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CALCULATION OF THE MAIN ENERGY CHARACTERISTICS OF PLANT STEAM TURBINES WORKING ON THE CLAUSIUS-RANKINE CYCLE WITH REHEATING

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ABSTACT: Through this work is shown the calculation procedure for the main energy characteristics of plant steam turbines working on the Clausius-Rankine cycle with reheating. The parameters that we are going to analyze are the level of usefulness η_{PPT}, specific heat consumption q_{PPT}, total and specific steam consumption M_{TVPu}, m_{PPT} and the unit useful work L_{iTeq} . This project was developed for maximum continuous power turbines of 235 MW, all the other parameters that were used in the calculation are listed in the the work. The aim of this research is to show the comprehensive budget mentioned turbines and making the schematic operation of the system with calculated characteristics, which could be used as a good basis for the design of thermal power plants.
Keywords: steam turbine, level of usefulness, Clausius-Rankine ciklus

1. INTRODUCTION

The steam turbine is a mechanical device which removes the thermal energy from pressurized steam, and converts it to useful mechanical work. Belongs to the group of heat engines, such as internal combustion engines (ICE) and the steam engine, which converts thermal energy into mechanical work. On the other hand, the steam turbine is among the turbomachinery together with pumps, fans, hydraulic and gas turbines and turbocompressors. Shortlist part of this group is the group of thermal turbomachinery consisting of steam and gas turbines and turbocompressors [1].

The plant steam turbine consists: a steam turbine, condenser, condensate pumps, regenerative heaters of low-pressure, feedwater tank, regenerative heaters high-pressure, connecting pipeline, the appropriate protection and regulating armatures. Calculation of the major energy characteristics of plant steam turbine for a power plant is great significance for the determination of key operating parameters, the degree of utility and other essential parameters. Upon completion of the budget starts the work out a scheme or a symbolic display of plants, This is the best way to display when we take into account a number of elements that exists in this construction as well as the clarity and transparency of the projected plant. [2]

2. INPUT DATA REQUIRED FOR THE CALCULATION OF THE MAIN CHARASTERISTICS OF THE THERMAL POWER PLANT

The thermal power plant with among heating up consists boiler, turbine high, medium and low pressure, generator, condenser, condensate pumps, feeding pumps and five regenerative heaters of which four are surface (Z1, Z2, Z4, Z5), and a territorially (Z3). Z1 and Z2 are heaters high pressure surface, and Z4 and Z5 are low pressure. The boiler is made of coal combustion and conversion of chemical energy of fuel into heat. The resulting heat is submitted to the working fluid.

The plant operates in condensation cycle, so there is no removal of steam for industrial purposes.Fresh steam at the turbine inlet of high pressure has the following values: p3 = 170bar, t3 = 515°C, while the temperature and pressure of the reheated steam at the turbine inlet has medium pressure p5 = 39 bar, t5 = 515°C.From the high pressure turbine there is a one subtraction steam MO1 = 0.0948 (PO1 4 bar) from the intermediate pressure turbine steam subtraction takes three places mo2 = 0.0520 (PO2 = 17.5 bar), mo3 = 0.0517 (po3 = 7 bar), mo4 = 0.0467 (PO4 = 2.8 bar), and from the low pressure turbine at one place MO5 = 0.0688 (PO5 = 0.9 bar). Subtraction is performed in order to increase the efficiency of the overall process. Reheating steam is released before entering the intermediate pressure turbine.From the low pressure turbine steam goes to the condenser pressure pk = 0.06 bar. The condensate pump pushes the condensate to the regenerative heaters low-pressure while heating the condensate. The task of feeding pump is to provide a working pressure of matter through regenerative heaters of high pressure (Z1 and Z2), after which the feed water enters the boiler and thus established a circular cycle.The data used in calculations are given in Table 1.In developing Qt diagrams were taken the following sizes:

Table 1. Input data to be used for the calculation of the thermal power plant.

