UDC 697.34:004.94-043.61

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DEVELOPMENT OF ELECTRONIC MODEL OF HEAT SUPPLY SYSTEM OF A CITY BASED ON TEPLOGRAPH INFORMATION GRAPHICS SYSTEM FOR TOWN OF DOBRYANKA, PERMSKIY KRAI, RUSSIA

Abstract

Analysis of existing challenges in heat supply systems of the cities showed that most of them appear due to spontaneity of the heat supply systems development, due to almost complete absence of updated data of the process data sheets and due to absence of a single recording system for defects and regular maintenance.

One of the key solutions of the objective for enhanced efficiency of a city heat supply system management is development of a single heat supply scheme based on up-to-date information-and-analysis systems, for example, based on software application of information graphics system 'CityCom - TeploGraph'.

Our report investigates development of on-line heat supply system for the town of Dobryanka, Permkiy Krai, Russia.

Client: Dobtyanka Heat-and-Power Complex JSC (Joint Stock Company).

Contractor: Power Systems Maintenance LLC (Limited Liability Company) in association with students of PNRPU and NRU Higher School of Economics.

Computerized simulation of the processes in the heat supply system of a city allows to estimate parameters of the current operation at the maximum possible accuracy, to calculate reliability, to investigate various options for future potential development of the system and within shortest timeframe to determine efficiently optimum solutions of heat supply of consumers in emergency situations which is extremely vital question in cases of low negative temperatures of the ambient air in the Ural region of Russia and in other parts of the world.

Keywords: heat energetics, heat supply system of a city, heat network, hydraulic simulation, on-line operation, accuracy, reliability, safety, accidents precaution.

General Description of the Facility under Investigation

Population of the town of Dobryanka is approximately 30 thousand people.

Heat energy is supplied by Production Process-and-Heating Boiler Plant of Inter RAO - Power Generation JSC (affiliate with Permskaya GRES power plant), installed heat capacity is 298 Gcal/hr. Temperature chart for direct supply and return water is 150/70 ^{0}C trimmed to 130/70 ^{0}C.

Heat energy consumption of the town (maximum) is 85 Gcal/hr (based on data provided by heat supply enterprise). Quantity of Central Heat Supply Station - 1, Individual Heat Supply Stations ~ 500. Length of heat supply lines is 101 km (double tube representation).

Objectives and tasks of the project, implementation means

The objective was defined as to generate **the first on-line heat supply system** of Dobryanka-town and to perform comprehensive analysis of heat supply system aiming to produce a package of measures intended to optimize the whole heat supply system. Solution of this objective allowed cutting the costs to a minimum level in terms of heat energy transfer from the heat source up to the end consumers, to calculate heat losses, to investigate various emergency situations and methods to minimize the damage from the non-standard situations (line ruptures etc.). [1-10]

Creating an integrated information system

Description of available source materials at the time of start of the project implementation is as follows:

- A list of users with their contractual loads based on data of subscriber service of a heat-supply company.
- Outdated but in the most cases still valid data provided by the Bureau of Technical Inventory of Dobryanka-town which is given in the form of data sheets of the trunk and quarter-based networks provided as diagrams showing the angles of turns, expansion joints and lengths.
- Schemes of heating chambers indicating current shut-off and control valves.
- Outdated utility database of Dobryanka-town (as of 1987), which acted as the main source of geodetic marks of heat supply networks (the Baltic system of elevations).

Creating a graphical representation of the urban area and of the heat supply system

The first challenge we had to face, when establishing the data base, is the generation of up-to-date electronic plan of the town with the valid addresses registry, and provision of details and topographical reference of the pipeline routes including the quarter-based piping networks.

The source was the existing copies of the obsolete maps of field survey maps M1:2000. The hard copy materials were scanned in portions. The bit-map images obtained were linked to the grid of the map at the overall coverage map, followed by conversion to the vector images by the CityCom SW package and simultaneous identification of the urban development and their addresses. The electronic plan was developed through this technique with coverage of almost all of the urban area which is practically true to life. Some deviations with the up-to-date reality of the urban infrastructure happened to be insignificant.

The town map was also amended with the help of satellite view provided by the Yandex Maps. The missing facilities in the newly generated model was really insignificant (approximately 10 buildings), that we made a decision to add them manually with the help of the TeploGraph SW.

Still the key issue for elaboration of the heat supply diagram of the town was obtaining of the up-to-date data about the heat supply system status. The heat supply company provided a layout sketch of trunk and quarter-based pipelines, and location of associated Booths and Heat boxes in DWG format which was created in the AutoCAD SW. This plan was successfully integrated into TeploGraph SW and through the layers method was applied to the generated model of the town. Hence, we developed the electronic map of the town with a draft- refer end of the heat networks layer. This was the end of the preparatory activities.

