Self Evaluation

MODULE B.2

STEAM GENERATOR

1. At power it is a design requirement that the mass of light water in the steam generator remains constant. This produces two advantages:

   (a) The heat sink for the reactor remains sensibly constant.

   (b) The effects of sudden changes of steam flow on boiler level are reduced.

   Suppose the boiler is full of liquid at the saturation temperature and we increase unit power. As more heat is rejected to the steam generator from the primary heat transport system steam is going to be produced in the steam generator. The steam is produced as vapour bubbles within the liquid which has the effect of "floating" the surface in the boiler to a higher level although the mass of "water" in the boiler remains constant.

   As the steam flow increases, to the full load value, the ratio of steam bubbles to liquid in the boiler continues to increase. The increased volume of vapour "floats" the level to its highest normal value.

   If the boiler level had not been at a relatively low value before the steaming rate was increased, the level would have reached the top of the boiler before full load was achieved and liquid would have entered the steam lines.

   This increased vapour production is the reason for having a programmed boiler level with steam flow, where the programmed level is low at low steaming rates and is high at the high steaming rates.

2. (a) The major problem of a very high boiler level is that a small change in operating conditions could result in liquid being pushed out of the boiler into the steam turbine.

In this event several effects may result. As the liquid enters the turbine quenching of the rotor will occur as the liquid meets the center. This may severely distort the hp rotor. The liquid then has to pass through the blading which it does with difficulty and the chances of blade failure at this point are very real. All told, this is an event to be avoided!

(b) In a similar manner a relatively small operating change could cause a drop in boiler level which would produce problems if the boiler level was already low to start with.

The first problem is that the level of the boiler may fall below the lowest level sensing point for level control. As a result the actual level is no longer the indicated level because the indicator is already operating at the minimum signal. How do you know where the boiler level has gone? You don't!

Secondly, as the 'water' inventory in the steam generator is reduced so the heat sink capacity for the reactor is reduced which is an undesireable trend.

Thirdly, if the level in the boiler falls so that the tube bundle becomes uncovered then dryout will occur and dissolved solids existing in the boiler will 'bake out' on the outer tube surfaces, thereby impeding future heat transfer. This problem is clearly not of the same priority as the previous two.

In both cases of extreme level, an alarm is initiated which may allow the operator to take some appropriate action. If the boiler level continues to rise after the alarm then a GSV trip is initiated to prevent water entering the turbine from the steam generator.

If the boiler level continues to fall after the alarm a reduction of reactor power is initiated to ensure that the reactor thermal power is more closely matched to the reduced thermal capacity of the reactor heat sink, ie, the boilers.

This reduction in reactor power may be as a setback or a trip depending upon the operating rationale at the station concerned.

3. The three basic elements which are used for boiler level control are:

   (a) Steam flow,
   (b) Feedwater flow,
   (c) Actual level,

   The steam flow measurement is used to derive the programmed boiler level.

   Comparator circuits check for mismatching between Steam/Feedwater flowrates and actual/programmed boiler levels.

   At low power levels the measurement of low flowrates is not very accurate and the control of feedwater flow via the feedwater regulating valves is rather insensitive. Consequently, the inputs of steam flow and feedwater flow at low values are effectively ignored and level control is achieved using the level controller alone.

   As the flowrates rise above 20% and the large feedwater regulating valves are in service, then the three element measurement is used to advantage.

4. You will have noticed that the question does not state "reactor leading" or "reactor lagging". You should know whether the 'normal' mode at your station is "reactor leading" or "reactor lagging".

   The fact that the speeder gear is on 'auto' implies that the offset for the steam reject valves is in effect.

Reactor Leading (Pickering NGS-A)

In this mode the reactor power remains constant and the BPC program varies the steam flow from the steam generator to control the boiler pressure to the pressure setpoint.

As the steam pressure rises above the setpoint the BPC program initiates a signal which opens the GSV's on the turbine and allows more steam to flow through the turbine.

If this action does not restore the boiler pressure to the setpoint value by the time the SRV offset is reached, the small SRV's open to allow excess steam to be vented to atmosphere. In the event that the mismatch is such that the large SRV's open, then a reactor setback is initiated and only stopped when the large SRV's close or 2% reactor power is reached.

Reactor Lagging (Bruce NGS-A)

In this mode of operation the turbine load remains constant and the reactor power is changed to correct the boiler pressure error.

If the reduction of demanded reactor power does not return the boiler pressure to the setpoint and the boiler pressure reaches the offset value for the small steam reject valves, the unit control changes to reactor leading.

In this case the small reject valves operate and if the large reject valves are required to operate a reactor setback is initiated to reduce the power mismatch. The setback stops when the large reject valves close or 2% reactor power is reached.

5. The BPC program relies upon being able to vary the steam flow from the steam generator to control the boiler pressure.

   In the "cooldown" mode of operation the volume of steam increases dramatically as the pressure falls. At 130°C the steam volume has increased by more than 13 times.

   Two problems arise from this lowering of the steam pressure. Even though the steam mass flowrate is much reduced the volumetric flowrate increases due to the larger specific volume and the pipe sizing for the SRV's becomes inadequate and the SRV's become full open and can no longer reduce the steam generator pressure.

   One problem of using the turbine "all the way down" is that as the pressure in the boiler falls, so the levels of moisture in the turbine become higher. The exercise then becomes one of economics of a small amount of generation plus low feedwater loss against the blade damage on the turbine due to accelerated erosion.

   The main reason for terminating the 'cooldown' mode of the BPC program at 170°C is that this effectively represents the point where the SRV's are no longer capable of regulating boiler pressure because they are full open. At this point the PHT system temperature is further reduced using shutdown cooling.

6. The objective of a "crash-cool" exercise is to reduce the reactor temperature in a short period of time. The action which is taken to "crash-cool" is to reject steam from the steam generator at a rate which lowers the pressure. The effect of lowering the pressure is to reduce the temperature in the steam generator which means

that there is now a larger temperature difference between the PHT system and the steam generator. As a result of the larger temperature difference, the rate at which heat is removed from the reactor increases and the rate of cooling increases.

7. An increase in the thermal resistance of the steam generator tubes means that a larger temperature difference is required to transfer the same amount of heat from the PHT circuit. The only way that this can occur is for the PHT D_2O average temperature to rise to a value where the same amount of heat is being transferred through the higher resistance of the steam generator tubes.

8. (a) The efficiency of the steam/water cycle is proportional to the temperature difference between the steam in the steam generator and the steam in the condenser. When the steam generator pressure is raised, the steam temperature in the steam generator will increase (ie, the water will boil at a higher temperature). This increase in steam temperature increases the temperature difference between the steam generator and the condenser, which will increase the work done and the cycle efficiency.

(b) The limit on raising the steam generator pressure is due to the temperature of the fuel. Since the fuel is a ceramic, it has very poor heat transfer characteristics. Thus, when the centre fuel maximum temperature is 2300°C, the temperature of the fuel sheath is about 350 to 400°C and, after heat transfer occurs from the fuel to the primary heat transport fluid and from the primary heat transport fluid to the light water in the steam generator, the temperature of the light water in the steam generator is about 250°C.

If the centre fuel temperature is designed higher than 2300°C, the temperature and pressure of the light water in the steam generator can be increased.

At centre fuel temperatures approaching 2800°C, the fuel will melt, releasing fission product gases which contribute to fuel sheath failure. Thus the maximum fuel temperature is limited to 2300°C (which gives a safety margin), and the maximum light water pressure in the steam generator is the saturation pressure for the resulting 250°C operating temperature, or about 4 MPa(a).

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When you have compared your answers ask the course manager to review your test.