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2. MODERNIZATION OF A HOUSING ESTATE HEATING SYSTEM WITH THE USE OF ELECTRICITY-HEAT BLOCKS, EMPLOYING GEOTHERMAL HEAT PUMPS AND OTHER RENEWABLE ENERGY SOURCES

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Abstract: A new local heat and power station, supplying heat and energy to two housing estates in Hel, where thermal improvements were introduced, is described in this paper. The technological system of this source consists of three fuel power-heating blocks and two water condensation boilers. Liquid natural gas (LNG) is the fuel. It is stored in a tank on the surface. Electric energy is partly used for feeding heating compressor pumps based on vertical probes, and for electrical heaters – an ideal individual source of heat for one housing estate. Geothermal heat pumps and solar collectors were used in these buildings for preparing warm useful water. The other housing estate is fed conventionally from a local heating system.

1. INTRODUCTION

Industrial and professional power industry is known for using a mixed-type economy, i.e. concurrent production of electricity and heat, to improve its profitability. Owing to a joint power-and-heat production as well as ability to have a central delivery of products, this type of economy turns out to be both profitable and environmentally friendly as far as the use of power minerals is concerned. Because of the high transformation of primary energy, joint economy considerably helps lower energy consumption. Thus, owing to the lower emissions level and smaller mining damage, raw minerals sources and natural environment are protected.

Is this model applied for heat production, waste energy from heat production and the renewables can be utilized for heating purposes. This is a case when renewable energy carriers have a too low temperature for direct heating and heating purposes. A specific energy carrier, especially from unconventional energy sources, can be used through compressor heat pumps, which in their lower source of heat predominantly employ low-temperature energy of, e.g. sewage, groundwater, mine's water, thermal water, atmospheric air and soil. Then, in the upper source of heat, they pass this energy and energy needed for driving heat pumps to the heating network water.

The energy of earth can be recovered indirectly, based on an additional carrier circulating between the heat pump and the heat exchanger. Two types of heat exchangers are applied. Among the most common ones are horizontal collectors disposed ca. 1.2 to 2.0 m b.s. When the space is limited, vertical borehole heat exchangers are used. Various pipe arrays are possible here. Using electrically-driven heat pumps (supplies of the Polish power stations, basing on heat power generation) usually results in a significant lowering of power efficiency of the undertaking, measured by, e.g. chemical energy consumption for a unit of heat, and sometimes its deterioration to the state before heat pumps had been installed. When the heat pumps are driven with electric energy generated in the heat plants within the joint economy model, the efficiency may improve. This can be done thanks to the management of unconventional energy resources.

We can presently observe more and more joint distributed systems in Poland, mainly based on fuel power-heat blocks. They consist of a fuel, piston or rotary engine (gas turbine), driving electric energy generators.

The main causes of such an interest and development of joint distributed systems are:

- independence of central planning procedures,
- no subordinance to the system operator,
- possible co-operation with distribution networks,
- investment advantages (short time of construction and smaller investment risk),
- exploitation advantages (high efficiency and joint operation),
- cost attractiveness,
- possible management of local energy reserves,
- minimization of transmission costs – sources are close to the customers,
- efficient environmental protection – use of natural gas from the Polish gas-power system and from local gas resources.

The economic transformation and constant techological progress in power and heat engineering cause that unconventional energy sources soon will greatly contribute and supplement the conventional systems, especially in view of environmental protection needs and constantly growing organic fuels prices.

Therefore, to rationally use unconventional energy sources, it seems feasible to join the energy sources in one common generation-production complex. In such fuel-fed joint heat-and-power complexes one can expect further lowering of unconventional energy prices.

As already mentioned, more and more joint distributed systems are implemented in Poland nowadays. They are based on fuel-fed power-and-heat blocks. Co-generation in direct heating supplemented by unconventional energy management will be discussed in detail on the example of the latest heat station construed in a housing estate.

Solar energy is planned to be used in one of the housing estates for warm water preparation, therefore let me present some basic data about it.

As already mentioned, transmission of heat between high-temperature waste gases from the fossil fuels combustion and network water results in serious exergy losses. Thus, solar energy radiation can be used to limit these losses and to save fuel.

