Turbine, Generator & Auxiliaries - Course 334

THE STEAM SYSTEM

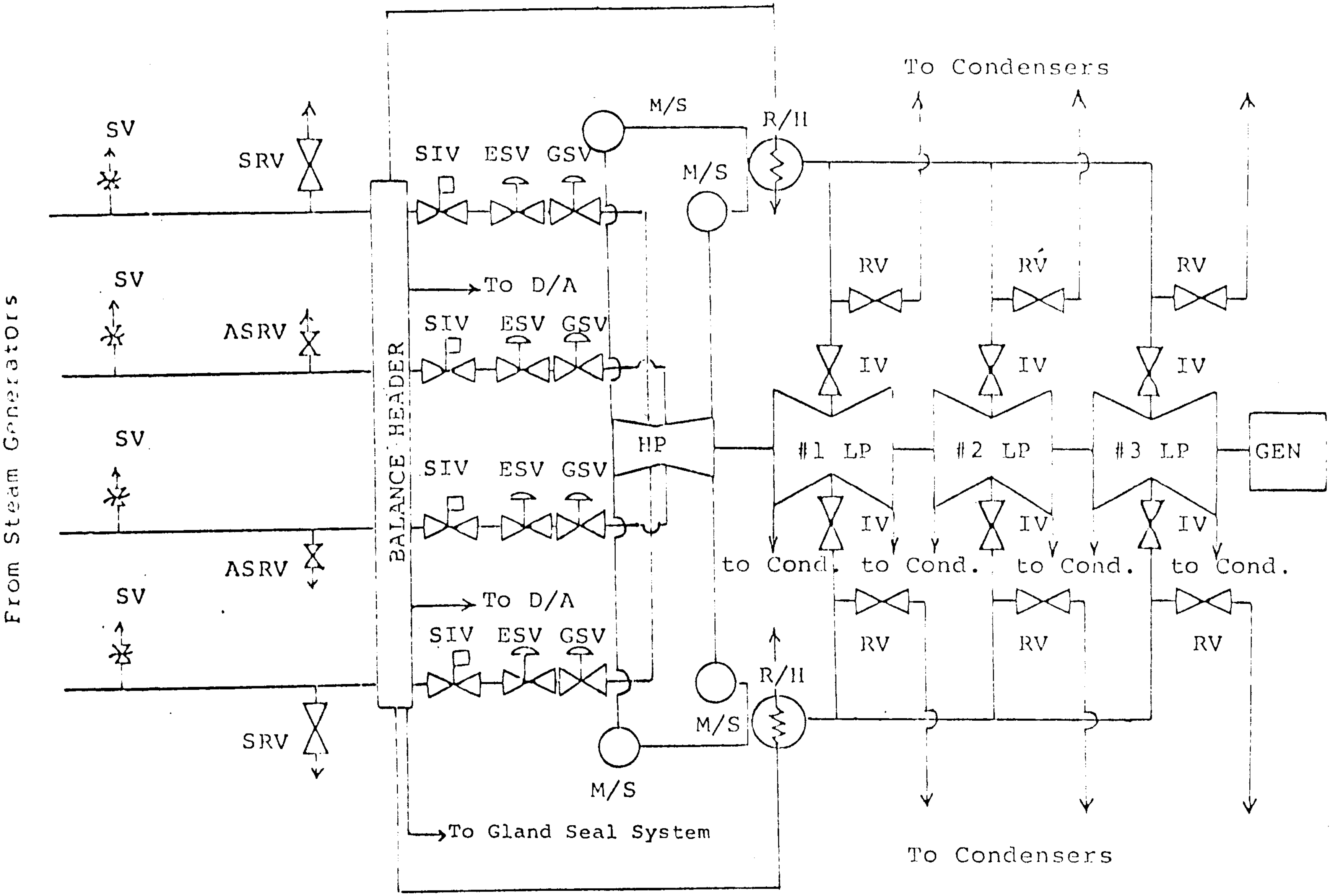
Figure 3.1 shows the steam piping and valves associated with a typical large CANDU turbine unit. The valves shown are not only the largest and most obvious valves in the steam system, they are also the most significant from the standpoint of turbine control and system safety.

