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# The Power Reactor Information System (PRIS) and its Extension to Non-electrical Applications, Decommissioning and Delayed Projects Information

IAEA
International Atomic Energy Agency

# THE POWER REACTOR INFORMATION SYSTEM (PRIS) AND ITS EXTENSION TO NON-ELECTRICAL APPLICATIONS, DECOMMISSIONING AND DELAYED PROJECTS INFORMATION

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# THE POWER REACTOR INFORMATION SYSTEM (PRIS) AND ITS EXTENSION TO NON-ELECTRICAL APPLICATIONS, DECOMMISSIONING AND DELAYED PROJECTS INFORMATION

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# FOREWORD

In the past four decades nuclear power has played a significant role in the generation of electricity: nuclear power currently provides 16% of worldwide electricity production. Well designed, well constructed and well operated nuclear power plants have proved to be safe, reliable, economic and environmentally benign. At the end of 2004 there were 441 operating nuclear reactors worldwide, with a total installed capacity of 367 GW(e), representing more than 10 000 years of accumulated operating experience.

There are very few publications, papers or presentations on the general subject of nuclear power that contain integral information referring to the number of nuclear power plants worldwide in operation or under construction, referring to their capacity, accumulated operating experience, energy availability or load factor achieved. This type of information is usually essential to illustrate the current status of nuclear power development, and thus establishes a basis for the argumentation to follow. It is therefore desirable to collect such information and have it concentrated in a single source, easily accessible and available for any purpose.

The IAEA's Power Reactor Information System (PRIS) contains detailed information on nuclear power plants worldwide since their start of commercial operation. It covers a broad range of information, including reactor design characteristics, plant general specifications and operating experience data.

PRIS covers the largest amount of worldwide statistical information on operating experience, and although there are other similar databases in existence, it is considered to be the most complete and authoritative source of statistical data on the subject.

This report describes all the elements of PRIS, explaining the rules, coding, terminology and definitions used in the system. It is the first IAEA publication to document the entire PRIS system since 1989.

The IAEA would like to express its gratitude and appreciation to all who participated in the meetings and discussions during the preparation of this report for their informative and valuable contributions. The IAEA is particularly grateful to J. Mandula for his assistance in preparing the final report. The IAEA officer responsible for this report was R. Spiegelberg-Planer of the Division of Nuclear Power.

*EDITORIAL NOTE*

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# 1. INTRODUCTION

Information and data on nuclear power plants worldwide have been collected by the IAEA practically since its establishment. Starting in 1970, operating experience data in addition to basic information and design data have been collected and published in annual reports. In order to facilitate analyses of power plant performance as well as to produce relevant publications, all previously collected data were computerized in 1980, and the Power Reactor Information System (PRIS) was put into operation. Since then, PRIS has been continuously updated and improved. It has been widely used and it constitutes an essential source of information on nuclear power for all concerned.

PRIS covers general and design information on nuclear power reactors as well as data on operating experience with nuclear power plants, including descriptions of and performance data on non-electrical applications. The IAEA is also currently collecting information on the decommissioning of nuclear power plants, and a project has been started to collect information on delayed plants.

Two types of information are held in PRIS:

(a) Plant specification data, including information on identification and on basic design characteristics;
(b) Plant performance data, including information on production, outages and non-electrical applications.

Selected specification and performance data held in PRIS are publicly accessible on the PRIS web site or in IAEA publications. The complete data, however, can be accessed and retrieved only by registered users in Member States. PRIS makes it possible for these registered users to perform flexible queries in accordance with a set of selected criteria, presenting the data in tables or charts, and enables data to be downloaded to any Windows application.

In view of the recent growing interest worldwide in applications of nuclear energy for non-power products, such as seawater desalination or district heating, the IAEA is in the process of extending the coverage of PRIS to relevant information on cogenerating plants, which provide energy for non-power products. An overview of this extended version of PRIS is presented in this report.

This report gives a complete description of the elements of PRIS. It provides guidance for both data entry and retrieval of information from the system. It describes PRIS application software and publications and gives an overview of the PRIS web site.

# 2. DESCRIPTION OF PRIS

PRIS includes all nuclear power reactors worldwide, either operating, under construction, planned or permanently shut down. The information held in PRIS is organized by reactor units, which are uniquely identified by their plant name, unit number and International Organization for Standardization (ISO) country code. The overall information on a reactor unit consists of two types of data: (a) specification data; and (b) performance data.

PRIS has recently been extended by the inclusion of data on heat production, and will be amended by the addition of data on decommissioning and delayed projects. Decommissioning data include information on progress in decommissioning activities at permanently shut down units, while delayed project data include information on planned units with a delayed construction start.

The PRIS database information structure is shown in Fig. 1.

## 2.1. BASIC UNIT INFORMATION

To identify a nuclear power plant, PRIS provides basic information that reflects the current status of the plant; this information is regularly updated. Figure 2 illustrates the basic information collected for a nuclear power plant. For each plant, this basic information includes the plant identification status (under construction, in operation, etc.), important dates and basic design electrical data.

The basic information starts with the name of the country (including its ISO code identification) and up to three digits to identify each plant in the country. The reference code for a nuclear power plant is therefore a code of up to five digits that comprises:

(a) A two letter ISO country code (e.g. AR for Argentina, BR for Brazil);
(b) Up to three digits, from 1 to 999, preceded by the country code (e.g. AR-1, AR-2).

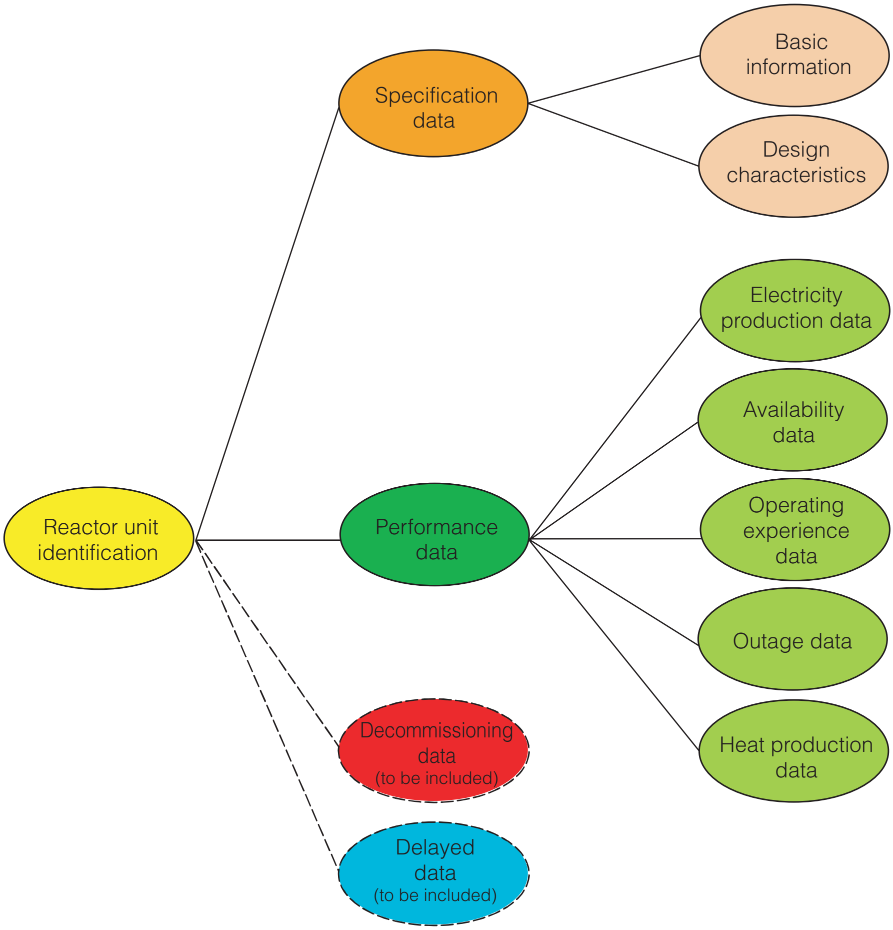



*FIG. 1. PRIS database structure.*

The countries contained in PRIS and their ISO codes are listed in Table 1.

The following information is collected for each nuclear power plant: the plant's name, site, operator and owner. The basic information on a nuclear power plant also includes the number of units on the site, the status (operational, under construction, shut down or planned), the type of reactor and the name and country of the supplier of the reactor and turbine. The thermal power and the gross and net electrical capacity (including the design and actual value) are also stored in PRIS.

