2017 58th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)

Continuation of analysis of heating processes of 32.3m^3 room - heated up by central heating boiler equipped with automatic briquettes feeding system - ABFS

Aigars Vitols, Ivars Rankis
Institute of Industrial electronics and Electrical Engineering
Riga Technical University

***Abstract* – This paper represents continuation from previously published paper of analysis of heating processes of 32.3m^3 room which is heated up by universal central heating boiler "Dacon – FB 36" which is equipped with experimental automatic briquettes feeding system – ABFS from.**

***Keywords* –Automatic briquettes feeding system, central heating boilers, briquettes, steel panel radiator, cast iron radiator**

I. Introduction

Nowadays when firewood, briquettes, biomass pellets, coil and natural gas are available in market for heating systems, the important aim is to decrease the costs for heating and at the same time increase the comfort level [1] of heating processes, because people's choice is based on two main parameters [2] the first - the price and how costly is technology and heat that will be produced, second is comfort level.

Historically in Latvia there are many universal central heating boilers [3] in private houses (with average heating area 200 m^2 and where natural gas is not available) which are usually heated with firewood, coil and nowadays with briquettes.

Usually such universal central heating boilers are with low comfort level, because it is necessary to load the fuel manually and there is no equipment available in the market to control temperature in these heating boilers more than 2 hours with these types of fuel, therefore it is not possible to regulate or provide constant temperature in heating system.

To increase the comfort level it was necessary to find out which type of usually used fuel can be automated. We know that coil has high amount of slag therefore that type can not be automated and fire wood has unpredictable geometric shapes and also can not be automated, but briquettes has low slag and predictable geometric shape [4], which allows us to make automation for such type of fuel. Also according above mentioned criteria that the price is important parameter we can make automation for such type of fuel to get optimal result to satisfy the people's choice, because the price of briquettes is not the highest in the market. From technical point of view from literature [5] we know that there exists auger and hydraulic feed mechanisms and etc. but no one is suitable for feeding briquettes [6].

According above mentioned facts it was decided to make research on automation for universal central heating boiler "Dacon – FB 36" and as a result the first version of experimental ABFS -automatic briquettes feeding system was developed and tested. In previous publications [8],[9] research target was to find out the automation method to heat up water in water boiler with briquettes and first analysis of heating processes of 32.3m^3 room which was heated up by central heating boiler equipped with automatic briquettes feeding system – ABFS. In a result the experimental automatic briquettes feeding system – ABFS was developed see Fig.2, but in this publication the main focus was to get experimental data with more precision which is very important for further. All experiments were carried out from 01.01.2017 till 01.02.2017 in city Limbazhi of Latvia.

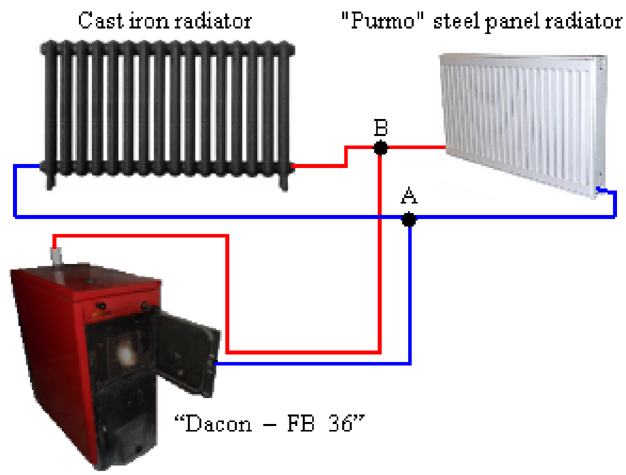

Fig. 1. Classic configuration of heating system

II. Introduction of heating system

In experiments which will be described in this manuscript later was used standard heating system [7] configuration which consisted of heating boiler "Dacon – FB 36" which was connected to "Purmo" (2017 W) steel panel radiator and to old fashion cast iron radiator (1280 W) which consists of 16 parts and each part has volume 2 liters see Fig.1. Those radiators were connected in parallel like in Fig.1. Distance between heating boiler and point A and B was 12 meters and length of hot pipe between cast iron radiator and point B was 0.5 meters and length of hot pipe between steel panel radiator and point B was also 0.5 meters. Length of cold pipe between steel panel radiator and point A was 1.5 meters and length of cold pipe between cast iron radiator and point A was 1.5 meters.

III. Description of Experimental Model

A. Electro-mechanical part of experimental ABFS

In Fig.2 we can see developed experimental ABFS - automatic briquettes feeding system which is connected to heating boiler “Dacon – FB 36”. Also in Fig.2 we can see that ABFS consist of metal frame – 1, 3 phase electrical motor with nominal power 1.5 kW - 2, pulley-3, power transmission tether strap -4, pulley-5, reducer (with moment transfer 1:27) - 6, pulley-7, power transmission tether strap -8, pulley-9, threaded rod-10, briquettes pusher -11, briquettes trap -12, special door for briquettes entrance in heating boiler -13, safety switch S1 – 14, control switch S2 -15, wheels – 16,17,18,19, briquettes-20, wire-X1, wire-X2, wire-Y1,wire-Y2 and 3 phase wire- W1.

