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Measurement elements and SCADA system operation in the remote heating system of the Faculty of Mechanical Engineering

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Abstract: The enormous amounts of energy consumed today for the production of thermal energy intended for households, on the one hand, and the reserves of all types of fuels available worldwide, on the other hand, require that a more rational consumption should be implemented among all consumers. One of the many enhancements to heating systems that aims to improve overall efficiency is the concentration of thermal energy output for a greater number of users, which produces a far better result. This has led to the implementation of a centralized supply of thermal energy for multiple buildings and facilities, residential blocks, and entire urban areas. This method of producing and transmitting thermal energy for heating purposes is called district heating. The thermal energy, produced centrally, is transferred via pipelines to substations, and then through heat exchangers and secondary networks to end-users. Due to the fact that energy consumption constitutes a significant part of the budgets of individual and collective users and requires compliance with the European Union directives on increasing efficiency in all spheres of energy transformation, there is a need for optimized production and consumption of thermal energy. Optimization involves adequate supervision of relevant parameters of the heating process, including production (boiler room), distribution (pipelines), transfer (substations), and consumption (end-user). Supervision entails the ability to command and monitor the operation and parameters of the process. To achieve this goal, the supervisory system must collect and display important process data to detect possible problems or causes of inefficiency in the process itself, thereby alerting the operator. The main goal of the supervisory system is to enable the operator to control and command a highly automated process. Therefore, supervision involves a series of tasks aimed at controlling the process and monitoring its parameters. The Supervisory Control and Data Acquisition (SCADA) system has wide application in district heating systems for monitoring, control, and data acquisition.

Keywords: SCADA system, remote heating system, measurement element

1. Introduction

SCADA (Supervisory Control And Data Acquisition) is a system used for automating general processes, collecting data from sensors and instruments located at remote stations, and transmitting and displaying this data at a central station for monitoring or control purposes. The collected data is typically observed on one or more SCADA computers at the central (main) station. In reality, a SCADA system can monitor and control up to hundreds of thousands of input and output values. Common analog signals monitored (or controlled) by the SCADA system include levels, temperatures, pressures, flow rates, and motor speeds in frequency regulation. Typical digital signals for monitoring (control) include level switches, pressure switches, motor status, and relays. As the name suggests, it does not have complete control over the system but is more focused on supervision and monitoring. As such, it is a software package positioned at the top of the hardware it relates to, mainly via PLC (Programmable Logic Controller) or other commercial hardware modules. SCADA systems have made significant advancements in functionality and performance over the years [1,2]. The term SCADA typically refers to the central system that monitors and controls the entire heat distribution system even over long distances (up to substations). Most of the control of a substation is actually automated by the PLC. The main control functions are almost always forbidden to the controller in the station. For example, the PLC may control the flow of heating water through part of the process, but the SCADA system can allow the operator to change the set flow value and can record and display any alarm conditions, such as loss of pressure or high temperature [3].

Data collection starts at the PLC level and involves reading measurements and statuses. Then, the necessary data is sent to the SCADA system, where it is translated and formatted so that the operator in the control room can make appropriate decisions based on them, which may be necessary to adjust or override normal PLC controls. Data can also be stored in a history, often supported by a database, for trend display and other analytical actions.

1.1. Work Technology of Substations

Heat energy is distributed to substations in buildings through primary piping and transferred to the secondary system indirectly through heat exchangers water-water. The transferred heat energy is distributed to consumers through secondary piping within the building itself, as well as to neighboring buildings. To achieve the required parameters of the secondary fluid, the substation is equipped with appropriate equipment: a digital controller with corresponding sensors, a calorimeter, a shut-off valve, dirt traps, control valves, pressure regulators, and a differential pressure regulator. The pressure regulator brings the fluid pressure to the desired value. In the heat exchanger, heat exchange with the secondary fluid occurs indirectly – the heat exchange is not accomplished by mixing fluids from these two systems, but by circulating the cooler fluid (secondary system) around the pipes through which the warmer fluid (primary system) flows. The desired flow rate is achieved by a transient electromotor control valve located on the return branch of the primary system. A differential pressure regulator that runs without additional energy provides the range of nominal differential pressure needed for the control valve to operate. By measuring the flow and the temperature difference of the primary fluid at the supply and return line of the exchanger, the computational unit determines the transferred amount of heat energy. The cooled fluid of the primary system passes through a dirt trap and returns through the heating network to the plant. The temperature of the fluid in the primary system is controlled according to a given sliding diagram in the plant, and additional regulation of the desired temperature of the secondary fluid is achieved by "flow change" in the primary part of the substation through the action of the regulator on the executive organ. The desired temperature of the secondary fluid is a function of the outside temperature, time of day, and day of the week, and is set as a program for the regulator. The pump operating mode is also programmed. The digital controller is equipped with sensors for measuring the outside temperature, supply and return temperatures, pressure of the primary and secondary fluids, room temperature, and fluid flow in the primary system. All controllers are connected to a personal computer in the dispatch center via cable or GPRS network, where data acquisition and monitoring of the heating system operation are performed. The controllers in the substations operate automatically in a programmatically defined mode. Change of controller operating mode, individual control parameters, and remote commands can be executed from the dispatch center. This establishes a system of remote monitoring and control of the entire heating system, with the operation of the heat exchange stations fully automated. Substations contribute significantly to the success of district heating and have evolved over time from installations made in accordance with standards to technologically advanced products that represent a link with the consumer. Low maintenance costs, standardization, and system optimization have outweighed previously detailed project solutions and on-site installations. The configuration of modern substations and equipment selection should enable the following:

- Remote monitoring of parameters,
- Remote control and management,
- Local regulation,
- Measurement of heat energy consumption,
- Reporting of alarm conditions,
- Ability to manage the technical system.

These requirements can be met by applying the following principles:

a) Selection of modern solutions and equipment:

- Plate heat exchangers,
- Integrated "combo" and control valves,
- Ultrasonic heat meters,
- Application of "PLC" controllers,
- Frequency regulation of rotation speed,
- Application of SCADA software.

b) Connecting to a unified network:

- Optical cable,
- Wireless Ethernet.

The equipment of the heat substation consists of a mechanical (thermos-technical) part and an electro-energetic part.

The thermos-technical installation contains all the necessary elements for the operation of the substation: a heat exchanger (in the case of indirect connection of consumers), a pressure regulator and a flow control valve (in the case of direct connection of consumers), an electromotor control valve or combination valve, an ultrasonic flow sensor (integral part of the heat meter), a dirt trap and sedimentation tank, a circulation pump, an expansion vessel or pressure maintenance device, a safety valve, and sensors for measuring water pressure and temperature.

The electro-energetic part includes:

- *Power equipment*: Fuses, contactors with overcurrent protection, switches, and pump operation indication,
- *Measurement and control equipment*: Microprocessor controller, acquisition module, heat energy meter computing unit, and transmitter power supply (sensors),
- *Communication equipment*: Dual communication module, communication converter, GPRS modem.

The microprocessor controller enables the regulation of heat energy delivery, i.e. limiting the maximum water flow through the primary part of the substation (via the control valve), changing the supply water temperature in the secondary part depending on the outside air temperature according to the sliding diagram, and changing the heating mode. Requirements related to the control unit are primarily determined by the function of the given building. Additionally, there may be functions that are desirable from the perspective of the district heating provider, but they must be justified both technically and financially. In any case, the control unit and control valve must comply with the technical requirements of the heat energy provider, and standard control units intended for use in district heating usually meet these requirements. The minimum functions necessary to achieve quality heat energy delivery are as follows:

- Control of the supply water temperature in the secondary heating system as a function of the outside temperature,
- Possible adjustment of the regulation curve for the supply water temperature to adapt to the building's requirements,
- For non-residential buildings, the ability to program heat energy delivery based on the number of hours and days of the week,
- The control unit must be user-friendly and easy to program.

The control unit will contain at least the following elements:

- One controller with a control curve,
- At least 2 analog inputs for sensors, typically with a resistance of 0 to 25 kΩ for PT1000 type sensors,
- At least 1 analog output, typically 0–10 V; other variations relate to increase/decrease type regulation,
- It should have a calendar and a time channel,
- At least one digital output (for pump control); there should be the possibility of adjusting the temperature for device activation (set value) and the time interval for activation.

All other functions are usually additional, for example:

- Control of the supply water temperature curve for the secondary supply line, depending on the reference indoor temperature; 1, 2, 3, 4, or more sensors,
- Control of the supply water temperature curve for the secondary supply line, depending on the time of day (reducing the set temperature at night, morning heating),
- Automatic adjustment of the control curve depending on indoor reference temperatures,
- Automatic humidification due to changes in outside temperature,
- Pump control; operation with one or parallel inline pumps,
- Automatic switching to a parallel pump if the first pump is not operating,
- Frost protection,
- Summer operation function with automatic pump activation for a very short period each day,
- Pump shutdown in case of building overheating,
- Alarm functions for pumps, temperatures, sensors, etc.,
- Communication with the main program containing data, usually via RS232 or RS485,
- M-BUS communication of heat meters, sub-controllers, electric meters, water meters, etc.,
- Flow limitation.

1.2 The microprocessor controller

The microprocessor controller features a functional keypad and a graphical LCD screen, enabling users to view current values of all measured parameters in the system, set setpoints, and manually control electric drives. Information is organized into 2 groups of screens.

The first group comprises INFO screens displaying system operation information (measured and set values, input and output statuses, alarms, etc.). The content and layout of INFO screens depend on the selected application, allowing users to define their own INFO screens when creating their programs.

The second group consists of standard MENU screens, which remain consistent and display or allow setting of setpoints, input and output statuses, date and time, communication parameters with connected devices, active application, user interface language, etc. To prevent unauthorized access, the controller is equipped with 2 levels of passwords (user - for changing setpoints and manual control, and system - for changing the active application and user interface language).