The dates of the start of construction, first criticality, first connection to the grid, start of commercial operation and shutdown are also held in PRIS.

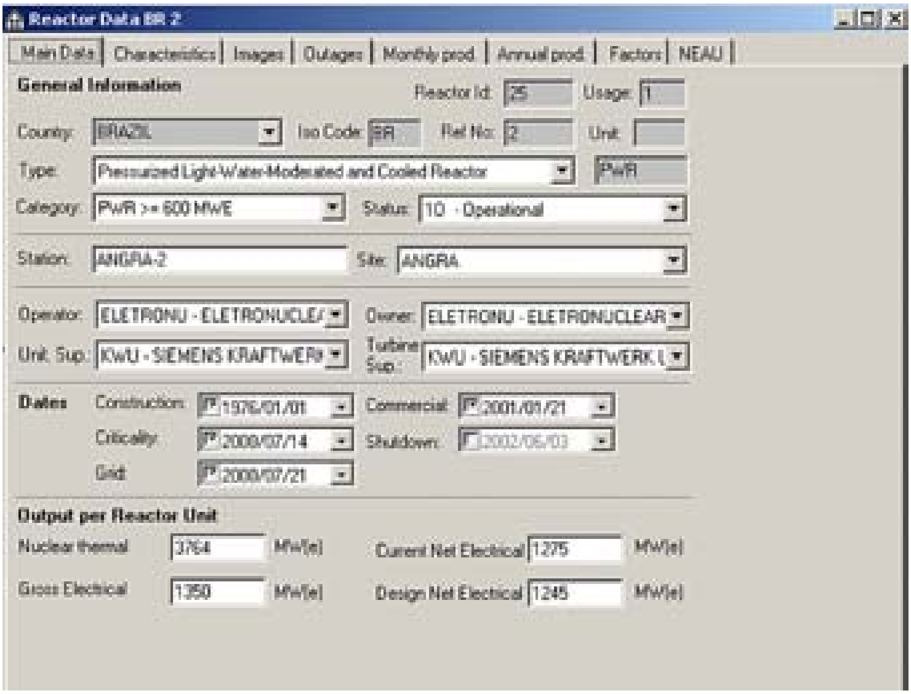



*FIG. 2. Example of basic information in PRIS.*

These dates are used to classify the plant's status as: (a) in operation (by grid connection date); (b) under construction; (c) shut down; (d) planned; or (e) cancelled or suspended while under construction.

The following definitions are used to classify a plant's status:

(a) Construction start: The date on which the first major placing of concrete, usually for the base mat of the reactor building, was carried out. It is the date used to identify a reactor that is under construction.

(b) First criticality: The date on which the reactor was first made critical.

(c) Grid connection: The date on which the plant was first connected to the electricity grid for the supply of power. The plant is considered to be in operation after this date.

(d) Commercial operation: The date on which the plant was handed over by the contractors to the owner and declared to be officially in commercial operation.

TABLE 1. COUNTRIES AND ISO CODES USED IN PRIS

| ISO code | Country name | ISO code | Country name |
|---|---|---|---|
| AM | Armenia | JP | Japan |
| AR | Argentina | KR | Korea, Republic of |
| BE | Belgium | KZ | Kazakhstan |
| BG | Bulgaria | LT | Lithuania |
| BR | Brazil | MX | Mexico |
| CA | Canada | NL | Netherlands |
| CH | Switzerland | PK | Pakistan |
| CN | China | RO | Romania |
| CZ | Czech Republic | RU | Russian Federation |
| DE | Germany | SE | Sweden |
| ES | Spain | SI | Slovenia |
| FI | Finland | SK | Slovakia |
| FR | France | TW | Taiwan, China |
| GB | United Kingdom | UA | Ukraine |
| HU | Hungary | US | United States of America |
| IN | India | ZA | South Africa |

(e) Shutdown: The date on which the plant was officially declared by the owner to be shut down and taken out of operation permanently.

The type of reactor is also codified and stored in PRIS as follows:

ABWR: Advanced boiling light water cooled and moderated reactor.
AGR: Advanced gas cooled graphite moderated reactor.
BWR: Boiling light water cooled and moderated reactor.
FBR: Fast breeder reactor.
GCR: Gas cooled graphite moderated reactor.
HTGR: High temperature gas cooled graphite moderated reactor.
HWGC: Heavy water moderated gas cooled reactor.
HWLWR: Heavy water moderated boiling light water cooled reactor.
LWGR: Light water cooled graphite moderated reactor.
PHWR: Pressurized heavy water moderated and cooled reactor.
PWR: Pressurized light water moderated and cooled reactor.

TABLE 2. SIZE CATEGORIES USED IN PRIS

| Category | Description |
|---|---|
| A | PHWRs 100–599 MW(e) |
| B | PHWRs ≥ 600 MW(e) |
| D | AGRs |
| F | GCRs 100–599 MW(e) |
| K | PWRs 100–599 MW(e) |
| L | PWRs ≥ 600 MW(e) |
| M | WWERs 100–599 MW(e) |
| N | WWERs ≥ 600 MW(e) |
| P | BWRs 100–599 MW(e) |
| Q | BWRs ≥ 600 MW(e) |
| T | LWGRs ≥ 600 MW(e) |
| X | Prototypes |

SGHWR: Steam generating heavy water moderated and cooled reactor.
WWER: Water cooled water moderated power reactor[1].

The IAEA also categorizes plants according to their capacity. Table 2 lists the PRIS categories for nuclear power plants. The plant's full address and the owner's and operator's addresses are also included in PRIS. This information is connected to all other types of information within PRIS, such as information on production, outages, non-electrical applications, decommissioning and delayed projects.

## 2.2. DESIGN CHARACTERISTICS INFORMATION

### 2.2.1. Design characteristics information for all nuclear power plants

Since 1990 the IAEA has compiled information on the plant design characteristics of sites with plants in operation. This information has been

[1] A WWER is a PWR with horizontal steam generators; the type category was included in PRIS to ease identification.

published in a large number of documents and includes the technical characteristics of plant systems, covering items related to the mode of plant operation, safety characteristics, safety features, the plant's environment, etc.

PRIS contains a selection of design characteristics that should provide sufficient information to describe the main features of the design of a nuclear power plant. Collection of the data described in the following paragraphs is not performed continuously; the data are updated every five years. The collection of the data was developed taking into account the differences in the design of each reactor type; therefore there are items that apply, for example, to PWRs but not to GCRs.

This PRIS file starts with information about the reactor core and reactivity control systems. The type of material is given for the fuel, fuel rod cladding, moderator, control rod neutron absorber, soluble chemical neutron absorber and burnable poison in the fuel. Mass and weight are given for the fuel inventory and moderator, respectively. The power of the core is characterized by the mean value of power density per volume unit for the total core, per mass unit for the fuel and per length unit for a fuel rod. The neutronic design of the core is described by the average discharge burnup, the initial enrichment (or enrichment ranges) and the reload enrichment at the status of equilibrium (for GCRs and AGRs) of the fuel. The refuelling procedure is defined by the type of refuelling (on or off power), the refuelling frequency (length of operating cycle) and the part of the core withdrawn at each refuelling. The active core height, core diameter and fuel cladding thickness define the geometry of the core. Also given are the number of fuel assemblies (of fissile and fertile fuel assemblies for FBRs), fuel rods per assembly, rod arrays in an assembly, control rod assemblies (the number of control rods for GCRs and AGRs) and control elements per assembly (for BWRs and PWRs).

The main design value for the reactor coolant system is the total thermal power and the reactor thermal power of the core to be removed by this system. The thermal hydraulic design includes the type of coolant, coolant mass flow rate through the core, operating coolant pressure and temperature of the coolant at the entrance and outlet of the core (or of the reactor in the case of a GCR).

The reactor pressure vessel of an LWR is defined by the material of the vessel and the cladding inside. The geometry of the vessel is given by the overall length (including the closure head), its inside shell diameter and its thickness. For LWGRs, PHWRs and GCRs the wall thickness and its material and number of channels are provided.

The mechanical design of steam generators (PWRs and PHWRs) is described in PRIS by the type, the number of steam generators per unit, and the material of the tubes and the shell. The thermal design is given by the thermal capacity per steam generator and by the surface area for heat transfer per steam generator.

