Modernization of the scheme for the delivery of thermal power from the state district power station

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Abstract. In connection with the high competition and strict requirements of the open electricity market, optimization of heat energy supply schemes to consumers is an important task for generating companies. The variant of optimization of the SDPS by construction of rapid cooling unit (RCU) 140/12 and reconstruction of strapping RCU 12/6 is considered in this article.

1. Introduction
Zainskaya state district power station (SDPS) is the only source of thermal energy for social and administrative facilities of the city of Zainsk, as all boiler rooms were dismantled earlier. Therefore, the variants of optimization of the scheme of delivery of thermal power to consumers of the city Zainsk from Zainskaya SDPS are considered in the framework of this work.

For reliable and uninterruptable supply of consumers with thermal energy during the heating period, Zainskaya SDPS operates part of the power units of the station, in forced mode at minimum loads (110MW), which leads to losses from the sale of electricity in the open electricity market (OEM), as the prime cost of electricity generated at some points of time (night, weekend and public holidays) exceeds market prices for electricity [1,2].

2. Methods
In order to optimize the heat supply without the inclusion of additional power units, it is proposed to build a RCU 140/12 with a capacity of 50 t/h steam (figure 1), which implies the supply of reduced steam to the station steam collector 12 atm, then to the main water heater MWH -500-I (33.64 t/h from RCU 140/12 and 24.49 t/h from two turbine selections through RCU 25/12) located in turbine compartment of the first stage of the main building and through RCU 12/6 and steam collector 7 atm on the MWH -500 - II (16.36 t/h from RCU 140/12 through RCU 12/6 and 16.1 t/h from two turbine selections through RCU 25/6) located in the turbine compartment. At the nominal steam capacity of...
the boilers of the unit that is 640 t/h and the nominal steam flow per turbine that is equal to 575.5 t/h, the reserve for steam capacity of the energy boilers of each power unit is 64.5 t/h [3 ].

**Figure 1.** Schematic diagram of connecting RCU 140/12.

The steam flow through the collector of 12 atm will be:
- with RCU 140/12 — 50 t/h;
- from the second selection of turbine units (2 power units) — 32.2 t/h;
- on MWH-500 of the first stage — 58.13 t/h;
- for the mazut-handling equipment - 7.71 t/h;
- on RCU 12/6 — 16.36 t/h.

The steam flow through the collector of 7 atm will be:
- with RCU 12/6 — 16.36 t/h;
- from the second selection of turbine units — 16.1 t/h;
- for the main water heaterMWH-500 of the second stage — 32.46 t/h.

The distribution of the heat output (at the outside temperature of -5.2°C) under the existing mode and mode of operation of RCU 140/12 is presented in table 1.
Table 1. Distribution of the heat output under the existing mode and mode of operation of DOC 140/12.

| From RCU 140/12 | The existing mode of the heat output | The proposed mode of the heat output |
|-----------------|--------------------------------------|-------------------------------------|
|                 | The first stage                       | The second stage                    | The first stage | The second stage |
|                 | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) |
| From 2nd extraction of turbines |  |  |  |  |  |  |  |  |
| From RCU 140/12 | - | - | 18,28 (33,64) | 8,9 (16,36) |
| From 2nd extraction of turbines |  |  | 9,28 (16,1) | 8,85 (16,1) |
| From 4th and 5th extraction of turbines | 3 | 1 | 1 | 1 |
| From 2nd extraction of turbines | 31.65 (63,24) | 16,08 (25,94) | 17,65 (27,7) | 17,65 (27,7) |

Table 1 shows that commissioning of the RCU 140/12 at the outside temperature of -5.2°C allows to decommissioning two power units and reduce the load on the remaining power units to 110 MW.

The distribution of the heat output (at the outside temperature in the range of -22÷-24 °C) under the existing mode and mode of operation of RCU 140/12 is presented in table 2.

Table 2. Distribution of the heat output under the existing mode and mode of operation of RCU 140/12.

| Source name | The existing mode of the heat output | The proposed mode of the heat output |
|-------------|--------------------------------------|-------------------------------------|
|             | The first stage                       | The second stage                    | The first stage | The second stage |
|             | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) |
| From RCU 140/12 | - | - | 18,28 (33,64) | 8,9 (16,36) |
| From 2nd extraction of turbines | 2 | 2.61 (4,8) | 6,18 (11,35) | 8,85 (16,1) | 8,85 (16,1) |
| From 4th and 5th extraction of turbines | 39,2 (63,24) | 19,6 (31,62) | 17,65 (27,7) | 17,65 (27,7) |
Table 2 shows that commissioning of the RCU 140/12 at the outside temperature -22° to -24°C allows to decommissioning one power unit and reduce the load on the remaining units to 110 MW.

The distribution of the heat output (at the outside temperature of -34°C) under the existing mode and mode of operation of RCU 140/12 is presented in Table 3.

