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Application of Internet of Things Hardware in Control Systems

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Abstract—**This paper discusses a new concept of control systems, characterized as the Internet of Things Control Systems (IoTCS), which is based on the control techniques of networked control systems and the concept of the Internet of Things. To obtain IoTCS, the Internet of Things hardware, which belongs to embedded systems and boards hardware class, is used. The example of temperature control shows how the concept of IoTCS can be practically realized with the selected Internet of Things hardware. The operation of the implemented IoTCS is based on the principle of a networked control system in which the Arduino Uno board is equivalent to a communication network. Temperature control is enabled by a PID controller designed in Simulink, which shows that software packages traditionally used for the synthesis and analysis of control systems can be effectively used for the synthesis and analysis of control systems based on the Internet of Things hardware.**

Keywords-control systems; Internet of Things; Internet of Things hardware; temperature control; PID controller;

I. INTRODUCTION

The evolution of the control systems over the last hundred years has been accompanied with the continuous development of various techniques and technologies, first in the field of electronics and communications, and then in computing and informatics. This resulted in emergence of several control strategies that have found their application in different areas of human activity. Control strategies and the systems in which they are implemented differ in the specific requirements that need to be met, as well as in the specific constraints that need to be overcome, in order for control tasks to be performed successfully.

Control systems that exist today are mainly based on networking concepts and information and computing technologies [1]. One type of such systems are networked control systems created by integrating network communication concepts and control systems. The first such systems appeared in the eighties of the last century, and their development continues even today. In a networked control system, the operation of all its components (plants, actuators, sensors and controllers) is coordinated via the communication network [2]. The industrial control systems that first used the communication network were based on the use of control-oriented communication networking technologies and protocols (CAN, DeviceNet) [3]. Due to the rapid development and availability to everyone, the Internet is nowadays increasingly used as a communication network in control systems, which enables the design and construction of large-scale control systems at low cost, system reconfiguration in a flexible manner and easy maintenance [4]. Thus networked control systems find their application not only in industrial plants but also in smart homes, traffic, teleoperations, agriculture, but what is the most important is a fact that fundamental theoretical development in networked control systems has led to the development of today's ubiquitous concept of the Internet of Things [5].

In the last fifteen years, there has been a dramatic development of information, communication and computing technologies, which has significantly influenced their usage in control applications. The evolution of information and communication technologies has given rise to numerous new categories of control systems such as embedded systems, hybrid systems, cyber-physical systems, multiagent systems [6]. Of particular importance is the development of the Internet of Things as a global communication concept that, in addition to modern computing concepts, such as cloud, fog and edge computing, and the big data collecting and processing, provides opportunities for their application in networked control systems, creating conditions for the emergence of new control techniques using communication network such as cloud control [7] and robotics in the cloud [8], as well as new control concepts such as the Internet of Things Control Systems [9]. New concepts of networked control systems require a multidisciplinary approach in all its segments, which makes them extremely complex for both synthesis and analysis. Therefore, it is of great importance that the popularity of the Internet of Things is recognized by leading software companies such as National Instruments and MathWorks, which have developed special interfaces and software packages to support the operation of prototyping boards used as Internet of Things hardware. The advantages of new technologies are also

This paper is a revised and expanded version of the paper presented at the XX International Symposium INFOTEH-JAHORINA 2021 recognized in the industrial sector, so special attention is paid to exploring the possibilities of their use in factory and process automation. The use of the Internet of Things and other modern information, communication and computing technologies reflected on industrial production with the advent of the Industrial Internet of Things and served as the basis for the fourth industrial revolution known as Industry 4.0 [10].