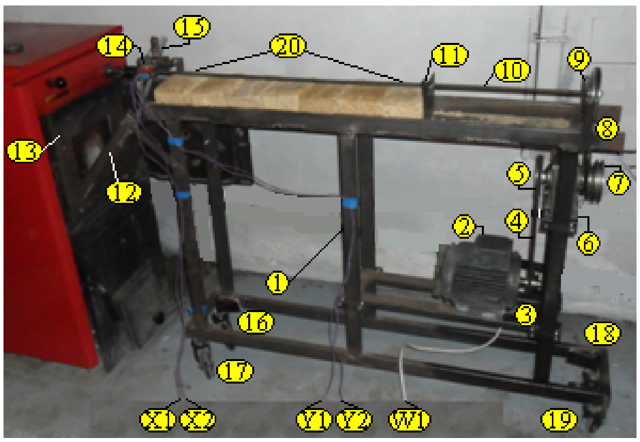

Fig. 2. Heating boiler equipped with experimental automatic briquettes feeding system - ABFS.

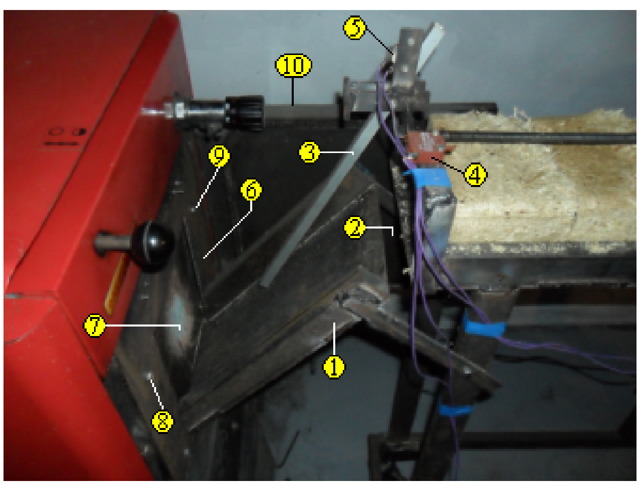

Fig. 3. Heating boiler equipped with experimental automatic briquettes feeding system – ABFS closer look on heating boiler entrance.

In Fig.3 we have closer look on entrance of heating boiler. The main parts there are briquettes trap-1, special air gap -2, rod of indicator -3, safety switch S1 – 4, control switch S2-5, special door for briquettes entrance in heating boiler-6, briquettes entrance in heating boiler -7, door fixing bolts - 8, 9, the original door of heating boiler – 10.

B. Power scheme of experimental ABFS

In Fig.4 we can see power scheme [9] of electrical drive system where electrical motor M1 is connected through automatic switch S4 (20A) to frequency converter [10] “Comander SK” with nominal power 2 kW and frequency converter is connected through 3 phase starter switch S3 to 3 phase power line with line voltage 380 V. (During the experiments 1.5kW motor was used because it was technically available and further optimization of motor drive system must be done in the future). In used frequency converter we have special control terminal block and we have used terminal B2 and B5 to operate our drive system.

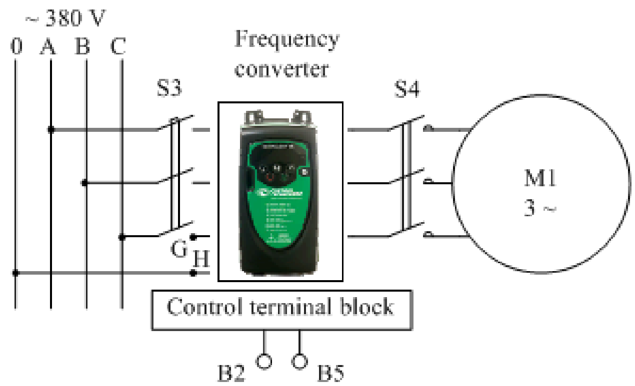

Fig. 4. Electrical scheme of motor drive system.

C. Control scheme of experimental ABFS

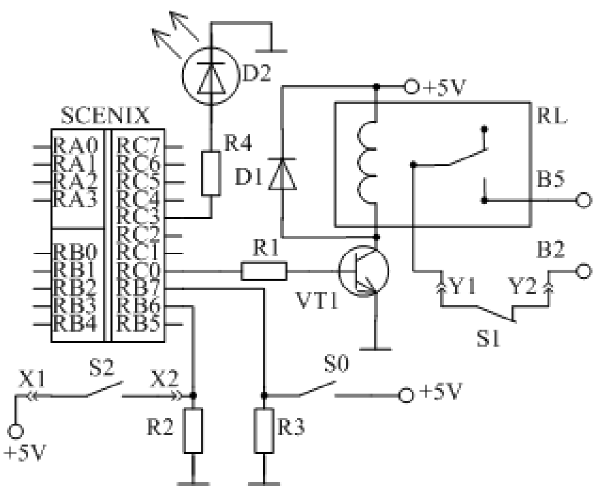

Fig. 5. Electrical scheme of control block of ABFS.

