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Wireless Monitoring And Control At Urban Heating Supply System

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ABSTRACT

The paper describes the functioning of the SCADA system for urban heating supply system. The proposed structure enables a stable and reliable data transmission from the modular boilers and central heating stations to the central dispatch server as well as the commands from this center at the PLC (Programmable Logic Controller) automation devices. The connection between the heating stations and the dispatch center is established with wireless data transfer using sensor networks (ZigBee) and mobile cellular networks. The operator in the dispatch center can monitor the functionality of the district heating networks on the SCADA screen, and alarm reports assist in locating faults, which contributes to a significant increase in maintenance efficiency.

Keywords: Monitoring, support decision, heating supply system, energy consumption, energy efficiency, SCADA, wireless sensor network, heterogenic network

INTRODUCTION

The main objective of district's water and heat supply of the city is to ensure consumers a desired quality hot and cold water for a given level of comfort and conditions payment of these services depending on the volume of consumption. In most region of the Russian Federation, the urban heat supply traditionally ensured by powerful central heating systems (CHS) based on thermoelectric steam power plant with cogeneration turbines of various capacities. District heating is a technology that transports energy in the form of hot water or steam from a central heat plant to customers, used mainly for collective heating systems in residential quarter of blocks with dense buildings. District heating supply system (DHS) is created on the basis of central heat supply stations (TSC), where located not only heat power equipment, but also plumbing, gas, electrical and fire-fighting equipment, making them centers of energy services. The buildings of different types of energy from the sources of its generation (cogeneration heat and power plants, boiler-houses and others) is served in four-, six-, and eigth-pipe distribution heat-supply pipelines.

In such systems, district heating power TSC taken from 12 to 35 MW (the sum of the maximum heat flux on the heating and the average hourly flow for hot water). Currently used transportable modular boilers-houses (MBH), which allow to reduce the cost of thermal energy by reducing the cost of heat supply stations, losses for transporting energy to the buildings on the pipelines. Individual heating items (IHI) is based on producing heat energy by the heating equipment inside a building. Such way of heating is typical for DHS in Russia. DHS satisfies demands of significant part of the customers both residents and industrial clients.

THE MAIN PROBLEMS

The disadvantages of DHS might include:

- low energy efficiency and great heat losses during energy transportation ,
- lack of technologies automated regulation at heat-separate buildings, depending on weather factors (outdoor temperature, wind speed and direction, pressure, humidity, etc.),
- lack of automatic possibility rapid transition to reduced or elevated temperature schedule depending on current weather conditions,
- low reliability heat and water supply systems,
- limited ability to backup thermal power heat sources due to the concentration of thermal power on TSC and radial structure deadlock heating networks,
- a significant imbalance of heat and overrun heat energy (30-50% of the calculated values),

A fundamental problem with transporting heat energy is losses to the surroundings during transportation due to insufficient insulation of the distribution pipes and heat substation leaks because of usage defective pipes and equipment. In Russia, energy losses in the distribution network can reach up to 70% in old and poorly maintained systems. Emergency situations at the district heating source or central pipelines of heating networks can lead to significant and long breaks in the heat supply to consumers and etc.

To solve the problems to be a shift from the district heating system to individual heat supply at buildings and individual consumers. This scheme will allow, to approach heating system to the end user, to reduce costs and losses during transportation heat energy. Secondly, necessary to go at the individual accounting energy for the end user. Third, the introduction of energy management systems will enable operative building energy management, depending on the changes in various internal and external factors, with the abandonment of the existing rules and regulations [1].

The most problems is solved by using a decentralized system with individual house or apartment heating points (IHP). Heat transfer points closer to end consumers increases the effectiveness of automatic thermal regulation heating, hot water supply quality. With automatic correction of thermal schedules depending changes in the outdoor and indoor temperature reaches a great heat savings. The problem also is practically solved by installing in each building buildings and individual metering devices of heat and water. Complex systems of intellectual analysis and forecast heat and hot water consumption for urban district and individual buildings are still only beginning to be created. Solution of the third problem also is still in the initial stage, in spite of the existing experience in creating energy management systems in Europe, where in 2011, operates an appropriate standard ISO 50001:2011 [2].