New control concepts, to which Internet of Things Control Systems belongs, relay on using IoT hardware components in a control system. Many examples of new concepts are not explicitly referred to as Internet of Things Control Systems, although with their structure and functionality they actually fall under this term. Some studies related to such concepts are given below. Thus, the paper [11] deals with how Arduino board is used with PI controller designed in Simulink in closed loop system for DC motor speed control, while [12] proposes the software tool for modeling and control of discrete-event and hybrid systems using timed interpreted Petri nets verified on DC motor speed control with Arduino board and PID controller. Liquid level control with different control methods based on Matlab/Simulink and Arduino is presented in [13]. A closed loop scan mechanism using a stepper motor based on Arduino is given in [14] and [15] provides PWM based closed loop speed control of DC motor with ATmega8 microcontroller. PID voltage control for DC motor using Matlab Simulink and Arduino in both open loop and closed loop system is studied in [16]. Design of an Arduino based PID Controller for temperature control is given in [17] and [18]. IoT based wireless networked control systems are proposed in [19] and [20] on the example of liquid level control with ESP8266 module, MyRIO hardware and PID controller, and on example of temperature control in smart buildings, respectively. Authors in [21] investigate the application of an Arduino based PID controller for vessels level control using hardware in the form of industrial scale instrumentation equipment to examine possibilities of using Arduino as an alternative to the industrial control system, and in [22] IoT based water tank level control system using PLC. Many IoT based control systems have been designed for applications in agriculture in recent years, such as the Arduino based closed loop system used in watering system studied in [23], poultry house temperature control using fuzzy-PID controller [24], Arduino and Matlab temperature PID control based poultry hatching incubator [25] and Arduino and LabVIEW humidity and temperature PID control based smart incubator [26]. In medicine applications, IoT hardware is used in [27] with PID controller for artificial pancreas research, and implementation of PID control using Arduino microcontrollers

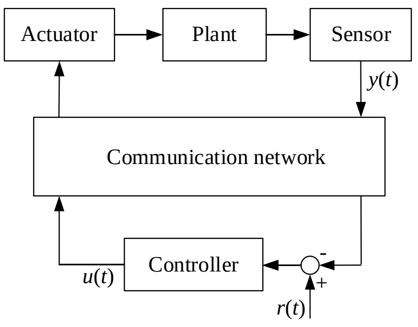

Figure 1. Block diagram of networked control system

for glucose measurements and micro incubator applications are studied in [28]. Intelligent autonomous-robot closed loop control for medical applications using Arduino and PID neural network controller is given in [29].

The paper is organized as follows. The second chapter briefly defines the concepts of networked control systems and the Internet of Things Relationship and possibilities of the networked control systems and the Internet of Things integration and the idea of the Internet of Things Control Systems as a new form of controlling the systems is described in the third chapter. The fourth chapter describes different classifications of devices that belong to Internet of Things hardware and facts to be considered when choosing them to be used in certain applications. In the fifth chapter, the practical realization of the Internet of Things Control Systems is demonstrated on the example of temperature control. At the end of the paper, conclusions and future research are given.

II. Control Systems and Internet of Things

A. *Networked Control Systems*

Networked control systems are feedback control systems in which the loop is closed over the communication network. A simplified block diagram of the networked control system is shown in Fig. 1, where its main components can be identified: plant, sensor, actuator, controller and communication network. The transmission and exchange of control data between the components of the control system over the communication network are implemented by a series of commercial and open source communication protocols for wired and wireless data transmission. The presence of the communication network in control structures has produced a number of communication constraints in a form of network induced delays, data loss, data packet rejection, bandwidth limitations and quantization. These constraints stand in the way of efficient control of systems and are the subject of numerous studies [30]. The restrictions that arise from the nature of communication protocols related to the degree of determinism and allowable data rates supported by a particular protocol can also be added to communication constraints. The communication constraints affect the behavior of networked control systems by degrading their performances and disturbing their stability [31]. The development of communication technologies over the last fifteen years has greatly influenced the development of networked control systems, while the development of information technologies and the Internet has enabled these systems to collect and process large amounts of data (big data) and react to fluctuations in the behavior of plant from anywhere, anytime.

