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Module 234-12

UNLOADING AND SHUTTING DOWN

OBJECTIVES:

After completing this module you will be able to:

12.1 Explain the reason(s) why:

a) It is a good operating practice to unload the turbine prior to tripping it (1); ⇔ *Page 4*

b) The gland sealing steam system must be shut down prior to switching off the turning gear (1); ⇔ *Page 5*

c) The turning gear must be switched off prior to shutting down the lube oil system (1); ⇔ *Page 5*

d) Condenser vacuum should be broken before shutting down the gland sealing steam system (2); ⇔ *Page 8*

e) The gland sealing steam system must be shut down prior to shutting down the CCW system (1); ⇔ *Page 8*

f) The gland sealing steam system must be shut down prior to shutting down the condensate system (2). ⇔ *Page 9*

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INSTRUCTIONAL TEXT

INTRODUCTION

During unloading and shutting down of the steam and feedwater cycle systems, they undergo a major operating transient. As the equipment is exposed to such adverse operating conditions as increased thermal stresses and vibration, its life is reduced and chances for damage are increased. To minimize these effects, it is important that you understand the reasons why the major activities, that occur during shutting down these systems, are performed in a certain way.

As in the other modules, the information presented here is very general and does not cover many station specific differences.

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MAJOR ACTIVITIES DURING UNLOADING AND SHUTTING DOWN OF THE STEAM AND FEEDWATER CYCLE SYSTEMS

In this section, you will learn the major activities performed to shut down the steam and feedwater cycle systems, and how and why these activities are sequenced. The approach taken to present these activities is identical with that used in the preceding module.

A pullout diagram (Fig. 12.1) at the module end depicts these activities. The points that mark the beginning and end of each activity are numbered in the typical order in which these activities occur during unit unloading and shutting down.

It is assumed in this diagram that in the final state of an extended shutdown, all major systems of the steam and feedwater cycle are shut down. Naturally, in the case of a short outage, some of these systems remain in service. For example, the turbine may be left on turning gear, and the boiler feed and condensate systems may continue to supply feedwater to the boilers operating at normal pressure.

Getting back to the case of an extended outage, you will notice in Fig. 12.1 that once the turbine generator is tripped (activity 2-3), the remaining activities are carried out on a few parallel paths, to save time:

- Activities 3-5-11-12-13-14 as well as 3-13 and 6-10 shut down the turbine and most of its auxiliary systems;
- Activities 3-4-7-9-14 shut down the systems associated with maintaining condenser vacuum. During this process, condenser pressure equalizes with atmospheric pressure;
- Activities 3-8-10-14 cool down the boilers, and then shut down the boiler feed and the condensate systems.

In the text below, each activity is described in more detail for your orientation. You do not have to memorize this description. Only the information addressing objective 12.1 is required for the checkout.

Unit unloading (activity 1-2)

Before a planned outage begins, the system control centre is contacted to determine when the unloading can begin and how fast it should be done. This minimizes the effect of unit unloading on the grid.

While the operator can unload the unit manually, usually it is done automatically by the unit DCC. In the latter case, the operator inputs the target load (zero, in our case of full unloading) and the predetermined rate of unloading, and the DCC carries out the unloading. As during unit loading, the

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mode of unit operation (reactor lagging or reactor leading) determines how load changes propagate through the unit.

When the turbine steam flow is gradually reduced, causing corresponding changes in the generator MW output, the following **major changes** occur in the steam and feedwater cycle systems at the proper turbine load:

- Boiler level setpoint is gradually ramped down;
- DA heating is transferred from turbine extraction steam to throttled boiler steam;
- Reheaters are gradually unloaded;
- The number of running CEPs and BFPs is gradually reduced to one of each;
- The HP feedheater drains pumps are automatically shut down;
- Moisture separator drains are automatically dumped to the condenser (rather then being directed to the appropriate feedheaters);
- Boiler and DA level control switches to the small control valves;
- Various groups of drain valves in steam pipelines open at different turbine loads.

