PI 21.01

AN INTRODUCTION TO RELIABILITY

OBJECTIVES

1.1 Explain the implications of station reliability for Ontario Hydro's objectives in the following areas:

a) Worker Safety
b) Public Safety
c) Environmental Protection
d) Reliability of Electrical Supply
e) Cost

1.2 State the working definitions of:

a) Reliability
b) Availability

1.3 State two basic limitations on the applicability of reliability theory.

COURSE NOTES

As far as nuclear reactors go, our CANDU units have historically done quite well when compared to other reactors around the world. This performance is attributable in part to a comprehensive and co-ordinated program of research and development, design, manufacturing, construction and operations. A significant feature of this program, which has been operating since 1942, is feedback of operating experience to researchers, designers and manufacturers.

By 1986, Ontario Hydro had accumulated ≈156 reactor years of operating experience with CANDU units. Right from the start, Nuclear Operations at Ontario Hydro has followed a Management by Objectives approach. This involves setting down objectives that describe where we are going and what we are trying to achieve. The basic objectives fall under the following headings:

- **Worker Safety**
- **Public Safety**
- **Environmental Protection**
- **Reliability of Electrical Supply**
- **Cost**

Numerical indices have been established to quantify performance in each of these five areas, so that performance can be measured, compared to targets and analyzed for trends. The reliability for plant systems is critically important to achieving objectives in all five areas.

How Plant Reliability Affects the Basic Objectives

High reliability of plant systems is crucial to achieving NGD's five basic objectives as explained below.

1. Worker Safety

   The safety of our employees is affected both directly and indirectly. Obviously the more reliable the plant equipment, the less likely we will have equipment failure which can injure or kill someone. Indirectly, if we have reliable equipment, fewer hours are required to maintain equipment which then lessens the exposure of workers to hazards which can cause injury or death.

2. Public Safety

   The risk to public safety is low unless both process and safety systems fail simultaneously. So, the more reliable these systems, the safer the public.

3. Environmental Protection

   The more reliable the plant process and safety systems, the lower the risk of damage to the environment resulting from releases of radiation or chemicals, noise, high temperatures, etc.

4. Reliability of Electrical Supply

   The more reliable the plant systems, the less likely the unit wil suddenly stop producing electrical power.

5. Cost

   The more reliable the plant process systems:

   a) The fewer maintenance personnel and replacement parts which may be required, in other words, lower maintenance costs.

   b) The less time that the unit is unable to produce power, the better the return on plant investment. In the long-term, if equipment is out of service, in need of modification, or requires extra outages to maintain, there will be higher costs in operating it.

It is important to note that although there are five objectives, they are not all equally weighted. The first three objectives dealing with the **safety and protection of the workers, the public and the environment must always have higher priority** than the two objectives dealing with reliability of electrical supply and cost.

However, it is clear that obtaining and maintaining highly reliable plant systems is a common objective to all five of the basic objectives of nuclear operations. Achieving highly reliable plant systems involves virtually every phase of the project: design, purchasing, commissioning, operations and maintenance.

EXERCISES

1. To minimize the cost of the plant and its operation, why don't we minimize the number of safety devices and systems?

2. Can you give an example of where the first objective given below must take precedence over the second?

   a) *Worker Safety vs Cost*

b) Public Safety vs Reliability of Electrical Supply

3. Explain how improved reliability of the overall station and systems affects:

a) Public Safety

b) Cost

Working Definition of Reliability of a Device

The term "**reliability**" has been used so far without definition because its technical meaning is similar to its meaning in common usage. However, a definition of reliability as a quantity which can be calculated or measured is required for technical applications. The working definition of reliability is therefore:

> *The probability that the device will perform it purpose adequately for the period of time intended under the operating conditions encountered.*

Note that the reliability is a probability and has a numerical value ranging from 0 for the impossible event, something totally unreliable (cannot succeed) to 1 for the inevitable event, or something totally reliable (always succeeds for the time intended). Note too that this probability usually has a time dependency which can be mathematically modelled. Although more advanced treatments model both degree of performance and variations in operating conditions, this introductory course assumes only two degrees of performance - either the device is fully capable of, or utterly incapable of, performing its intended purpose. The operating conditions are assumed constant.