For LWGRs the number of steam drums and the shell material are provided.

The pressurizer in a PWR or PHWR unit is described by its total volume, volume of steam at full and zero power, design pressure and temperature, and number and installed power of the heater rods.

The type of pump, the number of primary coolant or recirculation pumps or gas circulators, the mass flow rate per pump, its design head or pressure and the nominal power per pump (cold and hot for LWRs, and main and auxiliary for GCRs, AGRs and PHWRs) are stored in PRIS for the main coolant pumps.

The containment design is described by its type (e.g. dry or wet), total and free volume, design pressure and dry well design pressure. For BWRs this includes the design temperature and the design leakage rate. The total and free volume are given for the accident localization system or confinement for LWGRs and WWERs.

The nuclear power plant safety design features and safety related systems are also included in PRIS.

The number of extraction lines, pumps and feed and bleed connections is collected for the chemical volume control system. The volume of the boron tank and the concentration of boron within it characterize the boron injection system. For GCRs and AGRs the existence of a boron system in the plant is stated.

The design data of the emergency core cooling system include the number of pumps, design head or pressure of the pumps, design mass flow rate and minimum number of pumps necessary for coping with a design basis accident. These data are stored for the high and low pressure injection systems. The number of accumulators as a passive emergency system is also given. For a core spray system (e.g. a BWR), the number of pumps and feed and bleed connections is also available.

The number of trains and pumps is given for the component cooling system up to the ultimate heat sink. The type of ultimate heat sink (river, lake or other) is also specified.

The number of trains and pumps characterizes the containment safety systems in the spray system. The availability of other safety systems in the containment is stated, thereby identifying the existence of hydrogen recombiners or igniters, countermeasures against core melting, a venting system, inertization, a cooling system of the containment outside and inside (including the type) and other safety systems.

The number of trains and pumps for the emergency feedwater system is provided, together with the type of energy supply for the pumps (e.g. diesel or electric motor).

The design of the fire protection system is described by the presence or absence of certain design features. The features that require identification are: fire hazard areas (related to nuclear safety and radiological protection), provisions to minimize fire loads in safety related areas, specification of storage of combustibles and/or flammable liquids or gases, definition of fire ignition sources (e.g. special requirements for electrical equipment), measures against fire spread (e.g. fire retardant coating of cables), separation of independent safety trains, fire detection systems in all building areas or only in selected rooms, list of detector types (e.g. optical, ionization chamber or temperature sensors), fire suppression systems in all buildings, list of fire extinguishing system types for special areas and on-site dedicated fire brigades or plant operators in charge of fire fighting.

It is clarified in PRIS whether the reactor protection system consists of physically and functionally separated and independent trains, and the hierarchy concept of this system (e.g. two steps or three steps) is stated. In addition, the following information on a plant is available: a list of reactor trip signal parameters, an outline of the general protection logic, a specification of whether systems are analog or digital, the location of the system in the main control room, the existence of a centralized safety system panel different from the main operating panel and the existence of a decentralized safety shutdown panel.

The type (e.g. diesel, gas turbine or grid connections) and number of trains and diesel generators per train describe the emergency power supply system. The existence of other non-interruptible AC emergency sources (e.g. a motor generator) and an AC/DC supply system is stated, and the type of system (e.g. rectifier, converter or battery) is identified. As an important design value, the estimated time reserve of the emergency power supply is provided.

The conventional thermal cycle (or conventional island) includes data on the turbine system, the condenser and the main generator.

For the turbine system the following information is available: type (e.g. saturated or superheated steam condensing turbine), number of turbines per reactor, turbine rating, number of turbine sections or cylinders per unit (e.g. high, intermediate or low pressure) and rotating speed of the turbine. The thermal design is characterized by the steam conditions at the inlet of the high pressure turbine, consisting of the temperature, the pressure, the moisture content and the mass flow.

The condenser system is specified by its type (e.g. box type surface), number of condensers per turbine, condenser vacuum and condenser cooling mode (river, sea, lake or tower). The type (e.g. a three phase synchronous generator or a DC generator), apparent and active power and frequency illustrate the design of the main generator.

The spent fuel storage system is outlined by the number of pools, the volumetric capacity and the maximum number of fuel rods (assemblies) in storage. The full list of reactor design characteristics is given in Annex I.

### 2.2.2. Design characteristics data for cogenerating plants

Design characteristics data are structured in one general level for all units, with three additional levels given: (1) general; (2) heat source; (3) intermediate system; and (4) application system. Levels (1) to (3) specify how energy (heat or on-site electricity) for the non-electrical application systems is extracted from the nuclear power plant, whereas level (4) identifies the key parameters of the application system. Basic data items for each level are summarized below. The questionnaire sheets for design characteristics are part of the PRIS questionnaire data sheets sent to the liaison officers for the collection of data for PRIS; these questionnaires are shown in Annex II.

#### *2.2.2.1. General*

Three pieces of information are given in this section: firstly, the name of the nuclear power plant or unit identifies the nuclear unit providing heat (and/or electricity) to the application system for non-electrical products; secondly, the starting date of heat application (year and month) identifies when the unit started to provide energy to the application system; thirdly, the end of service date of heat application (year and month) states when this nuclear unit finished providing energy to the application system.

#### *2.2.2.2. Heat source*

This section describes the condition of the heat taken from the nuclear power unit. If the heat application system is connected to more than one nuclear power unit, these other units are also identified at the beginning of this section. In many cases more than one unit is connected to the application system, in order to avoid interruption of heat delivery. If only one unit is connected, a separate backup heat source is usually reserved to ensure the reliability of the heat source.

Figure 3 illustrates the heat source for an application system.

The following data are given to identify the heat source:

(a) The names of the other nuclear units connected to the application system. In many cases more than one unit is connected, to avoid interruption of

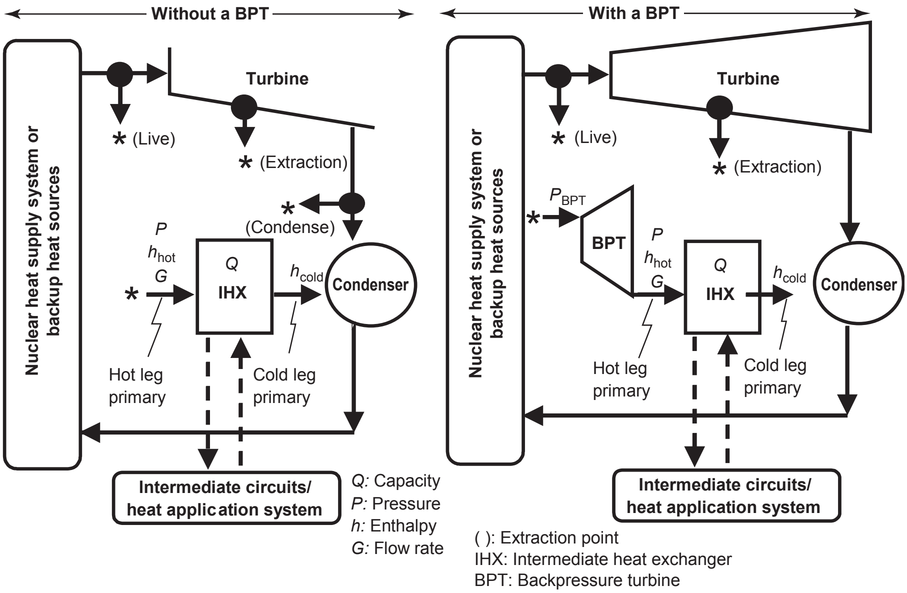



*FIG. 3. Schematic diagram of the heat source for an application system.*

energy supply to the application system. If only one unit is connected, a separate backup heat source is usually reserved to maintain the reliability of the heat source. This should be specified in the next item.

(b) The backup heat source types and their capacity. An example is a gas fired boiler of 100 MW(th).

(c) The heat transport medium between the nuclear system and the application system.

(d) The medium extraction points in the nuclear power plant balance of plant circuit. This specifies where heat is extracted from the unit. Locations could be: live (from the outlet of steam generators, from heat exchangers or direct from BWRs); live backpressure (live medium from after the backpressure turbine); extraction (from the high pressure turbine or the low pressure turbine); extraction backpressure (from after the backpressure turbine); or condenser (from after the condenser or from after the low pressure turbine).

