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REACTOR, TURBINE AND FEEDWATER REGENERATIVE SYSTEM - ASSEMBLY BEHAVIOR

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The paper presents the results of heat balance calculation of complete secondary circuit of NPP Cernavoda Unit 1. We made several calculation in order to calculate the abnormal regimes caused by loss of one of the of the regenerative reheater. Previous calculation made by General Electric took in consideration reduce of the reactor power from nominal power to 90% of nominal power. The loss of power due to abnormal operation was of about 12-14% of nominal power. In our calculation we considered that reactor power was kept at a constant level - nominal power- in order to reduce the loss of power due to operating in an abnormal regime. From our calculation resulted a loss of power of maximum 4% of nominal power, much less then the prior case in witch reactor power was reduce to 90%.

We concluded that operating at 100% of reactor power in abnormal condition of loss of one of regenerative reheaters is both more safety and more economical (about 50000 Euro/zi) and we recommend changing the operating procedures for this abnormal regime.

Keywords: heat transfer, thermal efficiency, secondary circuit.

1. Introduction

The reliability of some auxiliary equipment e.g. regenerative preheaters of steam generators feedwater can affect in a large scale global efficiency of secondary circuit of a nuclear power plant and through that the global efficiency of power plant.

Removal from different reasons of feedwater heaters conducts to reducing of thermal efficiency of the plant by 2÷4 percents thing that impose a very important analyze to condition to be considered in order to mitigate undesired effects caused by out of function of some of reheaters.

It is to mention that this percentage drop of thermal efficiency is in a first analyze the same in both cases of analyze: heat source (nuclear reactor and steam generators) is maintained at nominal power 100% and in case of heat source are dropped to 90% of nominal power, such as if there is the problem of insuring of national energetic system with as more electric power as possible is obvious

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profitable to maintain reactor power at 100% of nominal power. In this case power production is at a level of about 96% of nominal power, comparing with the case in which reactor power is reduced to 90% of nominal power with an electric power effective produced of 86.4% of nominal power.

The paper explores this aspects, taking in consideration economical analyze together with technical analyze.

Maintaining constant the reactor power at 100% of nominal power avoid reactor power changing with some advantages from point of view of management and operating of a nuclear power plant. It is obvious that in both situations the global effectiveness and respective fuel spent are affected.

Operating for a long period of time with several feedwater heaters out of function are not a desirable behavior in time of power plant equipment (especially the inlet temperature of feedwater in steam generators lowered from nominal value, the thermal plate of steam generators are operating at higher temperature difference between his sides).

This paper presents the divers situations which can occur in operating of a nuclear power plant, making some recommendations and observations which can be take in consideration in operating procedure of a nuclear plant.

We took in consideration the referential technical data provided by General Electric (US) - the turbo-generator (TG) supplier. The data used came from a 660 MW turbine from Cernavoda Nuclear Power Plant.

2. Computational assumptions

The study of behavior of Steam Generator, Turbine, and reheating system implies assembly implies a complex approach of some technical issues of heat and mass conservation so that for approaching of the theme we made several assumptions in order to simplify the calculation part without affecting the precision of the calculations. In the following we are presenting the main assumptions:

- global heat transfer coefficient is kept constant for loads under 100% of nominal flow;
- the values of enthalpy of bleeding steam is considered as weighted mean value by load between nominal flow and 80% of nominal flow - this values are provided in operating diagrams supplied by GE;
- mass weight between moisture separator reheater drain and the main steam flow is considered constant (this assumption is confirmed by the operating diagrams of the turbo-aggregate of 700 MW supplied by General Electric;
- the computation was made taking in consideration several abnormal conditions that could affect the operating efficiency of the installation:
  - loss of one of the three of the first low pressure heater (LP1);

  - loss of one bank of the second and the third low pressure heater (LP2 and LP3);
  - lost of one of the high pressure heater (HP5);
- we considered that the flow of bleeding steam is direct proportional with its power;
- we made three equation systems on 96, 97, and 98% of nominal power in order to see which one of the partial load the system gets the best solution.

From the beginning we should mention that:

- loss of one HP5 and one bank of LP2 plus LP3 the electrical power of the turbo-aggregates goes to about 96% of nominal power;
- loss of LP1 leads to a level of power about 98% of nominal power.

The computations were made using computational program MATHCAD 13. In the following we will present the three cases analyzed.