Working Definition of the Availability of a Device

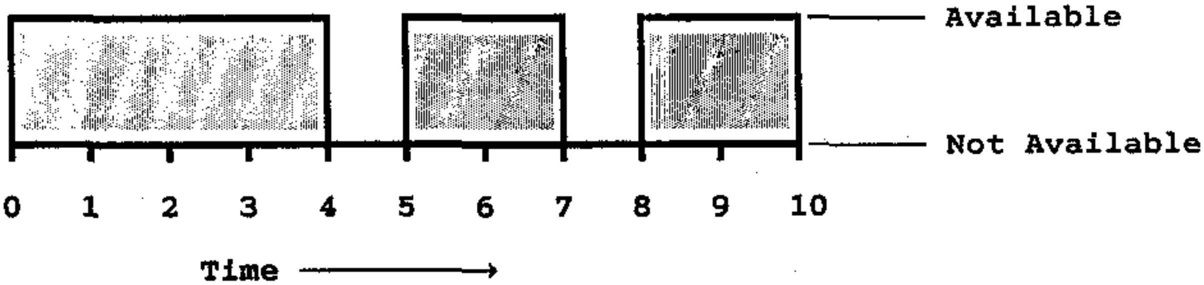
The term **availability** is often used interchangeably with reliability but in fact it has a different meaning.

> *Availability is the fraction of time that a device is available to perform its function if it is called upon to do so.*

This figure is also between 0, meaning that the device is never available and 1, meaning that it is always available. The term availability is often used in describing the devices or systems which are normally not in operation but may be called upon to operate in some circumstances. We also use the term **unavailability**, fraction of time not available, when talking about safety systems.

To differentiate between these two terms, let's look at a new pump we are going to put into service. We can estimate the reliability of the pump for, say, the first year of operation, by looking at historical data for pervious pumps of this type. Say this is 0.99. This means that there is a 0.99 (99%) probability that the pump will still be in working order at the end of the year. Or again, a (1 - 0.99) = 0.01 (1%) chance that it will not be. Note that the longer the pump runs, the lower will be its probability of working over the whole period. In other words, the probability of running without failure is higher for one year than for two (assuming, of course, no preventative maintenance). So, you can see how reliability is dependent on the time period being look at.

We usually use the term availability when talking about systems which are poised, ready to operate (e.g., systems needed in an emergency). It is measured by the fraction of time a system is available to perform its function. The following figure shows a system with an availability of 0.8 (this is only for illustration - CANDU systems must be much more available than this!).



Both reliability and availability are unit-less: reliability is a probability and availability is a fraction. Note, however, that for the system shown in the figure above, if you pick a time in the figure at random, the probability that the system will be working at that time is 0.8.

EXERCISES

4. Without looking back, try to fill in the blanks in the following definitions and then check your answers:

   RELIABILITY: The ______________ that the device will ______________ its ______________ adequately for the ______________ of ______________ intended under the ______________ ______________ encountered.

   AVAILABILITY: The ______________ of ______________ that a device is ______________ to ______________ its ______________.

Limitations of Reliability Techniques

Reliability theory is the application of the methods of probability and statistics to predict the system reliability on the basis of operating experience (failure rates). There are two basic limitations on the application of this theory in practice.

1. The validity of reliability theory calculations is based on the assumption of **statistical regularity** in equipment failures due to normal causes. Failure due, for example, to sabotage or to collisions between earth and other celestial bodies or to the construction of an intergalactic bypass do not enter the picture.

2. Reliability theory cannot be used to predict precise events or times thereof, only probabilities and statistical averages. For example one could not calculate the precise time and duration of the next forced outage on Bruce A Unit 3, but one could calculate the expected frequency and average duration of forced outages on Unit 3, or the probability that a forced outage will occur within say, 90 days.

SUMMARY

In this module we have looked at:

- The five major objectives of NGD:

  1. Worker Safety
  2. Public Safety
  3. Environmental Protection
  4. Reliability of Electrical Supply
  5. Cost

  and have seen how station reliability impacts on them. Refer to the notes for a detailed look at these impacts.

- The Working Definition of Reliability is:

  The probability that the device will perform its purpose adequately for the period of time intended under the operating conditions encountered.

- The Working Definition of Availability is:

  The fraction of time that a device is available to perform its function if it is called upon to do so.

- Two limitations on the applicability of reliability theory are:

  1. It assumes normal causes of failures only (statistical regularity).

  2. It is only a statistical average and not a precise prediction.

ASSIGNMENT

1. Which of the following are the five major objectives of NGD?

_____ Environmental Protection	_____ Reliability
_____ Trained Staff	_____ Production of Electricity
_____ Worker Safety	_____ Cost
_____ New Technology	_____ Public Safety

2. What implications does station reliability have on:

   a) <u>Worker Safety</u>

   b) <u>Cost</u>

3. State the working definition of Availability.

4. What are the two limitations on the applicability of reliability theory?

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