In Fig.5 is showed electrical scheme of control block, which consist of programmable microcontroller SCENIX SX-24 [11] and to its RC0 terminal through 5kΩ resistor R1 is connected the base of n-p-n type transistor KT315Б. Emitter of transistor is grounded, but collector is connected to diode D1 and relay’s coil. The relay’s coil is in parallel connection with the diode D1. Cathode of diode is connected to power source with 5 volts and also another terminal of relays coil is connected to power source with 5 volts. Relay's switch is used in normally opened state which is connected in series with normally closed switch S1. To SCENIX RB6 terminal is connected resistor R2 with 1kΩ resistance and between them is connected one terminal of control switch S2 another terminal of control switch is connected to power source with 5 volts. To SCENIX RB7 terminal is connected resistor R2 with 1kΩ resistance and between them is connected one terminal of start switch S0 another terminal of control switch is connected to power source with 5 volts. To SCENIX RC3 terminal is connected resistor R4 with 1kΩ resistance in series with LED D2.

D. Explanation of operation principles of experimental ABFS

All ABFS was developed so that it is not necessary to make any change in heating boiler "Dacon – FB 36" construction to connect ABFS for operation. This was achieved by creating two special brackets that gives possibility to affix special door for briquettes entrance at the heating boiler by two door fixing bolts. When special door for briquettes entrance is fixed to heating boiler then remainder part of the system on wheels must be moved to that special door for briquettes entrance and fixed by briquettes trap. Then all ABFS becomes immobile and ready for use. Connection and fixing ABFS to heating boiler takes maximum 4 – 5 minutes of time. When ABFS is connected then (max 11) briquettes can be loaded into ABFS. After that by switching S1on (see Fig.4) power supply must be connected to converter and control block. Here we want to mention that power supply block with 5 V is connected in electrical scheme of motor drive system between switch S1 and frequency converter at points G and H and automatic switch S2 is usually in on position. Then briquettes must be loaded in combustion chamber of heating boiler through the bottom doors (see Fig.1) and must be fired. Then start switch S0 must be pushed (see Fig.5) and ABFS will start to operate according control algorithm from Fig.6.

After pushing start switch S0 the 5 V are connected to microprocessor's RB7 input port which means for microprocessor's program that S0 is switched on and LED D2 (indicator in control block) will be lighten. Then timer (timer is realized programmatically) counts 4020 seconds time and then 1140 seconds time, its necessary to start proper firing process. After 5160 seconds motor is switched on and briquettes pusher is pushing briquettes towards briquettes entrance in heating boiler while first briquette (first briquette is on left side in Fig.2) begins to lift up rod of indicator which will switch control switch S2 on and 5V will be connected to microprocessor's RB6 input port. Then microprocessor's program will receive logical input 1 and will start to count 1 second time after that program will check if really S2 is on in seventh block of control algorithm. If S2 will be really on then program will start to wait for logical zero input in microprocessor's RB6 input port.

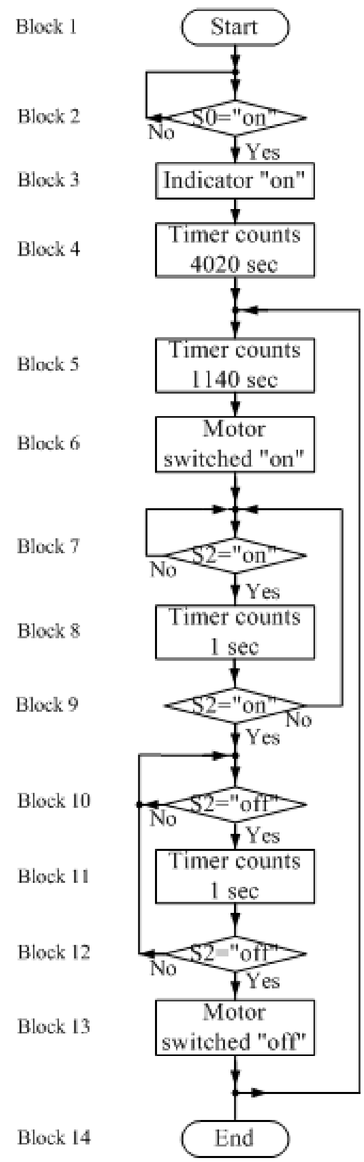

Fig. 6. Block scheme of control algorithm.

When briquette will be pushed on briquettes trap after some time briquette will fall in combustion chamber through briquettes entrance in heating boiler and will release rod of indicator in its initial position and logical "0" signal will be supplied to microprocessor's RB6 input port what will be checked by program into 10th to 12th control algorithm blocks. When microprocessor's program will get stable logical "0" signal, it will switch of motor by deactivating relay RL which and it will provide "0" signal to frequency converter and frequency converter will stop the motor and briquettes pusher also. When last briquette will be loaded the briquettes pusher will push safety switch and frequency converter will stop the motor M1 totally.