B. *Internet of Things*

The Internet of Things (IoT) is a term first used in 1999 to denote physical objects tagged with RFID tags that used a unique global identifier for their identification [32]. From then, the Internet of Things has changed its meaning depending on the development of information and communication technologies, and the diversity of its application. Consequently, new terms have been coined such as: Internet of Everything, Internet of Nano Things, Medical Internet of Things, Consumer Internet of Things, Industrial Interne of Things, Enterprise Internet of Things, Human Internet of Things, Narrow Band Internet of Things, Identity of Things, Future Internet. Closely related to the concept of the Internet of Things are the concepts of wireless sensor networks, cyber-physical systems (CPS) and M2M (Machine-to-Machine) communication, which represent technologies without which IoT would not be possible to exist. The Internet of Things emerged as a logical sequence of the development of communications, the Internet and information technologies [10], where each new generation of communications and services emerges with the appearance of more advanced, i.e. "smarter", communication and computer networks, services and devices, as shown in Fig. 2.

The concept of the Internet of Things is defined in different ways. Definitions of various standardization bodies such as ITU-T, IERC and ETSI or influential companies such as CISCO are most often cited. In essence, the Internet of Things is a concept and paradigm that considers the general presence of things/objects in a particular environment that interact with each other based on unique addressing schemes and wired or wireless connections to create new applications or services that contribute to achieving a certain goal. Simply put, the Internet of Things is the network of physical objects (things) embedded with hardware, software, usually with sensors, and network connectivity, which enables data collection and exchange data [33].

The IEEE launched an Internet of Things initiative in which it described this concept from the point of view of the complexity of its implementation [34]. For less complex systems, Internet of things is described as a network that connects uniquely identifiable things to the Internet. Things have sensors/actuators and are potentially programmable. Using the unique identification, information about things can be collected and monitored and things' status can be changed at any time, from anywhere and by anything. For extremely complex systems, Internet of Things should have an adaptive and complex self-configuring network infrastructure that connects things to the Internet using standard communication protocols. Things connected in this way have their physical or virtual representation in the digital world, can be programmed, and can be uniquely identified. A representation of an item contains a variety of information about it, including identity, status, location, or any other relevant business, social, or private information. Things provide a variety of services, with or without human intervention, through sensing, actuation and communication. Services are exploited through intelligent interfaces and are available at any time from any place.

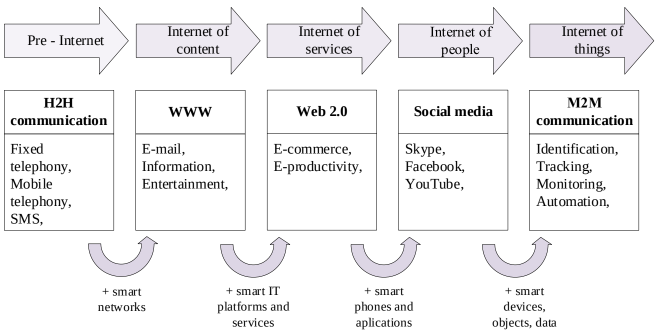

Figure 2. Internet of Things evolution

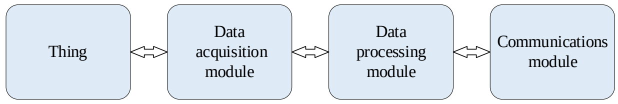

Figure 3. Internet of Things device hardver

In general, an IoT system consists of hardware, middleware, and applications [35]. The hardware part of the IoT system has the following components [36]:

- sensors used to collect data and convert them into an electrical signal,
- computing node that processes data received from sensors,
- actuator which, based on the decision made by the computing node, triggers the appropriate device to perform a certain task,
- things/devices that perform a certain task when triggered by an actuator,
- communication module.

As shown in Fig. 3, the hardware of the IoT device, in general, consists of:

- thing,
- data acquisition module,
- data processing module,
- communications module.