DECISION SUPPORT SYSTEM

For monitoring and analyzing the parameters of the heating consumption, as well as characteristics of the operations to improve energy efficiency and reduce fuel consumption and heat losses in the generation, transportation, consumption and disposal of heat energy, is developed and implemented SCADA system. The main purpose of these systems is automated data collection and data processing about heat consumption objects. Today SCADA (Supervisory Control And Data Acquisition) is a system for measuring, data collection, monitoring and control of industrial systems [3]. The SCADA network consists of one or more MTUs (Master Terminal Unit) which are actually computer stations equipped with appropriate software and operating system. These stations are used by operators to monitor and control one or more RTUs (Remote Terminal Unit). RTU is also a computer device which is typically designed for use in industrial environments. Its job is to collect data from a digital and analog sensors or transmit commands to devices which in some way alter the status of the managed system. The standard of different wire networks (Ethernet, Modbus, ProfiNET, etc.) are used for data transfer between MTU and RTU [4].

However, as in the case of DHS, and the introduction of IHP, it is necessary to develop decision support system (DSS) with OLAP, situational analysis, forecasting to optimize energy consumption and energy efficiency with the ability to rapidly respond to changes in different factors [5]. Such systems are designed to upgrade dispatching SCADA systems. The synthesis and implementation of the decision support system (DSS) has a goal to achieve energy efficiency in the process of supervisory control and accounting. The main functions of the DSS, we assume the following:

1) Collection and processing telemetry information to the dispatch server about the heating objects, heat and hot water consumption;
2) Data transmission to the dispatch server via the heterogeneous wireless network in various ways depending on the object distance (using directional antennas, the intermediate repeaters, GSM/GPRS cellular modems);
3) Preparation of timely and accurate information on energy use in real time;

4) Cloud management data warehouse to support decision-making on energy efficiency, reducing energy losses, protection of utilities, population and energy;
5) Operational control of the process heat generation, heat and hot water consumption when changing external factors;
6) Accounting and control costs for the use of various forms of energy;
7) Acquisition, processing and analysis of information on energy for heating units and buildings;
8) Multivariate analysis and forecasting of energy consumption on heating units and end-users;
9) Monitoring of abnormal and emergency situations at heating units and heat pipelines;
10) Modeling and evaluation of crisis situations in relation to objects, subjects and energy and evaluate possible consequences;
11) Forecasting threats to the population and engineering communications, the study of the dynamics change their protection, depending on natural, technological and human factors
12) Analytical processing of data using a multidimensional and geospatial analysis to visualize and provide the results of analysis, forecasting and modeling for decision-makers
13) Decision support for the implementation of measures to ensure the safe operation of utilities, safe transporting energy, prevention and localization of crisis situations and emergency response;
14) Providing safety of information resources for decision support systems from unauthorized access and other information-related threat
15) Remote access to the monitoring results and multivariate analysis of mobile communications. Locating and tracking the movements of mobile communications managers [16] and emergency repair services for timely alert decision-makers about the events at the monitoring objects in order to implement contingency management and prevention of abnormal and emergency situations;
16) Presentation and visualization of information in the form of structured reports, charts, graphs and recommendations. Presentation of the monitoring results to display on city maps, plans and schemes of engineering communications using GIS technologies (Fig. 1).

HETEROGENEOUS WIRELESS NETWORK

Heterogeneous networks for monitoring of heat supply system may include [6]:

1. Terminal clusters of ZigBee network with sensory nodes associated with industrial automation devices, various sensors, fire and security alarm systems, which are running coordinator.
2. Terminal clusters of Bluetooth network with nodes associated with industrial automation devices, various sensors, fire and security alarm systems, which are running master device [7].