Important part in the control algorithm is realized by program in control algorithm blocks from 7 to 12. That program code is showed below.

E. Program code of control algorithm blocks from 7 to 12

```
;- waits for S2 "on" or "1"
    MOV 1AH,#00000000B
S2:   MOV 1AH,rb
    SB$1A.6
    JMP S2
;-if S2 is "on" Timer for one sec must be activated
    CALL  Tsec
;-checks if S2 is really "on"
    MOV 1AH,rb
    SB$1A.6
    JMP S2
;-waits for S2 "off" or "0"
    MOV 1AH,#00000000B
S22:  MOV 1AH,rb
    SNB $1A.6
    JMP S22
;-if S2 is "off" Timer for one sec must be activated
    CALL  Tsec
;- checks if S2 is really "off"
    MOV 1AH,rb
    SNB $1A.6
    JMP S22
```

All program is programmed in assembler level in program language for SCENIX microprocessor.

IV. Experimentation Part

A. First experiment

In odder to get experimental data with higher precision than in previously published paper [12] it was decided that the temperature over "Purmo" steal panel radiator should be measured digitally not as it was done in previous time – manually. Therefore special additional device was made which consisted of resistor R1 and thermistor R2 see Fig.7.

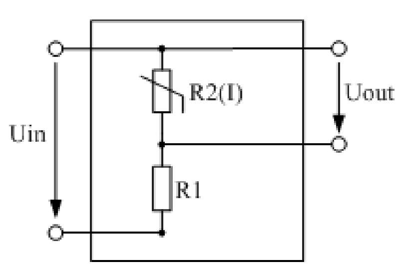

Fig. 7. Additional device for temperature measurement.

All experiments were carried out in 32.3 m^3 room of two storey house in city Limbazhi (Latvia) mentioned in Fig.8, where we can see two radiators – one of them is cast iron radiator and another one is "Purmo" steel panel radiator, these radiators were heated up by automatic briquettes feeding system – ABFS during experiments. During the experiments the temperature in point A which is geometrical center of room see Fig.8 was measured by infrared thermometer with measuring range [-50C-380C] manually, but at point B which was point on steel panel radiator see Fig.8 was measured by following method using additionally made device see fig.7 with thermistor.

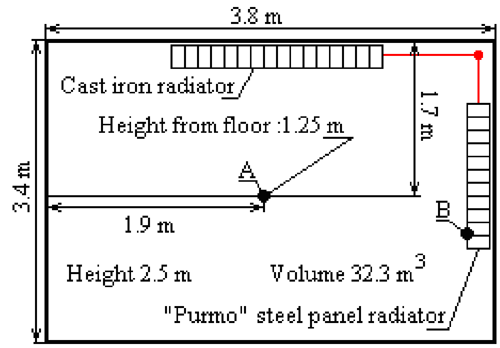

Fig. 8. Arrangement of radiators in room.

Before the experiments additional device was connected to DC regulated voltage source PS1502A with voltage 5 volts. Then heating boiler was heated up from 4.5 to 62.8 C to get experimental characteristic Teks=f(Uout) of temperature and voltage relation see fig.9.

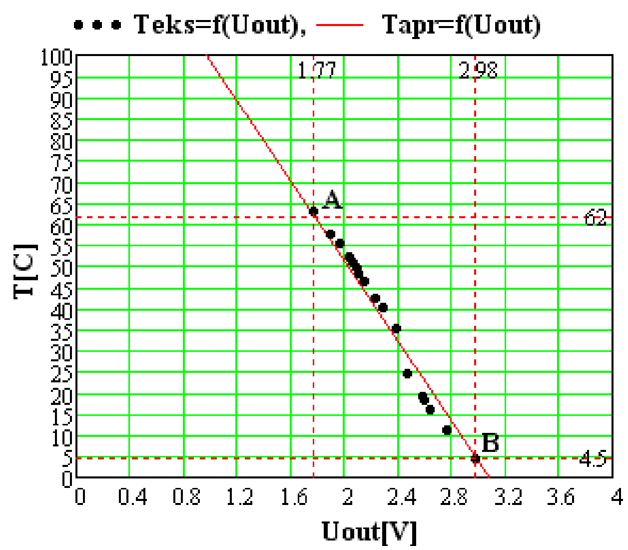

Fig. 9. Experimental Teks=f(Uout) and aproximated Tapr=f(Uout) characteristics of temperature and voltage relation.

From experimental characteristic Teks=f(Uout) we can find out values of point A(1.77,62) an point B(2.98,4.5) and after we can find out coefficients k and b from equitation system (1) and (2).

$$\begin{cases} T_A = k \cdot V_A + b \\ T_B = k \cdot V_A + b \end{cases} \quad (1)$$

$$\begin{cases} 62 = k \cdot 1.77 + b \\ 4.5 = k \cdot 2.98 + b \end{cases} \quad (2)$$

After solving equitation system (1) and (2) we can get values of coefficient k=-47.521 and coefficient b= 146,112 for formula of approximated function Tapr=f(Uout) and construct mathematical expression of that function (3).

$$T_{apr} = -47.521 \cdot U_{out} + 146.112 \tag{3}$$

When we know approximated function Tapr then we can connect Velleman PC-SCOPE (PCSU1000) oscilloscope to output terminals and in recording regime collect values of output voltage in data file in form which we can see in fig.10.

