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Module 234-8

THE TURBINE SUPERVISORY SYSTEM

OBJECTIVES:

After completing this module you will be able to:

8.1 State the reasons for monitoring each of the following parameters:

- a) Turbine generator bearing vibrations (2); ⇔ *Page 2*
- b) HP turbine casing expansion (1); ⇔ *Page 3*
- c) HP and LP turbine axial differential expansions (1); ⇔ *Page 3*
- d) Shaft axial position (2); ⇔ *Page 3*
- e) Assorted temperatures of the turbine generator (1); ⇔ *Page 4*
- f) Turbine speed (4); ⇔ *Page 4*
- g) Steam valve positions (2). ⇔ *Page 4*

8.2

- a) Explain what is meant by *rotor eccentricity*. ⇔ *Pages 5-6*
- b) State two reasons for monitoring rotor eccentricity. ⇔ *Pages 6-7*
- c) Explain how turbine speed limits the applicability of each of the following indications for adequate monitoring of turbine generator operation: ⇔ *Page 7*
  - i) Rotor eccentricity;
  - ii) Bearing vibrations.

8.3 For each of the following parameters, state the system responses to exceeding a limit on the parameter:

- a) Bearing vibration (2); ⇔ *Page 8*
- b) Other parameters (1). ⇔ *Page 8*

8.4 State two typical information sources, other than the turbine supervisory system, that are used for adequate monitoring of turbine generator operation. ⇔ *Pages 8-9*

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

You will recall from the previous turbine courses that the turbine supervisory system monitors, under all operating conditions, a multitude of turbine generator operating parameters. Information provided by the system is used by the control room operator to verify that the turbine generator is operating within the safe limits. And, if this is not the case, the operator should take appropriate actions to protect the machine from abnormal conditions that could result in damage. In most stations, the system also stores records of the major operating parameters for future diagnostic purposes in the event of equipment malfunction or failure.

In this module, the following topics are discussed:

- Typical parameters monitored by the system, including the reasons for their monitoring;
- System responses to an exceeded safety limit;
- Other sources of relevant information that, together with the turbine supervisory system, allow for adequate monitoring of turbine generator operation.

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

PARAMETERS MONITORED BY THE TURBINE SUPERVISORY SYSTEM

Neglecting station specific differences, the following list outlines the most typical parameters monitored by the turbine supervisory system:

Obj. 8.1 a) ⇔

1. **Turbine generator bearing vibrations.**

   Monitoring of bearing vibrations is very important for two reasons:

   - It is **necessary to protect the turbine generator from excessive vibration.** If allowed to persist, the vibration could cause damage due to rubbing, fatigue or loosening of components.

   - Unusual bearing vibrations (even if still below the alarm range) are very often the first indication of something wrong. Thus, their monitoring **allows early detection of some potentially dangerous operational problems** such as water induction, rubbing, or cracks in the rotor.

   More information about turbine generator vibrations is provided in modules 234-11 and 234-14.

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2. **Rotor eccentricity.**

   This parameter is discussed separately on pages 5-7.

3. **HP turbine casing expansion.** ⇔ *Obj. 8.1 b)*

   The HP turbine casing is supported on the foundation in such a way that its generator end is fixed in the axial direction. Thermal expansion/ contraction of the casing in this direction is accommodated at the other end (referred to as *front end*). Its support on the foundation allows for small axial displacements relative to the foundation while still maintaining proper alignment with the rotor. This is the place where the HP turbine casing axial expansion is measured.

   The major reason why this parameter is monitored is to **detect excessive resistance of the front casing support to the casing thermal expansion/contraction**. This abnormality could result in casing deformation leading to increased vibration and even rubbing inside the turbine. Damage to the casing supports due to overstressing could also occur.

   Excessive resistance to casing expansion **shows itself by jerky** – as opposed to normally smooth – **changes in the measured expansion**. Once identified, the problem can usually be rectified by greasing of the key joints of the casing front support or removing a foreign object (eg. a bolt) that got jammed in a key joint.

4. **HP and LP turbine axial differential expansions.** ⇔ *Obj. 8.1 c)*

   Turbine axial differential expansion is covered in module 234-11. For now, it suffices to state that for some reasons the turbine rotor and casing expand/contract differently from each other. If the difference is excessive, some axial clearances inside the turbine can close. **To prevent rubbing damage**, the axial differential expansion of each turbine is monitored.

