Module 234-7

THE TURBINE GOVERNING SYSTEM

OBJECTIVES:

After completing this module you will be able to:

7.1 Given a simplified block diagram of a typical turbine governing system, state the function and describe the operation of each of the following components:

- a) Load limiter; *⇔ Pages 3-4*
- b) Unloaders. *⇔ Pages 4-5*

7.2 Given a simplified diagram of a typical hydraulic actuator of a turbine control valve, describe:

- a) The actuator operation in response to:
  - i) A control signal; *⇔ Pages 7-8*
  - ii) A trip signal; *⇔ Pages 8-9*
  - iii) A test signal; *⇔ Page 9*
- b) Its major fail-safe feature. *⇔ Page 6*

7.3
- a) Describe three adverse consequences/operating concerns caused by impurities in the hydraulic fluid used in a turbine governing system. *⇔ Page 10*
- b) Describe two ways of maintaining its proper purity. *⇔ Page 11*

7.4 Given a simplified block diagram of a typical turbine governing system, describe the system operation:

- a) During turbine runup and power manoeuvres; *⇔ Pages 12-13*
- b) During unit steady power operation; *⇔ Page 13*
- c) In response to:
  - i) A turbine trip; *⇔ Page 14*
  - ii) A load rejection; *⇔ Pages 14-15*
  - iii) A reactor trip. *⇔ Page 15*

NOTES & REFERENCES

Page 16 ⇔ 7.5 a) i) Define turbine runback.

ii) State a typical range of runback rates expressed as a percentage of full power per second.

iii) State the difference between latched and unlatched runbacks.

Pages 16- 17 ⇔ b) List five typical operating events initiating a turbine runback and for each of them:

i) Explain the purpose of the turbine runback;

ii) State the type of the runback.

Page 18 ⇔ 7.6 a) List two operating conditions during which turbine speed can reach the overspeed trip level.

Page 18 ⇔ b) State three factors that contribute to enhanced turbine overspeed protection by the emergency overspeed governor.

Pages 19-20 ⇔ c) Describe the principle of operation of a typical emergency overspeed governor.

Page 20 ⇔ d) List two types of tests of the governor.

Page 20 ⇔ e) Explain how emergency overspeed can be simulated while testing the governor.

Page 20 ⇔ f) State the mandatory action that must be taken if the governor fails an actual overspeed test.

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

In the previous turbine courses which you have taken so far, the functions and the structure of the turbine governing system are described. Based on this general knowledge, this module discusses the following topics:

- Functions of the system components;
- Hydraulic actuation of turbine steam valves;
- Operation of the system during various unit operating states;
- Emergency overspeed governor.

The turbine governing systems installed in different stations differ significantly from one another. It is not the intent of this module to cover these differences. Instead, a more general approach, with focus on common features, is taken. However, an inherent result of this generalization is that the technical terminology (eg. the names of system components) used throughout the module may differ somewhat from that used in your station.

Similar to the preceding modules, a simplified pullout diagram of the system is attached at the end of the module, for easy reference.

FUNCTIONS OF THE SYSTEM COMPONENTS

Most of the system components have already been discussed in the previous turbine courses. Two new components are now introduced: a load limiter, and unloaders. For your convenience, in Fig. 7.1, the new components are highlighted to stand out from the rest of the turbine governing system.

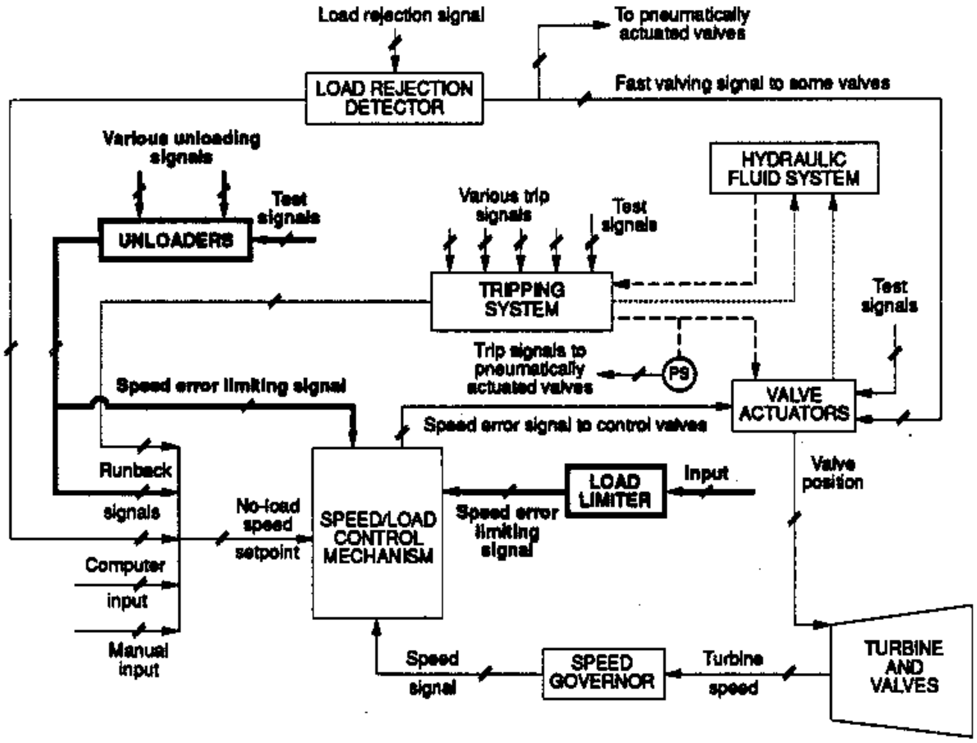

Fig. 7.1. Load limiter and unloaders in a typical turbine governing system:

—/— Signals ------ HP fluid .... Drains

Load limiter

The load limiter, as its name suggests, **limits the maximum allowable turbine generator load to any desired value.** This is achieved by restricting the speed error signal (also called *valve demand signal*). As a result, the maximum allowable opening of the governor valves (and, in some stations, of the intercept valves) is limited.

⇔ *Obj. 7.1 a)*

Note that **to limit turbine load, it is not enough to limit the no-load speed setpoint to the speed/load control mechanism.** After all, the speed error signal depends also on turbine speed. The latter is locked to the grid frequency as long as the generator is synchronized. Therefore, a reduction in the grid frequency (due to a grid upset) would increase the speed error signal, thereby demanding increased valve opening. If the valves are not already fully open, execution of this demand would increase turbine generator output, perhaps above the existing load limit. To prevent this, **the load limiter restricts the speed error signal.** In effect, the valve opening – and hence, turbine load – are limited regardless of turbine speed. Note that the load limiter does not interfere with the normal control action as long as the speed error signal does not demand a turbine load above the limit.

During normal unit operation, the load limiter setpoint is typically kept somewhat above full turbine load. This prevents the load limiter from interfering with operation of the rest of the turbine governing system. However, the load limiter setpoint is reduced appropriately when some operational problem (eg. loss of reheating) forces unit derating.

Unloaders

Obj 7.1 b) ⇔

A typical turbine governing system has two unloaders – one activated by **low condenser vacuum**, and the other by **low boiler pressure**. The activated unloader acts similarly to the load limiter, ie. it restricts the valve demand signal, thereby limiting the steam flow, and hence, turbine generator load. **The lower the condenser vacuum or boiler pressure, the larger the load restriction.** If the actual load is below the restriction, the unit operation is not affected. Otherwise, the load is reduced as demanded by the active unloader*. Note that **unloading can be performed very quickly** because the unloading signal is supplied directly to turbine valves, overriding the no-load speed setpoint.