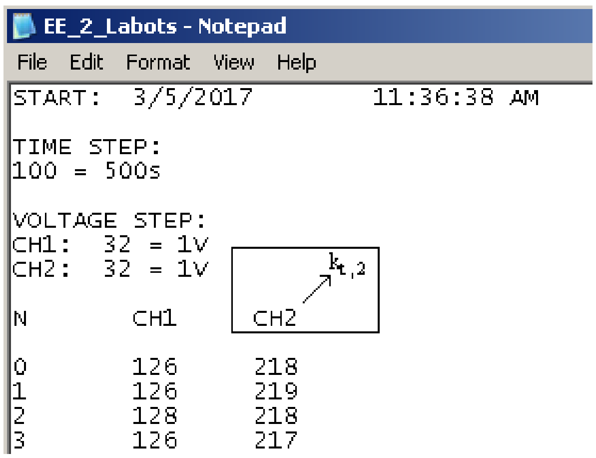

Fig. 10. Data file with data points of output voltage.

In fig.10 we also can see the date and time when data point file is created as well as time step which was chosen so that 100 data points corresponds to 500 seconds and also voltage step is shown in this time it was chosen that value 32 corresponds to one volt.

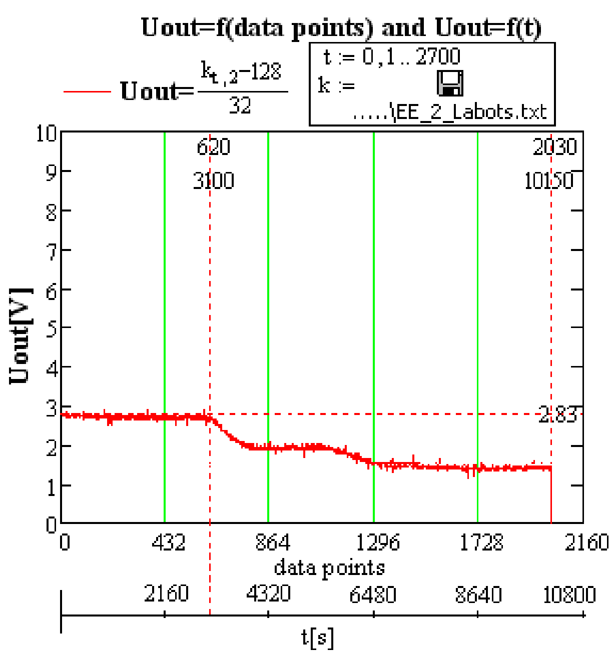

Fig. 11. Output voltage characteristic created in program MathCAD.

All data were collected in two columns. During the experiments the second channel of oscilloscope was used therefore all data were taken from second column in mathematical program Matcad as values of variable $k_{t,2}$ for further calculations.

In fig.11 is shown characteristic of output voltage constructed from collected data file EE_2_Labots.txt. Therefore voltage is saved in data points also MatCAD automatically shows us voltage dependence of data points but since we know time step and voltage step we can express output voltage as function of time. In fig.11 are showed two scales data point scale and time.

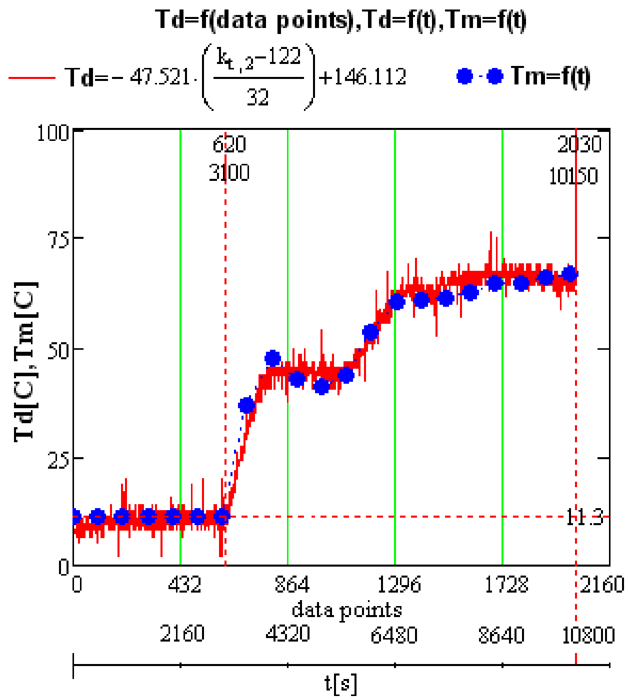

Fig. 12. Comparison of two curves - first Td is digitally and second Tm is manually obtained curves.