5. **Shaft axial position.** ⇔ *Obj. 8.1 d)*

   Usually, the position is measured relative to the thrust bearing pedestal. This parameter is monitored for two reasons:

   - **To detect abnormal axial thrust on the turbine generator rotor** (as outlined in module 234-1). The thrust indicates some operational problems in the turbine (eg. in the extraction steam piping) and, if not corrected, can damage the thrust bearing.
   - **To detect excessive wear or failure of the thrust bearing** before the resultant axial displacement of the turbine generator rotor can damage turbine seals through rubbing.

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Obj. 8.1 e) ⇔

6. **Assorted turbine generator temperatures.**

There are significant station specific differences regarding the locations where temperatures are monitored by the turbine supervisory system. As a minimum, these are the HP and LP turbine inlet steam and metal temperatures. In some stations, LP turbine exhaust hood temperatures, bearing metal temperatures, lube oil temperatures or generator temperatures are also included. The general purpose of monitoring the assorted temperatures is **to detect conditions which promote machine failure.** For example, an excessive steam-to-metal temperature difference means that the turbine is subjected to excessive thermal stresses. Similarly, an excessive top-to-bottom temperature difference indicates abnormal cooling of the casing bottom, eg. due to water induction via an extraction steam pipe.

Obj. 8.1 f) ⇔

7. **Turbine speed.**

This parameter is monitored particularly closely **during turbine runup and rundown** for reasons such as:

- Verifying the automatic actions that should happen at certain levels of turbine speed. For example, during turbine rundown, the jacking oil pumps should start up at the proper turbine speed.
- Avoiding, during turbine runup, prolonged operation in the turbine generator critical speed ranges.
- Synchronization.

In addition, turbine speed is very closely monitored **during actual overspeed tests** of the emergency overspeed governor to verify its operation without subjecting the turbine to excessive overspeed.

Obj. 8.1 g) ⇔

8. **Steam valve positions.**

They are monitored in order **to discover unusual cycling or trending of the valves, and to evaluate valve performance during their tests.** Abnormal valve position or substandard performance during tests indicates control/mechanical problems in the actuator or the valve, eg. excessive deposits or a bent stem.

SUMMARY OF THE KEY CONCEPTS

- Turbine generator bearing vibrations are monitored to protect the machine from excessive vibration which, if allowed to persist, could result in serious damage. In addition, abnormal vibrations are usually one of the first indications of some potentially dangerous operational problems.
- The HP turbine casing axial expansion is monitored mainly to detect excessive resistance of the casing front supports to its thermal expansion/contraction.

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- HP and LP turbine axial differential expansions are monitored to prevent turbine damage due to axial rubbing caused by closing of axial clearances.
- The shaft axial position is monitored to detect abnormal axial thrust on the rotor. This can damage the thrust bearing and signifies some operational problem in the turbine. Monitoring of the shaft axial position allows also detection of excessive wear or failure of the thrust bearing before the resultant axial displacement of the rotor can cause rubbing damage to turbine seals.
- Assorted turbine generator temperatures (eg. the HP and LP turbine inlet steam and metal temperatures) are monitored to detect conditions that promote machine failure, eg. due to excessive thermal stresses.
- Turbine speed is monitored particularly closely during turbine runup and rundown. The purpose is to verify proper operation of turbine auxiliaries, to avoid prolonged operation in the critical speed ranges during runup, and to synchronize the generator with the grid. It is also closely monitored while performing actual overspeed tests of the emergency overspeed governor.
- Steam valve positions are monitored to detect unusual cycling or trending of the valves, and to evaluate their performance during tests.

Rotor eccentricity

⇔ Obj. 8.2 a)

Rotor eccentricity is a measure of how much the rotor is bent. Measurements are limited to the HP turbine rotor which is considered as a representative sample of the whole turbine generator shaft. This choice is based on the fact that, being the hottest part of the whole shaft, the HP turbine rotor is more susceptible to thermal deformations than the other parts of the shaft.

The **principle of eccentricity measurements** is illustrated in Fig. 8.1 on the next page.