Typically, the maximum turbine **unloading** is not continued to zero load, but **ends at about 10-30% FP**, depending on the station. By doing so, prolonged turbine operation with a small or no steam flow is avoided. You will recall that such operation promotes some operational problems in the turbine last stage(s).

When turbine load is being reduced by either unloader, the no-load speed setpoint to the speed/load control mechanism is also being reduced to the value corresponding to the actual reduced turbine load. This action – typically referred to as ***fast turbine runback**** – is much slower than unloading. In other words, turbine runback, at least in this particular case, follows rather than causes a reduction in turbine load.

The actual purpose of a turbine runback under these circumstances is **to prevent turbine load cycling**. Here is how it could happen if turbine un-

* The purpose of turbine unloading in these circumstances was covered in modules 234-3 and 234-5.

* More information about turbine runbacks is provided later in this module.

loading were not accompanied with the appropriate runback. A reduction in the turbine steam flow brought about by turbine unloading would reduce the condenser thermal load and the boiler thermal output. As a result, the unloading parameter (low condenser vacuum or boiler pressure, as the case may be) may begin to return to its normal range, thereby reducing the load restriction imposed by the activated unloader. This would cause an increase in turbine load as demanded by the unchanged no-load speed setpoint. The turbine steam flow would increase, causing unloading to recur again. And so, cycles of unloading and loading would follow.

SUMMARY OF THE KEY CONCEPTS

- The load limiter restricts the maximum allowable turbine generator load. This is achieved by restricting the speed error signal supplied to the valves controlling the turbine steam flow.
- The low condenser vacuum unloader and the low boiler pressure unloader can restrict the turbine load. The lower the condenser vacuum or the boiler pressure, the larger the load restriction. If the actual turbine load exceeds the limit, turbine unloading occurs until the restriction is met. In addition, the no-load speed setpoint is run back until it matches the unloading signal. The runback is performed to prevent turbine load cycling.

You can now do **assignment questions 1-2.**

⇔ *Page 23*

HYDRAULIC ACTUATION OF TURBINE STEAM VALVES

In this section, two topics are covered:

- Operation of the typical hydraulic actuator of a turbine steam valve and;
- Purity of the hydraulic fluid used for valve actuation.

Hydraulic actuators

The actuator of a large turbine steam valve must generate **large forces** that are required to overcome forces exerted by the steam flow and friction in the valve stem seal. **Valve positioning** must be **accurate** for adequate control of turbine generator load (when synchronized) and speed (during runup and synchronization). And proper equipment protection requires **fast and reliable action** of the valves during emergency conditions. Compared with other types of valve actuators (eg. mechanical or electrical), hydraulic actuators meet the above requirements best. This is why they are commonly used to operate steam turbine valves.

Many design variations of hydraulic actuators for large turbine steam valves are used in different CANDU stations. Even in the same station, different valves have actuators of different design. The information presented in this module does not refer to any particular design, nor does it attempt to cover the design variations. Instead, one of many possible ways of accomplishing the major required features of any actuator is described. The more general case of actuation of a control valve, as opposed to an on-off stop valve, is discussed.

In addition to the three actuator features stated above, two others are required as well. Namely, any valve actuator must:

- **Fail** in the valve **safe** position and;
- Allow **on-power valve tests**.

How all these requirements can be met is illustrated in Fig. 7.2 a) through d) where new details are gradually introduced to facilitate understanding of the actuator operation. In each of these drawings, the newly introduced details are highlighted for your convenience.

Obj 7.2 b) ⇔

In the actuator shown in Fig. 7.2 a), the power piston is spring-loaded with the spring attempting to close the valve. To open the valve against the spring force, high pressure hydraulic fluid must be supplied underneath the power piston. The arrangement provides an important **fail-safe feature** – upon a loss of hydraulic fluid from the actuator, the valve assumes its safe position (closed) in which steam flow to the turbine is stopped.

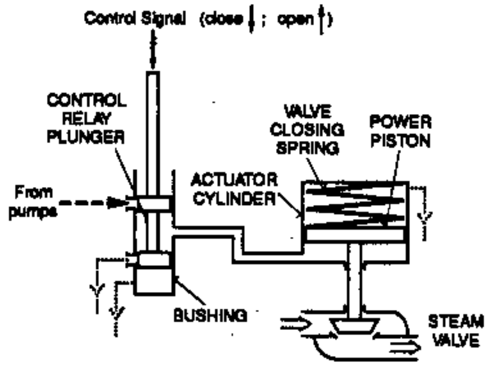

Fig. 7.2 a). Steam valve hydraulic actuator:
- - - - Power fluid ——— Drains —⫽— Signals

Advantages: *Fail safe feature, signal amplification.*
Deficiencies: *No valve position feedback, no means of tripping and testing the valve on power.*

Obj 7.2 a) i) ⇔

The **actuator operation** depends on the position of the control relay plunger with respect to the bushing. In the neutral position shown in the diagram, the hydraulic fluid under the power piston is trapped as it is isolated from both ports in the bushing. When the control signal demands increased valve opening, the relay plunger moves upward, uncovering the fluid supply port (while still blocking the drain port). This allows the fluid to enter the actuator cylinder where it drives the power piston upward against the valve closing spring. Thus, the valve opening is increased.

When a "close" control signal is applied, the relay plunger moves downward, uncovering the drain port (of course, the fluid supply port remains blocked). The fluid in the actuator cylinder is pushed out by the valve closing spring, and the valve closes.

Note that this actuator is a powerful amplifier of the control signal. Moving the control relay plunger does not require a large force and displacement due to the small size of the relay. The power piston, however, is much larger. Its size, combined with the high pressure of the hydraulic fluid, allows the actuator to develop very large forces adequate to operate a large steam valve.

However, this simple actuator has considerable deficiencies as noted in the diagram. Lack of valve position feedback means that the actuator cannot provide accurate positioning of the valve. Fig. 7.2 b) shows how this deficiency is eliminated by using a **valve position feedback mechanism**.

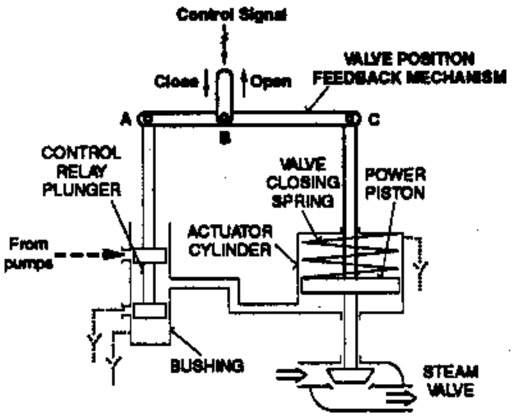

Fig. 7.2 b). Steam valve hydraulic actuator:
---- Power fluid ——— Drains —⫽— Signals

Advantages: Fail safe feature, signal amplification, valve position feedback.
Deficiency: No means of tripping and testing the valve on power.

