introduction of Internet of Things and Cloud computing are considered. The hardware and software design and possibilities of a smart transducer with extended networking capabilities are presented. The customers are able to access the developed remote HMI from anywhere in anytime using Standard Web browsers. The proposed transducer is intended for Internet based SCADA system development. Laboratory tests using power system simulator have been conducted. The presented results will be used in further investigation of more complex systems for electric power management.

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