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DIGITAL CONTROL SYSTEMS FOR THERMO-ENERGETIC PROCESSES

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Abstract. *The main objective of this paper is to propose a numerical control structure that serves existing installations at a thermal energy distribution point, from a large urban heating network. The control solution involves the design of the relevant control systems for thermal points of the thermo-energetic distribution network, including the parameters that are technologically important in the process providing the heat transfer operations from agent to product. After a brief introduction, the dynamic model of the transfer energy from the thermal agent to the product is identified by WINPIM software, and RST polynomial control algorithms are designed using the dedicated software WINREG. The scientific research work validated in simulation demonstrates the effectiveness of the proposed solution. After some improvements based on adaptive or robust control strategies, there will be the possibility to transfer the results on real thermo-energetic process implementations).*

Keywords: thermo-energetic process, energy distribution point, digital solution, modeling, control., simulation.

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1. Introduction

The automation solution is proposed for a series–parallel technological configuration that exists at a thermal point in the urban heating network. This configuration is used to ensure an efficient heat transfer between the agent-product pair for domestic heating and domestic hot water [1}, [8], [9],[12],[1], [20],[21]. In principle, centralized heating systems have heat transfer processes that present a high degree of complexity and pose many problems in their operation manner. We propose an efficient solution that provides the following functions: measuring and acquiring data throughout the process, monitoring information, modeling and control of the main technological parameters at the thermal point for energy transfer.

The automatic control function targets the technological parameters of the facility for which the following control systems are provided: TRC-1, the temperature of domestic hot water for which the operating variable is the primary thermal agent

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(at the inlet of the installation); TRC-2, the temperature of the secondary heating agent for which the operating variable is a partial flow rate from the thermal agent; DPRC-3, the pressure drop at the thermal point, with the operating variable being the output flow rate of the thermal agent. Besides these process parameters, there are also flow and temperature of thermal agents, and input and output energy at thermal point, which are measured by the data acquisition system. These control systems ensure operation of the facility at a nominal point at the values imposed on the operator by the rules of operation. To design these control systems, mathematical models were estimated using the RLS identification methods,[1],[4],[7],[10],[16].The control algorithms, which ensure dynamic performance, were calculated using the usual digital design techniques,[3],[5],[],[7],[9],[13],[22].The performance requirements for closed-loop systems were validated in simulation by dedicated software, [7],[10],[16],[21].

2. Design of the control system

The scope of the paper is a system consisting of a thermic point which is part of the Electric District Heating Plant. There are primary and secondary thermic agents which address the heating of water for domestic house water consumers and for heating. In this regards the system must regulate the pressure of the installation (DPC3), the temperature of the primary temperature agent (TRC1) and the temperature of the secondary temperature agent (TRC2) in order to provide a stable temperature of the water to the consumers.

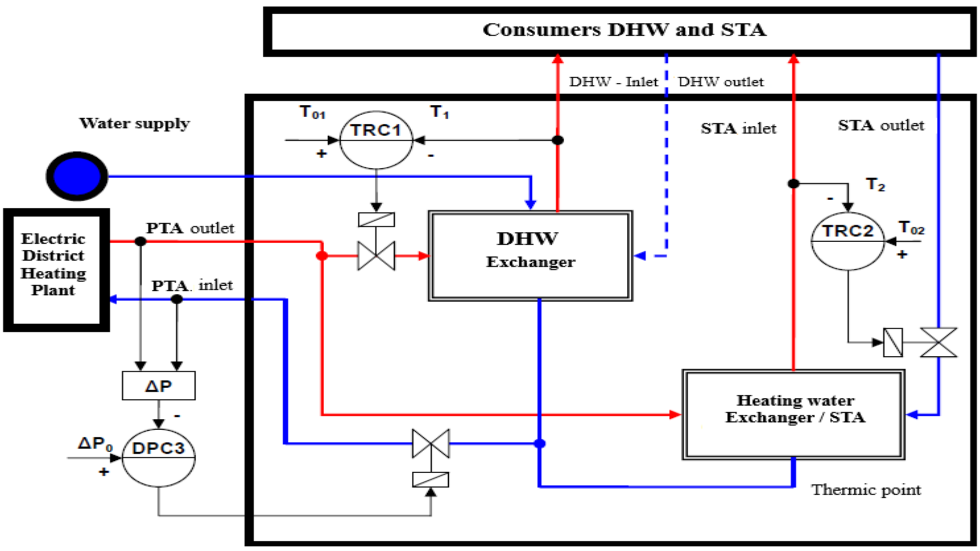

Fig. 1. . Implementation of Automatic Control Systems.

