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Module 234-9

THE TURNING GEAR

OBJECTIVES:

After completing this module you will be able to:

9.1 a) For each of the turbine operating states listed below, state the purpose(s) of the turning gear operation:

i) During turbine startup (2); ⇔ ***Page 2***

ii) While shutting down the turbine (1). ⇔ ***Page 4***

b) For each of the operating states listed in point (a), describe turning gear operation, addressing the following points: ⇔ ***Pages 3** (startup), **and 4-5** (shutdown)*

i) When the turning gear motor is started up / shut down;

ii) When the turning gear is engaged to / disengaged from the turbine generator rotor;

iii) The reason why during turbine runup the turning gear motor continues running for some time after the turning gear has disengaged from the turbine generator rotor;

iv) The reason why during turbine rundown the turning gear motor is started up some time before the turning gear is actually needed to rotate the turbine generator rotor.

c) For each of the operating states listed below, describe the adverse consequences/operating concerns caused by failure to turn the turbine generator rotor as required:

i) During turbine startup (2); ⇔ ***Pages 3-4***

ii) While shutting down the turbine (3). ⇔ ***Pages 5-6***

9.2 Explain the major operational concern caused by excessive use of the turning gear. ⇔ ***Page 6***

9.3 a) i) State the general operator action that should be taken, to protect the turbine, if the turning gear fails to start during a turbine rundown. ⇔ ***Pages 7-8***

ii) Explain how this action protects the turbine.

iii) Describe three alternate methods of turning the turbine rotor that can be used under these operating circumstances.

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Page 8 ⇔

b) Assuming that the turbine rotor has been left stationary for too long during the cooldown that follows a turbine rundown:

   i) State one important precaution that must be taken prior to attempting to turn the rotor by the turning gear when it becomes available;

   ii) Explain the reason why this precaution is necessary;

   iii) State the required action if, as a result of this precaution, the turning gear must not be used.

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

In the turbine courses which you have taken so far, the function and structure of a typical turning gear as well as the phenomena of turbine generator shaft hogging and sagging are described. This general information is supplemented in this module with a detailed description of turning gear operation during turbine startup and shutdown. Effects of the turning gear unavailability while shutting down the turbine are also covered.

TURNING GEAR OPERATION DURING TURBINE STARTUP

Obj. 9.1 a) i) ⇔

Purposes

The major purposes of turning gear operation during turbine startup are:

1. **To roll out shaft hogging or sagging before runup is begun.**

   As mentioned in the previous module, any attempt to run up the turbine with an excessively deformed shaft is bound to fail because high vibration would sooner or later force a turbine trip. Meanwhile, the turbine generator would be unnecessarily exposed to increased risk of damage due to high vibration and/or rubbing.

2. **To enable uniform prewarming of the turbine generator.**

   If the turbine generator were prewarmed with the rotor held stationary, rotor and casing hogging would develop due to thermal stratification of the atmosphere inside the machine as outlined in the earlier turbine courses. This would make runup impossible until the hogging is rolled out.

Operation

⇔ *Obj. 9.1 b)*

To achieve these two objectives, the turning gear is started early during unit startup such that the turbine generator can spend enough time on turning gear. In principle, **the duration of turning gear operation must be enough to:**

- Straighten up the turbine generator shaft such that the HP turbine rotor eccentricity is within the acceptable limit, and
- Meet the additional requirements (if any) regarding the minimum time on turning gear that is necessary to equalize turbine casing temperature. This allows us to make sure that the casing is straight, despite lack of instrumentation that would measure casing hogging or sagging.

  The required minimum time on turning gear varies from station to station, reflecting the operating experience of the turbine manufacturer. Usually, the minimum time depends on the duration of the preceding shutdown during which the turbine generator rotor was left stationary, and may reach up to 24 hours.

When the turning gear is started up, its motor is energized and the turning gear drive is engaged to the turbine generator rotor. Normally, the turning gear is started manually, but in some new stations, this – along with many other startup activities – can be done automatically by appropriate DCC software.

When turbine runup begins, the turning gear disengages automatically as soon as turbine speed starts increasing. The turning gear motor, however, keeps running until turbine speed reaches a certain level* at which the motor switches off automatically. The extended period of motor operation is a precaution taken to make sure the turning gear is available for proper turbine shutdown, should the turbine runup have to be aborted.

* 100-1000 rpm, depending on the station.

Adverse consequences and operating concerns caused by inadequate operation

⇔ *Obj. 9.1 c) i)*

Failure to turn the turbine generator rotor long enough prior to runup causes the following adverse consequences/operating concerns due to turbine generator operation with an excessively bowed rotor:

1. **Increased risk of rubbing damage to turbine generator internals*.**

   Recall that at low speeds rubbing can go undetected because indicated bearing vibration can be misleadingly low despite the abnormal rotor deformation.