The Steam Generator Safety Valves

The steam generator safety valves are installed either on the main steam piping or on the steam generators. There should not be an isolation valve between the safety valve and the system it protects. The function of these valves is to prevent the steam generators and steam piping from being overpressurized to the extent that the strength of the pipework could be exceeded. The steam generator safety valves are required by law and must be capable of relieving the full design steam flow of all the steam generators without the steam pressure rising above 110% of design working pressure. If a steam generator safety valve is inoperative, the maximum steam flow from the steam generators must be reduced so that the operable safety valves can relieve the entire flow.

Figure 3.2 shows a typical steam generator safety valve. When the steam pressure under the disc reaches the set pressure, the upward force overcomes the spring force, the valve pops open and steam escapes to atmosphere. A not infrequently encountered refinement in safety valves is to assist the opening of the valve with either an air operator or an electric solenoid which can be energized on receipt of a signal from the control room automatic control equipment or from the control room operator.

Safety valves are set to open at about 6% above the maximum working pressure. Once the valve has opened or lifted, it will remain open until the pressure is reduced significantly below the opening pressure. The percentage difference between lifting and reseating pressure is known as reseating blowdown and is typically set between 3% and 10% of the pressure at which the valve opens. If the safety valve had no blowdown, the valve would rapidly open and shut at its lift pressure as the steam pressure below the disc fluctuated due to flow through the valve. This "chattering" would rapidly destroy the valve seat and disc. On the other hand, if the blowdown was too large, there would be an unacceptable loss in pressure and water mass from the steam generators when the valve lifted. The safety valve blowdown must be

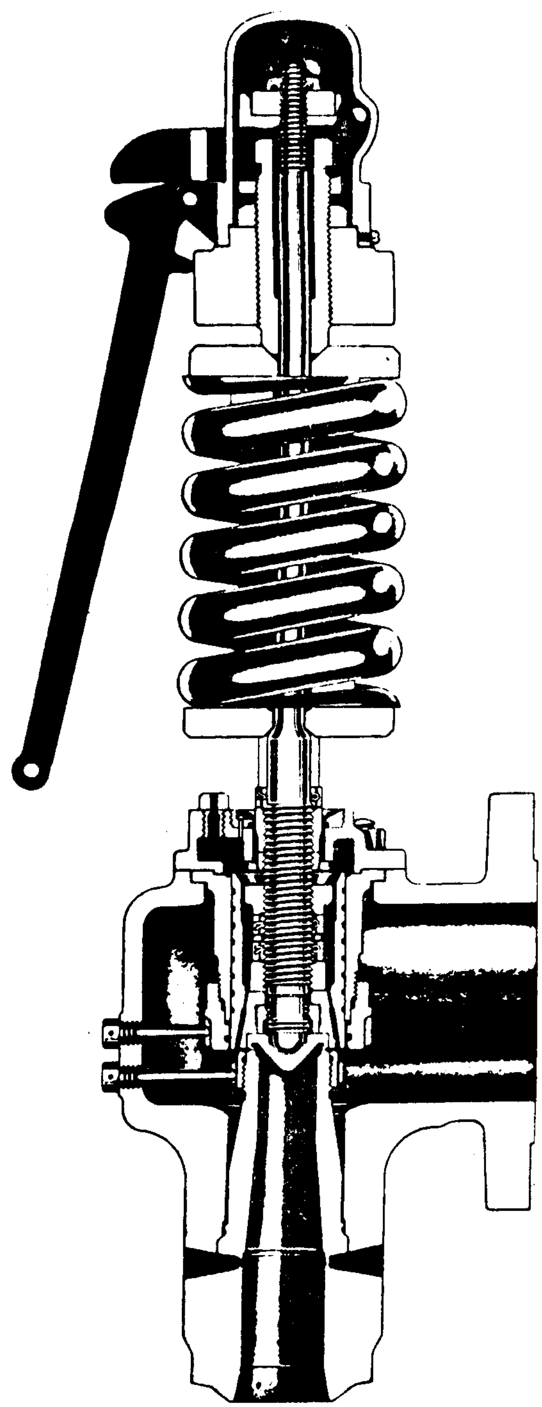


SV = Steam Generator Safety Valves
SRV = Large Steam Reject Valves
ASRV = Small Steam Reject Valves
ESV = Emergency Stop Valves

GSV = Governor Steam Valves
RV = Steam Release Valves
IV = Intercept Valves
SIV = Steam Isolating Valves

Figure 3.1

large enough to ensure an adequate reduction in pressure and yet small enough to limit the loss of fluid and fluid pressure to acceptable values.