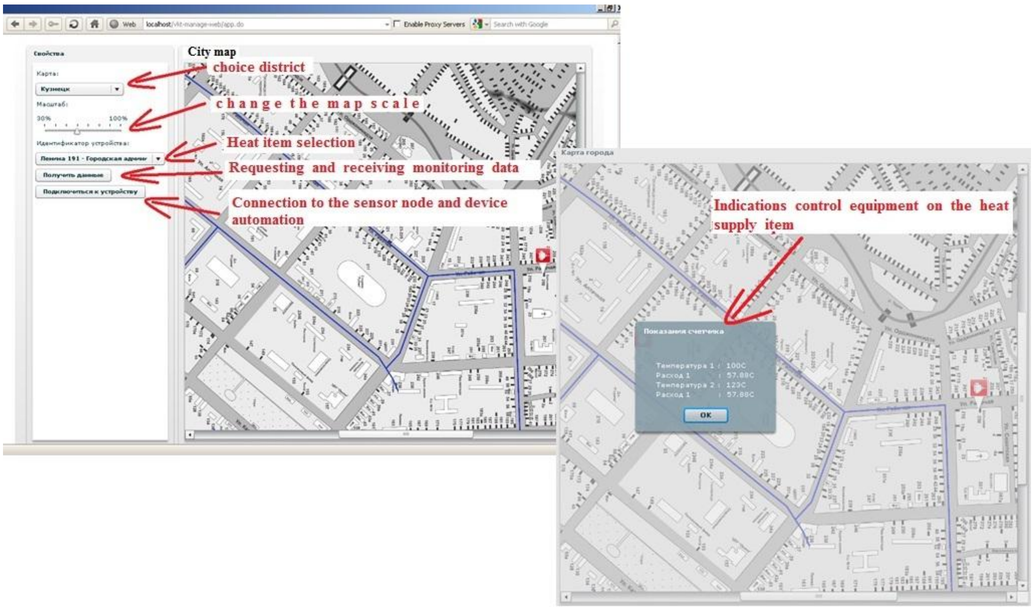

Fig. 1 Visualization telemetry data on city maps

3. Cellular network of mobile operators to collect data from remote sites which are difficult or not economically feasible to maintain the chain of sensory repeaters.
4. Satellite navigation system for the transport monitoring of company's vehicles.
5. WiFi or Ethernet LAN segments on a heat points and control rooms.
6. Internet segment to remote access to information resources SCADA system.

To ensure the required communication range in urban environments, you can use the following methods of data collection via wireless network:

1) Installation and connection GSM/GPRS modems to relay collected data with heat calculators and other energy meters via a cellular network. As a method of transmitting information, GSM-systems use SMS-messages, modem connection (CSD), the transfer of parcels tone mode (DTMF) and a packet messages (GPRS). For today a wireless system based on GSM are widely used due to their relatively low cost and simplicity of installation and operation. Controllers with built-in GSM modem installed on objects the heating network and ensure the collection, storage and processing of data from a variety of meters (electricity, heat, gas meters, etc.) with subsequent transfer to the dispatch server via GSM / GPRS-connection channels. However, a significant disadvantages of these systems is low jamming immunity, low stability of cellular communication, openness cellular network to a variety of attacks, depending on the workload of the cellular network's, financial dependence from the provider cellular network.
2) Installation and connection of sensor nodes Zigbee on objects the heating network (TSC, MBH, pipelines), their amalgamation into a cluster of sensor

network (Fig. 2), facilitates the wireless communication cluster coordinator with the central control server, using:

a. remote antennas with a high gain;
b. low-power sensor network intermediate repeaters, that can be installed:

- at high buildings or poles of power lines;
- On the ground measuring terminals for underground heat pipelines with remote control leaks, which are set at 300 meters. In this case, the repeater can also be used for leak detection and localization.

Wireless sensor network are ideal for the implementation of the DSS and SCADA [9]. The sensor network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment [10]. There are four basic components in a sensor network: (1) an assembly of distributed or localized sensors; (2) an interconnecting network (usually, but not always, wireless-based); (3) a central point of information clustering; and (4) a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining. The sensor units is used the so-called sleep mode and sends data to the master device only on call or in case of alarm detection [11]. In this case the company uses a virtual private network for the collection of data, that allows to provide the information security of the SCADA system, reduce the cost of services to providers of cellular network, eliminate dependence on them [11].