Some of these actions are manual, and others automatic, depending on the station. The operator must **check** that the **automatic actions** occur at the proper turbine load as specified in operating manuals (if any action fails to occur, it must be performed manually).

In addition, the operator must **monitor important operating parameters** (eg. the turbine supervisory parameters) closely to ensure safe operation. Remember that during unloading, the turbine is subjected to increased thermal stresses and differential expansions due to cooling by the steam*. As a result, vibration levels are likely to rise. Potential for other operational problems (eg. DA pressure control problems or water induction to the turbine) is also increased when the unit undergoes this large transient. This is why it is very important to monitor the critical parameters and not rely entirely on automatic protection.

* Recall that steam temperature decreases due to throttling by the GVs, and – in the LP turbines – due to reheater unloading.

Turbine generator trip (activity 2-3)

The turbine generator is tripped manually, when its unloading is complete. Usually, full unloading of the machine can be confirmed by the GVs being in the closed position and reverse generator power.

When the turbine generator is tripped, the turbine valves operate appropriately*, and the generator is disconnected from its electrical loads. This starts the turbine generator rundown.

* Details of valve operation are given in module 234-3

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Obj. 12.1 a) ⇔

Except for emergency conditions, **the machine should not be tripped before it is fully unloaded.** This operating practice (ie. first unloading, then tripping) gives extra protection against turbine generator overspeed. Note that the machine would overspeed if it were tripped when loaded, and the trip logic failed to execute a sequential trip*. While such failure is very unlikely, it is still possible. But if the machine is fully unloaded before it is tripped, overspeed is prevented even if the trip logic is faulty.

* Recall that during a sequential turbine trip, the generator remains connected to the grid until the turbine steam flow has been stopped.

Turbine generator rundown (activity 3-5)

When the turbine steam flow is stopped and the generator is disconnected from the grid, a turbine generator rundown begins. With no driving torque, the machine slows down due to a countertorque produced by various friction losses in the machine: mainly windage in the turbine and generator, and friction in the bearings. Assuming no bearing problems and no rubbing in the machine, the rundown can take up to two hours, depending mainly on how early in the process the condenser vacuum is broken.

At the proper level of decreasing turbine speed, the following major automatic actions should occur:

- The auxiliary oil pump starts up (in some stations, the pump is started manually before the rundown begins);
- The jacking oil pumps and the turning gear motor start up;
- The turning gear engages* and begins to drive the turbine generator rotor.

* Recall that in some stations, this action is performed manually after the turbine generator has come to full stop.

The operator checks that **these actions** occur at the proper turbine speed, and performs them manually if they do not. The operator also **monitors** the turbine supervisory and other **important parameters**. Remember that during rundown, the machine passes through its critical speed ranges, and the oil wedge in the bearings becomes thinner due to decreasing speed. These are just some of the reasons why monitoring of the machine condition must be continued during the rundown.

SUMMARY OF THE KEY CONCEPTS

- During unit unloading and turbine generator rundown, potential for equipment damage is increased due to many reasons such as increased thermal stresses or vibration levels. To ensure safe operation, the operator should monitor the turbine supervisory and other important parameters particularly closely. The operator should also check that required automatic actions occur at the proper turbine load (or speed) and perform them manually, if necessary.
- Except for emergencies, the turbine generator should not be tripped before it is fully unloaded. This operating practice protects the machine

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against overspeed upon the trip due to possible failure of some steam valves to stop the steam flow.

Turbine generator on turning gear (activity 5-11)

Recall that following the rundown, the turbine generator is quickly put on turning gear to prevent excessive hogging. The machine is left on turning gear until the highest temperature has dropped below a certain limit*. This process may take up to two days.

* About 100-150°C, depending on the station.

Shutting down the turning gear (activity 11-12)

⇔ *Obj. 12.1 b)*

In addition to the temperature limit mentioned above, another prerequisite must be met before the turning gear may be shut down. This prerequisite is that **the gland sealing steam system must be shut down**. Otherwise, hot gland sealing steam would leak into the turbine, causing the stationary rotor to hog.