(e) The pressure at the backpressure turbine inlet, if backpressure turbines are used.

(f) The number of intermediate circuits between the heat source (intermediate heat exchanger) and the heat application system (system heat exchanger).

For the primary side of the intermediate heat exchanger the following data are stored in PRIS: the capacity (MW(th)), the flow rate (kg/s), the pressure (MPa), the hot leg enthalpy (kJ/kg), where ‘hot leg’ corresponds to the inlet line of the intermediate heat exchanger, and the cold leg enthalpy (kJ/kg), where ‘cold leg’ corresponds to the outlet line of the intermediate heat exchanger.

### *2.2.2.3. Intermediate system*

This part contains the key specifications of the intermediate system (i.e. between the heat source (intermediate heat exchanger) and the heat application system (system heat exchanger)). Items are divided into four groups. Figure 4 illustrates an intermediate system.

For the intermediate heat exchanger the following information is defined: the heat transfer area ($m^2$), the material of the tube, plate and shell, the heat transport medium of the secondary side (e.g. steam or hot water) and the capacity (MW(th)).

The secondary side of the intermediate heat exchanger is defined by the mass flow rate (kg/s), the pressure (MPa), the hot leg enthalpy (kJ/kg), where ‘hot leg’ corresponds to the outgoing line of the intermediate heat exchanger, the cold leg enthalpy (kJ/kg), where ‘cold leg’ corresponds to the return line of the intermediate heat exchanger, the number of pumps, the water head of pumps (m of $H_2O$), the total pipe length (m), the nominal diameter of the main pipe (m), the pipe material, the pipe location (e.g. underground or above ground) and the pipe insulation method for reducing heat loss.

Two items specify the monitoring methods of the intermediate system, as in most cases the intermediate system must be monitored for safety reasons: the radioactivity monitoring method and the leakage detection method.

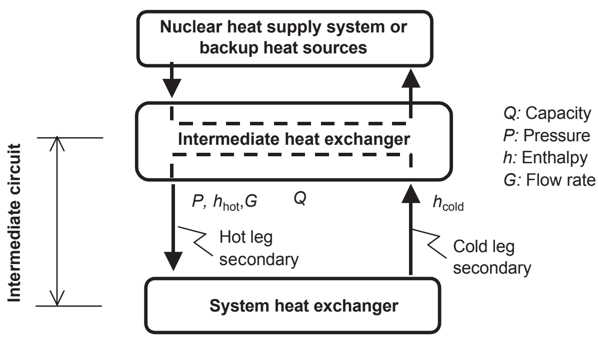



*FIG. 4. Schematic diagram of an intermediate system.*

Four items specify the chemistry control system of the intermediate system: the chemistry control method, the pH, preferably with its range (maximum, minimum and nominal), the conductivity (µS/cm), preferably with its range (maximum, minimum and nominal), and the de-aeration method.

*2.2.2.4. Application system*[2]

This section contains the key specifications of the application system. The data stored in this section of PRIS depend on the type of application system, which can be either a process heat application, a district heating application or desalination.

For process heat applications the data items contain the key technical specifications of the system heat exchanger necessary for the production process. Figure 5 illustrates a process heat application system.

The following data are stored in PRIS:

(a) The service date, defining when the nuclear unit started its service to the application system.
(b) The closing date, specifying when the nuclear unit ended its service to the application system.
(c) The user industry (the industry's name or type).
(d) The product or commodities of the application system.

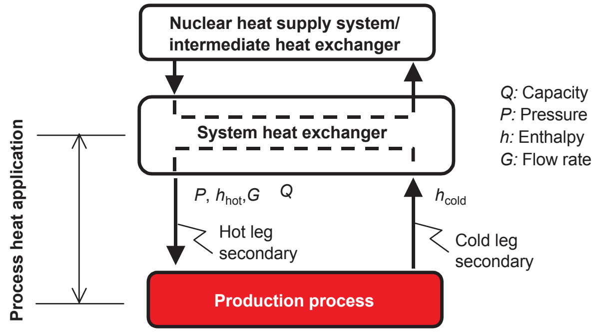



*FIG. 5. Schematic diagram of a process heat application system.*

[2] Unless the application system is operated by the nuclear utility, the data provision for this item requires the involvement of the application industry. Coordination by the PRIS country liaison officers with such industries is therefore required.

(e) The design production capacity per day (or year).

(f) The design heat consumption rate of the nuclear power plant (MW(th)), specifying how much heat is to be delivered to the application system from the nuclear unit.

(g) The design electricity consumption rate (MW(e)), stating how much electricity is to be delivered to the application system from the nuclear unit.

For the system heat exchanger, the capacity (MW(th)), the heat transfer area ($m^2$) and the material (tube, plate and shell) is given.

The following data are given for the secondary side of the system heat exchanger (the heat delivery system): the heat transport medium (e.g. steam or hot water), the mass flow rate (kg/s), the pressure (MPa), the hot leg enthalpy (kJ/kg), where ‘hot leg’ corresponds to the outgoing line of the system heat exchanger, the cold leg enthalpy (kJ/kg), where ‘cold leg’ corresponds to the return line of the system heat exchanger, the number of pumps, the design value of the makeup water quantity (t/h) (when the application system has an open circuit for supplying hot water or steam, as often practised in the Russian Federation or in eastern European countries, the heat transport medium is given) and the water head of the pump. Also given are the total pipe length (m), indicating how distant the application system is from the nuclear unit, the nominal diameter of the main pipe (m), the pipe material, the pipe location, the pipe insulation method, the radioactivity monitoring method, the leakage detection method, the chemistry control method, the pH range, the conductivity (μS/cm) and the de-aeration method.

For district heating applications the following information is stored in PRIS: the service date, defining when the nuclear unit started its service to the application system, the closing date, describing when the nuclear unit ended its service to the application system, the number of heat connection points from where end users receive heat for heating, the total capacity of heat connections (MW(th)), defining the maximum total heat capacity that can be delivered, the individual capacity of the heat connections (MW(th)), including the maximum, minimum and average capacity of the heat connections, and the end user interface, which clarifies whether end users receive heat directly from the system (i.e. from the system heat exchanger via piping) or indirectly via another heat exchanger. Figure 6 illustrates a district heating network.

The system heat exchanger is described by the number of heat exchangers, the capacity (MW(th)), the heat transfer area ($m^2$) and the material (tube, plate and shell). For the secondary side of the system heat exchanger (the heat delivery system), the following data are available: the heat

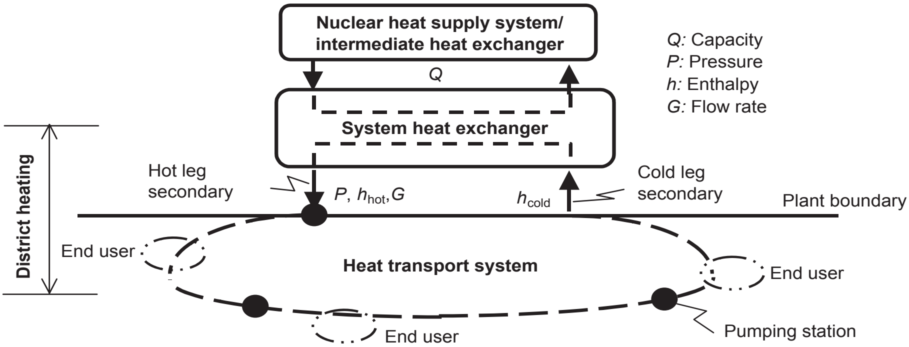



*FIG. 6. Schematic diagram of a district heating network.*

transport medium, the medium inventory (t), the mass flow rate (kg/s), the system pressure (MPa), the hot leg enthalpy (kJ/kg), the cold leg enthalpy (kJ/kg) and the makeup water quantity (t/day) (since district heating systems have big seasonal changes in heat load, the maximum value is given).

The following data items specify the heat delivery system from the nuclear plant's boundary to off the site: the number of pumping stations, the longest delivery distance from the boundary of the plant (km), the nominal pipe diameter at the boundary of the plant (cm), the pipe material, the pipe location, the pipe insulation method, the radioactivity monitoring method, the leakage detection method, the chemistry control method, the pH range, the conductivity (μS/cm) and the de-aeration method.