We mention that in all cases analyzed the reactor power it was considered constant (100% nominal power), the loss of power is due to low efficiency of the secondary circuit.

In order to make the computation of the heat exchanger we used the following equations:

- on the subcooled drain side (small letters in annotations):

$$g_1 c_1 (t_1' - t_1'') = g_2 c_2 (t_2' - t_2'') = ks \Delta t_{ml} \tag{1}$$

- on the condensing side (caps in annotations):

$$g_2 c_2 (T_2'' - T_2') = KS \Delta T_{ML} \tag{2}$$

where Δt_{ml} and ΔT_{ML} are logarithmic mean temperature difference.

- from the saturation curve

$$x = f(i, T_{sat} = t_1') \tag{3}$$

From these previous equations we obtain: $t_2''(=T_2')$; T_2''; t_1'; t_2'; p and x.

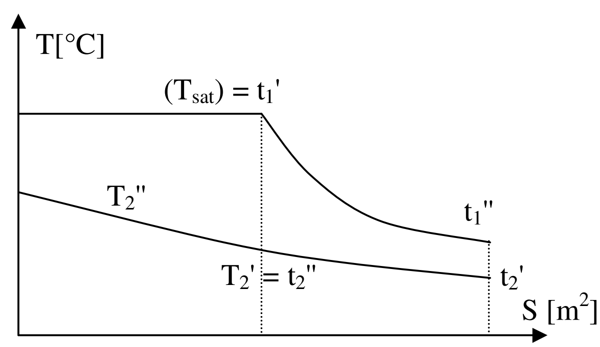

Fig.1. Heat transfer diagram.

It is mentionable that a value "i" of a enthalpy is imposed by operating parameters of the turbo-aggregate. This leads to determination of steam pressure and quality from condensation part of the heat exchanger.

Finally, after each feedwater reheater, we are interested by condensate temperature and especially by feedwater temperature (T_2"), which is after the last reheater the temperature of feedwater at steam generator nozzle.

Heat balance of steam generator (SG) determines the steam flow which goes to the turbo-aggregate (TA), and electric power (in percent) obtained at the electric generator, relative to nominal power.

3. Computation stages

For each of the three cases presented we wrote heat and balance equations for 96-97-98% of nominal flows and we compared the results of equation system in order to decide which of the three regimes is more close to the input data.

In each of the three situations we have three abnormal regimes:

α) loss of one of the three of the first low pressure heater - (LP1);

β) loss of one bank of the second and the third low pressure heater (LP2 and LP3) - they are considered together because the bypass line is for a bank of a LP2-LP3. there are two banks in parallel in installation;

χ) lost of one of the two high pressure heater (HP5).

Combining the three calculating flows of 96-97-98% of nominal flow with the three abnormal operating cases we get 3 x 3 = 9 cases to compute.

Table 1

The values of stationary regimes

initial	α	β	χ
96%	0.9797	0.965	0.957
97%	0.9811	0.9732	0.955
98%	0.9816	0.9854	0.955

4. The results

After examining the data from table 1 we kept just the cases where the initial values are closest to the results obtained by solving the equation system of regenerative system.

In conclusion we will keep the following 3 pairs of values:

$$(\alpha 98\%) \longrightarrow 98.16\%$$

$$(\beta 96\%) \longrightarrow 96.5\%$$

$$(\chi 96\%) \longrightarrow 95.7\%$$

From this data we can conclude that loosing one of the three LP1 is less affecting the global efficiency of the secondary cycle. The loss of a HP5 or a bank of LP2 and LP3 leads to a 4% loss of electrical power - 2 times more then loss of a LP1.

5. Conclusions

From this analyze we can conclude that the influence of the HP5 and the bank of the LP2 and LP3 is much greater then lost of LP1 i.e. from loss of 2% to 4% nominal power.

In present the operating procedure implies that the power of the reactor to be reduced from 100% to 90% in case of loosing one of the LP or HP. The idea was that the efficiency of secondary circuit is kept under design condition. But in stead of keeping the efficiency of secondary circuit we get a reduce of power from 100% to 88% of electrical nominal power in case of reduction of reactor power to 90%. The difference in electrical power between this operating case and calculated case are about 8-10% of nominal power, a very large number in economic figures.

As we presented in initial chapter, this paper can be put in practice when the effective operating procedures of a plant.

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