The mechanism operates as follows. When an "open" control signal is applied, lever A-B-C pivots initially around point C because the power piston is still stationary due to the control relay plunger covering both ports in the bushing. Turning around fulcrum C, the lever moves the plunger upward, eventually uncovering the fluid supply port. This results in valve opening due to supply of high pressure fluid into the actuator cylinder. The upward movement of the power piston causes the lever to turn counterclockwise around point B which is fixed under assumption that the control signal has stopped changing. This makes the control relay plunger descend until it resumes the neutral position again. Thus, high pressure oil is supplied to the actuator cylinder for only as long as it is necessary for the valve to reach the required position.

NOTES & REFERENCES

The opposite processes occur when a "close" control signal is applied. This time, the drain port in the bushing is temporarily uncovered until the valve position feedback mechanism returns the control relay plunger to its neutral position when the demanded valve position is reached.

Obj 7.2 a) ii) ⇔

How the valve can be **tripped independently from the control signal** is shown in Fig. 7.2 c). Valve tripping is initiated by the tripping mechanism. This mechanism does not belong to any particular actuator, but is a separate part of the turbine governing system. When a turbine trip signal is applied, the mechanism dumps the tripping fluid (normally pressurized) to drains. The rate of drainage considerably exceeds the rate of the fluid supply (by the pumps) which is restricted by an orifice in the supply piping. Consequently, the tripping fluid pressure drops quickly.

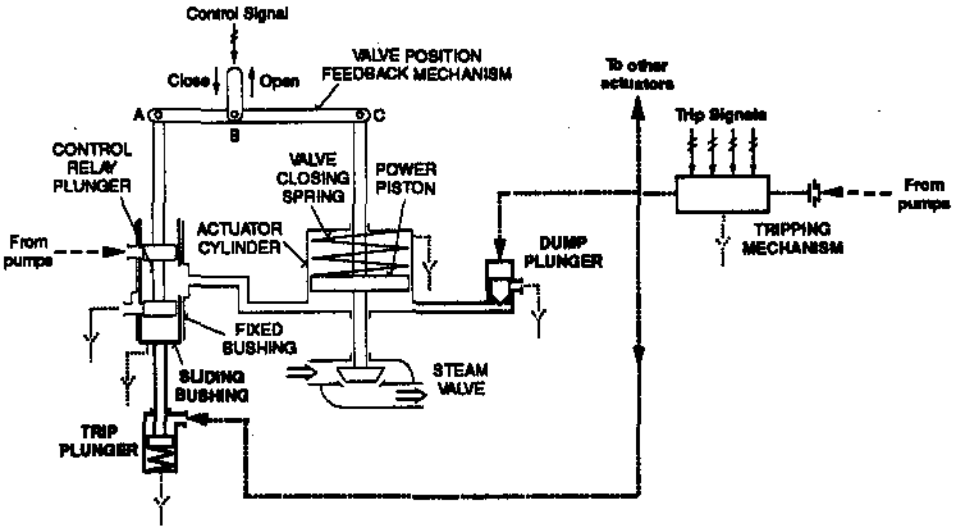

Fig. 7.2 c). Steam valve hydraulic actuator:
---- Power fluid —— Tripping fluid ········ Drains —⁄— Signals

Advantages: Fail safe feature, signal amplification, valve position feedback, two independent means of tripping the valve.
Deficiency: No means of testing the valve on power.

This results in **two independent actions.** First, **the spring loaded trip plunger rises**, driving the sliding bushing upward (note that in the two previous drawings, the bushing was assumed to stay in a fixed position). As a result, the drain port in the bushing is uncovered, regardless of the position of the control relay plunger, ie. **regardless of the control signal.** The valve closing spring now pushes the fluid out of the actuator cylinder, tripping the valve closed.

At the same time, the **dump plunger rises**, too. The plunger is hydraulically unbalanced as its upper surface is larger than the bottom one. Therefore, it is pressed against its seat as long as the tripping fluid is at full pressure. When the pressure is lost on a turbine trip, the plunger is raised by the high pressure fluid in the actuator cylinder. This opens another drainage path for this fluid.

This arrangement of two independent plungers increases the reliability of tripping the valve – either plunger can fail, and the valve will still trip, although a bit slower. The fail-safe feature is also enhanced.

⇔ Obj 7.2 a) iii)

Fig. 7.2 d) below shows two test valves that are used – one at a time – to perform **on-power valve tests.** Installed at the inlet to the trip and dump plungers, the valves simulate a turbine trip condition by depressurizing the tripping fluid acting on either plunger. To do this, the selected test valve isolates supplies of high pressure tripping fluid and dumps to drains the fluid that is downstream. Due to the isolation, the high pressure of the tripping fluid upstream of the test valve is retained. Thus, action of the test valve affects only the plunger under test, and does not spread over to other parts of the governing system.

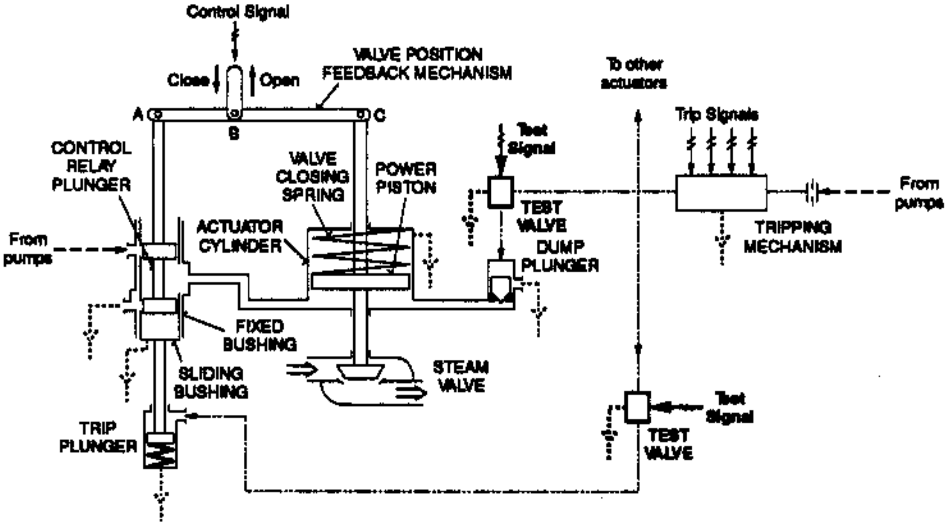

Fig. 7.2 d). Steam valve hydraulic actuator:
- - - - Power fluid —— Tripping fluid ········ Drains —⫽— Signals

SUMMARY OF THE KEY CONCEPTS

- When the control signal calls for a valve movement, the control relay plunger moves in the appropriate direction, uncovering either the fluid supply port (if the valve is to be opened more) or the drain port (if the valve is to be closed more). The resultant valve movement returns (via the valve position feedback mechanism) the control relay plunger back to its neutral position once the valve has reached the demanded position.
- Upon a turbine trip signal, the tripping fluid pressure drops rapidly. The hydraulically unbalanced dump plunger rises from its seat, opening a drain path for the fluid under the power piston. At the same time, the spring-loaded trip plunger rises, driving the sliding bushing of the control relay upward. This action uncovers the drain port in the bushing, thereby opening another path for evacuation of the hydraulic fluid from the actuator cylinder.

NOTES & REFERENCES

- On-power tests of the dump and trip plungers are performed using test valves which dump to drain the tripping fluid supplied to either plunger while maintaining essentially normal fluid pressure elsewhere.