In fig.12 are shown two curves. The first one is Td – temperature dependence of time on "Purmo" steel panel radiator which was measured by using thermistor device and the second one is Tm – temperature dependence of time on the same "Purmo" steel panel radiator but data for the characteristic was obtained manually with infrared thermometer. In fig.12 we can see that characteristics corresponds each other if they are putted over each other. In previous research when temperature was obtained only manually – it was not possible precisely detect the time moment at which temperature starts increase. Therefore it was necessary to develop additional device with thermistor to obtain more precisely the time when temperature starts arise and also we can see that to obtain the data with thermistor device is more complicated than by manually measuring method. During the experimentation many experiments were carried out but here we will represent the important information which is necessary to detect the time after firing the briquettes in combustion chamber of heating boiler. The characteristics which are represented in fig.11 and fig. 12 were obtained in Latvia in city Limbazhi when outside temperature was 5 Celsius degree and firing process was started with 5 briquettes start. All experiments continued while the temperature in point A in fig.8 reached temperature 20 C.

From fig.11 and 12 we can also obtain the precise time when burning process starts and when temperature starts to arise in radiator and when temperature in room reaches 20C, then it was considered that experiment is finished.

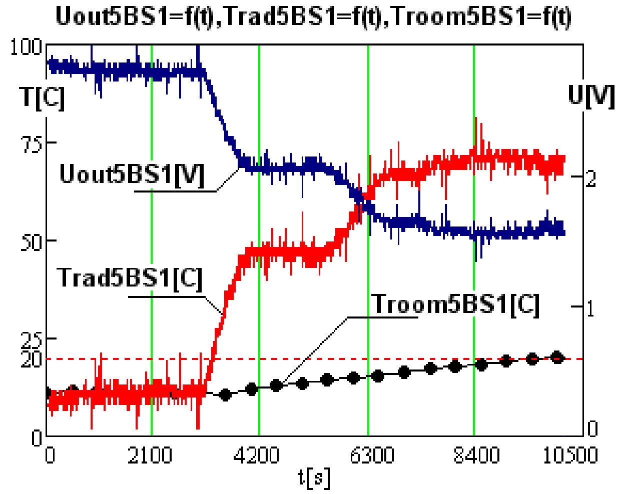

Fig. 13. Characteristics from first experiment with 5 briquettes start.

In Fig.13 is shown how voltage Uout over thermistor is changing and how temperature over radiator Trad is increasing while room temperature Troom reaches 20C. We can say that all information represented in fig. 7-13 are the first experiment which is with detailed explanation how characteristics can be obtained and in next figures characteristics will be represented to better understand the heating processes in heating system if it is operated with automatic briquettes feeding system –ABFS. And also all further characteristics are dependent on data points – but for this manuscript they will be represented as functions which are dependent of time.

B. Second experiment

The second experiment was made on 10 March 2017 when outdoor temperature was also 5 C in city Limbazhi (Latvia) and at the same temperature the first experiment was made to be sure that the obtained data are not causal and are similar when burning processes are repeated. In fig.14 really we can see that the shape of characteristics is similar with the similar dips shortly after the temperature stars its raising process and also duration time of burning process is similar. For better comparison the fig.15 is presented where we can see, that Trad5BS1 – temperature over radiator in first experiment with 5 briquettes start is increasing little bit faster than the Trad5BS2 - temperature over radiator in second experiment with 5 briquettes start. The difference is explainable with fact that the briquettes are falling in combustion chamber in different positions – therefore the intensity of burning process are little bit different which approves the characteristics obtained in our experiments. In fig.15 also are showed characteristics of voltage change and they are also similar.

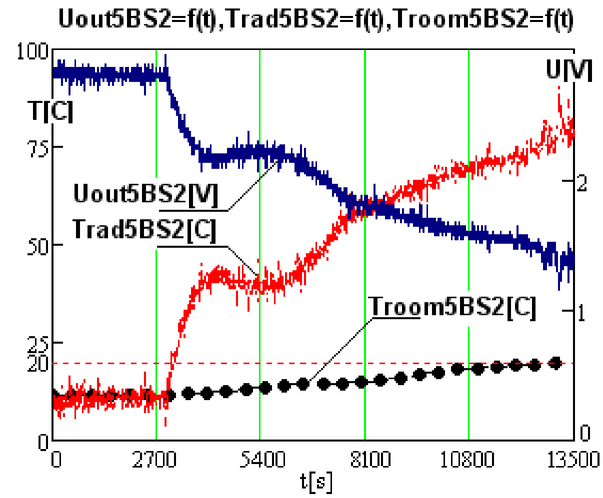

Fig. 14. Characteristics from second experiment with 5 briquettes start.