A thing is an entity to be controlled or monitored, measured, regulated, etc. The data acquisition module acquires information about the physical properties of things in the form of signals and convert them into digital signals, so they can be processed by computers. This module contains a large number of sensors that monitor various parameters of things. In this module, signal conditioning, noise suppression, signal scaling and some other operations are also performed. The data processing module is a computer, i.e. data processing node, in which local data analysis, storing data locally and other edge computing are performed. The communication module enables the hardware to communicate with the cloud or some other communication network, global or commercial.

Middleware is software that acts as an interface between hardware and user applications and allows them to communicate with each other. It also defines IoT platforms. Applications represent any application from the domain of the IoT concept usage.

III. NETWORKED CONTROL SYSTEMS AND THE INTERNET OF THINGS RELATIONSHIP

As networked control systems, especially industrial ones, generally consist of a large number of control components (sensors, controllers, actuators, plants) that are connected via communication network, they were a model for the appearance of systems in which not only sensors, actuators and controllers are connected by a communication network but other electronic devices that have the ability to exchange data. Networked control systems, with their appearance and development, have actually set up the foundations and provided guidelines for the development of communication systems that are encompassed in the Internet of Things concept.

The relationship between networked control systems and the Internet of Things is reciprocal. Although the development of networked control systems was the basis for the emergence of the concept of the Internet of Things, the Internet of Things has become a paradigm without which many modern networked control systems cannot be imagined today, especially those that should meet the requirements of the fourth industrial revolution. Attention in the concept of the Internet of Things is primarily focused on wireless sensors, cloud connectivity, big data analytics and mobile applications. However, the vision of the Internet of Things is now extended to control systems, both open-loop and closed-loop systems.

The analogy between the components of networked control systems and the hardware of the Internet of Things is obvious. Namely, computing node corresponds to the controller and the thing corresponds to the plant. The connection between sensors and actuators is realized by algorithms, the existence of built-in microprocessors in things enables the processing of control signals so the thing can act as a controller (not only as a plant), and communication is performed over the Internet as a communication network.

In control systems applications that use the concept of the Internet of Things, data processing and storing play an important role. Data may be measurement and control data, and data related to the things that belong to the control system. The number of sensors in such control systems is very large, so the amount of data existing in the systems is very large as well. The development of high-performance processors and high-capacity memory units as well as measuring instruments of high reliability and precision has contributed to the data acquisition and processing, in the domain of the Internet of Things and then in the domain of control systems of which they are part, to be done very efficiently. In addition to measurement and control data, data obtained from different devices that can be an integral part of the control system may exist in networked control systems as well, which make the already large amounts of data present in the system even larger. This primarily refers to mobile data collecting devices, cameras, microphones, RFID readers, etc. All things and devices from the domain of the Internet of Things are connected to large databases via non-deterministic communication networks, most often the Internet, which makes communication constraints, present in networked control systems, even more distinct. In this case, the requirements necessary for high-quality real-time control exceed the capabilities of standard networked control systems because they are unable to handle big data due to their limited communication and computing resources.

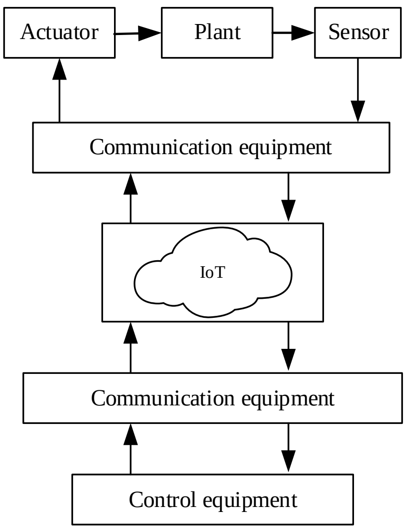

Figure 4. Block diagram of Internet of Things Control Systems

Therefore, the use of the Internet of Things in networked control systems is emerging as an ideal solution to overcome these problems. Further convergence of the Internet of Things and control systems should go in the direction of standardization of communication protocols and big data representation and processing [37].