Solar radiation is a stream of energy emitted by the Sun equally in all directions. Outer layers of the Earth's atmosphere are exposed to an energy stream of 1.36 kW/m^2, i.e. solar constant. Passing though the atmosphere, solar radiation is weakened due to reflection, dissipation and absorption by dusts and gas particles. Solar radiation can be divided into two components:

- direct radiation, i.e. part of radiation capable of getting through the atmosphere,
- dissipated radiation, part of solar radiation reflected or absorbed by dusts and gas particles, which gets to the Earth surface in no-direction.

The sum of these components – total radiation – in optimum conditions (clear, cloudless sky, in the noon hours) is maximally ca. 1.0 kW/m^2. Out of 8760 hrs/annually we can manage from ca. 1400 to ca. 1900 solar hrs. Due to the distribution of these hours throughout the year, the total daily solar radiation on a flat surface is from ca. 2.2 kWh/m^2 in December to ca. 18.2 kWh/m^2 in June. The average yearly sum of solar radiation in Poland is ca. 1000 kWh/m^2. Depending on the type of collector used, ca. 75% of total radiation can be transformed into useful heat.

Because of the temperature level of the carrier used for solar collectors, it seems especially favorable to apply a system employing solar energy for useful water preparation. In the heating season, aditional heat sources will have to be involved to provide sufficient amounts of warm water.

This paper is devoted to a new heat station in Hel, being a joint system producing heat and electric energy. It is based on a fuel power-and-heat block. The heat station has its own source of electric energy, therefore part of the energy can be used for driving compressor heat pumps, feeding the heating systems of one of the housing estates. Lower sources of heat pumps co-operate with the vertical probes, taking the energy of the ground. The buildings are also equipped with solar collectors aiding the process of useful water preparation. Prior to the introduction of a new heating system, the building had been thermally adjusted.

Apart from this introduction, the paper consists of a brief description of the state of buildings thermally improved with the scope of the adjustment as well as a description of the new technological heating system.

2. PREVIOUS STATE AND SCOPE OF THERMAL ADJUSTMENTS OF HOUSING ESTATES

The heat station in question supplies heat and energy to buildings in Hel, in the Coastal Landscape Park. Thermal adjustments, preceded by an exchange of heat sources, were made in two housing estates.

The first of them consists of 25 blocks of flats constructed in the 1930s, previously equipped with tile stoves. Warm water was prepared in individual electrical heaters.

The other housing estate consists of 16 large-panel blocks, constructed in the 1970s. Heat and warm water were supplied from a steam-water underground network, housed in brick canals. The buildings are equipped with water central heating installment (90/70^{0}C), hydraulically regulated with an orifice.

A four-conduit network is installed in the buildings: separately for heating purposes (90/70^{0}C) and separately for warm useful water preparation.

In the older estate, the buildings were given:

- additional thermal insulation on the outer walls, new windows, new roof;

- solar collectors,
- heat pumps, intaking the lower source of heat in the form of vertical probes,
- a new district heating installment based on heat pumps and electrical heating system.

In the large-panel estate, the buildings were given:

- additional thermal insulation on the outer walls, new windows, thermal insulation of the roof,
- modernization of internal installments, i.e. introduction of armatures for automatic hydraulic regulation and thermostatic valves,
- replacement of four-conduit network disposed in underground canals by a pre-insulated network.

A new water boiler place was elevated to supply heat to the large-panel buildings. The boiler station was equipped with 3 block power-and-heat stations and 2 condensation water boilers.

2. TECHNOLOGICAL SYSTEM OF A JOINT SOURCE

The following elements were installed in the new boiler place:

- 3 block power-and-heat stations by Viessmann 2 _ 122 kW + 225 kW, totalling to 469 kW of electrical power and 2 _ 204 kW + 360 kW, totalling to 768 kW heating power, a a basic source of heat, and
- 2 condensation boilers by Viessmann - 895 kW each, being a peak source of heat.

The boiler station was also equipped with:

- two pump nodes for district heating purposes – one for internal instalment of the boiler place, and the other one for pumping water to the external network for the large-panel buildings,
- two-level node for useful water preparation, equipped with a pump system, plate exchangers for warm useful water – primary and final ones, tanks for warm useful water, energy of feedback water from the external network is used in useful water heating primary node for additional cooling the water before it is directed to the power-and-heat blocks and condensation boilers,
- pressure system securing the heating installment,
- accumulation tanks for heating water, cooperating with power-and-heat blocks,
- pump systems at the power-and-heat blocks and boilers,
- cooling system for water directed to the power-and-hear block, prepared for one block of capacity 122 kW, consisting of:
  - ventilator cooling device outside the boiler place,
  - plate exchanger (heating water: glycol solution) outside the boiler place,
  - motor-operated circulation pomp for glycol solution.