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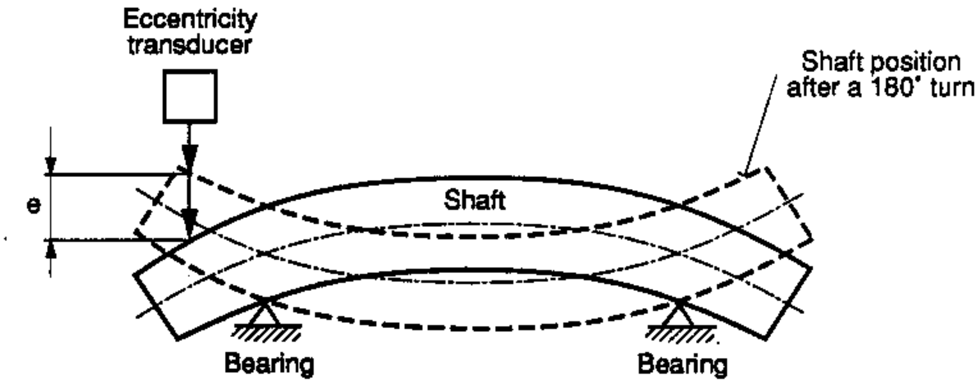

Fig. 8.1. Principle of the shaft eccentricity (e) measurement.

As you can see, eccentricity is measured as the radial displacement of the shaft surface closest to the eccentricity transducer when the shaft is turned by 180°. Based on this sketch, you will notice that:

1. The shaft must be turning for the eccentricity measurements to be available.
2. In a general case, the measured eccentricity *(e)* is different from the maximum shaft deflection.

The latter results mainly from the transducer location outside the turbine casing (to protect the transducer from hot steam and to facilitate maintenance), whereas the maximum deflection typically occurs about halfway between the bearings. As a result, the measured eccentricity can be several times smaller than the maximum deflection of the shaft. This is taken into account by the turbine manufacturer while determining the operational limits on the measured eccentricity.

Obj. 8.2 b) ⇔

Rotor eccentricity is **monitored for two reasons**:

1. **To make sure that turbine runup is not begun until the rotor is straight enough.**

   Satisfactory rotor eccentricity is one of the major factors which determine the time the turbine should spend on turning gear during startup. Note that any attempt to run up the machine despite excessive rotor eccentricity is bound to fail because sooner or later high vibrations would force a turbine trip. Meanwhile, the machine would be exposed to unnecessary risk of damage due to high vibration and/or rubbing.

2. **To detect excessive rotor deformation during turbine operation at low speed.**

   Even when turbine runup has begun with a satisfactory rotor eccentricity, some operating conditions (eg. excessive heatup rates) occurring

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during the runup may change it. Therefore, the need for eccentricity monitoring continues.

⇔ *Obj. 8.2 c)*

At low turbine speed, monitoring rotor eccentricity is particularly important because the available **bearing vibration indications are too low for reliable interpretation.** Note that for a given shaft eccentricity, the unbalanced centrifugal forces that excite turbine vibration increase proportionally to the second power of turbine speed. Therefore, at low speeds, misleadingly low bearing vibrations may be indicated despite rotor deformations that may be sufficient to cause rubbing.

However, **with increasing turbine speed, the eccentricity indication conveys less and less meaningful information regarding the rotor deflection.** Recall that the eccentricity measurement is based on radial movement of the rotor surface as shown in Fig. 8.1. This movement **is affected** not only by the rotor static deformation (which is what the eccentricity measurement is supposed to indicate), but also **by rotor vibration**. While at very low turbine speeds the disturbing influence of turbine vibrations can be neglected, this is not true at higher turbine speeds.

Because of this influence, in some stations **rotor eccentricity monitoring ceases when turbine speed exceeds a certain level***. At this rotor speed, bearing vibration indications can provide adequate information on the rotor dynamic condition. In other words, if the rotor were excessively bent, high bearing vibrations would certainly be present.

* Usually about 600-1000 rpm, depending on the station.

In some stations, this approach is taken to extreme with the eccentricity measurements available only when the turbine is on turning gear. In these stations, a prudent operating precaution is to minimize the time spent during turbine runup in the low speed range (say, below 600 rpm) where bearing vibrations cannot be relied on to detect rubbing, as mentioned above.

SUMMARY OF THE KEY CONCEPTS

- Rotor eccentricity is a measure of the rotor deflection from the perfectly straight shape.
- This parameter is measured as the radial displacement of the shaft surface facing the transducer when the shaft is turned by 180°. Hence, the shaft must be rotating in order to measure its eccentricity.
- Rotor eccentricity is monitored to make sure that turbine runup is not begun until the rotor is straight enough. It can also detect excessive rotor deformation during turbine operation at low speed.
- At low turbine speeds, misleadingly low bearing vibrations may be indicated, even though the rotor may be bent enough to cause rubbing inside the turbine.

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- At medium and high turbine speeds, rotor eccentricity is influenced not only by the rotor deflection, but also by turbine vibrations. Their disturbing influence is the reason why, in most stations, monitoring of rotor eccentricity ceases once turbine speed is high enough for bearing vibration indications to be able to detect an excessively bent rotor.