The section on desalination is divided into two: one on general data on the desalination systems and the other on process dependent items. The application of nuclear energy to desalination is basically a type of process heat application; however, owing to the high interest in nuclear desalination, as recommended by the International Nuclear Desalination Advisory Group, it was decided to create a separate set of tables for desalination, and exceptionally this desalination section is designed to contain data on aspects through to the end product, namely fresh water.

General data items include: the service date, defining when the nuclear unit started its service to the application system, the closing date, defining when the nuclear unit ended its service to the application system, the desalination method connected (multistage flash (MSF), multieffect distillation (MED) or reverse osmosis (RO)), the number of units connected, the unit capacity ($m^3$/day), stating the water production capacity per desalination unit, and the total capacity ($m^3$/day) of water production of the whole desalination facility.

The following data on the intake sea water are stored in PRIS: the design capacity ($m^3$/day) of the seawater intake for desalination, the design temperature (°C) of the intake sea water, the design total dissolved solids (TDS) (ppm) and the silt density index.

The following data on the product water are stored in PRIS: which water quality standard is to be met (possibilities are the World Health Organization standards, European Commission standards or respective national standards), the regulatory limit of TDS (ppm), illustrating the regulatory requirement of the TDS of the product water, the design TDS (ppm), the regulatory limit of pH (which is the same as the TDS), the design pH, the regulatory limit of conductivity (µS/cm) (which is the same as the TDS), the design conductivity (µS/cm) and the pretreatment methods for potable water (if applicable).

For discharge water similar data are given: the location of the radioactivity monitoring system, the regulatory limit of TDS (ppm), the design TDS at the boundary of the plant (ppm), the regulatory limit of the temperature rise (°C) and the design temperature rise (°C).

If the desalination system employs a distillation process (MSF or MED), the following items are specified. Figure 7 illustrates a distillation system.

For a distillation system the following data are stored in PRIS: the number of distillation stages or effects, the gain output ratio, the specific heat consumption (kW(th)·h/$m^3$), the specific electricity consumption (kW(e)·h/$m^3$) and the material (of the vessel or tube).

The system pressure (MPa) and the maximum brine temperature (°C) are defined for the flashing chamber (system heat exchanger).

If the desalination system employs an RO process, the following items are specified: the type of membrane, the number of stages, the number of modules per unit, the pressure (MPa), the design recovery ratio, the specific electricity consumption (kW(e)·h/$m^3$), the recovery of energy (%), the system control method, options being 'constant recovery ratio' or 'constant pressure', and the

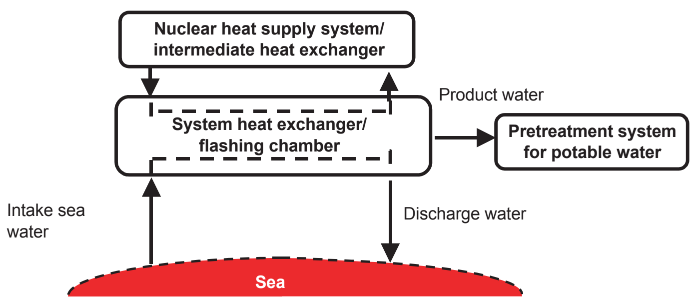



*FIG. 7. Schematic diagram of a distillation system.*

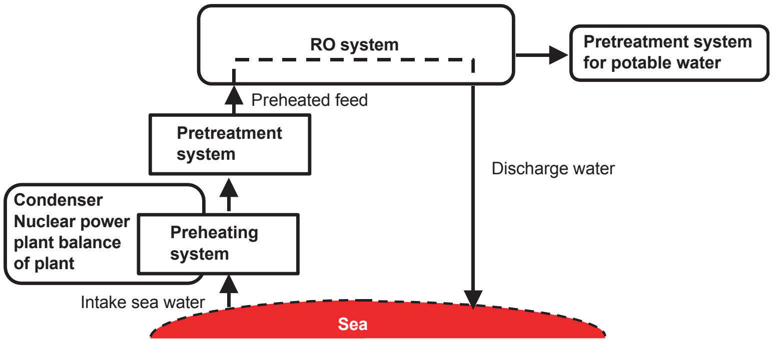



*FIG. 8. Schematic diagram of an RO system.*

membrane lifetime (years). The type of pretreatment system is also given. Figure 8 illustrates an RO system.

For the preheating system, if the feed sea water is preheated, the following information is available: the number of heat exchangers, the capacity (MW(th)), the heat transfer area ($m^2$), the material (tube, plate and shell) and the design seawater (feedwater) temperature at the hot leg (°C).

## 2.3. PRODUCTION INFORMATION

The performance data include monthly and annual information on power production, production losses and outages of operational nuclear power plants. These data are periodically updated and amended. They are provided by national regulatory bodies or directly by the plants through assigned liaison officers. The data reporting questionnaire is given as Annex II. The IAEA verifies data for completeness and consistency.

The operational data stored in PRIS represent an efficient tool for worldwide plant performance analyses using both PRIS raw data and performance indicators calculated from these data. Thanks to its outage coding system, PRIS contains comprehensive information on all production losses, which makes it a unique source of information worldwide and allows the performance of very detailed analyses of the nature and causes of outages.

Similarly to electricity production, data are collected on power production at cogeneration plants. In this way, PRIS provides complete information on energy production and allows a relevant comparison and evaluation of units that produce and deliver a part of energy in the form of heat for non-electrical applications.

### 2.3.1. Production information for all nuclear power plants

One of the objectives of data collection for PRIS is to provide a complete view of the energy produced but not available to be delivered to the electricity grid. Data on energy production and energy losses for each month following the commercial operation of the nuclear power plant are therefore collected.

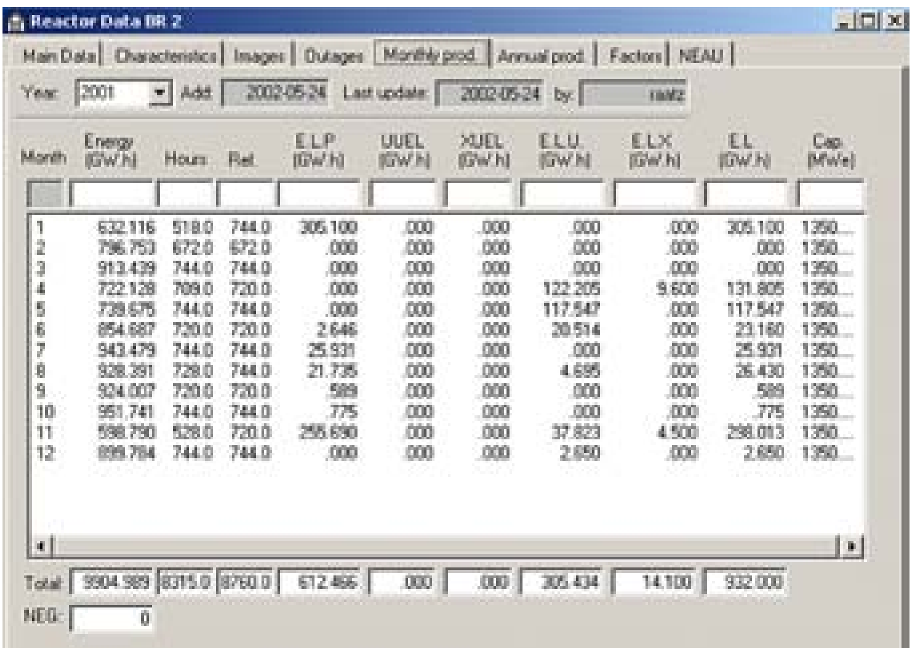
To provide a complete view of plant operation in terms of energy generation, data on the energy generated monthly, the total time the plant was on-line during the month and the reference unit power are collected.

Figure 9 illustrates the energy data collected monthly for an operating nuclear power plant since the first grid connection.

The energy generated monthly is the energy generation in GW·h. This is the net electrical energy produced, as measured at the unit outlet terminals.

Together with the energy generated every month, the system also stores the monthly on-line hours and the reference hours. This information is used to calculate two performance indicators: the load factor and the operating factor.