The maximum continuous power turbine	P_{pPT}	235	MW
Pressure fresh steam	p_3	17	MPa
The temperature of the fresh steam	T_3	515	°C
Pressure of the reheated steam	Nm,	3.9	MPa
Temperature of the reheated steam	T_5	515	°C
Pressure in place subtraction 1	p_{o1}	4	MPa
Pressure in place subtraction 2	p_{o2}	1.75	MPa
Pressure in place subtraction 3	p_{o3}	0.7	MPa
Pressure in place subtraction 4	p_{o4}	0.28	MPa
Pressure in place subtraction 5	p_{o5}	0.09	MPa
The pressure in the condenser	p_k	0.006	MPa
The inner level of usefulness of steam turbine p.	η_{iTVP}	0.86	-
The inner level of usefulness turbine middle p.	η_{iTSP}	0.88	-
The inner low level of usefulness turbine p.	η_{iTNP}	0.87	-
Efficiency first heaters high p.	η_{z1}	0.99	-
Efficiency second heaters high p.	η_{z2}	0.99	-
Mechanical level of usefulness the turbine	η_{mT}	0.99	-
Efficiency level of the generator	η_G	0.98	-
The inner the degree of usefulness feed pump	η_{iNP}	0,85	-
The inner level of usefulness condensated pumps	η_{iKP}	0,85	-

» Subcooling condensate at the condenser ΔtkK does not exceed 0.40;
» The temperature difference at the entrance to the low pressure heaters Δtzu usually adopts from 4 to 12°C, except that at the coldest regenerative heaters it could be higher;
» Minimum temperature difference in regenerative heaters, low-pressure Δtzmin usually adopts from 1 to 8°C
» Minimum temperature difference in regenerative heaters of high pressure usually adopts -1 to 4°C;
» The pressure at the turbine inlet of high pressure is 6% lower than the vapor pressure at the main valve;
» Subcooling the condensate due to the economy should not be in the case of regenerative heaters, low pressure of more than 40 - 50°C, while in the case of regenerative heaters of high pressure should not exceed 20 - 40°C.

3.CALCULATIONOF THE MAIN CHARACTERISTICS OF THERMAL POWER PLANT

Based on the pressures, which are given in the context of the input data and preliminary budget entropy, which represents the entropy fresh steam entering the turbine at high pressure determines the enthalpy of the location of steam subtraction . To determine the real value of the enthalpy we are using the internal level of efficiency turbines that can be seen from Figure 2.Internal expansion turbine level of usefulness is defined as the ratio of the actual technical work of the internal turbine and internal technical work in isentropic expansion, as can be seen from the previous image. The temperature at the place of the seizure steam (out of the high pressure turbine) at the entrance to heater Z1. From the tables are read corresponding values of enthalpy and temperature of the pressure at the place of the seizure

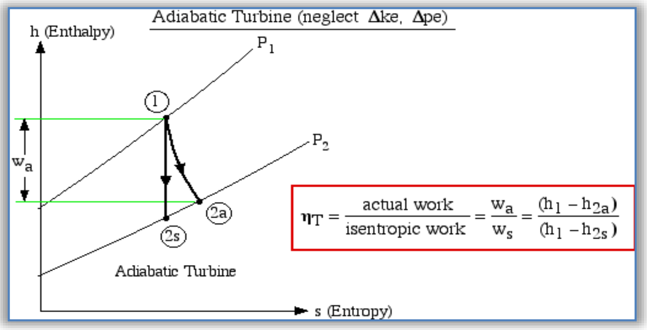

Figure 1. Internal level of usefulness for the turbine

steam. Interpolation gives the temperature at the exit of the high pressure turbine.

$$t_4 = t_1 + \frac{h_{01} - h_1}{h_2 - h_1}(t_2 - t_1)$$

In the same way are calculated entropy at entrances to other turbines, but because of the limitations we will not show any particular. An example of the heaters will be shown through the heater Z5. For the pressure p (0,9 • PO5) determine the temperature of the table directly or with interpolation.