A. *Internet of Things Control Systems*

The integration of the Internet of Things and the control systems enabled appearance a new form of control systems called the Internet of Things Control Systems (IoTCS) [9]. In fact, these are networked control systems in which the feedback is closed over the Internet of Things as a communication medium which task is to connect the components of the control system to exchange information in order to complete the control task. The components of the IoTCS system are smart sensors, actuators, controllers and other control equipment, while the control information refers to sensor readings, control commands, results of control commands taken, control algorithms, control objectives, equipment status, etc. Fig. 4 provides a simplified block diagram of IoTCS with basic hardware elements:

- control equipment, which implies intelligent agents that control the system and processes, including smart controllers, smart computers, smart control software,
- communication equipment, which includes personal computers, mobile phones, PDAs, and which enables authorized persons to remotely control the control equipment and monitor its operation via the Internet, i.e. the equipment that enables communication of sensors and actuators with the Internet of Things infrastructure,
- Internet of Things infrastructure based on hardware, wired and wireless communication networks and processing systems, analysis and storage of control and other data (cloud, databases).

IV. Internet Of Things Hardware and Temperature Control

The practical realization of the vision of the Internet of Things requires the development of new IoT devices, platforms and technologies. IoT devices, which are usually small in size and combine microcontrollers and microprocessors with other components, such as memory, input-output devices, peripherals, wireless networking interfaces, etc. play a crucial role in the development of the Internet of Things. IoT devices can be open source or proprietary and may be classified, as shown in Fig. 5, to [38]:

- wearable devices and gadgets,
- embedded systems and boards.

The use of wearable devices and gadgets is limited by the purpose of the device itself (smart glasses, watches, shoes ...). These devices cannot be modified for any other use, only the functions that the devices already have within their original purpose can be changed by software. Embedded systems and boards are not limited to use in certain applications, but are subject to hardware and software modifications in order to be used in different applications. These devices can be further divided into [39]:

- low-end devices,
- middle-end devices,
- high-end devices.

Low-end devices are limited in using operating systems e.g. Windows or Linux, low RAM and flash memory capacity, and low processing unit capabilities. These devices are designed for basic use in non-demanding data acquisition applications and simple actuation. Middle-end devices have better resources than low-end devices, primarily regarding the memory and data processing, and support many communication technologies for data transmission. High-end devices are small computers that have powerful processing units, enough RAM and peripheral memory to install and run an operating system. These devices can perform complex computing, they have built-in interfaces for various network technologies, cameras, etc. and are very often used as gateway devices or network edge devices because of their ability to adapt to new services.

Embedded systems and boards can also be classified into [39]:

- microprocessor-based devices,
- microcontroller-based devices.

Microprocessor-based devices are specialized computers with an operating system, high-capacity memory and high-end devices features. These devices easily connect to the Internet and are programmed with different programming languages and tools. The disadvantage of these devices is their high price and high energy consumption. Microcontroller-based devices consists of an integrated circuit board that contains multiple components such as a processing unit, memory, programmable input-output peripherals, etc. They are mostly cheap, but have limitations in terms of data processing, memory and communication, and are mostly produced in different versions depending on the combination of resources they possess.