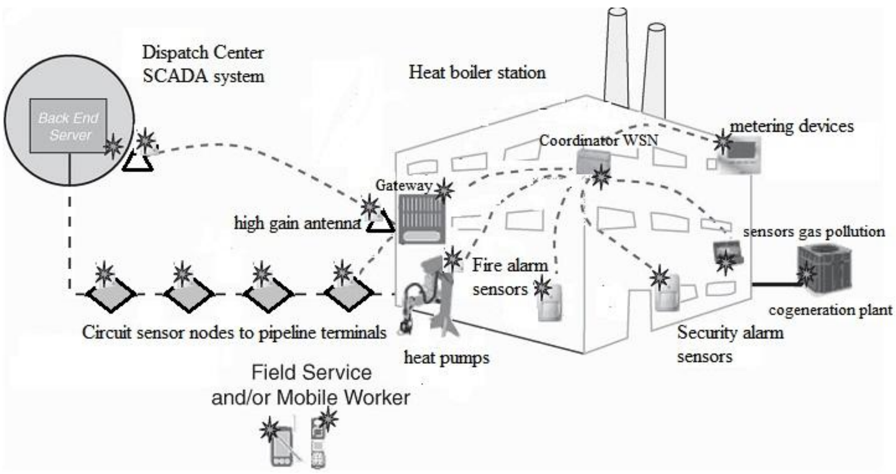

Fig. 2 Sensor network cluster (Zigbee) at heating items (TSC, MBH)

At the organization direct data transmission channels on the server on the terminal heating units installed directional antenna type ANT 2.4 YA-R03 (Pro-Cell) with a gain of more than 12 dBi, which provides connection to 10 miles in direct view, which is enough to create a wireless network in the urban district. If in urban areas is not possible to provide direct radio to transmit data to the control server, you can use the repeating intermediate sensor nodes that provide technologies for building sensor network mesh topology, Such nodes WSN can be installed on power poles or tall buildings to provide power supply to devices.

Another interesting solution is to place the sensor repeaters on the inland terminals, which are equipped with modern underground heat pipelines with a wired remote control system (RCS). This is possible if the urban heat network uses double pipes with internal insulation and wiring system for the control of the moisture insulation. Connecting to the RCS conductors is performed by the measurement points, called terminals, which are connected to the pipe conductors and is outputted to surface (Fig. 4).

According to the standards terminals set every 300 meters and on the branches over 30 meters, and the final - at the ends of the track. This wire system pipe in the insulating layer can be used to supply power to the sensor nodes. Thus wireless repeaters terminals will be used to transfer data from sensor nodes installed in heat points, along the chain to the dispatching server.

For large urban areas in terms of creating a reliable transport medium for telemetry data collection and transfer should use all types of available wireless networks [12]. This will create a reserve data channels. In this way can to submit the wireless heterogeneous network for collecting and processing data from geographically distributed technogenic objects to support the dispatch SCADA system (Fig. 3).

CONCLUSION

Decision support system based on distributed monitoring instrumentation and control equipment of energy consumption on objects of engineering communications can improve management efficiency, optimize energy consumption, implement a system of early warning freelance and emergency situations, minimize repair costs of engineering communications.

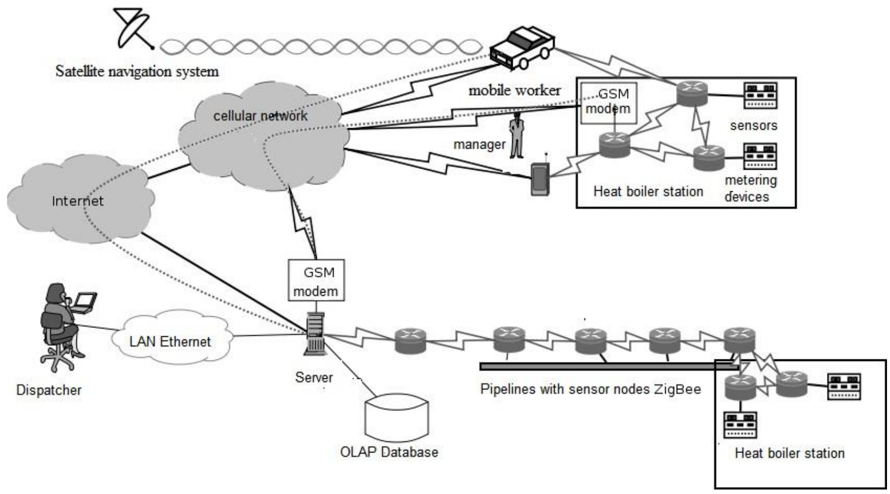

Fig. 3 - Wireless heterogeneous network for SCADA system

In conclusion, we list a number of major challenges, that arise before developers of SCADA systems for dispatching services:

1. The problem of "opacity" of information. It is known that most of the information systems implemented even within the same company, store data and results in a form unsuitable for use by other systems. Software developers and hardware do this intentionally to get consumers to buy only their products. Proprietary protocols and data formats does not allow to transfer them to another program or or require significant financial, time and labor costs. The company falls into the "informational dependence" from the developer, which is exacerbated by the termination of technical support on his part and can lead to catastrophic consequences.
2. The problem of information's mismatch. This problem is related to a variety of hardware and software systems from different manufacturers to collect and process data and assign them to a specific task. Today, manufacturers of equipment only produces for the heat supply system more than 60 types of devices for data collection and processing parameters with uncoordinated data sets. At different enterprises often use the same data that is collected and stored in various formats, which leads to a mismatch in the data when solving common problems or merger databases. Synchronizing data requires considerable effort and corresponding costs, and control this process is often impossible.
3. The problem of mismatch of information flows in networks. Network technologies to tackle the problem of information mismatch in different departments. However, the absence of a common policy in the use of telecommunications solutions and hardware from different manufacturers and providers leads to a mismatch of information flows in different network segments.
4. Problem of accounting for industry-specific data. The problem is related to the solution of specific tasks within different companies, classified information to third party companies and complexity of information sharing between agencies for various reasons.
5. Problem associated with the lack of energy management systems in the urban heating system. This problem is largely determined by the absence of a single mechanism of interaction between producers and consumers of thermal energy, the presence of intermediaries in the chain of supply of heat energy to the final consumer.

Discussed problems hamper the introduction of new technologies to support decision making, forecasting and energy management and thermal points of heat consumption of buildings to achieve the required energy efficiency.

REFERENCES

1. Combined Heat and Power and District Heating report. Joint Research Centre, Petten, under contract to European Commission, DG Energy 2013. http://setis.ec.europa.eu/system/files/JRCDistrictheatingandcooling.pdf
2. ISO 50001:2011 «Energy management systems – Requirements with guidance for use»
3. Boyer, Stuart A. (2010). SCADA Supervisory Control and Data Acquisition. USA: ISA - International Society of Automation. p. 179. ISBN 978-1-936007-09-7
4. "Introduction to Industrial Control Networks". IEEE Communications Surveys and Tutorials. 2012
5. Finogeev, A.G.; Bozhday, A.S.; Bogatirev V.E. Formalization of the principles and methodology of decision support based on the monitoring of engineering communications Housing / Scientific and practical journal "Public Education" in 2011. Number 2 (86) Part 2., An international conference "Information technologies in education, science and business." The May session, Ukraine, Crimea, Yalta Gursuf, 20-30 June, 2011. - P.210-214.
6. Bershadsky, A.M.; Finogeev, A.G.; Bozhday, A.S. Development and modeling of heterogeneous wireless infrastructures for information support of monitoring // News of higher educational institutions. Volga region. Engineering. Penza Univ PSU. - 2010. - № 1. - With. 36-45.
7. Maslov, V.A.; Finogeev, A.A.; Finogeev A.G. Identification technique and event management of mobile devices based on the technology Bluetooth // Proceedings of Higher Education (Volga region). - Penza, Ed. PSU 2008. - № 1. - P.108-120.
8. Finogeev, A.G.; Finogeev A.A. Mobile sensor networks for decision support. / / Proceedings of the Scientific and Practical Conference. "Innovations in the development of information and communication technologies" (INFO-2009). - . Russia, Sochi, 1-10 October 2009. - With. 146-149.
9. Dargie, W. and Poellabauer, C., "Fundamentals of wireless sensor networks: theory and practice", John Wiley and Sons, 2010 ISBN 978-0-470-99765-9
10. Sohraby, K., Minoli, D., Znati, T. "Wireless sensor networks: technology, protocols, and applications, John Wiley and Sons", 2007 ISBN 978-0-471-74300-2
11. Tiwari, Ankit et. al, Energy-efficient wireless sensor network design and implementation for condition-based maintenance, ACM Transactions on Sensor Networks (TOSN), http://portal.acm.org/citation.cfm?id=1210670
12. Finogeev, A.G. Wireless data transmission technology for the creation of control systems and information support personal / All-competitive selection of an overview and analytical articles on priority "Information systems", 2008. - 51. URL: http://window.edu.ru/window/library?Prid=56177