$$t_{kz5i} = t(0{,}9 \cdot p_{o5}) - \Delta t_{zmin}; t_{ko5} = t_{kz5u} + \Delta t_{zu} \quad (1)$$

If the temperature t (0.9 • PO5) -who 5>Δtzmax then: $t_{ko5} = t(0{,}9 \cdot p_{o5}) - \Delta t_{zmax}$

If this condition is not satisfied the value is left as calculated in formula (1). Enthalpy and entropy at the exit of condensated pump is determined from tables based on the temperature and pressure tkz5i pkz5i. In the same way we determine the value for the other of the regenerative heaters. Figure 3 shows a schematic representation of heaters Z5.

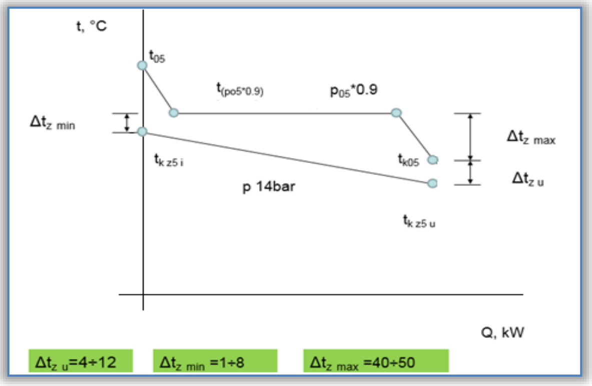

Figure 2. Heater Z5

Specific steam consumption gross, shows how the flow of fresh steam, that this condition is required at the turbine to achieve the desired beneficial work in the gross amount at the generator clamps.

$$m^b_{ePPT} = \frac{1}{L^b_{ePPT}}$$

» total consumption of steam: $m_{gv1} = \frac{p^b_{eppt}}{l^b_{eppt}}$

» level of usefulness plant steam turbine gross: $\eta^b_{eppt} = \frac{l^b_{eppt}}{q_{do}}$

» specific consumption of heat plant steam turbine: $q^b_{eppt} = \frac{1}{\eta^b_{eppt}}$

» specific consumption of heat plant steam turbine gross: $q^b_{ePPT} = \frac{3600}{\eta^b_{ePPT}}$

3. PRESENTATION OF THE RESULTS

For the process of calculation is developed a program in Microsoft Excel, which considerably facilitate calculations, drawing graphs and present the results.

Table 2. Calculated values of the main characteristics

Unit operation turbine	L_{iTeq}=1226,68 kJ/kg
Unit operation feedwater pumps	L_{iNP}=25,54 kJ/kg
Unit operation of the plant steam turbine gross	L^b_{ePPT}=1190,12 kJ/kg
Specific steam consumption	M^b_{ePPT}=0,000840 (kg/s)/kW
Total gross consumption	M_{GV1}=197,5 kg/s
Brought quantity of heat	q_{do}=2710,7 kJ/kg
Level of usefulness plant steam turbine	η^b_{ePPT}=0,439
The specific heat consumption of steam turbine plant	q^b_{ePPT}=8200,46 kJ/kWh

Main calculated values are presented in Table 2, a scheme of functioning of the plant with other computed data is shown in Figure 4.Figure 3 shows the Qt diagrams with all heaters and a condenser. For their drawings is also used Microsoft Excel.