The next stage of elaboration of the online map of the town heat supply system was to manually draw the heat supply networks and their facilities to the town plan. This work was followed by simultaneous filling of the data sheets and recording of the engineering diagnostics results in the database. As the snap shots were fed into the informational-graphics system with provision of the descriptions of the networks, our field crew effected the survey, diagnostics and obtaining of the datasheet parameters. The same crews performed comparison, while the operators made a mendments to the data for the internal connections of the pipelines within the heat boxes and description of the valves.

Simultaneously based on the data from the heat supply company and parameters of the heating units of users we provided details and clarifications to the parameters of the heat consumptions by the users, and this data was also fed into informational system. Content soft of the data base was performed in strict compliance with the technique prescribed by the CityCom SW for mathematical modelling of the heat supply networks. Respectively, by the time of datasheets completion for ach completed segment of the heat supply networks sketch (starting from local source up to terminal equipment inputs), we actually generated its mathematical model for the hydraulic calculations.

The finishing stroke in development of this model was its calibration, namely making the calculation results consistent with the pressure readings data at the reference points under certain conditions.

The suppressors evaluates for the purpose of the system calibration were taken from daily lists provided by the heat supply company. Based on data of the heat metering devices at the output of the Power plant in 2014 we performed analysis of the heat supply in the cold (heating) season and in non-heating period.

Actual data of provided heat during the cold season was calculated against rated ambient air temperature, we determined the peak heat load at the outlet of the heat supply source: **Qmax=83.7 GCal/h.** Actual data of provided heat load during the non-heating summer period defines the heat load at the outlet of heat supply source which is used to ensure hot water supply: **Qhot water sup.aver.=11GCal/h.**

Heat load at the outlet of heat supply source when calculated against ambient air temperature **tamb.=-35^{0}C** is comparable to the contractual loads of users which is an important practical conclusion.

Analysis of heat on the results of the readings of thermal energy

Based on results of the facilities data sheets update of the heat supply system we made hydraulic calculation of heat supply networks.**The calculation shows unsatisfactory hydraulic performance in certain local areas:**

- Available head of the users at the pumping station upper zone is 8-9 m of water column which is unstable for normal operation of elevator type units of the users.
- The minimum pressure in the supply pipeline in the units of the private houses districts from AP-11 plant is 26 m of water column, which is less than the boiling point pressure of the heat-transfer agent under rated temperature. The maximum possible temperature of the heat-transfer agent under rated pressure in the unit is 135 ^{0}C, which corresponds to a predetermined temperature range.

The proposed recommendations based on results of the description and hydraulic calculation of heat supply networks are as follows:

- Perform overhaul (industrial safety expertise appraisal only is allowed at the first stage) of certain areas of heat supply networks followed by replacement of pipeline having service life at least 30 years. Special attention should be paid to a trunk pipeline with no redundancy 2DN500 at the distance from Booth No.3 to Arbitrary point No.65 which has been in operation since 1979.

- In order to ensure satisfactory available head at the upper zone of pump station and to avoid boiling of heat-transfer agent under temperature exceeding 135 ^{0}C we propose to increase pressure at the supply pipeline at the outlet of Power plant followed by adjustments at the users of the upper zone of pumping station.
- In order to enhance system reliability and survivability it would be better to construct the 3rd supply pipeline 1Dn500 at the area from booth No.3 up to arbitrary point No.65. In this case increase of pressure at the heat source outlet can be omitted.

Key results of the project

The generated computer model of heat supply system with the database including process data sheets which was revised and updated upon engineer diagnostics results has allowed reaching the objectives of the project.

With the existing scheme of the consumers hookup we managed to calculate the design parameters of the adjustment tools of the consuming users in such a way as to equalize the hydraulic parameters of supply from the source up to the most remote consumers, hence ensuring more saving and more efficient way to give load to the heat source and central heat supply system.

When these measures are implemented this will cut the specific costs for supply of the heat energy and to ensure proper and sufficient heat energy to the most extreme and remote consumers under the assumption of non-growing production of heat energy sources.

The potentialities for multi optional simulation of hydraulic operation control have allowed selecting the optimum solutions in terms of quality and implementation costs during generation of prospective plan for heat supply in the town.

Within the framework of the project we also investigated various emergency situations, the diversity of such situations predetermined involvement of young and promising manpower, namely the students. Section 'Isolation of emergency and non-standard situations' includes recommendations for practical and smart switching of the valves, and recommendations for installation of additional valves which is deemed necessary for enhanced efficiency of the heat supply system functioning of the town in general.