Three types of energy loss caused by plant unavailability are defined in PRIS: planned energy losses, unplanned energy losses due to causes under the control of the management of the plant and other energy losses due to




| Month | Energy (GW.h) | Hours | Ref. | E.L.P. (GW.h) | UUEL (GW.h) | XUEL (GW.h) | E.L.U. (GW.h) | E.L.X. (GW.h) | E.L. (GW.h) | Cap. (MWe) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 632.116 | 518.0 | 744.0 | 305.100 | .000 | .000 | .000 | .000 | 305.100 | 1350... |
| 2 | 796.753 | 672.0 | 672.0 | .000 | .000 | .000 | .000 | .000 | .000 | 1350... |
| 3 | 913.439 | 744.0 | 744.0 | .000 | .000 | .000 | .000 | .000 | .000 | 1350... |
| 4 | 722.128 | 709.0 | 720.0 | .000 | .000 | .000 | 122.205 | 9.600 | 131.805 | 1350... |
| 5 | 739.675 | 744.0 | 744.0 | .000 | .000 | .000 | 117.547 | .000 | 117.547 | 1350... |
| 6 | 854.687 | 720.0 | 720.0 | 2.646 | .000 | .000 | 20.514 | .000 | 23.160 | 1350... |
| 7 | 943.479 | 744.0 | 744.0 | 25.931 | .000 | .000 | .000 | .000 | 25.931 | 1350... |
| 8 | 928.391 | 728.0 | 744.0 | 21.735 | .000 | .000 | 4.695 | .000 | 26.430 | 1350... |
| 9 | 924.007 | 720.0 | 720.0 | .589 | .000 | .000 | .000 | .000 | .589 | 1350... |
| 10 | 951.741 | 744.0 | 744.0 | .775 | .000 | .000 | .000 | .000 | .775 | 1350... |
| 11 | 598.790 | 528.0 | 720.0 | 255.690 | .000 | .000 | 37.823 | 4.500 | 298.013 | 1350... |
| 12 | 899.784 | 744.0 | 744.0 | .000 | .000 | .000 | 2.650 | .000 | 2.650 | 1350... |
| Total | 9904.989 | 8315.0 | 8760.0 | 612.466 | .000 | .000 | 305.434 | 14.100 | 932.000 | |
| NEG: | 0 | | | | | | | | | |

*FIG. 9. Monthly energy data stored in PRIS.*

constraints that cannot be controlled by the management of the plant. All values collected for PRIS are net values. Figures 10 and 11 explain the various elements considered in the energy scheme of a nuclear power plant.

A planned energy loss is the energy that was not delivered during the month because of planned shutdowns or planned load reductions due to causes under the control of the management of the plant. Shutdowns or load reductions are considered to be planned if they are scheduled at least four weeks in advance (generally at the time when the annual overhaul, refuelling or maintenance programme is established), and if the beginning of the unavailability period can largely be controlled and deferred by the management of the plant.

An unplanned energy loss is the energy that was not delivered during the month because of unplanned shutdowns or unplanned load reductions or outage extensions due to causes under the control of the management of the plant. Shutdowns or load reductions due to causes under the control of the management of the plant are considered to be unplanned if they are not scheduled at least four weeks in advance.

A forced energy loss is the energy that was not delivered during the month because of unplanned shutdowns or unplanned load reductions due to causes under the control of the management of the plant.

An extension of planned energy loss is the energy that was not delivered during the month due to unplanned extensions of planned load reductions or shutdowns, if the causes of these extensions were under the control of the management of the plant.

Other energy losses is the energy that was not delivered during the month due to constraints reducing plant availability and being beyond the control of the management of the plant.

### 2.3.2. Production information for nuclear power plants with non-electrical applications

The primary purpose of the information contained in PRIS is to show the reliability of the nuclear power plant as the energy source for the application system. The secondary purpose is to record the quantity of energy used for non-electrical applications. The production data of application systems are also of great interest, but in many cases these application systems are not under the same organizational body as the nuclear power plant, except for on-site applications such as seawater desalination.

The energy data provided by nuclear power plants for non-electrical application systems are collected and analysed as production data. For on-site