Different IoT platforms and devices can be used in different applications. To select the appropriate IoT platform, the following should be considered [40]:

- field of application,
- price which is very important in case a larger number of copies of the platform is to be used,
- processor capabilities that are essential for complex algorithms and data processing,
- memory capacity of the platform implemented on the board or on memory cards,

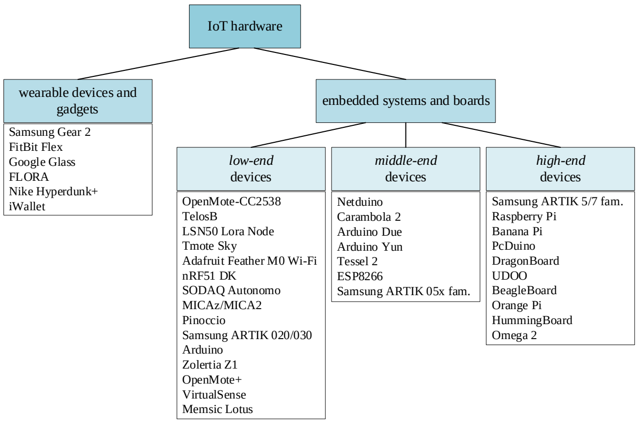

Figure 5. Internet of Things devices classification

- input and output interfaces that are used to connect additional hardware components (cameras, LCD panels, sensors ...),
- flexible programming,
- energy consumption, which should be as low as possible,
- communication technologies (Wi-Fi, Bluetooth, Ethernet, LoRa, 4G/5G ...),
- robustness, meaning the platform will work properly for a long period of time.

There are currently many IoT platforms, such as the Arduino, Raspberry Pi, BeagleBone and ESP8266, that can be used in a variety of applications. From the point of view of control systems, it is desirable to use platforms based on microcontrollers. Of particular importance for the design of control systems that use Internet of Things hardware is the fact that software packages traditionally used for control systems synthesis and analysis can also be used for synthesis and analysis of control systems based on Internet of Things. Thus, National Instruments developed the LabVIEW interface for Arduino boards that allows data collection from Arduino boards and their processing in the LabVIEW graphical programming environment [41], while MathWorks supports the operation of a large number of Arduino boards through software packages to support Matlab and Simulink [42]. These packages allow Matlab and Simulink to be used, among other things, for:

- acquisition of analog and digital data from Arduino boards,
- open-loop and closed-loop feedback control of different devices, DC motors, servo and stepper motors via digital and PWM output pins,
- accessing to peripherals connected to the Arduino board via I^2C, SPI or Simulink blocks,
- process identification,
- design and adjustment of controllers,

- development and simulation of algorithms used on Arduino boards (instead of algorithms written in Arduino IDE environment),
- setting the initial configuration of Arduino boards,
- communication of Arduino boards with other devices via Ethernet and Wi-Fi libraries,
- configuration and access of input and output pins on Arduino boards via Simulink blocks,
- interactive parameter setting and signal monitoring.

A. Temperature Control Experimental Setup

The following hardware was used for temperature control: heater, Arduino Uno board, temperature sensor module and relay, as shown in Fig. 6. For simplicity and visual control of whether the system works properly, a 40 W incandescent bulb was used as a heater. Temperature control is performed using a PID controller implemented in Simulink. The Arduino Uno board provides power to the sensor and reads analog values of the temperature generated at its output and generates a digital signal that turns the relay (heater) on and off. The control logic that determines when the relay will switch is implemented in Simulink. A block diagram of an implemented system is presented in Fig. 7 from which it can be noticed that this system, by its configuration, represents IoTCS. Namely, the feedback is closed via the Arduino Uno board as the hardware of the Internet of Things. On one side the Arduino Uno board is connected to the plant and on the other side it is connected to the controller. In this way, IoTCS based on the principle of networked control systems was realized, in which the equivalent for the communication network is Arduino Uno.

An analog sensor module KY-013 consisting of a thermistor with a negative temperature coefficient and a 10 kΩ resistor was used to measure the temperature. The Steinhart-Hart equation [43] was used to determine the temperature of the sensor module depending on the resistance

$$T(R) = \frac{1}{C_1 + C_2 \ln R + C_3 \ln^3 R} \tag{1}$$

where $T(R)$ is the thermistor temperature expressed in kelvins, R is the thermistor resistance expressed in ohms, and C_1, C_2 and C_3 are the coefficients which values for the 10 kΩ resistor are as follows: C_1=0.001125308852122, C_2=0.000234711863267 and C_3=0.000000085663516.