Further ventilator cooling devices can be additionally installed.

Liquid natural gas, gathered in the surface tanks outside the boiler place, is used as a fuel in the boiler systems. The main component is evaporated in the form of liquid methane in two special evaporators, naturally heated with atmospheric air, disposed outside the boiler place. After gasification of the Hel Peninsula, a network gas-fed boiler station is planned.

Heat produced in power-and-heat blocks is used as warm water for district heating purposes and warm water preparation in large-panel buildings. Electric energy generated in the power-and-heat block feeds heating systems in the old housing estate. It is based on individual heat pumps and electrical water heaters; the excess of energy is directed to the Polish power network system.

Blocks and boilers are planned to operate in a cascaded system. First, blocks are successively implemented; in the peak period, additional condensation boilers are put to operation.

To eliminate idle time in the power-and-heat block operation in the summer season, caused by a too high temperature of water directed to the blocks (temperature cannot exceed 70^0C), a ventilator cooling device was installed.

To provide a desired minimum temperature for water taken by the blocks, a mixing valve was installed at the circulation pump, which services a given power-and-heat block.

Accumulation heating water tanks were planned to avoid temporary lack of heat from water disposed of by the power-and-heat blocks.

The operation of the whole heat and power system will be visualized to rationally operate and monitor the heating system, in that: a cogeneration source, transmission through heat and electrical energy receivers.

4. DESCRIPTION OF THE HEATING INSTALLMENT IN AN "OLD" HOUSING ESTATE BUILDING

As already mentioned, charcoal tile stoves and water tank heaters were removed from 25 buildings making up the „old" housing estate. Then, typical thermal improvements were made in these objects.

In each of these blocks-of-flats, a new heating system and a system for warm useful water preparation were installed. The system was based on a heat pump and solar collectors. Swedish heat pump Auto Term 309 with a three-grade electrical heater was installed. The heating power of the heat pump was 9 kW, covering about 50% of heat demand; the power of the heater was 9 kW (or, 3 or 6 kW). Soil is the lower source of heat pumps. Vertical probes (extending down to ca. 90 m of depth) collect the energy of soil. A non-freezing fluid circulated inside the probes, supplying the heat pump evaporator, through which the installation water flows. Solar collectors (PKO 3 type), produced by the Sunergy Company, are mostly disposed 6 items per building. Each of them has a surface of an absorber made of selective titanium, equal to ca. 2.6 m^2 , obtaining a maximum power of 2 220 W.

Heat pump supported by a heater feeds the internal installment of the building, based on convective heaters, and an operational tank of 500 dm^3. This tank is connected with the useful water tank of 300 dm^3, also supported by an electrical heater of 6 kW. The solar system, usually based on 6 collectors, co-operates with the tanks. A system of pumps supports the system: circulation district heating pump, mixing circulation pump, low-temperature fluid pump, warm useful water circulation pump and solar circulation pump. The system is also equipped with collector tanks, suitable armature, gauges and control systems

5. RESUME

A new power-and-heat station servicing two selected housing estates in Hel was presented in the paper. Managing of various forms of unconventional energy, e.g. waste energy or energy of renewables, usually requires a joint power-and-heat approach. This is especially true in a situation when the carriers have a too low temperature for district heating purposes. In the case of accessible geothermal resources and solar radiation, an advantage of the low temperature of the carrier can be made. It is purposeful to apply compressor heat pumps, which in their lower source make use of these resources to transmit it to the network water in its upper source of heat. The energy is enlarges by the driving energy of heat pumps.

Driving heat pumps with electric energy, generated in the joint system, in an own heat station, improves the power yield of the undertaking. This is possible thanks to the management of useless unconventional energy resources. The use of electric energy from the Polish power system (based on heat power stations!) for such purposes usually results in a significant lowering of power efficiency in comparison to the period before the installments were introduced.

The positive effect is expected in the new heat station in Hel. The joint system has another advantage – it is fed with an environmentally friendly gas. In the lack of a gas-power system on the Hel Peninsula, liquid natural gas was applied. The presented modernization of the heating system for two housing estates deserves popularization as energy attractive and environmentally friendly.

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