Steam Generator Safety Valve

Figure 3.2

The number of safety valves protecting a large steam system is generally between 10 and 20. The lift pressures for the valves are generally staggered so that all valves do not lift at the same time. For a steam system with a maximum operating pressure of 4000 kPa(a) and say sixteen safety valves, the lift pressure might typically be 4 safety valves at 4240 kPa(a) (106% of working pressure), 4 safety valves at 4280 kPa(a) (107%), 4 safety valves at 4320 kPa(a) (108%) and 4 safety valves at 4360 kPa(a) (109%). The purpose of this scheme of staggered lift pressures is to ensure that:

1. only the required number of safety systems to handle the overpressure are called upon to operate

2. the rapid increase in steam flow when the safety valves lift is held to values commensurate with steam generator and reactor plant design limits, and

3. the mechanical and thermal shock to the system is held to acceptable values.

Steam Reject Valves (SRV)

The steam generator safety valves are required to protect the steam generators from an overpressure condition which could have catastrophic results. They must be extremely reliable; the simpler the construction the better. For both legal and practical reasons, we cannot design safety valves to perform too many complex functions or they may not be able to always perform their intended primary function. It is desirable however, to be able to exercise precise control of steam pressure by varying the rate at which steam is released from the steam system. This requirement is fulfilled by the steam reject valves. There are three basic requirements to release steam from the steam system:

1. for minor variations in pressure above the desired pressure due to temporary mismatches between reactor power and turbine power

2. for large boiler pressure transients which may result from a turbine trip with the unit at power, and

3. to release approximately 60% of design steam flow to prevent xenon poison out when the turbine is unavailable to remove reactor power.

Large CANDU generating stations have two sets of reject valves:

1. small valves (three inches in size) which are used for minor pressure transients, and

2. large valves (ten inches and larger in size) which are used for large pressure transients and to maintain steam flow above 60% during a turbine outage, to prevent xenon poison out.

The reject valves are pneumatic valves operated to open on receipt of an electrical signal from the control computers. The valves are held shut by steam pressure within the steam system and will not open unless the actuators receive the proper electrical signal.

If the boiler pressure rises above the desired programmed valve, the small reject valves open. If pressure continues to rise, indicating the small valves are passing insufficient flow to control boiler pressure, the large reject valves open. If the large reject valves open, a limit switch is operated which initiates a reactor setback.

The Steam Balance Header

The steam balance header, or main steam header as it is also called, is a large cylindrical steel vessel. It receives the steam from all the steam generators and equalizes the steam pressure before the steam goes to the turbine. The balance header also absorbs the expansion forces set up by the thermal expansion of the steam piping as it heats up.

The steam balance header and the steam piping adjacent to it supply steam to the following:

1. the turbine
2. the reheaters
3. the turbine gland seal system
4. the steam air ejectors (if the station uses this type of air extraction system)
5. the main steam which supplies the deaerator during poison prevent and startup when extraction steam from the turbine is available, and
6. steam to the heavy water plant (if applicable to the station).

The Steam Isolating Valves (Boiler Stop Valves)

The function of the steam isolating valves, or boiler stop valves as they are frequently called, is to isolate the turbines from the steam generators. This will allow maintenance to be performed on the turbine while the steam generators are hot and the steam piping pressurized with steam.You will notice that the steam generators cannot be isolated from one another on the steam side.

The steam isolating valve is normally a parallel slide valve as shown in Figure 3.3. This type of valve presents little restriction to flow when fully open and gives virtually complete isolation when shut. When the valve is shut and under pressure from the steam generator side, the disc on the turbine side is held in tight contact with the seat by steam pressure. When the valve has little pressure difference between the inlet and outlet sides, the discs are kept in contact with the seats by the spring. This overcomes the chief disadvantage of a normal single disc gate valve in that such a valve has a tendency to leak at low differential pressures. The steam isolating valve is normally operated by an electric motor.