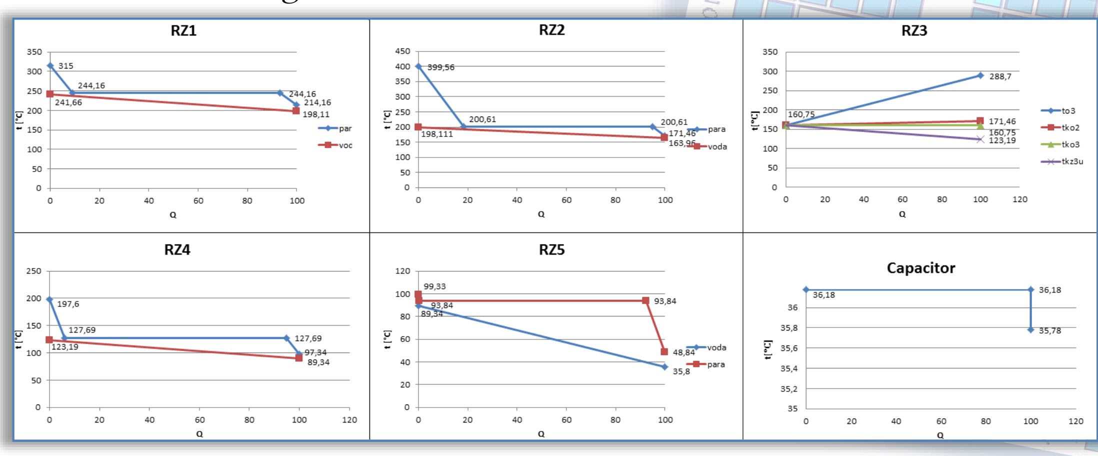

Figure 3. Q-t diagrams for RZ1, RZ2, RZ3, RZ4, RZ5 and condenser

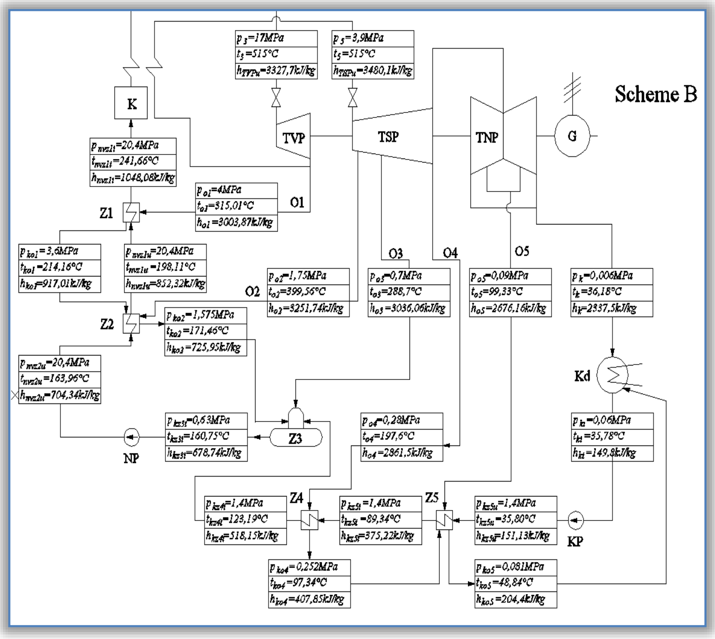

Figure 4. Schematic operation of a thermal power plant

4. CONCLUSION

Calculation of thermal power plants, regardless of its purposes is a very complex task, and it is very important to know all the characteristics and principles of operation of the plant. It is also important to define the input data, which largely depend on the purpose of the plant which is projected.

The calculation is very comprehensive, there are a lot of different charts and data which exists in the calculation, and this is the spot where the most frequently errors occure. It is important to establish a good concept of the calculation in one software package, to reduce computation time and possible errors that arise.

Some of the future steps would be the creation of software that a larger part of the calculation independently will be worked, it would also include load data from tables and charts, as well as their drawing. For such an undertaking would be necessary to combine multiple software packages such as Matlab, Microsoft Excel, Visual Basic and AutoCad.

The calculation was made using software packages by which a large part of the calculation is automated and thus obtained the quality and time.

Note: This paper is based on the paper presented at The 12th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology – DEMI 2015, organized by the University of Banja Luka, Faculty of Mechanical Engineering and Faculty of Electrical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA (29th – 30th of May, 2015), referred here as [3].

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