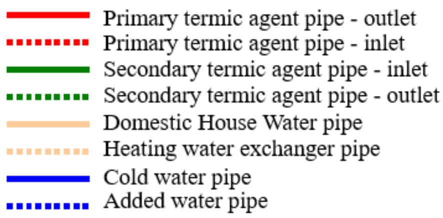

Fig. 2. Pipe types colors.

The computation of an analytical model for the heat exchanger (its quantitative evaluation) is practically impossible due to the difficulty of evaluating the heat transfer and especially the seasonal fluctuation of the values of the description parameters (constants, material characteristics, flow and temperature values, etc.). A procedure for extracting the mathematical model from the data acquired from the process, through experimental identification, is used. For the computation of the command, the transfer function of the fixed part and the closed-loop system performances are taken as independent objectives in regulation and tracking

The RST polynomial control algorithm and placement poles design method for all the three systems are proposed offering good performances both in regulation and in tracking [ ].

2.1. TRC1 Design

The control system for regulating the temperature of domestic hot water (DHW), TRC1, which has as its execution variable the flow rate of the primary heat agent (controlled per flow), is designed based on the identified mathematical model and the performance requirements imposed by the beneficiary.

The system is modelled as a slow process with dead time, having the dead time τf = 60 sec and the time constant Tf = 480 sec, given by the following transfer function:

$$H_f(s) = 1.8\frac{1}{480s+1}e^{-60s} \quad (1)$$

By discretizing the fixed part transfer function $H_f(s)$ with a sampling period of 60s, the model is obtained:

$$H_f(z^{-1}) = \frac{0.2z^{-1}}{1-0.89z^{-1}}z^{-1} \quad (2)$$

The corresponding polynomial control algorithm is computed:

$$\begin{cases} R(z^{-1}) = 10.67 - 6.81\, z^{-1} \\ S(z^{-1}) = 1 + 0.65\, z^{-1} - 1.65\, z^{-2} \\ T(z^{-1}) = 4.65 - 1.02\, z^{-1} + 0.27\, z^{-2} \end{cases} \tag{3}$$

2.2. TRC2 Design

In the design of TRC2, the control system for regulating the temperature of heating water / secondary heat transfer fluid (STA), the chosen execution variable is the secondary heat transfer fluid (STA) flow rate. The mathematical model is obtained from the step response of the heat exchanger. The following transfer function is modelled:

$$H_f(s) = 3.56 \frac{1}{2100s + 1} e^{-900s} \tag{4}$$

The equivalent discrete model is:

$$H_f(z^{-1}) = \frac{0.48z^{-1}}{1 - 0.85z^{-1}} z^{-3} \tag{5}$$

and the numerical RST controller is computed:

$$\begin{cases} R(z^{-1}) = 0.26 - 0.22z^{-1} \\ S(z^{-1}) = 1 - 0.98z^{-1} + 0.006z^{-2} + 0.007z^{-3} - 0.14z^{-4} \\ T(z^{-1}) = 2.10 - 3.72z^{-1} + 1.65z^{-2} \end{cases} \tag{6}$$

2.3. DPC3 Design

For the design of DPC3, the control system for regulating the pressure drop at the thermal point, the chosen execution variable is the primary heat transfer fluid flow rate (PTA).

In an similar approach to that presented for the TRC1 and TRC2 subsystems, respectively, the mathematical model for the controlled process is identified, through a second-order system.

$$H_f(s) = \frac{0.61}{(10s + 1)(30s + 1)} \tag{7}$$

The equivalent discrete model is:

$$H_f(z^{-1}) = \frac{0.018z^{-1} + 0.014z^{-2}}{1 - 1.45z^{-1} + 0.52z^{-2}} \tag{8}$$

The correspondent RST controller is computed as :

$$\begin{cases} R(z^{-1}) = 23.37 - 35.40z^{-1} + \ 13.45\, z^{-2} \\ S(z^{-1}) = 1 - 0.58z^{-1} - 0.42z^{-2} \\ T(z^{-1}) = 28.23 - 44.82\, z^{-1} + 18\, z^{-2} \end{cases} \tag{9}$$

3. Simulation results

The system performances are validated in simulation using the WinREG software.

The designed controllers with dead beat time ensure reference tracking and the rejection of disturbances.