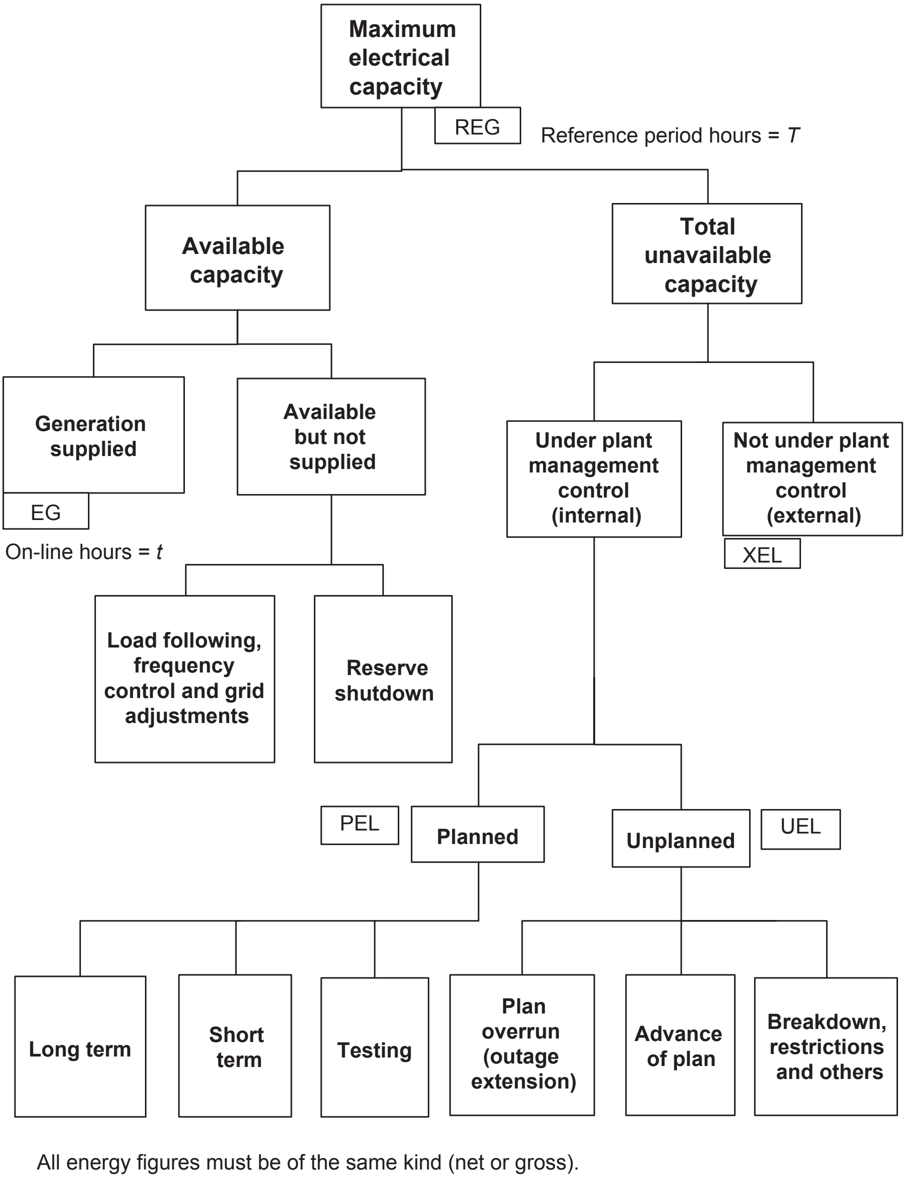



*FIG. 10. Energy schematic.*

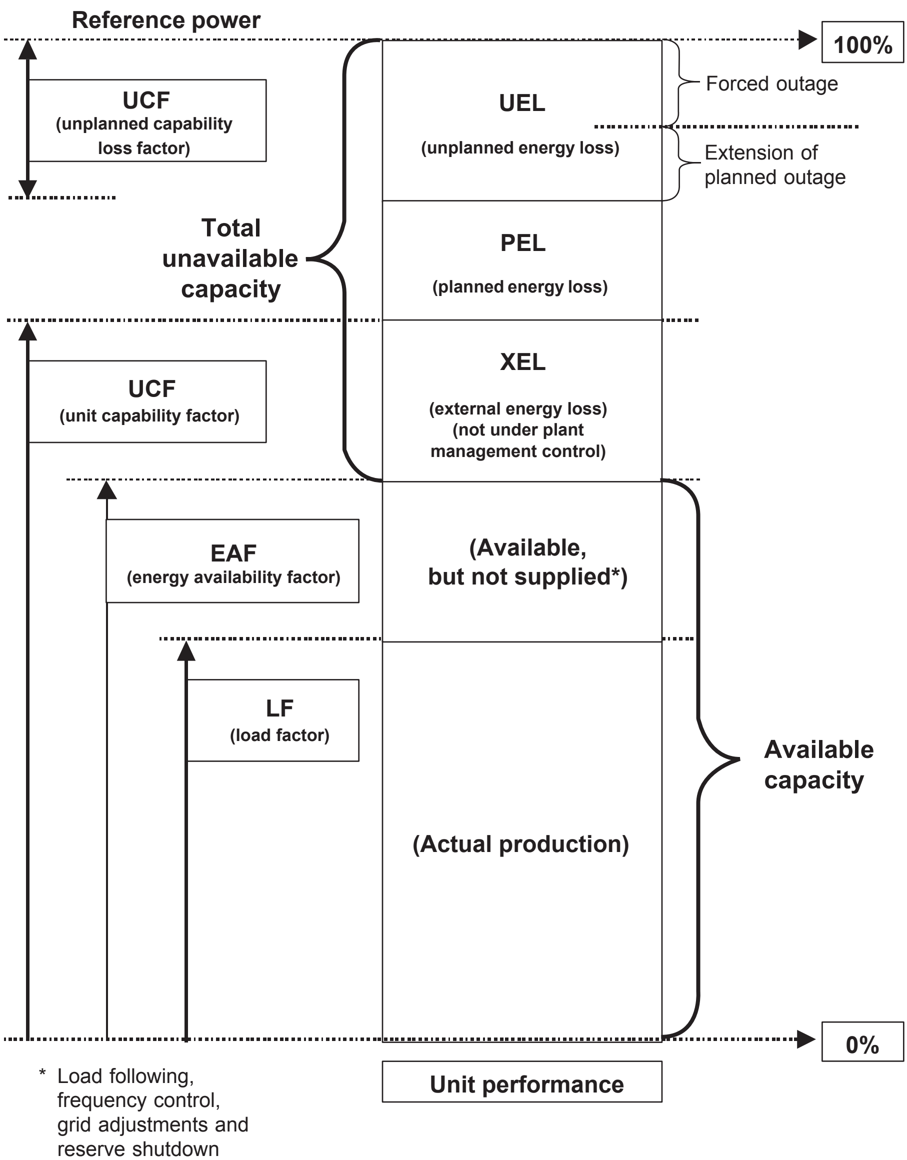



*FIG. 11. Schematic diagram of energy generation and losses.*

seawater desalination applications, the production data of the application system are also collected.

It is understood from trials that in most cases the cause of an outage or unavailability of an application system is unknown to the nuclear utility. It therefore seems not appropriate and of no immediate use to collect information related to the causes of outages of application systems.

The questionnaire for all data elements collected for non-nuclear applications is shown in Annex II.

### 2.3.3. Operating experience data

PRIS also includes information on significant operational conditions. The text field allows highlighting of specific operational circumstances. In addition to the text description, quantitative information on all reactor scrams is also stored. A reactor scram is defined as a reactor shutdown achieved by rapid insertion of negative reactivity into the reactor core, which can be performed either manually or automatically. Planned scrams performed as a part of planned tests are not reported.

## 2.4. OUTAGES

An outage is defined as a power reduction resulting in a loss of energy corresponding to at least 10 h of continuous operation at maximum capacity. PRIS contains more than 70 000 records of significant outages. Outage analysis provides indications of reasons for plant unavailability.

A record is made for each significant outage or unavailability of the unit during the year; this record contains the date and duration of the outage, the total energy lost, the type and main cause of the outage and the type of system or component affected. The outage records could be used to look at the operating history of a plant in order to make various outage analyses and to survey incidents and events inside the plant.

Detailed information on outage data collection is provided in Annex II, including definitions and examples of how the outage coding should be used.

## 2.5. DECOMMISSIONING DATA

A significant number of nuclear power plants worldwide have been operating for more than 30 years, while many others have been shut down and their operating organizations have started the decommissioning process. It was therefore decided to collect information on decommissioning, although this information is not yet included in PRIS.

Activities such as characterization, decontamination, dismantling and demolition of the installations are performed during particular periods in the decommissioning process.

In order to complement the existing databases on nuclear power plants, collect experience on decommissioning, compile information on techniques used in decommissioning activities and disseminate decommissioning references to Member States, the IAEA is developing a computerized database on decommissioning. In addition to the details on nuclear power plants already included in PRIS, it is necessary to collect information on the different phases and activities of the decommissioning process. This information will eventually complement PRIS.

To assist the IAEA in developing this decommissioning database, information based on either current or planned activities has been requested from the designated PRIS national correspondents and liaison officers. Data were collected at the end of 2001 and 2002 and are currently under analysis at the IAEA before their inclusion in PRIS. An adequate means to collect data for this part of PRIS needs to be incorporated in the new web based data acquisition system. Annex III gives details of the data collected in this project.

## 2.6. DELAYED PROJECTS

PRIS contains information on nuclear power plant projects from their construction to their final shutdown. A number of projects under construction experience delays of five years or more with respect to their original scheduled operation (grid connection) date. In 1997 the IAEA initiated a programme to provide assistance in the management of such delayed projects directed at implementing measures to maintain readiness for resuming the project implementation schedule when conditions permit. The implementation of this programme allowed the collation of information specific to delayed nuclear power plants, which was provided by participants at meetings organized by the IAEA between February 1997 and October 2001. The information collected at these meetings, which contains preliminary data on the subject of delayed nuclear power plants, has been summarized; the latest version of this summary, Rev. 3, October 2001, is presented in Annex IV.

The information gathered on delayed nuclear power plants shows a wide range of issues reflecting various situations in Member States. Some significant issues in several States are sometimes not relevant to, or only have limited affect on, other States. In spite of these differences, the subject of delayed nuclear power plants is progressively perceived in a wider context and is not regarded as an isolated problem for one State but as a significant subject with difficulties shared by several States. Along with this recognition, the collection of preliminary data on delayed nuclear power plants by the IAEA was regarded as an initial step that could be built upon through a more precise definition of inputs, regular updating and dissemination of specific information. It has been recommended that the IAEA consider integrating data on delayed nuclear power plants into PRIS.

Information on delayed nuclear power plants was discussed in a meeting on PRIS in March 2002. A meeting of PRIS liaison officers and national correspondents held in October 2002 suggested that PRIS should not include cost related data but that data on delayed nuclear power plants could be included and collected in the scope of PRIS if cost data were excluded. A questionnaire on delayed nuclear power plants without cost information is currently under revision.

# 3. DATA GATHERING

## 3.1. DATA ACQUISITION SYSTEM

The IAEA has collected information on nuclear power plants since the early 1970s. The system of data collection has evolved with time following improvements in information technology over the past decades. In the 1970s data were collected through annual questionnaires, which were sent to the IAEA by fax or mail. Later, with the spread of the Internet, most States sent data electronically via email or the collaborative work environment known as the IAEA Virtual Office.

To speed up the process of data collection, and to bring more transparency for the data provider in terms of data collection and data validation and use, the IAEA started the development of a data acquisition system using web technology. This new system, called WeDAS, Web-based Data Acquisition System, was put into operation in January 2003.

WeDAS has been developed in phases, with the objective of collecting all data on the status of nuclear power plants, energy production and losses, outages and non-electrical applications. The PRIS system currently contains all these items, but does not include data on decommissioning and delayed projects information. The IAEA is working in the current development phase to incorporate some important features that will allow data providers to benchmark their data against

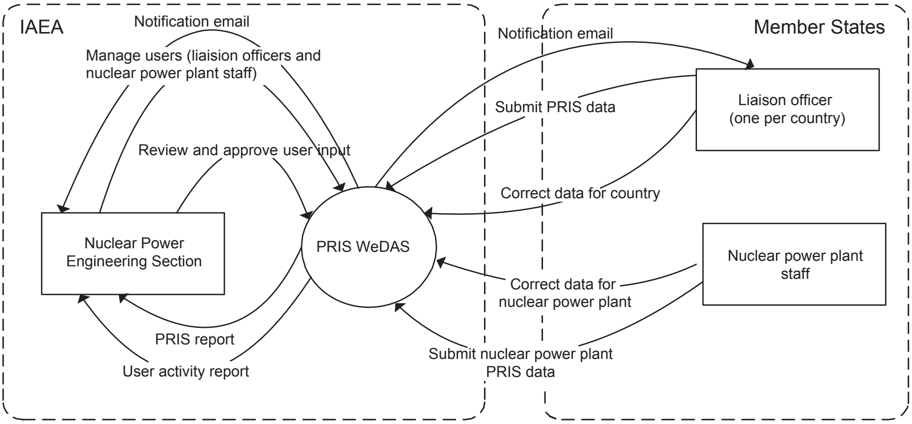



*FIG. 12. Concept of PRIS WeDAS.*

other plants of the same type and against worldwide values. WeDAS also provides on-line help and consistency checking of data entry.

