DESIGN OF A HEATING CIRCUIT WITH EXTRACTION STEAM CONDENSING TURBINE IN PRECHEZA COMPANY

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ABSTRACT

This paper deals with the design of the machinery with an extraction steam condensing turbine in Precheza corp. In this paper there is performed the calculation of the heat-flow diagram of the steam turbine and the calculation of heat and produced electrical power at basic operational states. In the end there is mentioned the economical evaluation of the whole project, using the fundamental economical methods, such as net present value method, or profitability index, including the calculation of the return period.

1. INTRODUCTION

Secondary resources questions are lately often reminded on the field of power savings. Pressure for producers of different products pushes them to make significant lowering of power consumption and to manage their sources much better than formerly. But it is also very important, how these savings influence the economics of company production and if it is profitable, to make such modifications at all. Therefore is company Precheza interested in project of design of heating circuit for producing of electrical energy.

2. DESIGN OF A STEAM CIRCUITE WITH THE CONDENSING TURBINE

This project deals with design of steam turbine, which can be added to the unit for sulphuric acid production, located in company Precheza. Because the reactions at the acid production are very exothermic, this heat can be used for steam production and the steam can be further used for electrical energy production.

Evaluation of this steam circuit is important from the view, how much energy can be gained and this depends on service parameters, especially how much steam is needed for other technological purposes in different steam extractions at different operational states. This is also important, because we need to know, how much energy is needed for the supply water and condensed water regeneration. These evaluations are performed in accordance with heat balance equations, which are regularly used [1].

The steam generator produces 61.56 t/h of steam with parameters: pressure 5.88 MPa and temperature 472 °C. Thermodynamic efficiency of the turbine is linear and about 80 %.

For the regeneration of the supply and condensed water is used steam 0.5 MPa from the company steam grid. Into this grid the steam is brought from the extraction in the turbine [2].

2.1. STEAM TURBINE

For this circuit we will use the condensing high-speed turbine with 12 MW power output. For the production needs it will have 3 steam extractions (not regulated 2.6 MPa, regulated 0.7 MPa and 0.5 MPa for supply of water regeneration and technological use. Emissive steam from the turbine is dissipated to the steam condenser with the pressure of 10 kPa.

2.2. STEAM CONDENSER

Steam condenser is used for changing the state of water, temperature and pressure do not change their values. For feeding of a condenser it is used a water with temperature about 20 °C. Heating of this water reaches 10 °C. The condensed water is then being heated in the steam-jet air ejector condenser within 3 °C to approximately 50 °C.

2.3. REGENERATIVE HEATER OF CONDENSED WATER

Condensed water is being heated to approximately 100 °C in this heater with 0.5 MPa steam from company steam grid. Condensed water is then mixed with condensed heating steam and continues into the degassing mixing exchanger and into the feeding tank.

2.4. DEGASSING EXCHANGER AND THE FEEDING TANK

Thermal degassing is performed in the degassing exchanger. Heating steam 0.5 MPa is delivered into the exchanger through the bottom and ensures that the feeding water is rid of the air, which gets into the circuit through some leakages and causes lowering of efficiency and corrosive processes, that lower lifetime of the whole system. In this exchanger the feeding water is heated only within 5 °C in order to prevent losses of energy, when the heating steam is lost with separated gases. Because amount of produced steam from boilers is constant and amount of condensed water is changing in order to demands for steam in other technologies, additional water is needed to be added into this exchanger from the heater of additional water.

2.5. REGENERATIVE HEATER OF ADDITIONAL WATER

Additional water for the feeding tank has to be heated at 100 °C, before it can be added into the degassing exchanger. This is performed in regenerative heater of additional water from the temperature about 20 °C by 0.5 MPa steam circuit. Amount of additional water is variable, according to amount of steam, taken from the circuit for other technological operations.

2.6. COMPRESSION OF FEEDING WATER IN FEEDING PUMP

Because this circuit needs for its operation a feeding pump, we need to consider this element too. In this element is the feeding water pressed a little bit and also heated in order about 1 °C. Feeding water of a temperature 106 °C is then delivered into the water boilers in the unit for sulphuric acid production.

3. EVALUATION OF PRODUCED ELECTRICAL ENERGY

Produced electrical energy is evaluated for 3 basic operational states – minimal, maximal and average demands for steam for other technologies. Process of producing of electrical energy is not lossless. I already mentioned thermodynamic efficiency of a turbine, but there are more attributes. Two important efficiency attributes are involved in this calculation, mechanical efficiency of turbine (96 %) and electrical efficiency of generator (97 %) [2]. There is also performed calculation of heat, used for production of electrical energy and instantaneous power of generator. Equations used for this evaluation are well known, and they are presented in [1].

Maximal consumption of steam for technologies:

- Instantaneous power – 6.4 MW
- Consumption of heat – 4.9 MJ/kWh

Minimal consumption of steam for technologies:

- Instantaneous power – 11.5 MW
- Consumption of heat – 11.4 MJ/kWh

Average consumption of steam for technologies:

- Instantaneous power – 8.8 MW
- Consumption of heat – 9 MJ/kWh

4. ECONOMICAL ANALYSIS

Last chapter of this work is an economical analysis of the whole project.

4.1. Costs

Costs of this project consist of cost of construction, which is one time investment in amount of 140 mil CZK, cost of operation (cost of heat) and other cost (repairing, personal costs, oils and others), which are in amount of 4.55 mil CZK.r^{-1}.

4.2. Amortization

Amortization is expression of lowering the price of the equipment. It is the value of the equipment, which participates in the value of the product, in this case, electrical energy. Tax depreciation is regulated by law. This equipment belongs to 3. amortization group with amortization period of 12 years. Amortization in first year is 6.02 mil CZK, in other years it is 12.18 mil CZK.