3.1. TRC1 simulation

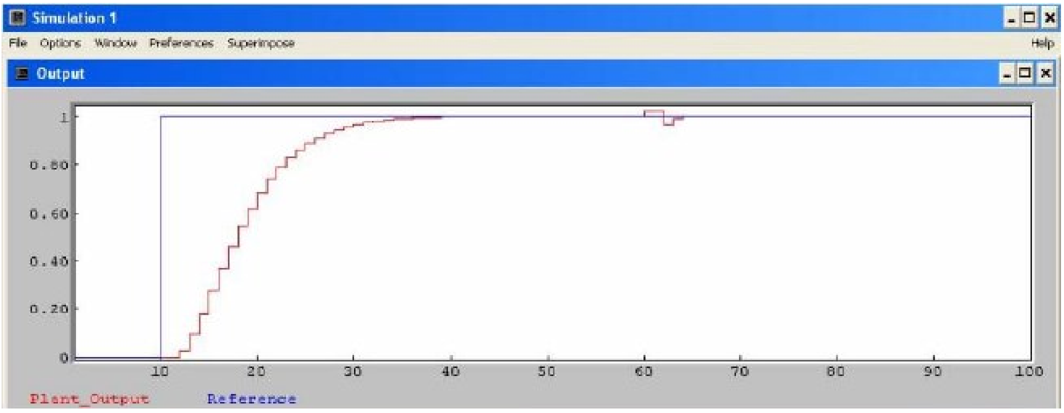

Fig. 3. System performances for regulating the temperature for the DHW

3.2. TRC2 simulation

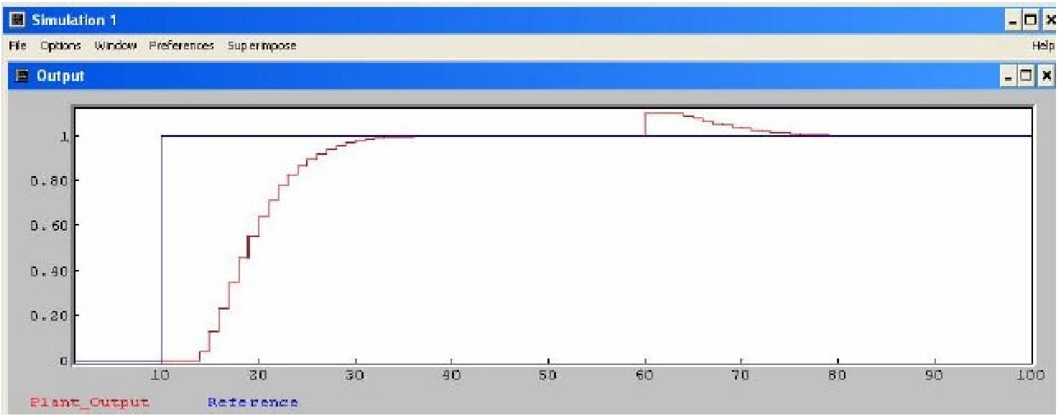

Fig. 4. System performances for regulating the temperature for the STA

3.3. DPC3simulation

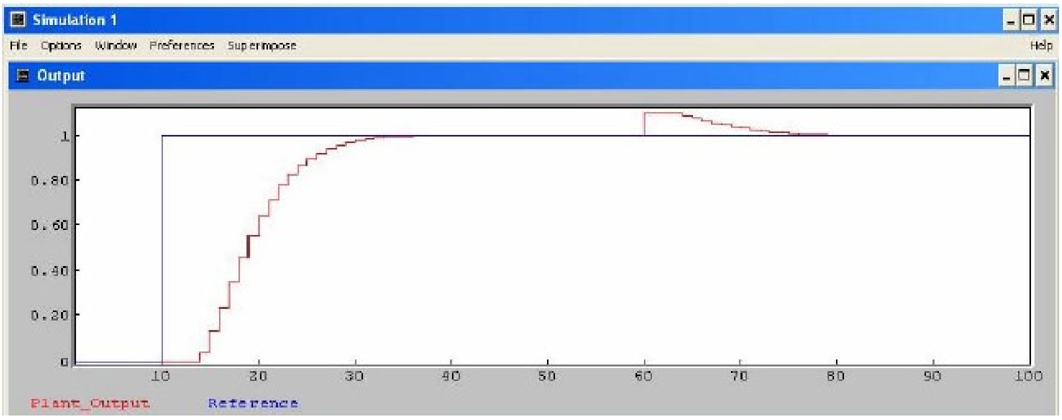

Fig. 5. System performances for regulating the temperature for the PTA

4. Conclusions and perspectives

1. The main objective of this paper is to propose a numerical control solution that serves existing installations at a thermal energy distribution points, from a large urban heating network.

2. The control solution involves the design of the relevant control systems for point of the thermo-energetic distribution network, including the acquisition and regulation of parameters that are technologically important in the process providing the heat transfer operations.

3. After a brief introduction, the dynamic model of the transfer energy from the thermal agent to the product is identified by WINPIM software, and RST polynomial control system for the main parameters of the heating products is designed using the dedicated software WINREG.

4 .The simulation results confirm the quality of the research and the possibility of transferring these scientific results to industrial applications. And the conclusions and perspectives are presented.

5.The results of the research work validated in simulation, demonstrate the effectiveness of the proposed control solution and after some improvements based on adaptive or robust control strategies, will guaranty the possibility to transfer obtained results on real thermo-energetic process implementations.

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