Set parameters are permanently stored in the controller's internal memory, ensuring their retention in case of power loss. The built-in real-time clock enables the execution of time-based programs (heating reduction, operation within specified time intervals, operation in time sequences, time-based setpoint changes, etc.).

The MBUS master communication port allows direct connection to up to 4 devices with built-in MBUS slave communication ports (heat energy meters, circulation pumps, or similar smart devices).

By utilizing one of the available communication interfaces (RS232 or RS485), the microprocessor controller can be connected to a remote monitoring and control system. Built-in standard protocols facilitate integration of the controller into SCADA systems of leading global manufacturers and ensure full compatibility with standard software development tools.

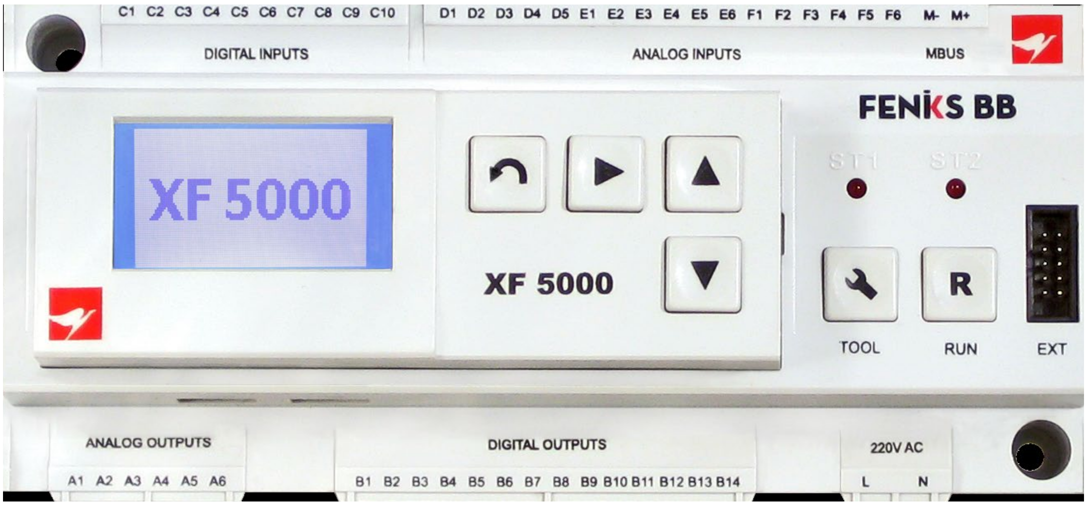

Figure 1. FX 5000 Appearance

1. 3 The communication network

Communication of the central system (i.e. computers and microprocessor units) is based on the standard RS 485 communication interface, allowing direct connection of multiple stations at various distances. The connection is direct, two-wire, and of the "bus" type. The RS 485 connection on the PC is provided by converting the standard RS 232 port. An internal PC card is used for this conversion. The connection to the local controller should already be provided on a standard 9-pin connector on the device's housing.

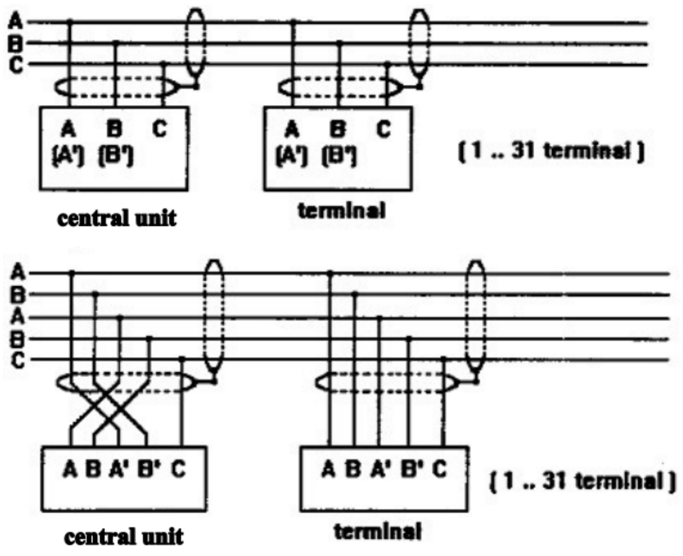

Figure 2. RS 485 interface connection

The RS 485 interface connection consists of two active conductors, labeled as A and B on the transmitter side, i.e., A' and B' on the receiver side, and a common ground. Depending on the requirements and application, a two-wire or four-wire network connection can be used, as shown in the previous pictures. The signal status is defined by the voltage difference between the A and B lines, or A' and B' lines, making it highly immune to electrical interference. The C (C') line is the network ground for equalizing the potential of the individual device grounds. Standard signal cables should be used for communication.

2. Regulation Systems

Depending on the location where regulation is implemented, there are central, group, local (district), and individual regulation systems [4].