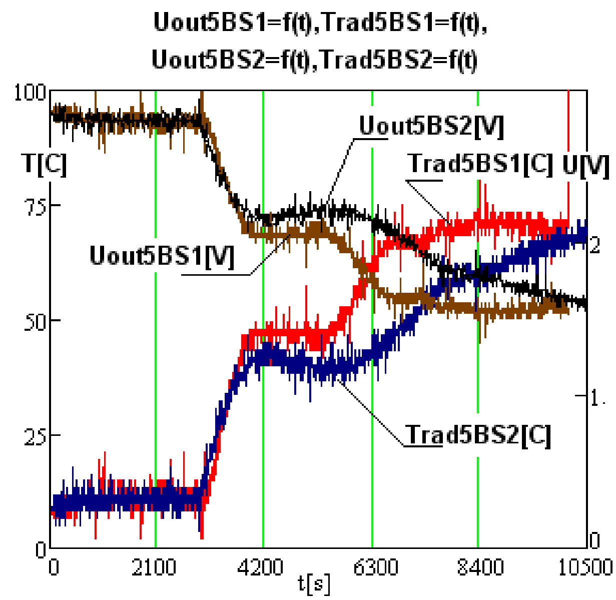

Fig. 15. Comparison of characteristics of first and second experiments.

C. Third and fourth experiment

Third and fourths experiments were done to find out when temperature will start to arise earlier if burning process will be done with five or seven briquettes start. In fig.16 are shown how voltage over thermistor is changing when burning process is started with five briquettes start and seven briquettes start. From fig.16 we can find out precisely that temperature starts to arise on radiator after 2250 seconds when burring process is started with 7 briquettes start and when burning process is started with five briquettes start then temperature is starting to arise after 3000 seconds. It means that the speed of water flow in heating system is higher when burning process is provided with seven briquettes start. Also from fig.16 we can see that the shapes of characteristics are similar with the same dips after burning process has started. These dips appears because the briquettes which were at the beginning of firing process putted in combustion chamber are losing their energy and temperature is starting to decrease and at that moment next briquette is supplied in combustion chamber and then the temperature in starting to increase see also fig. 17 where characteristics of temperature over radiator is presented for two methods of feeding the heating system with five briquettes start and seven briquettes start.

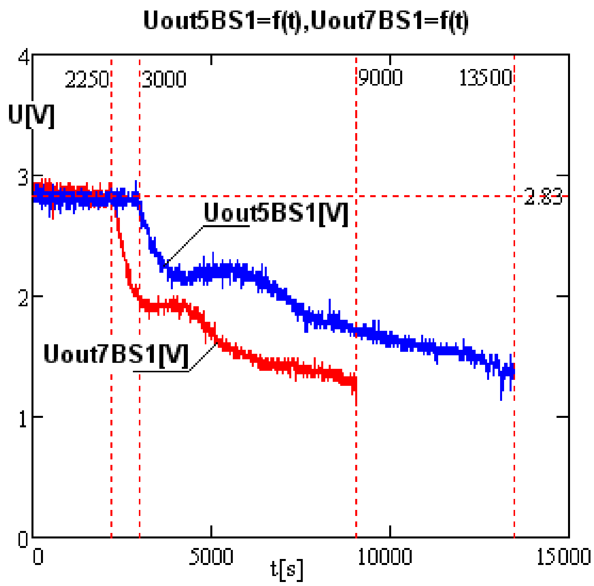

Fig. 16. Comparison of characteristics of output voltage when burning process was carried out with 5 briquettes and 7 briquettes starts.

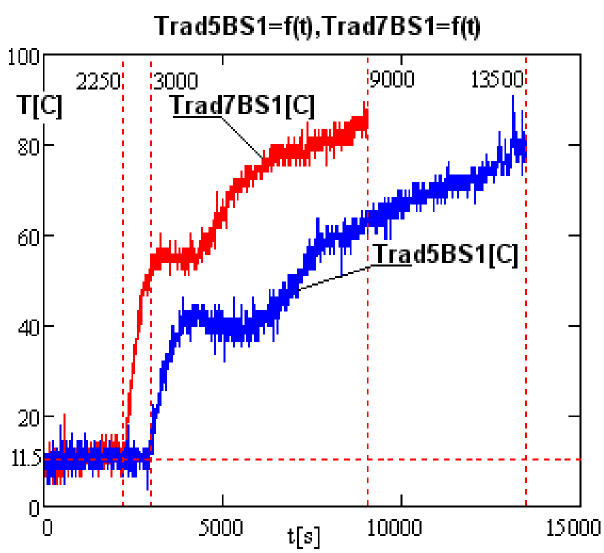

Fig. 17. Comparison of characteristics of temperature when burning process was carried out with 5 briquettes and 7 briquettes starts.

In fig. 16 and 17 we can see that time when temperature reaches 20C in the center of room is smaller when burning process is started with seven briquettes star.

V. Conclusions

Experiments carried out shows that automatic briquettes feeding system – ABFS can heat up to temperature 20C the 32.3m^3 room with plastered aerated concrete masonry at different outside temperatures during winter time in geographical location city Limbaži state Latvia.

From characteristics obtained during experiments we can judge about character of heating possesses and important part in this manuscript is that we can get more precisely data of temperature when we use device with thermistor and oscilloscope which is collecting data in digital form. That gives us important information for further research and upgrade of automatic briquettes feeding system – ABFS.