Hydraulic fluid purity

Obj. 7.3 a) ⇔

In modern turbine governing systems, the hydraulic fluid pressure is kept very high (in the order of 10 MPa) in order to reduce the size of turbine valve actuators. This makes the system respond faster to emergency conditions (turbine trips, load rejections) because much less fluid must be transferred through the system when turbine valves close.

As in any other high pressure hydraulic equipment, **tight clearances*** are used in the actuators and other hydraulic parts of the turbine governing system. This minimizes internal leakages. Under these circumstances, trouble-free operation of the turbine governing system requires maintaining a high purity of the hydraulic fluid. Otherwise, accumulation of **particulates** in tight clearance areas causes the following **adverse consequences/ operating concerns:**

1. **Accelerated wear** of components, such as control relays and trip or dump plungers, due to scoring and abrasion. Increased maintenance costs result.
2. If adequate maintenance were not done, the **system performance would deteriorate** due to sticking of various relays and plungers, resulting in:
   a) **Sluggish speed/load control;**
   b) Increased risk of **catastrophic damage and serious safety hazards** to personnel due to failure of some turbine valves to respond properly to an emergency condition, like a turbine overspeed trip.

Besides forming corrosion products which contribute to the above consequences/concerns, **chemical contaminants** (water, oxidation products like acids, etc.) result in yet another adverse consequence:

3. **Accelerated deterioration of the hydraulic fluid** due to oxidation and hydrolysis, with acids and metal salts acting as catalysts.

   The resultant loss of the fluid's desirable properties (lubricative, anti-rust, etc.) leads to **accelerated wear** of system components. In addition, in the systems using a synthetic fire resistant fluid (FRF), **electrokinetic erosion** of system components is promoted when the fluid resistivity decreases due to accumulation of acids, salts and other ionic impurities. The erosion occurs due to small electric currents generated when the fluid is in motion. Mineral oils that are used in the turbine governing system of early CANDU units do not exhibit this problem.

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* Of the order of a few microns (1 micron = .001 millimeter).

NOTES & REFERENCES

⇔ *Obj 7.3 b)*

To prevent/minimize the above consequences, care must be taken to maintain **proper purity of the hydraulic fluid** which, in most CANDU stations, is an FRF. Its purity is typically **maintained by:**

1. **Continuous purification by the following methods:**
   - **Fine filters** which remove particles.
   - **Fuller's earth*** cartridges which remove chemical impurities such as oxidation and hydrolysis products, water, chloride.
2. **Routine chemical analyses and proper corrective actions as required.**

   Fluid samples are taken at regular intervals (weekly to monthly) and the fluid chemistry is checked against its specifications. The results may indicate a need for a corrective action such as extra purification or partial replacement with new fluid for dilution of the impurities. The extra purification usually involves vacuum treatment* during which air, water and other soluble impurities come out of solution, whereas particles are removed by fine filters at the vacuum chamber inlet.

In the few CANDU units where turbine lubricating oil, instead of FRF, is used in the turbine governing system, proper oil purity is maintained as described in module 234-10. Additional filters are also installed in the oil feed line to the turbine governing system.

SUMMARY OF THE KEY CONCEPTS

- Particulates in the hydraulic fluid used in a turbine governing system result in accelerated wear. Without adequate maintenance, the system performance would deteriorate, leading to sluggish speed/load control. In the extreme case, turbine valves may fail to respond properly to an emergency, resulting in catastrophic damage and serious safety hazards.
- Chemical impurities in the hydraulic fluid promote formation of corrosion products which contribute to the above problems. In addition, such impurities cause accelerated wear of the system components due to deterioration of the fluid, and – in the systems using an FRF – electrokinetic erosion.
- Proper purity of the hydraulic fluid is maintained by continuous purification whose effectiveness is checked by routine chemical analyses of the fluid.

You can now do **assignment questions 3-5.**

⇔ ***Pages 24-27***

* Fuller's earth is a hydrated compound of mainly silica and alumina, distributed under a few trade names. Because it absorbs many chemicals, its typical application is purification of liquids.

* At about 25-30 kPa(a).

NOTES & REFERENCES

OPERATION OF THE TURBINE GOVERNING SYSTEM DURING VARIOUS UNIT OPERATING CONDITIONS

The following operating conditions are discussed in this section:

- Turbine runup and power manoeuvres;
- Steady power operation;
- Turbine trip, load rejection and reactor trip.

In addition, you will learn about various types of turbine runback, their causes and objectives.

Obj. 7.4 a) ⇔

Turbine runup and power manoeuvres

Turbine speed (during runup) and load (when the generator is connected to the grid) are controlled by positioning of the valves which control the turbine steam flow*. Fig. 7.6 at the end of the module shows that valve positioning is controlled by a speed error signal (also called *valve demand signal*). The signal is generated by the speed/load control mechanism which compares the actual turbine speed with the no-load speed setpoint. The latter can be adjusted either manually or, more typically, by the DCC (digital control computer) controlling unit operation. While in different stations, the physical nature of all these signals can be completely different (they can be voltages, mechanical displacements, hydraulic fluid pressures, etc.), the effect of the speed error signal on the turbine steam flow is the same (Fig. 7.3).

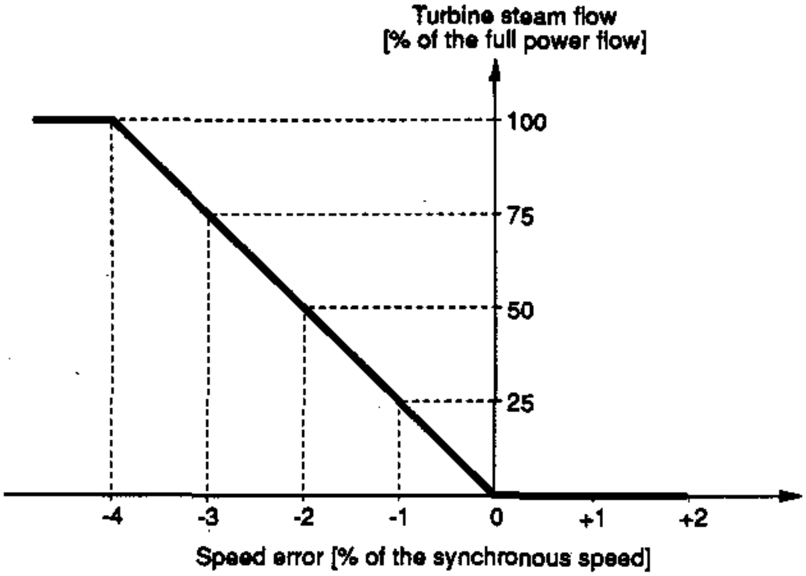

Fig. 7.3. Effect of the speed error signal on the turbine steam flow.

Note: Speed error = Actual speed - No-load speed setpoint.

* Recall that the turbine steam flow is controlled mainly by the governor valves. In some stations, the emergency stop valves and/or intercept valves are also involved at light loads and/or during runup. Because of these differences, a general term *controlling valves* is used in this section.

Note that **to increase the turbine steam flow, the speed/load control mechanism** – which essentially is a proportional controller – **must tolerate a larger and larger speed error**.