**Table 3. Distribution of the heat output under the existing mode and mode of operation of RCU 140/12.**

| Source name | The existing mode of the heat output | The proposed mode of the heat output |
|-------------|-------------------------------------|-------------------------------------|
|             | The first stage | The second stage | The first stage | The second stage |
|             | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) | number of power units | Q, Gcal/h (G, t/h) |
| From RCU 140/12 | 5 | - | 3 | - | 4 | 18.28 (33,64) | 3 | 8,9 (16,36) |
| From the 2nd extractio n of turbines | 6.67 | 4.26 | 13.31 (24,49) | 9,28 (16,1) |
| From 4th and 5th extractio n of turbines | 98 (158,1) | 58,8 (94,86) | 78,4 (126,48) | 58,8 (94,86) |

Table 3 demonstrates that commissioning of the RCU 140/12 at the outside temperature -34°C allows to decommissioning one power unit.

In order to increase the variability of the cogeneration plant work during the commissioning of the new RCU 140/12, it is important to provide a transverse connection between the power boilers by sharp steam, so that when one of the power units is stopped, the RCU 140/12 remains in operation [4,5]. Assessing the time of operation of power units and features of plant configuration, it should be noted that the transverse connection by sharp steam should be organized between power units №3, №4, №7 as the most loaded [6-10]. The diameter of the sharp steam collector to ensure the required performance of the RCU 140/12 is 125 mm.

The existing thermal power of the main water heater MWH-500 of the first stage at the parameters of the heating steam P = 8 atm and t = 250°C is 13.4 Gcal/h that corresponds to the consumption of heating steam of 24.69 t/h on the MWH - 500 of the first stage and the steam output for the mazut-handling equipment of 7.71 t/h.

To increase the steam consumption on the MWH- 500 of the first stage up to 58,13 t/h (31.58 Gcal/h) it is required to carry out the re-laying of the existing steam pipeline of 12 ataD-cond250 mm:
- on the section from RCU140/12 to the tapping in the collector 12 atm of the first stage on D-cond 350mm;
- in the area from the tapping of the collector with RCU 140/12 to the tapping of the collector on MWH— 500 of the first stage on D-cond 400mm;
- on the sector from the MWH - 500 of the first stage to the tapping in the collector 12 atm on D-cond 350 mm.

3. Results
The existing thermal power of the main water heater MWH-500 of the second stage at the parameters of heating steam P = 7 atm and t = 250°C is 15.13 Gcal/h that corresponds to the consumption of
heating steam of 27.8 t/h on the main water heater MWH-500 of the second stage (the practical capacity of the steam pipeline is 27.8 t/h).

To increase the steam consumption on the MWH-500 of the second stage up to 32.46 t/h (17.75 Gcal/h) it is required to carry out the re-laying of the existing steam pipeline 7 atm $D_{\text{cond}}$ 250 mm on the sector from RCU 12/6 to the MWH-500 of the second stage for $D_{\text{cond}}$ 300mm and replace the regulator RCU 25/6 with binding due to unsatisfactory technical condition.

The specific consumption of conventional fuel for the production of thermal energy at commissioning of the RCU 140/12 remains at the level of the existing actual values and is 170 — 172 kgoe/Gcal.

The cost of implementing the option is summarized in Table 4.

**Table 4.** The cost of implementing the solution.

| №  | Name of work                                        | Estimated cost, th. Rub. |
|----|-----------------------------------------------------|--------------------------|
| 1  | equipment                                           | 19000                    |
| 2  | finalizing the existing project                    | 250                      |
| 3  | replacement of regulator PRU 12/6 with strapping   | 2000                     |
| 4  | replacement of collector 12 ata on $D_{\text{cond}}$ 400mm and installation of valves for the possibility of operation mode switching | 3000 | |
| 5  | replacement of collector 12 ata up to NWH-500      | 1500                     |
|    | Total                                               | 25750                    |

A simple payback period is determined by the formula:

$$C = S_{\text{cost}}/S_{\text{econ.}} - S_{\text{year costs}}$$

where:

- $S_{\text{cost}}$ is costs for the implementation of the project, th. Rub. ;
- $S_{\text{year costs}}$ is annual costs for the implementation of the project, th. Rub. ;
- $S_{\text{econ.}}$ — the total economic effect of the project implementation, for the heating period, is determined by the financial results of the source's activity in the open electricity market for months, in which had suffered losses.

Simple payback period will be:

$$PP = 25.750/50 = 0.5 \text{ heating period.}$$

At the same time, the specific capital investments per 1 Gcal are determined by the formula:

$$K = S_{\text{cost}}/W_{\text{capacity}},$$

where:

- $W_{\text{cost}}$ is the thermal capacity of newly introduced equipment, Gcal/h (25.95 Gcal/h).

Specific capital investments per 1 Gcal will be:

$$Ci = 25,750/25,95 = 0.99 \text{ million rubles/Gcal.}$$

### 4. Discussion

The proposed variant of optimization of the scheme of heat output to consumers, due to the construction of the RCU 140/12 with a capacity of 50 t/h, will partially cover the heating load of the station in volume of 25.95 Gcal/h and to provide the withdrawal of one power unit of the station from the mode of forced heating production. The remaining power units can be operated at a load of 110 MW.

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