The discs of the steam isolating valve may be as much as .67 meters in diameter. With full steam generator pressure on one side and atmospheric pressure on the other side, the force holding the disc against the seat may be as large as 500,000 newtons. This force may exceed the capacity of the motor to open the valve and even if it did not, the force may be sufficient to damage the valve if it is opened.For this reason, the steam isolating valve is normally fitted with a small bypass valve to allow pressure equalization before the main valve is opened. The bypass is operated by the same switch which energizes the main valve motor and opens fully before the main valve opens. The bypass valve does not shut until after the main valve is fully shut.

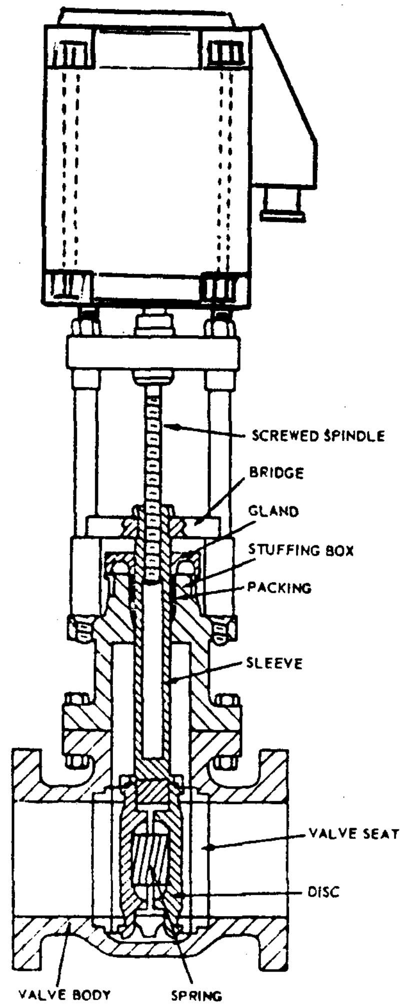
Steam Strainers

Immediately before the emergency stop valves, the steam passes through steam strainers. These strainers are designed to prevent solid impurities which may have contaminated the steam from entering the steam admission valves where these impurities could foul the valve seats or cause valve sticking by fouling the valve stems. The strainers also prevent impurities from entering the turbine where considerable damage could be done to the blading.

The Emergency Stop Valve (ESV)

The primary function of this valve, which is shown in Figure 3.4, is to immediately stop the flow of steam to the turbine in any emergency situation which, if allowed to continue, could damage the turbine.

The emergency stop valves are held open by high pressure hydraulic fluid (either the turbine lubricating oil or a separate hydraulic fluid system). The fluid pressure operating on the underside of the operating piston compresses a spring above the piston. On a turbine or generator fault which requires the valve to shut, the oil pressure is released from the underside of the operating piston and the spring slams the valve shut.



Steam Isolating Valve (Boiler Stop Valve)

Figure 3.3

The emergency stop valves are held open by high pressure hydraulic fluid (either the turbine lubricating oil or a separate hydraulic fluid system). The fluid pressure operating on the underside of the operating piston compresses a spring above the piston. On a turbine or generator fault which requires the valve to shut, the oil pressure is released from the underside of the operating piston and the spring slams the valve shut.