To raise turbine speed **during runup**, the no-load speed setpoint is increased. **The actual speed follows the setpoint with nearly no offset** because the speed error is very close to zero. As can be seen in Fig. 7.3, this stems from the fact that the turbine steam flow is very small, because there is no load on the generator.

Once the generator is synchronized, turbine speed is locked to the grid frequency, regardless of **the no-load speed setpoint**. The latter can, therefore, be **used to control turbine generator load**. For instance, to operate the turbine at full load, the no-load speed setpoint must be raised to about 104%. Because the actual speed remains at 100%, a minus 4% speed error signal is generated (100% - 104% = -4%) as required to admit the full power steam flow to the turbine (Fig. 7.3). Likewise, to reduce load to 75%, the no-load speed setpoint must be lowered to about 103%, thereby producing a minus 3% speed error signal.

Steady power operation

⇔ *Obj. 7.4 b)*

If all operating parameters were perfectly constant, there would be no need to adjust the no-load speed setpoint. In reality, however, various flows, temperatures, pressures and other parameters fluctuate continuously. When the fluctuations are too large, the no-load speed setpoint to the turbine governing system must be adjusted.

For example, in the reactor leading mode of unit operation, changes in boiler pressure, if large enough, cause BPC to adjust the speed setpoint such that the boiler pressure error is minimized. In turn, in the reactor lagging mode, maintenance of a constant generator MW output despite fluctuations in boiler pressure, condenser vacuum, feedheater performance, etc. may require minor adjustments of the speed setpoint. This is normally performed automatically by the DCC, using a control program called Unit Power Regulator (UPR).

SUMMARY OF THE KEY CONCEPTS

- The position of the valves controlling the turbine steam flow depends on the speed error signal supplied to their actuators. Generated by the speed/load control mechanism, the signal depends on the actual turbine speed and the no-load speed setpoint. When the actual speed reaches or exceeds the speed setpoint, the controlling valves are closed. Otherwise, they are open, and the opening increases with increasing difference between the speed setpoint and the actual speed. When the setpoint exceeds the actual speed by 4% of the synchronous speed, the full power steam flow is admitted to the turbine.

- During turbine runup, an increase in the no-load speed setpoint is very closely followed by the actual speed. The speed error signal is nearly zero, since the turbine steam flow is very small.
- Once the generator is synchronized, turbine speed is locked to the grid frequency, no matter what the speed setpoint is. The latter is now used to control turbine load by appropriate adjustments to the speed error signal which regulates the position of the controlling valves, and hence, the turbine steam flow.

Obj. 7.4 c) i) ⇔

Turbine trip

No matter what its cause, any turbine trip **activates the tripping mechanism causing it to dump, to drains, the hydraulic fluid** which is normally supplied to the turbine valve actuators. When the fluid pressure is lost, **the spring-loaded actuators close the valves** as described earlier in the module. Loss of the fluid pressure is also sensed by some pressure switches (Fig. 7.6) which send **a trip signal to pneumatically actuated valves** such as extraction steam check valves. At the same time, **a fast runback of the no-load speed setpoint is initiated.** This action is continued until the setpoint is reduced to zero. In the meantime, resetting of the turbine trip is inhibited. The purpose of the runback is to prevent rapid reopening of turbine valves when the trip is reset, ie. when the normal hydraulic fluid pressure is restored. Otherwise, the valves would open as requested by the unchanged no-load speed setpoint. An uncontrolled turbine runup and another turbine trip (on overspeed or excessive acceleration) would result.

Obj. 7.4 c) ii) ⇔

Load rejection

Any modern turbine governing system has some specialized components whose function is to detect a load rejection as soon as it happens. **Early detection of this upset**, ie. without waiting for the turbine speed to increase, is very important. By expediting the response of the turbine steam valves, it greatly **reduces the transient overspeed**. Recall that on a high load rejection, the turbine generator rotor accelerates rapidly due to a large unbalanced driving torque. Hence, each second counts.

In Fig. 7.6 appended to the module, the components that provide early detection of a load rejection are generally shown as a **load rejection detector**. The detector **receives a load rejection signal** when a load rejection occurs. In different stations, generation of this signal is based on various events that accompany this upset. Listed below are a few examples:

- Opening of the generator main circuit breakers;
- Rapid acceleration of the turbine generator rotor;
- Large unbalance between turbine power and generator MW load.

When a load rejection is detected, the load rejection detector sends to the proper turbine valves a special **fast valving signal** that overrides the normal valve demand signal. This makes the valves operate quickly as outlined in module 234-3. The fast valving signal is quickly terminated*, at which time **the speed/load control mechanism resumes the control of turbine valves**, based on the speed error signal. This signal is so large that the valves remain closed (see Fig. 7.3) until the overspeed transient subsides.

* After about 0.5-5 seconds, depending on the station.

Meanwhile, a **fast runback** of the no-load speed setpoint is carried out. The purpose of this action is to lower the speed setpoint such that, after the overspeed transient is over, the unit service load is supplied at a frequency as close to 60 Hz as possible, and the generator is ready for resynchronization with the grid. Note that without the runback, the no-load speed setpoint would be too high, causing the turbine speed and generator frequency to stabilize at too high a level.

In some stations, **the runback is continued until the no-load speed setpoint has reached 100% of the synchronous speed**. If there were no load on the generator, its speed would stabilize approximately at this level. However, because the generator is now supplying the unit service load*, turbine generator speed settles somewhat below 100%, producing a speed error signal large enough to allow for the required steam flow. The speed setpoint must, therefore, be adjusted to bring the speed to 100%. In some stations, the need for this adjustment is minimized by having the runback terminate earlier such that the typical unit service load can be supplied at 100% speed.

* Typically, 6-7% FP.

Reactor trip

⇔ Obj. 7.4 c) iii)

In most stations, the turbine governing system responds to a reactor trip by a fast runback of the no-load speed setpoint which is continued until the steam flow is completely stopped. Typically, the runback is requested by BPC responding to decreasing boiler pressure and dropping reactor power.

If the runback fails to keep boiler pressure sufficiently high, the low boiler pressure unloader operates as described at the beginning of this module.

SUMMARY OF THE KEY CONCEPTS

- Upon a turbine trip, the tripping mechanism dumps, to drains, the hydraulic fluid used for turbine valve actuation. Loss of its pressure causes the hydraulically actuated valves to close under the spring force. At the same time, a low pressure switch is activated and sends a trip signal to the pneumatically actuated turbine valves. A fast runback of the no-load speed setpoint is also carried out in order to prevent rapid readmission of steam to the turbine when the trip is reset.

- When a load rejection occurs, the load rejection detector sends to the proper turbine valves a fast valving signal which overrides the normal control signal and puts the valves quickly in their safe position. When the signal is terminated, the speed/load control mechanism resumes control of the turbine valves, based on the speed error. Meanwhile, a fast runback is performed for better control of turbine speed when the overspeed transient is over, and the turbine generator is supplying the unit service load, waiting for resynchronization with the grid.
- In response to a reactor trip, a fast runback of the no-load speed setpoint is carried out until the turbine steam flow is stopped. Typically, the runback is requested by BPC, responding to decreasing boiler pressure and dropping reactor power. If the runback fails to keep boiler pressure high enough, the low boiler pressure unloader takes over, directly affecting the valve demand signal.