- Central regulation is performed in the heating plant according to the change in heat load for most consumers when the heat load in the area is uniform.
- Group regulation is conducted in central substations for groups of similar consumers, ensuring the necessary flow and temperature of the heat carrier.
- Local regulation is provided in-house substations (at the consumer's connection point) for additional correction of heat carrier parameters, taking local conditions into account.
- Individual regulation is carried out directly at the heat transfer exchanger (on radiators) and complements other forms of regulation. It requires the use of many individual regulators, which increases initial investments.

When using water as the heat carrier, the following methods of central regulation can be used:

- Qualitative regulation, which consists of regulating the released heat by changing the temperature of the heat carrier at the supply line to the heating device, while maintaining a constant quantity (flow) of the heat carrier supplied to the regulated plant.
- Quantitative regulation, which involves regulating the released heat by changing the flow of the heat carrier at a constant temperature at the supply line to the regulated plant.
- Qualitative-quantitative regulation, which consists of regulating the heat release by simultaneously changing the flow and temperature of the heat carrier.
- Interrupted regulation is achieved by switching off the system, i.e., periodic interruptions in releasing the heat carrier into the network. Central interrupted regulation is only possible in networks with similar loads. For dissimilar loads, interrupted regulation is used for local regulation.

The heat load of many consumers in modern district heating systems is neither homogeneous in terms of heat consumption nor in terms of heat carrier parameters. To ensure high-quality heat supply, combined regulation should be applied, which should be a rational combination of three levels of regulation - central group or district (local), and individual. This ensures the best balance between heat release and actual consumer needs.

Effective regulation can only be achieved through appropriate automatic regulation systems, not manually, as was the case in the early development of centralized heat supply.

2. 1 Automation of district heating systems

The most efficient way to regulate heat release in centralized heat supply systems with diverse thermal loads is a combination of central qualitative regulation with group or local quantitative regulation. The choice of the basic impulse for local regulation depends on the type and operating mode of the plant. Selecting an impulse for regulating heating loads is a complex task because temperatures in individual rooms of heated buildings can vary significantly and depend not only on the amount of heat supplied to the building but also on the characteristics of the building's heating system, conditions of use of individual rooms, heat gains from people, insolation, infiltration, as well as the arrangement of individual rooms in the building according to cardinal directions and wind roses. Therefore, to fully satisfy the thermal load, it is necessary to provide supplementary local regulation of individual rooms or zones in each building, exposed to different influences such as insolation, wind, heat distribution methods, and other conditions, alongside group or local regulation.

The parameters of interest are:

- Outdoor temperature,
- Primary supply temperature,
- Primary return temperature,
- Primary supply pressure,
- Primary return pressure,
- Secondary supply temperature,
- Secondary return temperature,
- Secondary side pressure,
- Current flow rate,
- Heat delivered.

States of interest include:

- Percentage of opening of the control valve,
- Pump operation indication,
- Pressure indication in the expansion vessel,
- Service intervention indication.

The SCADA solution for substations includes:

- Display of measurements and states in the substation,
- Adjustment of regulation parameters,
- Trend diagram of relevant measurements,
- Option to choose manual or automatic operation mode of the substation,
- In manual mode - control of valve and pumps,
- Display of alarm states,
- System transparency - most relevant data on one screen,
- Improved user awareness,
- Alarm lists, events, graphs – current and archived,
- Excel reports; Excel workbook dynamically linked to the SCADA system database,
- Simple and secure management - switching on/off pumps and opening/closing control valves,
- When managing the substation, the command and the user who issued it are registered,
- Optical network,
- Possibility of system expansion in the future.

Features of the considered SCADA system are:

- Universal system for visualization, monitoring, and control,
- Interface in Serbian language,
- Windows and/or Linux platform,
- Easy integration into existing IT environments,
- Client/server architecture,

- Object-oriented datapoint model,
- Unlimited number of datapoints,
- Direct drivers and OPC,
- Online design and engineering,
- Internet/intranet integration,
- WAP, SMS, email, fax, or voice messages.

On Figures 3 to 5, schemes of all measurements that are part of the SCADA system of the District Heating System MF Niš are shown, while in tables 1-3, technical specifications of all measuring devices installed are displayed.