* Rubbing damage is described in more detail in module 234-1.

2. **Increased turbine generator bearing vibrations.**

   As soon as speed is high enough, and particularly while passing through a critical speed range, the vibrations can become abnormally

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high. They may force a turbine trip and, in the extreme case, damage the machine.

SUMMARY OF THE KEY CONCEPTS

- During turbine startup, the turning gear is used in order to roll out shaft deformations before runup begins, and to enable uniform prewarming of the turbine generator.
- To achieve these objectives, the turning gear is started early during unit startup. Its operation is continued long enough to reduce the HP turbine rotor eccentricity to a satisfactory level, and to meet any additional time requirements as specified in the appropriate operating manual.
- As soon as steam is admitted to the turbine, causing its speed to increase, the turning gear should disengage automatically from the turbine generator shaft. The turning gear motor continues running until a certain turbine speed is reached. This ensures turning gear availability if the turbine startup had to be aborted.
- Failure to use the turning gear as required during turbine startup may result in rubbing damage during runup. Very high bearing vibrations may force a turbine trip, and even damage the machine.

TURNING GEAR OPERATION WHILE SHUTTING DOWN THE TURBINE

Obj. 9.1 a) ii) ⇔

Purpose

When the turbine generator is being shut down, the turning gear is used **to prevent excessive hogging of the turbine rotor and casing**. This would happen if, following the turbine rundown, the rotor were left stationary while the turbine is still hot.

Obj. 9.1 b) ⇔

Operation

During turbine rundown, **the turning gear motor should automatically switch on** at the same turbine speed at which it turns off during turbine runup. The turning gear, however, remains disengaged from the turbine generator shaft until turbine speed has decreased enough*. The early startup of the turning gear motor (at least several minutes before the turning gear is actually needed) gives the operator time to respond, should the motor fail to start. This upset is discussed in detail later in the module.

* Down to 0-20 rpm, depending on the station.

After turbine speed has decreased sufficiently, the turning gear is mechanically engaged to the turbine generator rotor. In most stations, this is performed automatically by a special self-shifting clutch. In other stations,

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the rotor must come to a full stop, and then the turning gear is engaged manually.

The turbine then remains on turning gear until the highest HP turbine metal temperature has decreased to a certain level*. At this low temperature, the turbine rotor can be left stationary without causing excessive hogging. Note that turbine cooldown to this temperature range may take up to two days. When the cooldown is complete, the turning gear motor is switched off, and the gear drive is disengaged from the turbine generator rotor.

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

Adverse consequences and operating concerns caused by inadequate operation

⇔ Obj. 9.1 c) ii)

Because turbine shaft and casing hogging is a fast process, **it is important that the turning gear start driving the turbine generator rotor with no delay**. In some stations, a delay as short as three minutes is considered sufficient to be able to cause excessive hogging. Likewise, **only short interruptions in turning gear operation can be tolerated** before the turbine has cooled down sufficiently. These restrictions decrease with decreasing turbine temperature. The cooler the turbine, the smaller the temperature gradients inside the machine, and hence, the potential for its hogging is reduced.

Failure to turn the turbine generator rotor as described above can result in the following adverse consequences/operating concerns due to excessive hogging of the turbine rotor and casing:

1. **The subsequent turbine startup would have to be delayed** to give the turbine enough time to cool down and straighten out.

   The larger the hogging, the longer the delay during which the turbine generator remains unavailable for service, possibly resulting in loss of production.

2. **Damage to turbine seals, and possibly bearings**, would likely happen if the radial clearances were closed and the rotor were turned despite abnormally high resistance.

3. **The turbine rotor may deform plastically** due to excessive thermal stresses.

   Should this happen, the turbine could not be returned to service because of excessive vibrations. The bowed rotor would have to be replaced with a spare one (if any) and/or shipped to the manufacturer for repairs or replacement. A long forced outage could result.

   To keep it in the proper perspective, it must be stated that **in CANDU stations**, as opposed to conventional thermal plants, **chances for**

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* 250-265°C compared with 535-565°C.

hogging that would produce plastic deformation of the shaft are very slim. This is due to the relatively low boiler steam temperature*. As a result, the maximum top-to-bottom temperature difference, that can form when the rotor is left stationary, is unlikely to be large enough to produce thermal stresses exceeding the yield point of the rotor material.