The Governor Steam Valves

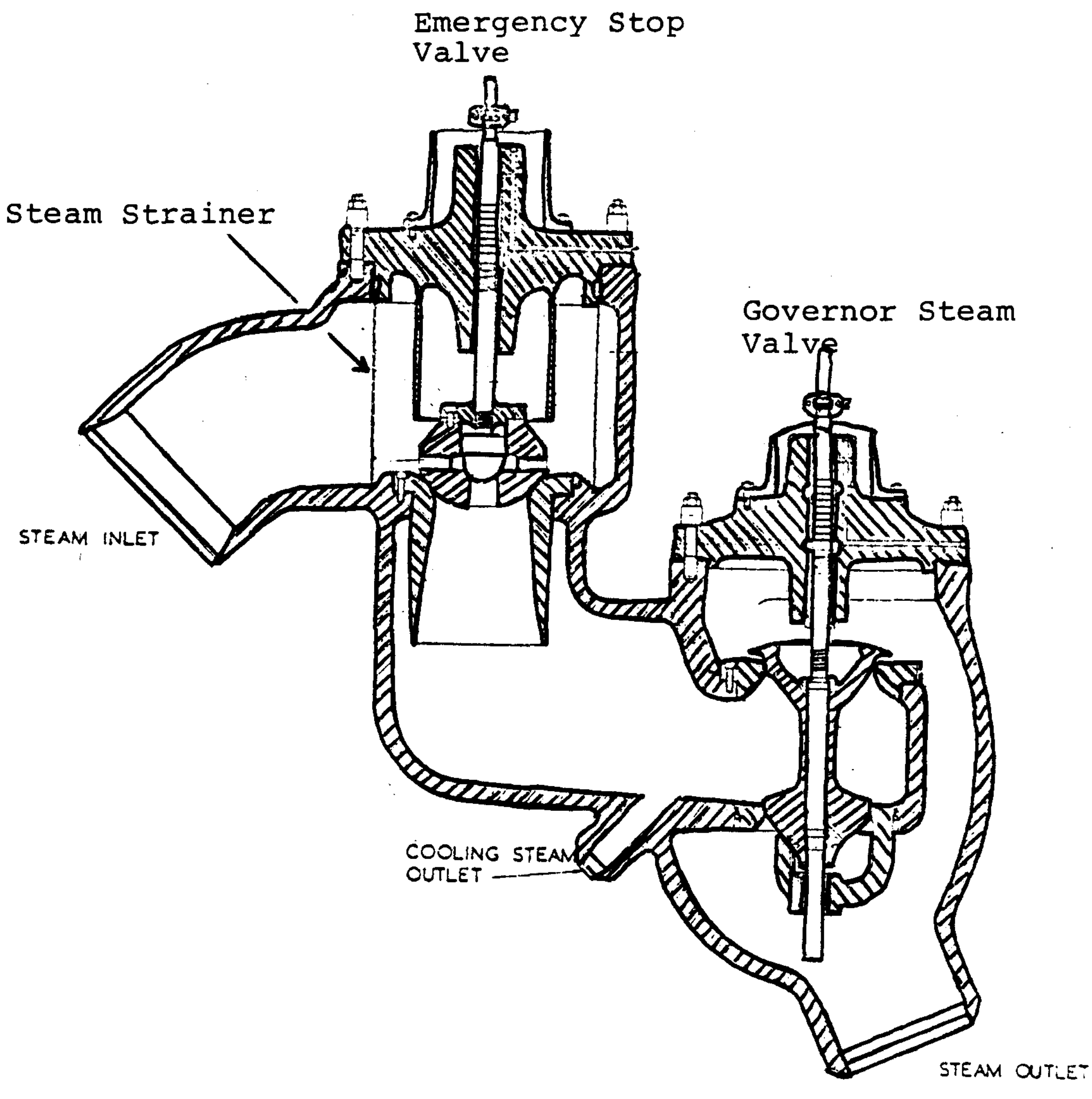
The function of the governor steam valves, also shown in Figure 3.4, is to control the quantity of steam flowing to the turbine so the electrical output of the generator can be varied.

The valves are operated by a combination of oil pressure and spring force. If the oil pressure under the piston is increased, the valve opens against spring tension. If the oil pressure is reduced, the spring tension forces the valve in the shut direction until the spring force is balanced by the oil pressure. The position of the governor steam flow to the turbine corresponds to the desired electrical load on the generator.

The governor steam valves are designed to control steam flow to the turbine over a rather limited speed range near the operating speed of the turbine. When the turbine is being started up, the governor steam valves are wide open and cannot properly control the steam flow to the turbine. For this reason, the steam flow to the turbine is controlled by gradually opening the emergency stop valve until the turbine is near normal operating speed. At this time, the governor steam valves can control the steam flow and the emergency stop valve is fully opened.