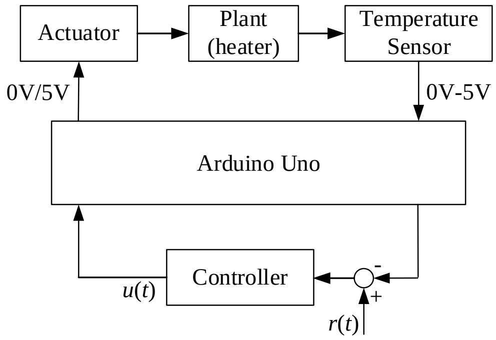

Figure 6. Block diagram of temperature control IoTCS

In the experiment, a solid-state relay SSR-25DA [44] was used to instantly switch the heater on and off, by which the temperature is changed (controlled). This relay is an electronic switch that can connect or disconnect a high-power load to AC power for small values of a DC input signal. In the temperature control experiment, the AC power source comes from the power grid, and a DC signal is provided from the output of the digital pin D9 on the Arduino Uno board.

The software part of the system, shown in Fig. 8, is implemented using standard Matlab Simulink blocks and Simulink blocks that are an integral part of the *IO package* software developed by MathWorks to support communication between the Arduino board and the computer running Matlab. The *Arduino IO Setup* block defines the communication port to which the Arduino board is connected. The *Real-Time Pacer* block allows recording the appropriate signals and monitor the flow of the experiment in real time. The *Arduino Analog Read* block is used to read the values on the analog pins of the Arduino board, while the *Arduino Digital Write* block writes the values to the digital pins. In the *Arduino Analog Read* block, the system sample period is set to T = 0.1 s. The temperature is read via the *Arduino Analog Read* block from pin A2 on the Arduino board and is proportional to the voltage on the given pin. As the Arduino Uno board has a 10-bit AD converter, the analog voltage values on pin A2, ranging from 0 V to 5 V, are converted to values from 0 to 1023. After the AD conversion, the obtained values are converted to degrees Celsius. A unit step function with a delay of 20 s is set in the *Step* block. The delay was introduced since the sensor needs to take enough time to read the ambient temperature before the heater turns on and starts heating.