Shutting down the turbine lube oil system (activity 12-13)

⇔ *Obj. 12.1 c)*

To prevent damage to the turbine generator bearings due to loss of lubrication, **the turning gear must be switched off before the turbine lube oil system is shut down**. Additional protection, as you may recall, is provided by interlocks in the turning gear motor control circuit. The interlocks switch the motor off when the lube or jacking oil pressure is too low. But the interlocks – as any other equipment – are not perfectly reliable, and may fail when needed. By switching the turning gear off prior to shutting down the turbine lubricating oil system, we do not have to rely on these interlocks for bearing protection – a simple, yet effective precaution.

Shutting down the system involves turning all the oil pumps and vapour extraction fans off and valving out cooling water to the lube oil coolers. Note that the coolers can be removed from service as early as several hours* after the turbine generator was placed on turning gear without causing bearing oil overheating. At this point of the shutdown, the heat input to the bearings from the hotter parts of the rotor is so small that heat losses through the system piping and oil tank walls provide adequate cooling.

* The exact time can be found in the system operating manual.

However, **it is not recommended to shut down the oil purifier** for a period longer than one week (and the shorter, the better) unless the system is to be drained. Otherwise, absorption of moisture from atmospheric air is likely to result in excessive water content in the oil.

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Shutting down the turbine governing system (activity 3-13)

Recall that in most stations a fire resistant fluid, and not the turbine lube oil, is used in the turbine governing system. Therefore, the system can be shut down independently from the turbine lube oil system.

Though the system can be safely shut down right after the turbine trip, this activity is typically delayed until turbine rundown is complete or nearly complete. This allows the operator to concentrate on other more critical or urgent activities such as monitoring of the turbine rundown. It also facilitates steam readmission to the turbine if the rundown had to be aborted for some reason.

In most stations, in the case of a short outage (a few days), the system is left in service. This prevents high vibration of the system piping due to pressure and flow surges caused by pump startup and shutdown. In these stations, operational experience shows that frequent startup and shutdown of the pumps can lead to fracture of the system piping.

When the system is shutdown, usually one FRF pump remains in service to maintain a sufficient flow through purification equipment to ensure satisfactory purity of the fluid. Also, the electronic control modules remain energized to allow testing. This equipment is shut down only when it is needed for maintenance.

In the few CANDU units that use lube oil for turbine steam valve actuation, the governing system is shut down when the lube oil pumps are turned off. If maintenance is necessary, the governing system can be isolated from the turbine lube oil system and drained before the oil system is shut down.

Shutting down the LP turbine exhaust cooling system (activity 6-10)

Because windage losses drop rapidly with decreasing turbine speed, the LP turbine exhaust cooling system can be shut down early during turbine rundown, without causing turbine overheating. But in practice, system shutdown is delayed until the rundown is well advanced or complete. The delay reflects the fact that during turbine rundown the operator is very busy, and early shutdown of the system is not critical (because the system is inactive when the turbine exhaust is cool).

Shutting down the turbine supervisory system (activity 13-14)

Since the turbine supervisory system monitors the operating state of the turbine generator and its auxiliaries, it is removed from service only after the machine and its auxiliaries have been shut down.

SUMMARY OF THE KEY CONCEPTS

- To prevent turbine hogging, the gland sealing steam system must be shut down before switching the turning gear off.
- To prevent damage to the turbine generator bearings due to loss of lubrication, the turning gear must be switched off before the turbine lube oil system is shut down.

Shutting down the condenser air extraction system and condenser vacuum breaking (activities 3-4-7)

As shown in Fig. 12.1, during an orderly unit shutdown, the condenser air extraction system is shut down before condenser vacuum is broken.