4.3. Earnings

This project has two basic parts of earnings. Major part of earnings stands in the cost of produced electrical energy, which will be used in the company and therefore it can be calculated as savings of unconsumed electricity from the supplier. For this calculation I consider the operational state with average demands for steam in other technologies and a working period of 8400 hours.r^{-1}. If considered self-consumption of this equipment, saved costs for electrical energy, system service and use of the grid, annual amount of earned finances is over 128 mil CZK. [2]

Minor part of this project's earnings stands in government grant for combined produce of electrical energy and heat, and for produce of electrical energy from secondary sources of energy. This grant is set by Power regulation authority and with the price of 45 CZK/MWh for combined produce of electrical energy and heat [4] and 45 CZK/MWh for produce of electrical energy from secondary sources [5] is the annual amount of finances over 6 mil CZK.

Annual earnings of this project are about 135 mil CZK.

4.4. INVESTMENT EFFICIENCY

Investment efficiency is the key element, which shows the investor, if this project would be profitable. From calculated values I can evaluate the profit of this project, taxed profit (VAT 19 % - calculations were performed in year 2009), then the annual income. Because it is necessary to consider the inflation and interest rates, this income needs to be actualized. Final summation of actualized incomes and initial investment is the last column in following table, cumulated cash flow (CF) [3].

year [-]	Depreciation [CZK/rok]	Profit [CZK/rok]	Taxed profit [CZK/rok]	Income [CZK/rok]	Act. Income [CZK/rok]	CF cumulated [CZK]
1	6 020 000	92 347 677	74 801 618	80 821 618	73 474 199	-66 525 801
2	12 180 000	86 187 677	69 812 018	81 992 018	67 761 999	1 236 197
3	12 180 000	86 187 677	69 812 018	81 992 018	61 601 817	62 838 014
4	12 180 000	86 187 677	69 812 018	81 992 018	56 001 652	118 839 666
5	12 180 000	86 187 677	69 812 018	81 992 018	50 910 593	169 750 258
6	12 180 000	86 187 677	69 812 018	81 992 018	46 282 357	216 032 615
7	12 180 000	86 187 677	69 812 018	81 992 018	42 074 870	258 107 485
8	12 180 000	86 187 677	69 812 018	81 992 018	38 249 882	296 357 367
9	12 180 000	86 187 677	69 812 018	81 992 018	34 772 620	331 129 987
10	12 180 000	86 187 677	69 812 018	81 992 018	31 611 472	362 741 459
11	12 180 000	86 187 677	69 812 018	81 992 018	28 737 702	391 479 161
12	12 180 000	86 187 677	69 812 018	81 992 018	26 125 184	417 604 345

Table 1: Economical summary

Economical analysis of this project is performed for 12 years, because it is the period of depreciation of equipment. Last value in CF column is also the value of NPV (net present value) index. This value shows net profit from this project during its lifetime. Other indicator of this project's profitability is PI (profitability index). This reaches almost 4, which indicates, that the initial investment is paid back almost 4 times [3].

Other indicator for investor is period of return of investment. It shows, when the project pays for own investment and starts to be profitable. It happens, when cumulated CF crosses from negative to positive numbers. In this case it happens in the second year of its operation [3].

5. CONCLUSION

This paper describes the possibility of construction of heat circuit with the condensing turbine to the unit for production of sulphuric acid. It combines the production of heat and electrical energy for covering the needs in the company Precheza. Evaluation of this heating circuit was performed with using the Matlab software. After input of consumption of steam for technologies in the company it evaluates amount of steam used for regenerative heating of condensed and feeding water and parameters of the water in key parts of the circuit.

Power of generator and consumed heat for electrical energy production is also evaluated with use of Matlab source code. Maximal power of the generator is about 12 MW_e [2] and the average consumption of heat for production of electrical energy calculated in accordance with [1] is about 9 MJ/kWh.

The economical analysis shows, that this project pays back already in second year of its operation. NPV of this project is over 400 mil CZK during its depreciation period 12 years. PI shows, that the initial investment returns to the investor almost 4 times. These all are very hopeful values, which suggest, that this project should be definitely realized.

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REFERENCES

[1] IBLER, Z. a kol. Technologický průvodce energetika - 1. díl., Nakladatelství BEN - technická literatura, vydání první, Praha 2002, ISBN 978-80-7300-026-4

[2] PRECHEZA, a.s., Provozní záznamy a podklady pro návrh tepelného okruhu

[3] SYNEK, M. a kol. Podniková ekonomika - 4. přepracované a doplněné vydání,

[4] ENERGETICKÝ REGULAČNÍ ÚŘAD Cenové rozhodnutí č. 8/2008, kterým se stanovuje podpora pro výrobu elektřiny z obnovitelných zdrojů energie, kombinované výroby elektřiny a tepla a druhotných energetických zdrojů [On-line] Energetický regulační věstník, částka 11, ze dne 26. 11. 2008 http://www.eru.cz/user_data/files/cenova%20rozhodnuti/CR%20elektro/OZ/CR_8-2008_OZE-KVET-DZ.pdf

[5] ENERGETICKÝ REGULAČNÍ ÚŘAD Cenové rozhodnutí č. 9/2008, kterým se stanovují ceny elektřiny a souvisejících služeb [On-line] Energetický regulační věstník, částka 12, ze dne 1. 12. 2008 http://www.eru.cz/user_data/files/cenova%20rozhodnuti/CR%20elektro/ER%20CR_9_2008.pdf