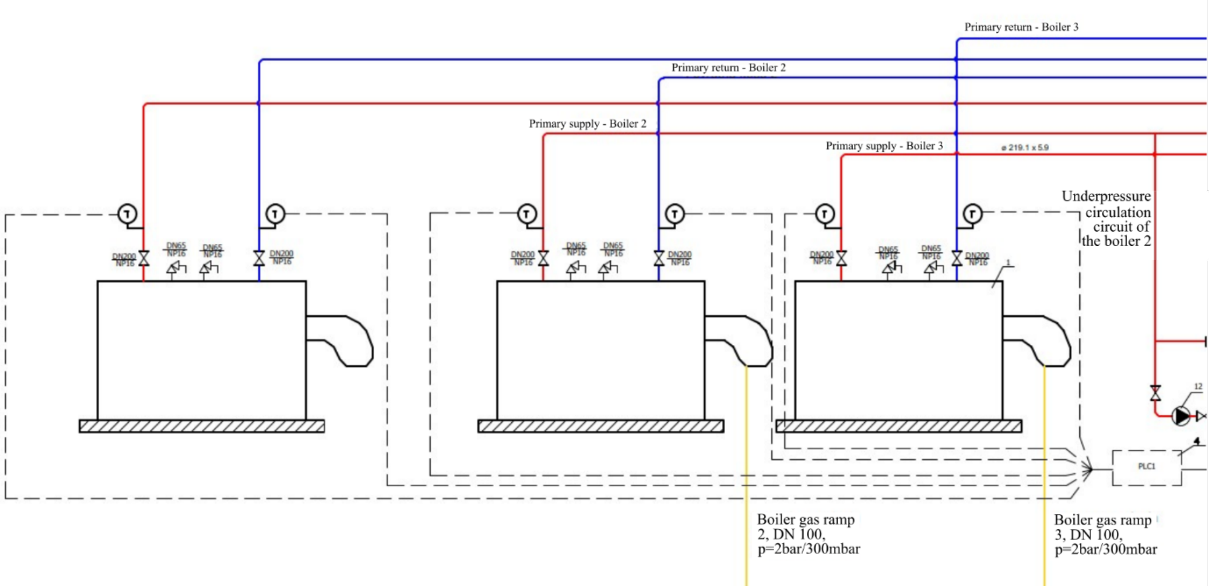

Figure 3. Diagram of measurements in the boiler circuit of the District Heating System

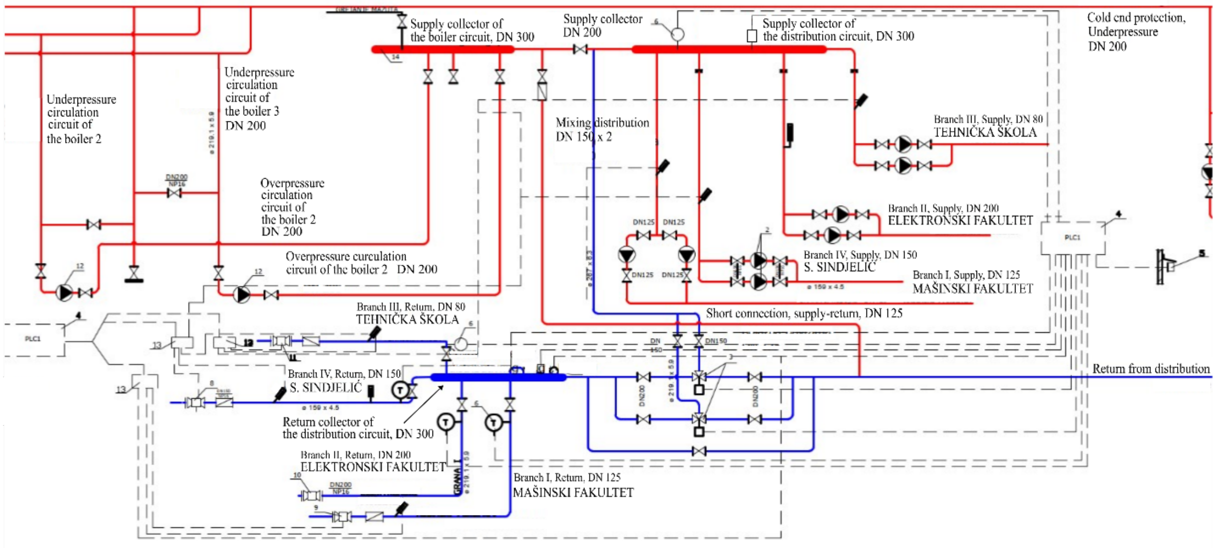

Figure 4. Diagram of measurements in the distribution circuit of the District Heating System