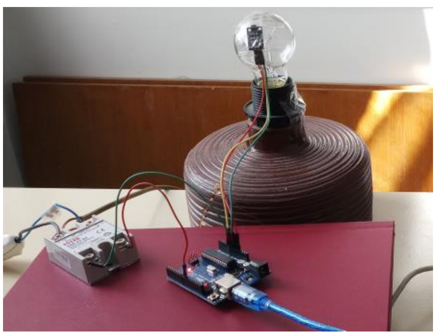

Figure 8. Experimental setup of temperature control system

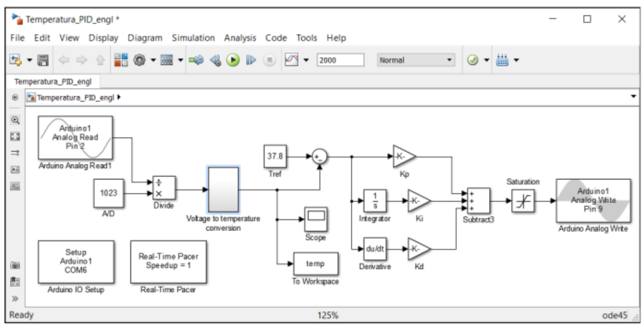

Figure 7. Software part of the temperature control system with PID controller

B. PID Controller in Temperature Control

The described system can be used in many applications. For example, if it is assumed to be used in poultry for incubation of hen eggs, the temperature in the incubators should be 37.8 °C and stay constant all the time [45]. Maintaining the temperature at this value should be provided by the PID controller. The control of any process by means of a PID controller must not be abrupt, but gradual. Since the principle of operation of the presented system is based on the instant turning on and off the plant, and the light intensity of the bulb cannot be influenced, gradual temperature control can be achieved if pins on the Arduino board for PWM signal generation are used. Gradual regulation (gradual change of the system output signal) is achieved by changing the duty-cycle of the input PWM signal, i.e. the percentage of time the bulb is on. For this purpose, the *Arduino Analog Write* block is used, which takes values from the input range from 0 to 255 from its input and sends a command to the Arduino board to set these values as an output on the corresponding pin in the form of a PWM signal. Thus, if the value read at the input of this block is 0, it means that the duty-cycle is 0%, and if 255, it means that it is 100%. This block is connected to the D9 digital pin on the Arduino board. The *Saturation* block keeps the output values of the controller within the appropriate limits.

In experimental testing of the temperature control system functioning, a step response is obtained and shown in Fig. 9. Reference temperature is set to 37.8 ° C and values of PID controller parameters are empirically determined to be Kp = 5, Ki = 0.2 and Kd = 4. It can be noted that the overshot is 15%, the rise time is 150 s and the settling time is 450 s. Also, it is obvious that integrator winding up is present in the system due to large integral control effort. Therefore, the error is being summed even after feedback stops to work and temperature overshoots the reference value. To put the system in normal operation again, the error needs to be negative for a long period of time. That is why the temperature undershoots the reference value when integral control effort starts to decrease. The integral control effort made the obtained response oscillatory and slow to settle.

V. Conclusion

Research in the field of networked control systems has significantly supported the development of the concept of the Internet of Things, enabling the creation of a fully interactive network environment in which the desired behavior of the system is possible to achieve. The paper discusses networked control systems and the concept of the Internet of Things, as well as the possibilities of their integration. A special intention is paid to Internet of Things hardware, since the IoT devices are becoming indispensable part of modern control systems. Based on the concept of the Internet of Things Control Systems, which combines the functionalities of networked control systems and the Internet of Things, a temperature control system has been designed. PID controller for controlling the temperature has been implemented in Simulink, showing that software packages traditionally used for the synthesis and analysis of control systems can be used for the synthesis and analysis of control systems based on the hardware of the Internet of Things.

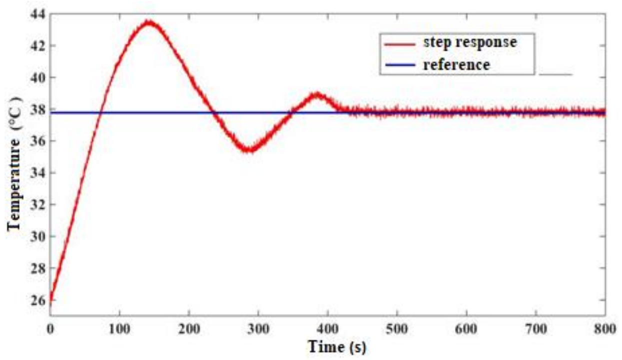

Figure 9. Step response of the temperature control system with PID

Although there is a vast number of examples of using IoT hardware in control systems applications, the usage of Internet of Things concept in control systems comes with certain advantages and disadvantages. Advantages can be expressed in terms of IoT hardware components low cost and simplicity of use, programming that doesn't require advanced skills, real-time control and possibilities of extending the functionalities of developed system in an easy way adding different shields and modules. Since such systems consist of hardware components in the control loop and possess some features of networked control systems, the disadvantages are expressed in a fact that these systems induce communication constraints, some components can fail functioning and thus control tasks couldn't be properly executed. A great disadvantage represents the lack of PID tuning methods for control systems based on IoT hardware which makes the process of determining PID controller parameters by trial and error procedure time consuming.

Further research will be focused on expanding the functionalities of the implemented system with the aim of remote temperature control using some of the communication network technologies for wired and wireless data transmission commonly used in the concept of the Internet of Things.

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