Obj. 9.2 ⇔

EXCESSIVE USE OF THE TURNING GEAR

In the preceding sections, you have learned that the turning gear must be used long enough to avoid operational problems during turbine startup and following rundown.

However, excessive operation of the turning gear should be avoided as this **may, in the long run, result in generator rotor ground faults caused by** a phenomenon known as **copper dusting**.

* Refer to the appropriate electrical course if you are not familiar with how the generator rotor field windings are held inside the rotor.

Copper dust can be formed due to fretting of the generator rotor field windings against the slot walls*. At high turbine speeds, no fretting occurs because the windings are firmly held in position against the slot wedge assemblies by the action of centrifugal force. However, at turning gear speed, centrifugal forces are negligible. Therefore, under their own weight, the windings have a tendency to move radially inwards and outwards within the slots once every rotor revolution. The movement of the windings will wear away the copper, creating copper dust. Actual movement can happen if any clearances are present between the windings and the slots, which is expected in machines that have been in service for several years. Naturally, station specific differences in the generator rotor design can affect the rate at which copper dusting can develop.

SUMMARY OF THE KEY CONCEPTS

- The purpose of turning gear operation while shutting down the turbine is to prevent rotor hogging.
- If allowed to happen, this could delay the subsequent turbine startup until the shaft bow is removed. Damage to turbine seals, and possibly bearings, could happen if the radial clearances there were closed and the rotor turned. In the worst – but extremely unlikely – case, the top-to-bottom temperature gradient in the rotor might produce thermal stresses sufficient to deform the rotor plastically. A prolonged outage to repair/replace the rotor would result.
- To prevent excessive hogging while shutting down the turbine, the turning gear operates as follows. The motor is switched on as soon as the turbine speed has decreased to a certain level. Engagement to the turbine generator rotor occurs at least several minutes later, after turbine speed has decreased to zero or nearly zero, depending on the station.

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The early startup of the turning gear motor gives the operator time to respond, should the motor fail to start. Turning gear operation is continued until the highest turbine temperature has decreased to a certain limit.

- Excessive use of the turning gear is not recommended, mainly because it promotes copper dusting in the generator rotor which can lead to generator ground faults.

You can now do **assignment questions 1-4**.

⇔ *Pages 11-13*

TURNING GEAR UNAVAILABILITY WHILE SHUTTING DOWN THE TURBINE

In this section, you will learn about:

- The action that the operator should take when the turning gear motor fails to start during turbine rundown;
- Alternate methods of turning the turbine generator rotor;
- Actions that should be taken if the rotor is left stationary for too long during the cooldown that follows a turbine rundown.

⇔ *Obj. 9.3 a)*

As stated earlier, during turbine rundown the turning gear motor should start at a certain turbine speed, at least several minutes earlier than the turning gear is actually needed. This gives the operator enough time to respond to failure of the motor to start.

Assuming that repeated attempts to start the motor fail, **the operator should arrange for an alternate method of turning** the turbine generator rotor. Ideally, the arranged method should be ready for use when the rotor has stopped. **In no case, should the rotor be left stationary for more than a few minutes** as it may be sufficient for excessive hogging to form.

Depending on the station, one or two of the following **alternate methods of turning the turbine generator rotor**, that can be applied quickly enough to avoid excessive hogging, are available:

1. **Handbarring** by 1-2 men pushing a lever attached to the coupling between the turning gear motor and the reduction box. Usually, the lever has a ratchet mechanism which is engaged with teeth machined on the coupling periphery. When not used, the lever is hung on the turning gear casing or nearby, so that it is readily available and can be applied quickly. Handbarring is the most common alternate method of turning the turbine generator rotor.
2. **A specialized electric or pneumatic tool** which, when needed, can be attached to the back of the turning gear motor rotor. Thus, it can drive the turbine generator rotor via the turning gear reduction box. The tool should be stored as close to the turning gear as possible so that it can be mounted quickly enough to prevent excessive turbine hogging.

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3. **An auxiliary turning gear** (available only in some units) which is independent from the main turning gear. As opposed to the other two methods, the auxiliary turning gear can drive the turbine generator rotor even when the main turning gear reduction box is unavailable.

Any of these methods can effectively protect the turbine from excessive hogging because the hot rotor is not left stationary. While the turbine speed that can be maintained is too small to ensure perfectly uniform cooling of the turbine, **continuous turning of the rotor minimizes hogging** because no excessive top-to-bottom Δt can build up in the rotor.

Obj. 9.3 b) ⇔

If, for some reason, the **turbine rotor were left stationary for too long*** during its cooldown period, the possibility that excessive hogging may have developed must be taken into account. To avoid **possible rubbing damage to turbine seals** under these circumstances, **precautions must be taken** prior to an attempt to turn the turbine rotor by the turning gear when it becomes available.