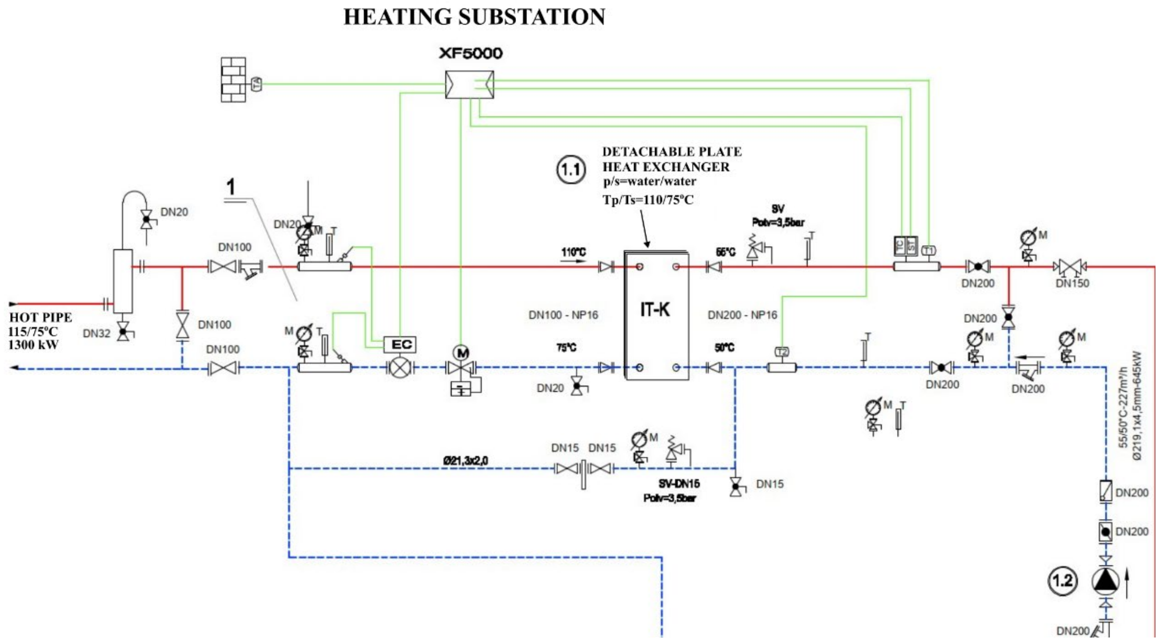

Figure 5. Diagram of measurements in the circuit of a typical consumer connected to the District Heating System

In tables 1 to 3, a list of applied sensors with their characteristics is shown.

Table 1. Characteristics of sensors in the boiler circuit of the District Heating System

Sensor	Description	Type, manufacturer	Min	Max	Unit	Signal type
Temperature sensor	Outdoor air temperature	STS-1, NTC	-40	+60	oC	AI, 0-10VDC
Temperature sensor	Initial temperature of water in boiler 3	Pt100	+30	+150	oC	AI, 4-20mA
Temperature sensor	Return temperature of boiler 3	Pt100	+30	+150	oC	AI, 4-20mA
Temperature sensor	Initial temperature of water in boiler 2	Pt100	+30	+150	oC	AI, 4-20mA
Temperature sensor	Return temperature of boiler 2	Pt100	+30	+150	oC	AI, 4-20mA
Temperature sensor	Initial temperature of water in boiler 1	Pt100	+30	+150	oC	AI, 4-20mA
Temperature sensor	Return temperature of boiler 1	Pt100	+30	+150	oC	AI, 4-20mA

The following statuses are displayed:
Burner operation status (for each boiler)
Indication of primary fuel: natural gas / fuel oil (for each boiler)
Boiler pump operation status (for each boiler)
Set temperature for boiler cold end protection (process parameter)

Table 2. Characteristics of sensors in the distribution circuit of the District Heating System

Sensor/device	Description	Type, manufacturer	Min	Max	Unit	Signal type	Accuracy

Heat energy meter	Ultrasonic	Depends on the consumer					
Temperature sensor	Primary supply water temperature	Pt100					
Temperature sensor	Return temperature of primary supply water	Pt100					
Pressure sensor	Pressure of primary supply water	WIKA	0	16	Bar	AI, 4-20mA	<1% mernog opsega
Pressure sensor	Pressure of primary return water	WIKA	0	16	Bar	AI, 4-20mA	<1%
Temperature sensor	Secondary supply water temperature	CTS-1/Pt Pt1000	-50	+200	oC		
Temperature sensor	Secondary return water temperature	CTS-1/Pt Pt1000	-50	+200	oC		
Pressure sensor	Pressure of secondary return water	WIKA	0	6	Bar	AI, 4-20mA	<1%
Temperature sensor	Outdoor air temperature	STS/Pt, Pt100	-35	+50	oC		

The following statuses/sizes are also displayed:
Circulation pump operation status for the secondary network (for each pump)
Circulation pump operation status (manual / automatic)
Failure of the circulation pump bimetallic strip (for each pump)
Electromotor control valve operation status (opening/closing)
Control valve position status (fully open - 100% / fully closed - 0%)
Set temperature of the secondary supply water (process parameter)
Water flow to the consumer (parameter from ultrasonic heat energy meter)
Current power of the heat substation (parameter from ultrasonic heat energy meter)
Cumulative heat energy delivered (parameter from ultrasonic heat energy meter)

Table 3. Characteristics of sensors in the circuit of a typical consumer in the District Heating System

Sensor/device	Description	Type, manufacturer	Min	Max	Unit	Signal type	Accuracy
Heat energy meter	Ultrasonic	Depends on the consumer					
Temperature sensor	Primary supply water temperature from the meter	Pt100					
Temperature sensor	Return temperature of primary supply water from the meter	Pt100					
Pressure sensor	Pressure of primary supply water	WIKA	0	16	Bar	AI, 4-20mA	<1%
Pressure sensor	Pressure of primary return water	WIKA	0	16	Bar	AI, 4-20mA	<1%
Temperature sensor	Temperature of the secondary supply water	CTS-1/Pt Pt1000	-50	+200	ºC		
Temperature sensor	Temperature of the secondary return water	CTS-1/Pt Pt1000	-50	+200	ºC		
Pressure sensor	Pressure of the secondary return water	WIKA	0	6	Bar	AI, 4-20mA	<1%
Temperature sensor	Outdoor air temperature	STS/Pt, Pt100	-35	+50	ºC		