The recommendations regarding 'Isolation of situations' covered more than 30 various emergency operation modes and three proposals for installation of additional valves, one of the most significant examples is the installation of additional cut-off valve in a pipeline Dn700 close to booth No.0.

Aiming to split the heat supply system of the town into two lines of Dn 500 during summer operation **will enable to avoid heat losses only in one supply pipeline Dn700 amounting to 2332.2 Gcal per year. Saving for the heat transfer company will amount to $ 30172.89 per year.**

Data about the quality and status of the heat insulation which is fed into the database that was obtained during the troubleshooting in conjunction with the hydraulic simulation allowed estimating the consolidated and reduced heat losses for each of the rated modes of heat delivery and heat consumption. This calculation is one of the most important final results, since the values of heat losses are introduced into cost rate for heat energy transfer from the source to the end user, and the measures aimed at cutting such heat losses will allow to significantly reduce the cost for the transfer of heat energy.When the generated model of heat supply system is submitted to the heat transfer company the company obtained a powerful tool to control routine tasks in general production and distribution processes.

Namely, in case of prompt distribution control the quality of the decisions and a higher degree of the 'emergency persistence' can be achieved due to the fact that any combination of actions (switch ON and OFF of pumping units, scheduled and emergency switching in the chambers, regulatory measures etc.) can be simulated in the computer model prior to their real implementation. This allows to estimate the consequences of expected actions and to minimize the risk of errors which may cause an emergency.

Issue of technical specifications for connection of new consumers or amendment of the contractual loads can be preceded by the verification of implementability of the requested requirements at the computational model of the existing network. It will be significantly easier to issue prompt reporting of selected parameters, extracts of data, reports of the heat supply system in general and for certain elements thereof. The data in the system can be simultaneously used by any amount of users of the company LAN. And any current modifications in the reference database implemented in accordance with the updating provisions will immediately be available to be accessed by any involved department.

The informational project described above was implemented 'from scratch' within less than two years. Numerous steps of designing, analysis and calculations were performed by students of PNRPU in association with NRU 'Higher School of Economics', two students are current employees of Power Systems Maintenance LLC. Two other students were involved in the research as young specialists in the sphere of Power Management.

Reference

1. About energy saving and energy efficiency improvements and about modification of certain legislative acts of the Russian Federation: the federal law from 23.11.2009 N 261-FL: ed. by 29.12. 2014 // Consultant Plus [Electronic resource: reference legal system: documents and comments: touring. inf. resource]. - Professional version, network. - Moscow, 1992.

2. About organization of heat supply in the Russian Federation and about modification of some acts of the Government of the Russian Federation: Governmental order of the Russian Federation dated August 8, 2012 N 808 // Consultant Plus [Electronic resource: reference legal system: documents and comments: touring. inf. resource]. - Professional version, network. - Moscow, 1992.

3. About the procedure for determining the standard process losses for heat transfer, heat transfer medium, norms of specific fuel consumption in the production of thermal energy required reserve of fuel for thermal energy sources (except for sources of thermal energy, functioning in the mode of combined production of electricity and heat), including for the purpose of state regulation of prices (tariffs) in the heating sector: Order of the Ministry of Energy of Russia from 10.08.2012 N 377: ed. By 22.08.2013 // Consultant Plus [Electronic resource: reference legal system: documents and comments: touring. inf. resource]. - Professional version, network. - Moscow, 1992.

4. Rulebook "Heating networks" actualized revision SNIP 41-02-2003 // Consultant Plus [Electronic resource: reference legal system: documents and comments: touring. inf. resource]. - Professional version, network. - Moscow, 1992.

5. Rulebook "Water supply. External networks and facilities "actualized revision SNIP 2.04.02-84 * // Consultant Plus [Electronic resource: reference legal system: documents and comments: touring. inf. resource]. - Professional version, network. - Moscow, 1992.

6. V.I. Manyuk Startup and operation of the water heating networks. Directory. / Manyuk V.I. [et. al.] M.: Stroyizdat, 1988

7. A. Nikolaev "Design of heating networks". Directory designer / Nikolai A. M .: Stroyizdat, 1965

8. I.V. Belyaykina Water heating networks: a handbook on the design. / Belyaykina I.V. [et al.] M .: Stroyatomizdat, 1988

9. Citycom [Electronic resource] / Publishing house «Citycom» - Moscow. - Access: http://www.citycom.ru

10. Information system for heat supply [electronic resource] / Publishing house «ROSTEPLO.RU» - Moscow. - Access: http://www.rosteplo.ru