Turbine runback

Obj. 7.5 a) ⇔

The term *turbine runback* refers to **a reduction of the no-load speed setpoint at a fixed preset rate** of about 1-10% FP/s, depending on the station. Typically, two rates of runback are available: **slow**, and **fast***. Fast and slow runbacks can be of two types:

1. **Unlatched** – meaning that the runback ends when the initiating condition has cleared;
2. **Latched** – meaning that the runback continues until the no-load speed setpoint has reached a predetermined level.

Obj. 7.5 b) ⇔

Fig. 7.4 on the next page describes turbine runbacks performed automatically in response to various operating events. You will notice that the first four cases have been discussed earlier in this course. The table is limited to the most typical initiating events. In some stations, other more specific events may apply. In addition, a manual turbine runback can also be done, either remotely from the control room or locally from a control console in the turbine hall.

SUMMARY OF THE KEY CONCEPTS

- Turbine runback refers to a reduction of the no-load speed setpoint at a fixed preset rate.
- The typical range of runback rates is about 1-10% FP/s, depending on the station and the type of runback (slow or fast).
- Unlatched runbacks end when the initiating condition has cleared, whereas latched runbacks continue until the no-load speed setpoint has reached a predetermined level.

* The slow rate is about 1-2.5% FP/s, and the fast one about 2.5-10% FP/s, depending on the station.

INITIATING EVENT	RUNBACK TYPE	PURPOSE OF THE RUNBACK
Turbine trip	Fast, latched1)	To prevent rapid reopening of turbine valves upon resetting the turbine trip which would cause an uncontrolled runup and another turbine trip on overspeed or excessive acceleration.
Load rejection	Fast, latched2)	To supply the unit service load at the correct frequency.
BPC request3)	Fast or slow4), unlatched	To reduce the turbine steam flow in order to return boiler pressure to its setpoint.
Low condenser vacuum or boiler pressure unloading	Fast, unlatched	To prevent turbine load cycling as explained on pages 4-5.
Low generator stator coolant flow	Fast, latched or unlatched5)	To reduce generator MW load in order to prevent generator damage due to overheating.

Notes:

1) *The runback is latched until the no-load speed setpoint has been reduced to zero speed. This prevents reopening of turbine valves during rundown, should the turbine trip be reset. Until the runback is complete, turbine trip resetting is inhibited.*
2) *In most stations, the runback is latched until the no-load speed setpoint has been reduced to a predetermined fixed value at which the typical unit service load can be supplied at 60 Hz. In the other stations, the runback is continued further until the no-load speed setpoint has reached 100%.*
3) *The unit is in the reactor leading mode of operation.*
4) *Depending on the signal generated by BPC, based on parameters such as boiler pressure error and the rate of reactor power decrease.*
5) *Depending on the station.*

Fig. 7.4. Typical automatic turbine runbacks.

- The most typical causes of automatic turbine runbacks are summarized in the table above.

You can now do **assignment questions 6-8.**

⇔ *Pages 27-30*

EMERGENCY OVERSPEED GOVERNOR

In this section, you will learn:

- When turbine speed can reach the overspeed trip level;
- How the emergency overspeed governor enhances overspeed protection;
- How this governor operates and how it is tested.

Introduction

Among various turbine emergency conditions, **excessive overspeed*** is probably the most dangerous. It **can result in massive destruction of equipment and create acute safety hazards to personnel.** Because of the severity of such an accident, numerous design and operating precautions

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* This emergency is discussed in more detail in module 234-13.

NOTES & REFERENCES

are taken to minimize chances for its happening. One of these precautions is the emergency overspeed governor which is a part of the tripping mechanism. The governor should operate whenever the **turbine speed reaches a preset overspeed trip level** which is typically about 110-112% of the synchronous speed. This can happen **during** the following operating conditions:

Obj. 7.6 a) ⇔

1. **Actual overspeed testing of the governor.**

   During this testing, the turbine generator is disconnected from the grid, and its speed is raised to the level at which the emergency overspeed governor should operate. More information about this testing is provided in module 234-13.

2. **A load rejection or a nonsequential turbine trip combined with failure of some components of the turbine governing system and/or some turbine valves.**

Obj. 7.6 b) ⇔

Under the dangerous operating circumstances stated in point 2 above, the probability of the turbine overspeed reaching a destructive level is greatly reduced by action of the emergency overspeed governor. Three factors contribute to it:

- This governor is independent from the other components of the turbine governing system which normally respond to a load rejection or a speed increase. Hence, the emergency overspeed governor can compensate for failure of these components.
- Compared with a load rejection, additional turbine valves are called upon to stop the turbine steam flow when this governor initiates a turbine overspeed trip. Thus, the governor action can make up for some failures of turbine valves being the cause of the emergency overspeed.
- The emergency overspeed governor is tested periodically and it has two independent channels of which either can fail without rendering the governor unavailable. The tests and redundancy ensure reliable operation of the governor.

It must be stressed that even though **the emergency overspeed governor** reduces the probability of an overspeed accident considerably, it **does not eliminate the risk totally**. For example, combined failure of the ESV and GV in the same steam admission line, if not discovered in time, would cause such an accident. Similarly, failure of the tripping mechanism to execute the trip signal produced by the emergency overspeed governor could be fatal, too. It is, therefore, very important to maintain turbine valves and the governing system in good operating condition, and **not to rely on the emergency overspeed governor as a perfect protection.**

Principle of operation

⇔ *Obj. 7.6 c)*

A typical emergency overspeed governor is a mechanical device mounted on the HP turbine end of the turbine generator rotor. As mentioned above, to increase its availability, the governor is duplicated. The core of each governor is a **spring-loaded, centrifugally-unbalanced object mounted radially inside the turbine rotor.** The object can be of various shapes, depending on the design. In the most common case, an **eccentric bolt** is used as shown in Fig. 7.5 below. The word *eccentric* reflects the fact that the center of gravity of the bolt is offset with respect to the axis of rotation. For simplicity, Fig. 7.5 illustrates only one of the two identical halves of the governor.

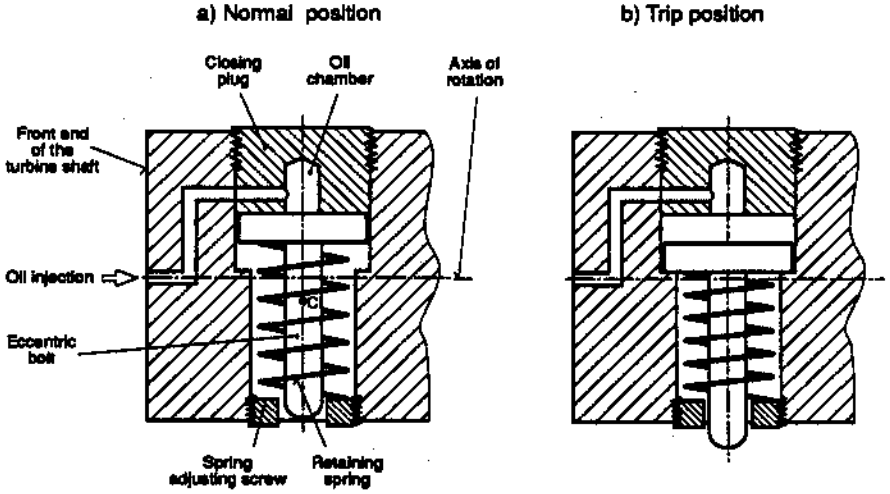


Fig. 7.5. Simplified typical emergency overspeed governor:
C= Center of gravity of the eccentric bolt.