The vacuum pumps in the condenser air extraction system can be shut down at different times during turbine rundown. In some stations, the pumps are switched off right after the turbine trip. Note that this action does not result in overheating of the LP turbine exhaust. Why? Because vacuum deterioration due to air in-leakage (into the condenser, LP turbines and associated equipment operating under vacuum) is normally very slow. By the time the vacuum has deteriorated significantly, the turbine speed drops so much that windage losses in the turbine become negligible.

In many stations, however, the condenser air extraction system remains in service until the turbine rundown is complete. Maintaining normal condenser vacuum during turbine rundown has some advantages that have already been described in module 234-5. For example, this practice delays accumulation of air in the condenser atmosphere, and thus, an increase in the dissolved gases content of the condensate.

When the condenser extraction system is shut down early during turbine rundown, condenser vacuum is not broken immediately afterwards. Instead, this action is delayed until turbine speed has decreased enough*. In the extreme case, turbine rundown must be completed first, before condenser vacuum can be broken.

* Details are given in module 234-5.

In the stations equipped with CSDVs, shutting down the condenser air extraction system and vacuum breaking are delayed as long as possible if the unit is to be cooled down. In these stations, the preferred method of boiler cooldown is by means of the CSDVs (if the ASDVs were used, steam discharge to atmosphere would result in increased consumption of makeup water). Because low condenser vacuum renders the CSDVs unavailable, sufficient vacuum must be maintained until low boiler pressure makes it impossible*.

* Recall that the gland sealing steam system and steam jet air ejectors in the condenser air extraction system cannot function when boiler pressure is too low.

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Obj. 12.1 d) ⇔

Shutting down the gland steam sealing system (activity 7-9)

Only when condenser vacuum is broken*, can the gland sealing steam system be shut down. Valving out the gland steam when condenser vacuum is too high, results in the following adverse consequences/operating concerns:

* In a few units, this requirement is less stringent, allowing for shutting down the gland sealing steam system once condenser vacuum is less than 50 kPa.

- Cool atmospheric air sucked into the turbine would quench the hot gland seals, possibly causing damage due to thermal overstressing.
- Lube oil may be sucked out of the bearings and drawn into the turbine. This can happen because the bearings are located close to the turbine gland seals to reduce the overall length and weight of the turbine generator. The contamination of boiler feedwater with oil can cause severe foaming and asphalt-like deposits in the boilers.

Shutting down the CCW system (activity 9-14)

Obj. 12.1 e) ⇔

When the gland sealing steam system is shut down and other possible sources of steam to the condenser are eliminated, the CCW system can be shut down. Otherwise, hot steam leaking into the condenser with no cooling water flow would lead to a gradual buildup of condenser pressure. Eventually, the pressure could rise enough to rupture or lift a disc in an LP turbine exhaust cover*.

* Recall that for overpressure protection, the LP turbine exhaust cover has a few rupture or lift discs (diaphragms), depending on the station.

Shutting down the CCW system, if done wrongly, can result in a severe water hammer. The general operating practices that are used to prevent it are described in module 234-5.

Boiler cooldown (activity 3-8)

Recall that a controlled boiler cooldown is used to reduce the heat transport (HT) system temperature such that transfer of reactor cooling from the boilers to the shutdown cooling (SDC) system can be done without causing excessive thermal stresses in the HT and the SDC systems.

During this cooldown, the boiler steam flow is adjusted to cool the HT system at a desired rate. The flow is controlled by the SRVs or CSDVs, depending on the station. For a constant cooldown rate, the **mass** flow rate of the discharged steam is approximately constant. But because of the compressibility of steam, the **volumetric** flow rate increases with dropping boiler pressure. To accommodate this increasing flow, the valve opening increases. At a certain HT temperature, the valves would open fully and could no longer maintain the desired rate of cooldown.

In the stations with large SRVs, that temperature is so low that reactor cooling is transferred to the SDC system well before the SRVs open fully.