* More than 5-30 minutes, depending on the station and the highest HP turbine metal temperature.

This is achieved by **handbarring the turbine rotor for one full turn** while checking for abnormally high resistance to turning and/or monitoring the HP turbine rotor eccentricity (depending on the station). If the handbarring indicates that the **rotor is bent excessively*, the turning gear must not be used.**

* Applicable limits should be specified in the turning gear system operating manual.

In most stations, the required action in these circumstances is to **leave the rotor stationary and let the turbine cool down** to the temperature range at which turning gear operation is normally terminated. Then, the rotor should be rotated by handbarring and checked for straightness, as described in the paragraph above.

Note that as the turbine cools down, the hogging that has developed decreases due to temperature equalization. Normally, such cooldown is effective in reducing the hogging to a level at which the turning gear can be used again. In the unlikely event that the turbine rotor could not be rotated by handbarring following the cooldown period, the Technical Unit would have to be informed.

SUMMARY OF THE KEY CONCEPTS

- If the turning gear fails to start during turbine rundown, the operator should arrange for an alternate method of turning the turbine generator rotor.
- These methods typically include handbarring or use of a specialized electric or pneumatic tool. In some units, an auxiliary turning gear is also available.
- Any of these methods can maintain turbine speed that is sufficient to prevent excessive turbine hogging.

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- If the turbine rotor were left stationary for too long before its cooldown is complete, precautions must be taken prior to putting it on turning gear when it becomes available. This is necessary to prevent rubbing damage to turbine seals because of the possibility that excessive hogging may have developed.
- This is achieved by handbarring the turbine for one full turn while checking for abnormally high resistance to turning and/or excessive eccentricity of the HP turbine rotor, depending on the station.
- If the rotor is believed to be bent excessively, the turning gear must not be used. In most stations, the required action is just to leave the turbine rotor stationary until the turbine has cooled down. This practice is very likely to reduce the turbine hogging to a level at which the turning gear can be safely used again.

You can now do **assignment questions 5-6.**

⇔ *Pages 13-14*

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ASSIGNMENT

1. During turbine startup:

   a) The two objectives of turning gear operation are:

      i) ______________________________

      ____

      ii) ______________________________

      ____

   b) If turbine runup began prematurely, ie. not enough time on turning gear, the following adverse consequences/operating concerns would result:

      i) ______________________________

      ____

      ____

      ____

      ii) ______________________________

      ____

      ____

      ____

   c) To avoid these consequences, the turning gear should be operated as follows:

      i) It is started ______________________________

      ____

      ____

      ii) It disengages from the turbine generator rotor when ______

      ____

      ____

      iii) Its motor is switched off when ______________________

      ____

2. While shutting down the turbine:

   a) The purpose of turning gear operation is ____________________

   ____

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b) Inadequate use of the turning gear results in the following adverse consequences/operating concerns:

i) ____

____

____

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ii) ____

____

____

____

iii) ____

____

____

____

c) The turning gear should be operated as follows:

i) It is started ________________________________

____

ii) It is engaged to the turbine generator rotor when ________

____

iii) It is shut down when ____________________________

____

3\. a) The reason why during turbine runup the turning gear motor continues running for some time after the turning gear has disengaged from the turbine generator rotor is ____________________

____

____

b) The reason why during turbine rundown the turning gear motor is started up some time before the turning gear is actually needed to drive the turbine generator rotor is ________________

____

____

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4. a) The major operational concern caused by excessive use of the turning gear is that it promotes ______________________________

____

due to a phenomenon known as ______________________________

b) This phenomenon can develop as follows:

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____

____

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____

5. Suppose that during a turbine rundown the turning gear motor failed to start and it turned out that it will remain unavailable for some time. In these circumstances:

a) To protect the turbine, the operator should ______________________________

____

b) Depending on the station, one or two of the following alternate methods of turning the turbine generator rotor is / are available:

i) Method: ______________________________

Description: ______________________________

____

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____

____

ii) Method: ______________________________

Description: ______________________________

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____

____

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iii) Method: ____________________

Description: ____________________

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c) Any of these methods protects the turbine from ____________________ because ____________________

____

____

6. Assume that a hot turbine rotor has been left stationary for several minutes due to a temporary loss of the turning gear, and after this period the turning gear is available for service again.

a) Prior to putting the turbine back on turning gear, the operator should ____________________

____

____

b) The reason why this precaution is taken is ____________________

____

c) If it turned out, as a result of this precaution, that the turning gear must not be used, the typical operating practice is ____________________

____

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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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