The automatic briquette feeding system – ABFS was tested for every days use for two year period and during that time the microprocessor Scenix of control block of ABFS came out of order and was replaced once and one time it has acted improperly because the frequency converter came out of order after water pipe explosion accident in cellar and made short circuit current through control block and after this accident the microprocessor Scenix was restarted and there were no mistakes after restart observed. It means that the ABFS is working properly under every day's regime and microprocessor Scenix can withstand hard interruptions during the accidents. Also further research on that direction will be carried out to ensure that system is working excellent.

The ABFS can be connected to any heating boiler which is similar to "Dacon – FB 36" heating boiler.

The first cost of such system is approximately 500 EUR because it was experimental model, but price can be decreased to 200 EUR by optimization of electrical systems.

The automatic briquettes feeding system – ABFS has been tested for two years and no fire safety risks were observed during operation because the door closes after each briquette properly and if the door is closed then there are no possibility for fire flames to come out and also from fig.3 we can see that for additional safety special air gap - 3 is made. That air gap provides slivers do not collect on briquettes trap and therefore even the fire flames could shot out of combustion chamber the briquettes in ABFS will be in save distance from fire flames.

References

[1] Brian F. Towler "The Future of Energy" Academic Press, 2014.

[2] http://www.inovacijas.rtu.lv/node/252 - information about Fuels comparison. (RTU innovation and technology transfer centre).

[3] U.S.Departmet of energy "DOE Fundamentals hand book - Thermodinamics heat transfer and fluid flow" Vol. 1 of 3, 1992.

[4] Enplus Briquettes manual for the certification of wood briquettes for the end user market. Deutsches Pelletinstitut GmbH (DEPI) Berlin 2013.

[5] D. Palmer, I.Tubby, G.Hogan,W.Rolls. W.(2011) "Biomass heating: aguide to medium scale wood chip and wood pallet systems". Biomass Energy center, Forest research, Famham.

[6] S. C. Bhatia "Advanced Renewable Energy Systems", (Part 1 and 2) CRC Press, 2015.

[7] Association of Plumbing & Heating Contractors "Understanding central heating systems" ,2013.

[8] Vītols, A., Raņķis, I., Apse-Apsītis, P. Analysis of Automation and Heating Processes of 120 L Water Boiler which is Heated up by Central Heating Boiler Equipped with Automatic Briquettes Feeding System - ABFS. In: 2015 56th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Latvia,

Rīga, 14-16 October, 2015. Riga: 2015, pp.125-130. ISBN 978-1-5090-0334-1. e-ISBN 978-1-4673-9752-0. Available from: doi:10.1109/RTUCON.2015.7343125

[9] McGraw-Hill (A division of the McGraw-Hill companies) “Principles and applications of electrical engineering”, McGraw-Hill Primis, Fifth edition, 2006.

[10] Emerson industrial automation ”Advanced user guide Commander SK – ac variable speed drive for 3 phase induction motors from 0.25kW to 110kW, 0.33hp to 150hp” International Issue 9, 2013.

[11] Gunther Daubach, “Programming the SX Microcontroller a complete guide” Parallax inc., Second edition.

[12] Vītols, A., Raņķis, I. Analysis of Heating Processes of 32.3m3 Room - Heated up by Central Heating Boiler Equipped with Automatic Briquettes Feeding System - ABFS. In: 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Latvia, Cēsis - Rīga, 13-14 October, 2016. Riga: 2016, pp.1-6. ISBN 978-1-5090-3730-8.

Aigars Vitols Dr.sc.ing has graduated Riga Technical university in 2007 and has received doctoral degree in electronics.
Since 2008 he is employed by the Institute of industrial electronics and electrical engineering of Riga technical university. Current position is senior researcher and docent at Institute of industrial electronics and electrical engineering of Riga Technical university. Research interests include power engineering, industrial automation, renewable energy and mechatronics.
Riga Technical university, Institute of Industrial Electronics and Electrical Engineering
Address: Azenes str. 12/1K (building 1) cab. 409, Riga, Latvia, LV-1010.
Phone +371 67089505, aigars.vitols@rtu.lv

Ivars Rankis, professor, Hab.Dr.sc.eng. He has graduated Riga Polytechnical institute in 1960 as engineer-electromechanic. Defended his first degree of Dr.sc. (candidate of technical sciences) in 1970. Defended his second degree Hab.Dr.sc.eng. in 1992 at Riga Technical university.
From 1958-1966 he worked as engineer at Riga Electrical machine building company. From 1966 he started studies as doctoral student, but from 1970 – as teacher of different subjects of electrical engineering at Riga Technical university. Research interests are connected with Power electronics and Industrial automation. Now is professor at department of Industrial electronics and electrical technologies of Riga Technical university.
Riga Technical university, Institute of Industrial Electronics and Electrical Engineering
Address: Azenes str. 12/1K (building 1) cab. 509, Riga, Latvia, LV-1010.
Phone +371 67 089 917, rankis@eef.rtu.lv

This is a post-print of a paper published in Proceedings of the 2017 IEEE 58th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON 2017) https://doi.org/10.1109/RTUCON.2017.8124765 and is subject to IEEE copyright.

ISBN 978-1-5386-3846-0 ©2017 IEEE