It is a different story in the stations using CSDVs. Decreasing boiler pressure reaches a level at which operation of the turbine glands and steam jet air

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ejectors deteriorates. The resultant poor condenser vacuum causes the CSDVs to unload and trip. This happens before the valves can open fully. To compensate for the unloading and the trip, the ASDVs open to continue cooldown (though at a reduced rate) to a HT system temperature at which the SDC system can be valved in without excessive thermal stresses.

Note that when reactor cooling is transferred to the SDC system, the heat transfer in the boilers reverses: cooling is now by the HT D_2O, which is in turn cooled by the SDC system. With decreasing temperature of the boiler water, boiler pressure drops accordingly (saturation conditions).

Shutting down the boiler feed and the condensate systems (activities 8-10-14)

Once boiler feedwater is not needed for reactor cooling, the boiler feed system can be shut down. To avoid problems with low DA level and BFP glands, the condensate system remains in service until the boiler feed system is shut down.

⇔ *Obj. 12.1 f)*

In addition, the gland steam sealing system must be shut down before the condensate system can be removed from service. Otherwise, loss of cooling to the gland exhaust condenser would result in the following adverse consequences/operating concerns*:

* They are explained in detail in modules 234-1 and 234-4.

- Steam egress from the turbine and steam valve gland seals due to loss of vacuum in the gland exhaust condenser;
- Overheating of the gland exhaust fans which are not designed to handle hot gland steam leakoff.

Note that steam hammer in the condensate system due to implosion of steam pockets in the gland exhaust condenser tubes (as discussed in module 234-6) is of no concern. The reason: in the absence of condensate flow, the steam pockets would not implode. Instead, they would condense gradually due to heat losses, and the process would be completed well before the condensate system is started up.

Finally, as shown in Fig. 12.1, the LP turbine exhaust cooling system – which needs the condensate to function – must be shut down (activity 6-10) before the condensate system is removed from service. In practice, the LP turbine exhaust cooling system is shut down well before the condensate system is ready for removal from service.

Typically, in their shutdown state, the condensate and boiler feed systems remain filled with water. Thus, feedwater supply to the boilers can be quickly restored, should reactor cooling require it. Only when it is necessary for maintenance, is the relevant equipment (eg. the DA storage tank) drained.

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SUMMARY OF THE KEY CONCEPTS

- Before shutting down the gland exhaust system, condenser vacuum must be significantly reduced. Otherwise, turbine glands can be damaged due to quenching by cool atmospheric air sucked into the turbine. In addition, bearing oil can be sucked into the turbine, contaminating boiler feedwater. This can lead to foaming and asphalt-like deposits in the boilers.
- The CCW system should be left in service until all sources of steam to the condenser have been eliminated. Otherwise, given enough time, steam leaking into the condenser can raise its pressure to a level at which a bursting disc in an LP turbine exhaust cover would rupture.
- The condensate system can be shut down only after the boiler feed, the gland sealing steam and the LP turbine exhaust cooling systems have been shut down.
- Shutting down the condensate system before gland sealing steam is isolated would result in loss of cooling to the gland exhaust condenser. This would lead to steam egress from the turbine and steam valve glands, and overheating of the gland exhaust fans.

Pages 11-12 ⇔

You can now answer **assignment questions.**

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ASSIGNMENT

1. The reason why unloading the turbine prior to tripping it is a good operating practice is ____________________________________

2. Each of the improper operating practices listed below results in the following adverse consequences/operating concerns:

   a) Switching off the turning gear prior to shutting down the gland steam sealing system:

   b) Shutting down the turbine lube oil system prior to switching the turning gear off:

   c) Shutting down the gland sealing steam system at full condenser vacuum:

      i) ____________________________________

      ii) ____________________________________

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d) Shutting down the CCW system with the gland sealing steam system remaining in service:

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e) Shutting down the condensate system with the gland sealing steam system remaining in service:

i) ____

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ii) ____

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

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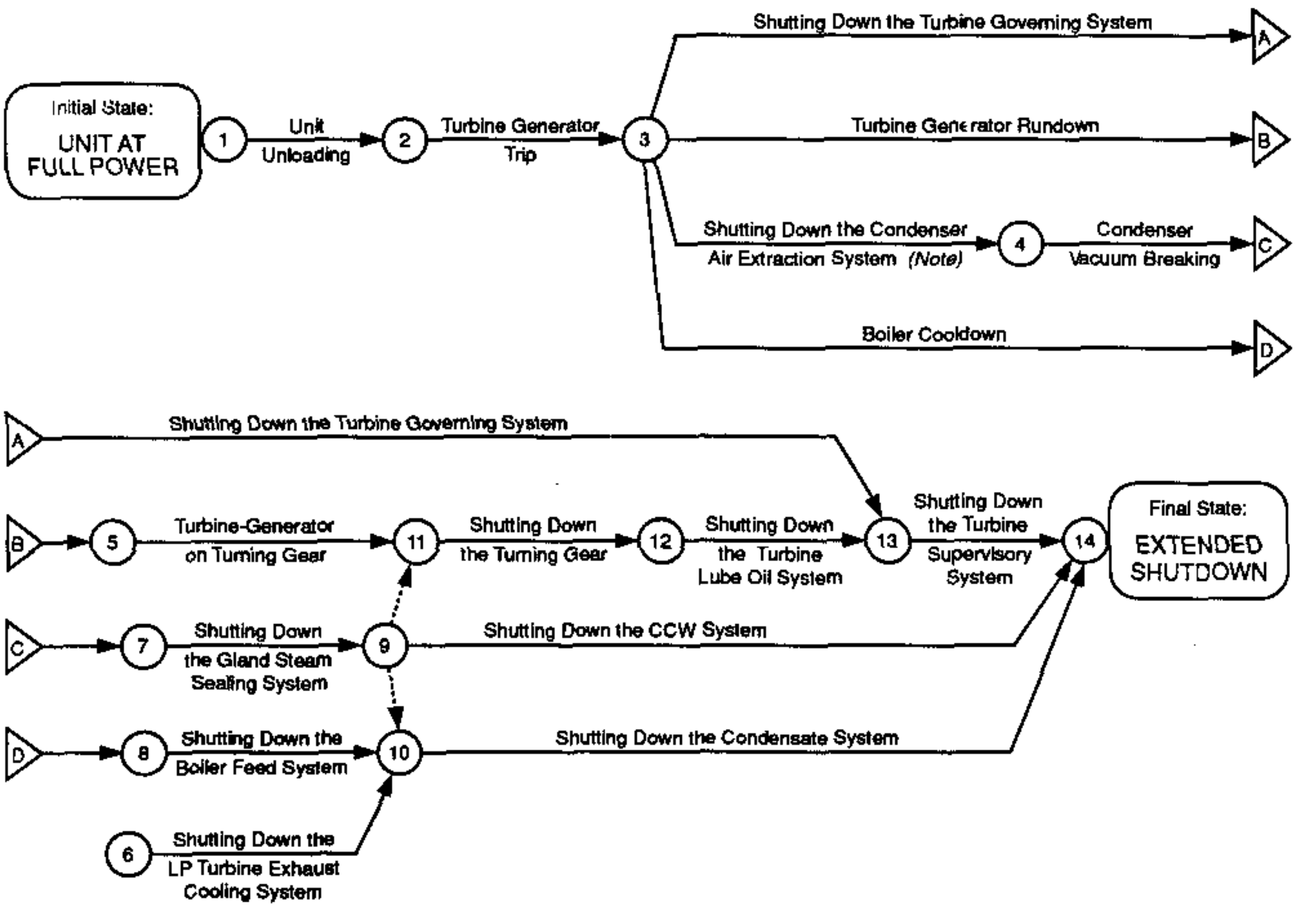

Fig. 12.1. Major activities during unloading and shutting down of the steam and feedwater cycle systems.

Activities Additional cross-links

Note: In the stations equipped with CSDVs, this activity is usually delayed to allow these valves to operate during boiler cooldown.