The eccentric position of the bolt inside the turbine shaft causes a **centrifugal force** to be exerted on the bolt whenever the shaft is turning. This force, which **attempts to move the bolt out of the shaft,** increases very quickly with turbine speed. **An opposing force is produced by the retaining spring** whose compression can be regulated during turbine shutdown by means of the adjusting screw.

If the governor is adjusted properly, the spring force is dominant, holding the bolt inside the shaft, as long as turbine speed is below the overspeed trip range. **Upon overspeed reaching the trip range, the unbalanced centrifugal force overcomes the spring force, causing the bolt to move outward.** The magnitude of this displacement is limited by the collar of the bolt striking a recess inside the shaft (Fig. 7.5 b). The recess is positioned such that the bolt moves far enough to strike its trip finger (lever) which is a stationary part positioned very close to the shaft surface. Under the force of the impact, **the trip finger turns around its fulcrum,** and this displacement activates the tripping mechanism causing it to trip the turbine.

When turbine speed eventually subsides to about 100%, the centrifugal force acting on the eccentric bolt decreases below the spring force, and the bolt retracts into the shaft. Though this happens, the rest of the tripping mechanism must be reset before normal hydraulic fluid pressure can be restored in the turbine governing system, and hence, the trip reset.

Testing

Obj. 7.6 d) ⇔

To confirm its availability, the emergency overspeed governor is periodically tested in two different ways. One of them – **actual overspeed testing** – has been mentioned earlier. Because it requires turbine generator unloading and disconnecting from the grid, and because it subjects the machine to increased stress level, it is performed relatively rarely.

Obj. 7.6 e) ⇔

Much more frequently, **on-power testing** is done. During this test, turbine generator load remains unchanged, and **overspeed is simulated by injection of turbine lubricating oil into the oil chamber of the governor** (Fig. 7.5). The pressure of oil in the chamber exerts an extra force on the bolt. In most stations, the pressure of oil injection – and hence, the additional force on the eccentric bolt – can be regulated. Thus, not only can a simple freedom of movement test be performed, but also the overspeed trip setpoint can be checked.

Naturally, on-power testing of the governor should not cause a turbine trip. This is achieved by proper design of the tripping mechanism such that the tripping action of the eccentric bolt under test is isolated and does not cause the tripping mechanism to dump the hydraulic fluid to drains. This isolation does not disable the other eccentric bolt which can still trip the turbine, should real emergency overspeed occur during the test.

Obj. 7.6 f) ⇔

Failure of either channel of the emergency overspeed governor to pass an actual overspeed test is clear evidence that this channel is unavailable for turbine protection. Because the emergency overspeed governor is so essential to turbine generator safety, such failure **results in a mandatory turbine shutdown to repair the governor.**

As for on-power tests, note that governor failure may be caused by malfunction of the test circuitry. Therefore, an investigation is necessary. Its results affect the required action. Details, available in the appropriate operating manual and/or test procedure, will be covered in the station specific training.

SUMMARY OF THE KEY CONCEPTS

- Turbine speed reaches the overspeed trip level during actual overspeed testing of the emergency overspeed governor. Such a high overspeed may also happen during a load rejection or a nonsequential turbine trip if the turbine governing system or some steam valves are malfunctioning.

NOTES & REFERENCES

- The emergency overspeed governor enhances turbine protection against an overspeed accident because the governor can compensate for certain failures of the turbine governing system or steam valves. First, the governor is independent from these components which normally respond to a load rejection or a speed increase. Second, compared with a load rejection, additional turbine steam valves are used to stop the steam flow. Finally, the governor is duplicated to increase its reliability, and undergoes frequent tests to confirm its availability.
- A typical emergency overspeed governor reacts to excessive overspeed by activating the tripping mechanism. This is done by an eccentric bolt (or a similar component) being flung out of the turbine shaft by an unbalanced centrifugal force overcoming the force produced by the retaining spring. The centrifugal force is generated because the centre of gravity of the bolt is eccentric with respect to the axis of rotation.
- Two types of tests of the emergency overspeed governor are performed: actual overspeed tests and on-power tests.
- During on-power tests, emergency overspeed is simulated by oil injection into the oil chamber inside the governor. This produces an extra force attempting to throw the bolt out of the shaft.
- If the emergency overspeed governor fails to pass an actual overspeed test, the turbine must be shut down and the governor repaired before turbine operation can be resumed.

You can now do **assignment questions 9-12.**

⇔ *Pages 30-31*

ASSIGNMENT

1. a) During normal operation, the load limiter setpoint is kept (at / somewhat above / somewhat below) full turbine load in order to ______________________________

____

b) The load limiter setpoint is appropriately reduced when ________

____

c) To limit turbine load it (is / is not) enough to limit the no-load speed setpoint to the turbine governing system because

____

____

____

____

____

2. a) Typically, turbine unloading can be initiated by either:

i) ______________________________

ii) ______________________________

b) The reason why the maximum turbine unloading is not continued to zero load is ______________________________

____

____

c) If unloading were not accompanied with the appropriate runback, ______________________ would occur as follows:

____

____

____

____

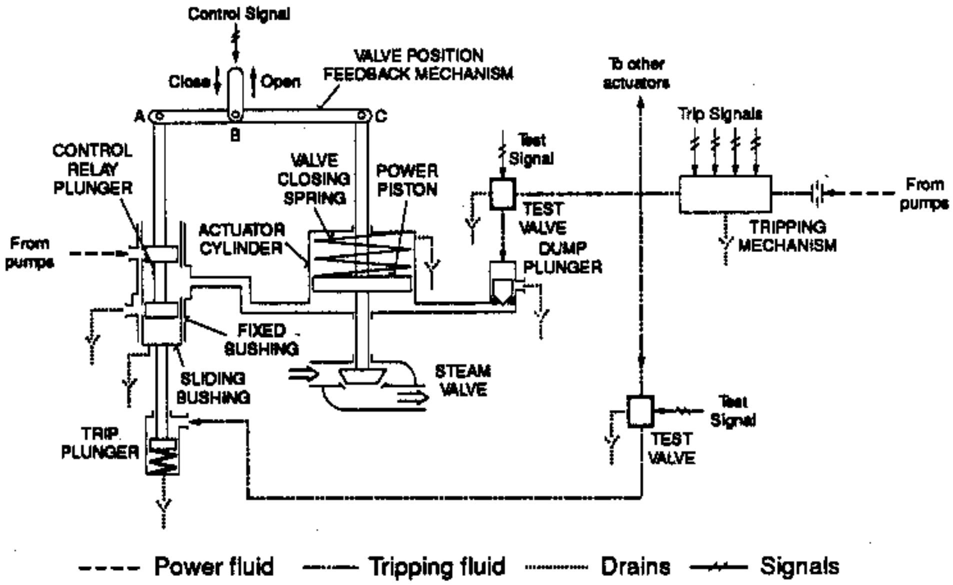
____

____

____

____

3. The following simplified diagram shows the typical hydraulic actuator of a turbine control valve.



a) The actuator responds to an "open" signal as follows: ________

____

____

____

____

____

____

____

____

____

____

____

b) When the control signal calls for valve closure, the actuator operates as follows: ______________________________

____

____

c) When a trip signal is applied to the tripping mechanism in the turbine governing system, the actuator operates as follows:

d) Both the trip and the dump plungers must be available in order the actuator could execute a trip signal. (False / true)

e) On-power testing of the actuator is performed as follows:

4. a) Solid impurities in the hydraulic fluid used in a turbine governing system can cause the following adverse consequences and operating concerns:

   i) Accelerated wear through ____________________

   ii) If adequate maintenance were not done, the system performance would deteriorate, eventually resulting in ________ ____________________ and possibly ____________________ ____________________ ____________________

   b) Typical chemical impurities of the fluid include ____________ ____________________ Their presence contributes to the above consequences and concerns through forming ________ ____________________ An additional adverse consequence of these impurities is ____________________ ____________ through ____________________

   In the governing systems using a FRF, chemical impurities promote ____________________ through lowering the fluid resistivity.