Thus, when the turbine is being brought up to operating speed, it is the emergency stop valve which is used to control the speed of the turbine. When the unit approaches operating speed, the governor becomes able to control the position of the governor steam valve to maintain the unit speed at a set value. The operator can vary this set value and thus has control of the turbine speed through the governor steam valve. However, once the output breaker has been shut and the generator is connected or synchronized to the Ontario electrical grid, the generator and therefore, the turbine, can only run at one speed which is determined by the grid frequency of 60 Hertz. The operator no longer can vary the speed of the turbine above or below its operating speed. If the operator now opens the governor steam valve and admits more steam to the turbine, the turbine and generator will not speed up. As more steam and therefore thermal power is admitted to the turbine, more electrical power will flow from the generator to the grid. In short, while the governor steam valve always is used to vary the steam supply to the turbine, the effect of this is to change the turbine's speed when the generator is not connected to the grid and to change the electrical power output when the generator is connected to the grid.

The governor steam valves on large CANDU generating stations all operate simultaneously. At 50% of maximum steam flow, all of the governor steam valves are passing 50% of their design maximum flow. At 100% of maximum steam flow, all the valves are passing 100% of design maximum flow. Such a governing system is known as <u>throttle governing</u> since the flow of steam to the turbine is controlled by throttling the steam with all the governor steam valves.



Steam Chest Assembly

Figure 3.4

The Intercept Valve

In the event of a turbine or generator fault which required the steam flow to the turbine to shut off, the emergency stop valve would shut. On large multicylinder steam turbines, the volume of steam which has already passed the emergency stop valves is sufficient to continue driving the turbine by expansion through the low pressure turbine. This "entrained steam", which is contained in the HP turbine, moisture separators, reheaters and low pressure piping, must be prevented from entering the low pressure turbine. An intercept valve, located on each inlet line to each low pressure turbine, performs this function.

The intercept valves are shut at the same time that steam is shut off to the high pressure turbine. The intercept valves are usually butterfly valves which provide good isolation when shut, low flow resistance when open and can be shut against a high flow rate through the valve. The valves are normally operated by either the same hydraulic fluid which operates the governor steam valves and emergency stop valves or by air operators.

The Steam Release Valves

When the intercept valves shut, the entrained steam must be removed from the turbine unit. This may be done either by steam release valves, which exhaust the steam to the condenser, or by reheater blow-off valves which exhaust the steam to atmosphere.

These valves will also function to protect the cross over piping against overpressure, such as might occur if an intercept valve shut while at power or a heater tube failed. The excess pressure would cause a signal to be sent to the release valve, opening it.

ASSIGNMENT

1. Draw a schematic diagram of the steam system for a large CANDU generating station having one double flow HP turbine and three double flow LP turbines, tandem compounded. Include in your diagram:

   (a) steam generators
   (b) steam generator safety valves
   (c) steam reject valves
   (d) balance header
   (e) steam isolating valves
   (f) emergency stop valves
   (g) governor steam valves
   (h) moisture separators
   (i) reheaters
   (j) intercept valves
   (k) release valves
   (l) connections for steam to the deaerator, air ejectors, gland seal system and reheaters.

2. What is the function of the steam generator safety valves? What is "blowdown" as it relates to a steam generator safety valve? What are the consequences of too large or too small blowdown?

3. Why are steam generator safety valve lifting pressure staggered so that all safety valves do not lift at the same time?

4. What are the functions of the steam reject valves? Why are most stations equipped with both steam reject valves and steam generator safety valves?

5. What are the functions of the emergency stop valves?

6. What is the purpose of the steam isolating valves?

7. What is the purpose of the governor steam valves?

8. What are the functions of the intercept valves and steam release valves?

9. What is meant by "throttle governing"?

10. How is turbine speed controlled:

    (a) on a startup below operating speed?
    (b) at operating speed when the generator is not yet synchronized with the grid?
    (c) at operating speed after the generator is synchronized with the grid?

11. Consider each of the following casualties and explain what would happen:

    (a) a governor steam valve fails and goes shut at 100% power
    (b) a governor steam valve stuck in the 100% power position
    (c) an intercept valve failed and goes shut at 100% power
    (d) an intercept valve stuck and did not shut on a loss of generator load from 100% power
    (e) two emergency stop valves stuck open on a loss of generator load from 100% power
    (f) a release valve failed and came open at 100% power.

R.O. Schuelke.