RESPONSE OF THE TURBINE SUPERVISORY SYSTEM TO AN EXCEEDED SAFETY LIMIT

Obj. 8.3 b) ⇔

Except for a few parameters such as valve positions, all others have at least one safety limit. Most of the limits are fixed, but there are some (usually, on bearing vibrations) that are time and/or turbine speed dependant.

The most typical response of the turbine supervisory system to an exceeded safety limit on any monitored parameter **is an annunciation in the control room**. This makes the operator aware of the problem. He should then investigate the problem and correct it, as outlined in the appropriate operating manual.

Obj. 8.3 a) ⇔

In the case of **bearing vibrations**, if another higher limit has been reached or exceeded, the turbine supervisory system responds either by **tripping the turbine automatically or, much more typically, by advising the operator to trip the turbine manually**. In most stations, the feature of automatic turbine trip on high bearing vibration is not used in order to avoid spurious trips due to instrumentation malfunction. This reflects past operating experience.

OTHER SOURCES OF INFORMATION USED FOR MONITORING OF TURBINE GENERATOR OPERATION

Obj. 8.4 ⇔

The turbine supervisory system is not the only one that monitors turbine generator operation. Normally, this is **also performed by** the unit DCC which monitors important operating parameters using control software, usually known under the names of **Unit Power Regulator (UPR) and Turbine Runup Program (TRU)**. Even though typically the same sensors are shared by the turbine supervisory system and the DCC software, the limits and actions performed are often different. For example, under UPR, high bearing vibration may result in inhibiting of further turbine loading. Details are left for the station specific training.

Another typical source of information, that is necessary for adequate monitoring of turbine generator operation, is **instrumentation belonging to numerous turbine generator auxiliary systems**, eg. the turbine lubricating oil system or generator seal oil system. This instrumentation provides con-

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trol room and field indications, as well as annunciations when a preset safety limit has been reached or exceeded.

SUMMARY OF THE KEY CONCEPTS

- The most typical response of the turbine supervisory system to an exceeded safety limit on any monitored parameter is an annunciation which alerts the control room operator.
- In most stations, when another higher limit on bearing vibrations has been reached, the operator is advised, by the turbine supervisory system, to trip the turbine manually. In the other stations, the turbine is tripped automatically.
- Adequate monitoring of turbine generator operation is not limited only to the information provided by the turbine supervisory system. The UPR and TRU control programs as well as the instrumentation belonging to turbine generator auxiliary systems also contribute.

You can now do **the assignment questions**.

⇔ *Pages 11-13*

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ASSIGNMENT

1. a) Turbine generator bearing vibrations are monitored in order to:

   i) ____________________

   ____

   ii) ____________________

   ____

   b) The HP turbine casing expansion is monitored in order to ______

   ____

   ____

   c) HP and LP turbine axial differential expansions are monitored in order to ____________________

   ____

   d) The shaft axial position is monitored in order to:

   i) ____________________

   ____

   ____

   ii) ____________________

   ____

   ____

   e) Assorted temperatures of the turbine generator, such as ______

   ____

   are monitored in order to ____________________

   ____

   f) Turbine speed is monitored in order to:

   i) ____________________

   ____

   ii) ____________________

   ____

   iii) ____________________

   ____

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iv) ______________________________

____

g) Steam valve positions are monitored in order to:

i) ______________________________

____

ii) ______________________________

____

2. a) Rotor eccentricity is a measure of ______________________

b) Rotor eccentricity can be measured when the rotor is stationary. (False / true)

c) The measured eccentricity specifies the maximum deflection of the rotor. (False / true)

d) Rotor eccentricity is monitored for the following reasons:

i) ______________________________

____

ii) ______________________________

____

3. a) Rotor vibrations are a reliable indication of the rotor dynamic condition (only at high and medium speeds / only at low speeds / throughout the whole speed range) because ______________

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____

b) Indicated rotor eccentricity conveys meaningful information about the rotor deflection (only at high and medium speeds / only at low speeds / throughout the whole speed range) because

____

____

____

c) In most stations, rotor eccentricity is measured (only above a certain turbine speed / only below a certain turbine speed / throughout the whole speed range).

4. a) The typical response of the turbine supervisory system to a safety limit on any monitored parameter being reached or exceeded is

____

b) In the case of bearing vibrations, an additional response of the system is ______________________________ or

____

depending on the station.

5. Adequate monitoring of turbine generator operation is based on information provided by:

a) ______________________________

b) ______________________________

c) ______________________________

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