5. a) Continuous purification of the fire resistant fluid used in a turbine governing system includes typically the following methods:

   i) ____________________

   ii) ____________________

   b) When a chemical analysis indicates excess impurities in the hydraulic fluid, the following corrective actions may be taken:

   i) ____________________ ____________________

   ii) ____________________ ____________________

6. The turbine governing system, shown in Fig. 7.6 at the module end, operates as follows:

   a) During turbine runup and power manoeuvres:

   b) During unit steady power operation:

c) In response to a turbine trip: ____________________

d) In response to a load rejection: ____________________

e) In response to a reactor trip: ______________________

7. a) The typical operating events initiating an automatic turbine runback are:

   i) ______________________

   ii) ______________________

   iii) ______________________

   iv) ______________________

   v) ______________________

   b) The typical range of turbine runback rates is ______________ depending on ______________________

   c) Definitions:

   i) Latched runback – ______________________

   ii) Unlatched runback – ______________________

8. a) Upon a turbine trip, a (fast / slow) (latched / unlatched) runback is carried out in order to ______________________

   b) When a load rejection occurs, a (fast / slow) (latched / unlatched) runback is performed in order to ______________________

   c) The purpose of a turbine runback initiated by a BPC request is ______________________

d) A (fast / slow) runback is performed when either unloader in the turbine governing system unloads the turbine. The purpose of the runback is ______________________________

____

e) A (fast / slow) runback is carried out when the generator stator coolant flow is ____________ Its purpose is ______________

____

____

9. Turbine speed can reach the overspeed trip level during the two operating conditions:

a) ______________________________________

____

____

b) ______________________________________

____

____

10. Three factors contributing to enhanced turbine overspeed protection by the emergency overspeed governor are:

a) ______________________________________

____

____

____

b) ______________________________________

____

____

____

c) ______________________________________

____

____

____

11. a) The centrifugal force exerted on the eccentric bolt of an emergency overspeed governor (increases quickly with turbine speed / remains approximately constant).

    b) The centrifugal force attempts to ______________________

    ____

    c) The spring force attempts to ______________________

    ____

    d) At the trip speed, the centrifugal force (is overcome by / overcomes) the spring force, causing the bolt to move __________

    e) The trip mechanism is activated by the __________________ moved due to ______________________________

    ____

12. a) Two types of testing of the emergency overspeed governor are:

    i) ______________________________________

    ii) ______________________________________

    b) While testing the governor at normal turbine speed, emergency overspeed is simulated by ______________________

    ____

    c) The required action in the event of failure of the emergency overspeed governor to pass an actual overspeed test is __________

    ____

Before you move on to the next module, **review the objectives** and make sure that you can meet their requirements.

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Revision date: June, 1994

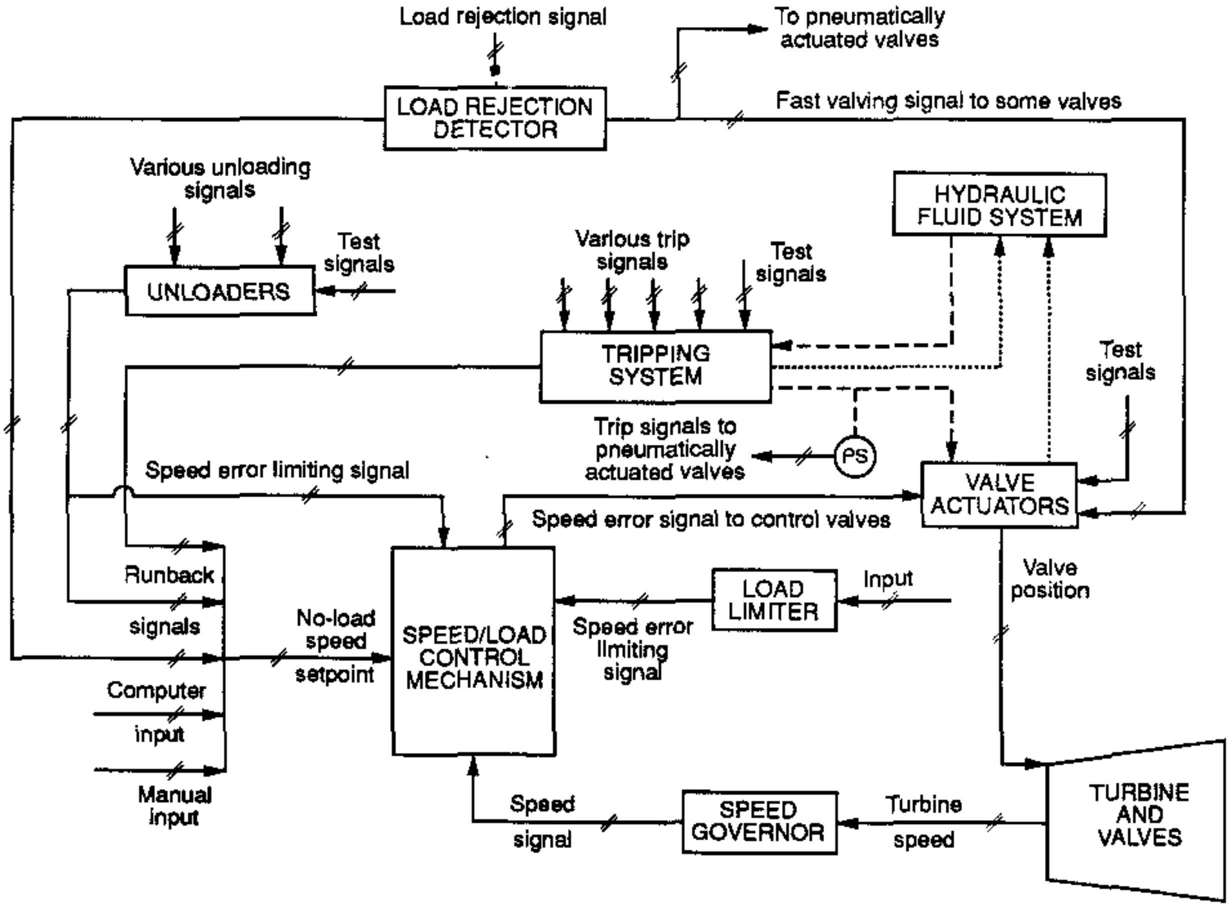

Fig. 7.6. Typical turbine governing system:

—/— Signals - - - - HP fluid ········· Drains