The following statuses/sizes are also displayed:
Secondary network circulation pump operation status (for each pump)
Circulation pump operation status (manual/automatic)

Failure of the circulation pump bimetallic strip (for each pump)
Electromotor control valve operation status (opening/closing)
Control valve position status (fully open - 100%/fully closed - 0%)
Set temperature of secondary supply water (process parameter)
Water flow to the consumer (parameter from ultrasonic heat energy meter)
Current power of the heat substation (parameter from ultrasonic heat energy meter)
Cumulative heat energy delivered (parameter from ultrasonic heat energy meter)

By implementing these modern solutions, the following objectives are achieved:

- Savings of delivered or produced thermal energy (automatic regulation of secondary water temperature based on changes in outdoor air temperature and limitation of maximum flow rate of each heat substation).
- Ensuring quality heat supply (remote management of heat substations from a single location - balancing and even distribution of thermal energy).
- Reduction of district heating system operation costs (automatic control and monitoring of operation, functional parameters, and equipment conditions enable planned preventive maintenance, reduced number of failures, longer lifespan, and lower maintenance costs).
- Increase in the availability of the district heating system (continuous automated monitoring and reporting (statuses, warnings, and alarms) in the dispatch center reduce intervention and downtime).
- Facilitating better payment rates and rational consumption (introduction of a system for individual measurement, registration, and calculation of delivered and consumed thermal energy for each consumer).
- Optimization of investments and preservation of investment value (application and transfer of technology and knowledge - end-user training - provision of technical support and spare parts (10-20 years)).

3. Characteristics of the heat substation

The measurement was conducted in a residential building, block 12, in the residential area "Stevan Sindelic" in Niš. The building is connected to the district heating system. The distribution of hot water is provided from the boiler room located within the Faculty of Mechanical Engineering building in Niš. A central heating system with hot water 90/70 °C and forced circulation is adopted for heating the building. The system is a two-pipe system with bottom water distribution. Steel radiators of the "Jugoterm" type are adopted for heating elements. All radiators are equipped with radiator valves and radiator thermostatic valves with thermostats. Thermostatic heads and heat meters are installed in one reference apartment (apartment number 2), and only heat meters are installed in the other two reference apartments. Hot water supply is provided from the substation, which consists of a mechanical (thermotechnical) part and an electro-energetic part.

The thermotechnical installation consists of:

- Heat exchanger Q = 600 kW,
- Adjustable flow regulator with integrated electromotor control valve (combination valve), KV-050/32 "Feniks BB" Niš
- Ultrasonic flow meter, which is an integral part of the heat energy meter,
- Circulation pumps,
- Sensors for measuring water temperature in the secondary part of the installation (supply and return water)
- Sensors for measuring outdoor air temperature.

The electro-energetic part contains a microprocessor regulator, a computing unit of the heat energy meter, a module for dual communication, as well as accompanying electrical equipment housed in the electrical cabinet: circuit breakers, contactors with overcurrent protection, switches, etc.

Connecting the heat substation to the distribution network of the district heating system is achieved via a plate heat exchanger. The heat substation performs qualitative-quantitative regulation of thermal energy delivery to consumers. Qualitative regulation is achieved by changing the water temperature in the primary water return of the district heating network depending on changes in outdoor air temperature, directly at the heat source (boiler room).

Quantitative regulation is achieved by local flow regulation in the heat substation. The task of the automation is to regulate the room temperature indirectly through the regulation of water temperature in the supply water of the secondary circuit. This function is performed by a microprocessor regulator (4-point regulation has replaced 2-point regulation), acting on the electromotor combination valve. The installed regulator XF5000 has replaced the existing MR5007/Q, both products of FeniksBB from Niš.

The central regulator in the boiler room is connected via GPRS to the regulator in the heat substation, which performs local regulation, thus ensuring data transmission in both directions: from the system to the operator and vice versa.

A system overview and remote parameter modification are enabled. Additionally, the central control system operator has insight into the statuses of all electrical drives and the ability to issue unconditional commands to all electrical drives (switching on, off, opening and closing valves).

4. Presentation of the CENUS program application

The ultimate goal of the district heating system is to achieve the desired temperature in heated rooms, as defined by the project conditions (target temperature = 20°C). This is achieved by regulating the temperature of the distribution water in the secondary network, changing the set values of system parameters via a sliding diagram. When defining the sliding diagram, consideration must also be given to the accumulation of thermal energy in the building itself. For this reason, instead of the classical fixed regime (90/40°C secondary supply water for external conditions of -15/12°C), remote control enables more frequent changes in the regime, with significantly lower values of the sliding diagram temperature.

Figure 6 shows a comparative diagram of the change in the temperature of the primary water in the secondary network tost (measured secondary supply water temperature) and trac (calculated secondary supply water temperature), the outside air temperature (ts), and the inside air temperature (tu) over time, after the implementation of the SCADA system and with the old type of controller (left) and the new type of controller (right) [5].

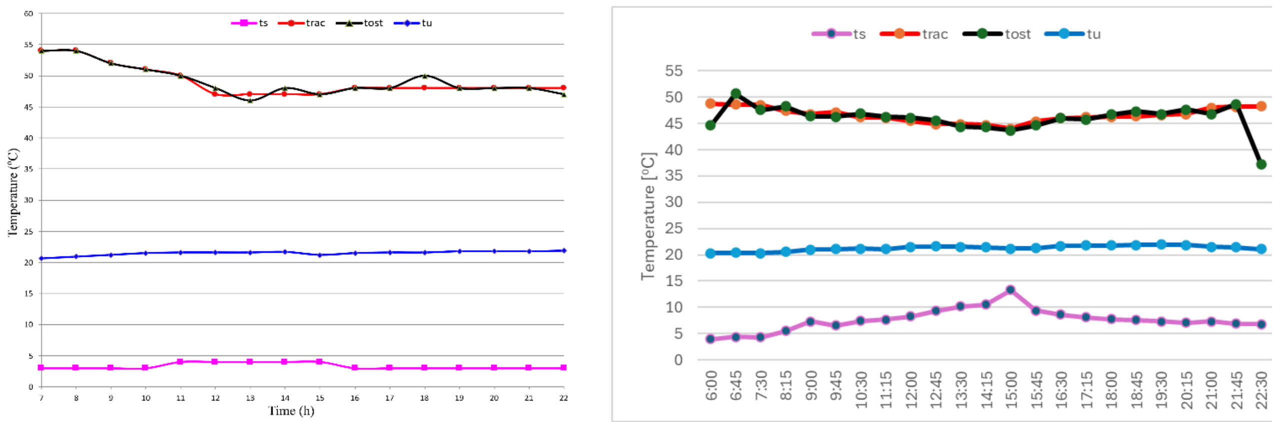

Figure 6. Diagram of temperature change with the SCADA system (tost - measured secondary supply water temperature, trac - calculated secondary supply water temperature, tu - indoor temperature, ts - outdoor temperature)

The diagram of temperature change before the implementation of the SCADA system is shown in Figure 7.

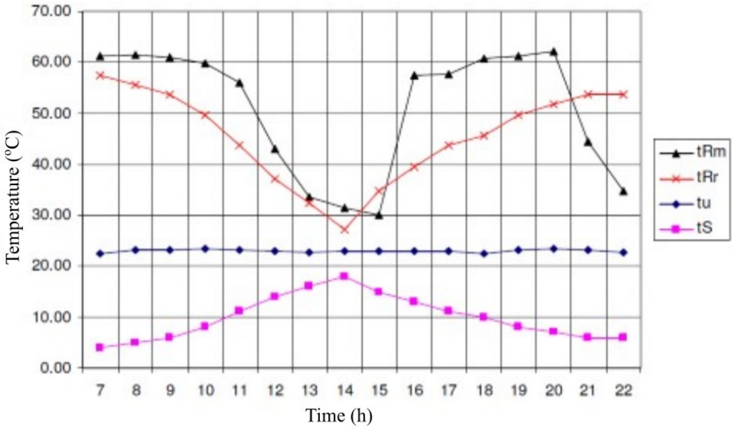

Figure 7. Diagram of temperature change without the SCADA system. tRm - measured temperature of the supply water in the secondary circuit, tRr - calculated temperature of the supply water in the secondary circuit, tu - indoor temperature, ts - outdoor temperature

From the diagram, it can be observed that the air temperature in the reference room was slightly higher than projected, but it was well regulated throughout the day primarily by the temperature of the supply water. The temperature of the supply water in the secondary circuit closely followed the trend of the calculated temperature values with the implementation of the SCADA system, mainly through changes in the sliding diagram (to a value of 60/40°C). In the case without remote monitoring and control, the temperature of the supply water in the secondary circuit was at a higher temperature level (averaging around +10°C), which represents an opportunity for savings and increased system efficiency.

5. Conclusion

Based on all measurements and the presented characteristic changes, the following conclusions can be drawn:

- The temperature of the supply water in the secondary circuit should follow the trend of calculated temperature values.
- The sliding curve of the supply water temperature in the secondary circuit should be adjusted to the characteristics of the facility, i.e., its thermal storage capacity, and should accommodate changes during the heating day.
- Changes in the sliding curve during the heating day are only possible through remote control, and such operation mode offers the potential for significant energy savings. Of course, provided that user comfort (indoor temperature) is not compromised, as evident from Figure 6.

Acknowledgements

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