WeDAS currently enables the capture of operating experience data from authorized persons in Member States within a defined timeframe (annually, semi-annually, quarterly or monthly), simplifies the collection of these data using an electronic version of the questionnaire and web technology, and allows authorized persons to self-assess and correct data submitted by them on-line.

The concept of WeDAS is illustrated in Fig. 12. The liaison officer, who could either be at the governmental or the nuclear power plant level, provides data to PRIS through WeDAS. Data are validated and checked automatically by the system, and the data provider corrects the data if necessary and advises the IAEA data administrator when finished. The IAEA data administrator publishes the data after revision and approval.

The IAEA data administrator manages WeDAS and is the IAEA staff member responsible for the initial set-up of the system and for procedures at the global and State level.

# 4. OUTPUTS

## 4.1. PERFORMANCE INDICATORS

The main nuclear power performance indicators currently used by the world nuclear industry for benchmarking cover:

(a) Energy generated;
(b) Plant availability and unavailability;
(c) Planned and unplanned outages;
(d) Nuclear safety related events;
(e) The unavailability of safety systems and support functions;
(f) Industrial safety;
(g) Radiation safety;
(h) Fuel reliability;
(i) Radioactive waste.

Other indicators have been developed and adopted by individual plants to monitor different stages of plant operation.

Among the internationally accepted set of indicators, PRIS provides information on:

(i) Operation factors;
(ii) Load factors;
(iii) Energy availability factors;
(iv) Planned energy unavailability factors;
(v) Unplanned energy unavailability factors;
(vi) Unit capability factors;
(vii) Unplanned capability loss factors;
(viii) Forced loss rates;
(ix) The number of scrams.

Performance indicators are a tool for identifying problem areas in which improvements are necessary, but they do not state either the root cause nor the solution. Care should therefore be taken not to give priority to a single performance indicator in an analysis, as this could distort the overall impression.

Definitions of performance indicators calculated by PRIS are presented in this section. More detailed definitions and examples are presented in Annex V. These factors are calculated taking into account the monthly energy production and losses reported to PRIS from the date of commercial operation of the plant.

- The load factor is defined as the ratio of the energy generation (net) during a given time period to the reference energy generation (net) during the same time period, expressed as a percentage. The reference energy generation term is determined relative to the reference ambient conditions.
- The operation factor is defined as the ratio of the number of hours that the unit or plant was on-line to the total number of hours in the reference

period, expressed as a percentage. It is a measure of the unit time availability and does not depend on the operating power level.

- The energy availability factor is defined as the ratio of the available energy generation (net) over a given time period to the reference energy generation (net) over the same period, expressed as a percentage. Both of these energy generation terms are determined relative to reference ambient conditions.
- The planned energy unavailability factor is defined as the ratio of the unavailable planned energy generation (net) over a given time period to the reference energy generation (net) over the same period, expressed as a percentage. Both of these energy generation terms are determined relative to reference ambient conditions. Energy losses are considered to be planned if they are scheduled at least four weeks in advance, generally at the time when the annual overhaul, refuelling or maintenance programme is established. Energy losses considered to be under the control of the management of the plant are further defined in the clarifying notes in Annex V.
- The unplanned energy unavailability factor is defined as the ratio of the unplanned unavailable energy generation (net) over a given time period to the reference energy generation (net) over the same period, expressed as a percentage. Both of these energy generation terms are determined relative to reference ambient conditions. Energy losses are considered to be unplanned if they are not scheduled at least four weeks in advance. Energy losses considered to be under the control of the management of the plant are further defined in the clarifying notes in Annex V.
- The unit capability factor is defined as the ratio of the capable energy generation (net) over a given time period to the reference energy generation (net) over the same period, expressed as a percentage. Both of these energy generation terms are determined relative to reference ambient conditions.
- The unplanned capability loss factor is defined as the ratio of the unplanned energy losses during a given period of time to the reference energy generation, expressed as a percentage.
- The forced loss rate is defined as the ratio of the unplanned energy losses during a given period of time, considering only the operating period, to the reference energy generation minus energy losses corresponding to planned outages and their possible unplanned extensions, during the same period, expressed as a percentage.
- Scram rate: the purpose of the unplanned automatic scrams per 7000 h critical indicator is to monitor performance in reducing the number of unplanned automatic reactor shutdowns. The indicator provides an

indication of success in improving plant safety by reducing the number of undesirable and unplanned thermohydraulic and reactivity transients requiring reactor scrams. It also provides an indication of how well a plant is being operated and maintained. Taking into account the number of hours that a plant was critical provides an indication of the effectiveness of scram reduction efforts while a unit is in an operating condition. In addition, normalizing individual unit scram data to a common standard (7000 h critical) provides a uniform basis for comparisons between individual units and with industry values. Manual scrams and, in certain cases, automatic scrams as a result of manual turbine trips to protect equipment or mitigate the consequences of a transient are not counted for unplanned automatic scrams indicator calculations, since operator initiated scrams and actions to protect equipment should not be discouraged. PRIS provides information about the total number of scrams, collecting data also on manual scrams.

## 4.2. QUERY SYSTEMS AND PRODUCTS

There are two main tools for querying PRIS, which are distributed free of charge to Member States and international organizations. These tools are:

(a) PRIS-PC (a front end tool interface with an on-line connection to PRIS through the internet);
(b) PRIS on CD-ROM.

These tools are currently distributed to more than 700 organizations. In addition, daily answers to a considerable number of ad hoc questions on nuclear power plant information and statistics are also provided.

PRIS-PC enables a direct connection to PRIS through the internet. PRIS-PC and PRIS on CD-ROM use the same concept for querying PRIS and contain many different possibilities for querying the system. The user can select an individual plant or a set of plants using different criteria and then apply predefined statistics to these plants. The criteria that can be used to select a set of plants are: world region, country, type of reactor, reactor capacity, reactor age, reactor status and site. Once the set of plants is selected, the user can choose from among a list of predefined statistics. The statistics allow grouping of the results by country, region, type or age of reactor and year. The list of available statistics is presented in Table 3.

TABLE 3. STATISTICS PROVIDED IN PRIS-PC AND PRIS ON CD-ROM

| |
|---|
| Number of reactors and capacity (age is based on the date of grid connection) |
| Connection to grid |
| Construction started |
| Shut down reactors |
| List of reactors in operation in a specified year |
| Performance indicators |
| Energy availability factor |
| Load factor |
| Operation factor |
| Planned energy unavailability factor |
| Unplanned energy unavailability factor |
| External energy unavailability factor |
| Unit capability factor |
| Distribution of reactors by range of lifetime energy availability factor |
| Distribution of reactors by range of year energy availability factor |
| **Statistics on unavailability or outages** |
| Causes of unavailability for non-prototype reactors |
| System unavailability for non-prototype reactors |
| **World statistics** |
| World electricity generation and nuclear share |
| Nuclear share of electricity generation by country |
| Number of reactors by age (age = 0 being the year of grid connection) |
| World factors |
| **Outages analysis** |
| Outage analysis: planned |
| Outage analysis: unplanned external |
| Outage analysis: unplanned internal |
| Outage analysis: equipment part 1 |
| Outage analysis: equipment part 2 |
| Outages |

TABLE 3. STATISTICS PROVIDED IN PRIS-PC AND PRIS ON CD-ROM (cont.)

| Reference Data Series tables |
| --- |
| Table 1. Nuclear power reactors in operation and under construction |
| Table 2. Reactor types and net electrical power, reactors connected to the grid |
| Table 3. Reactor types and net electrical power, reactors under construction |
| Table 4. Construction starts during (year) |
| Table 5. Connections to the grid during (year) |
| Table 6. Scheduled connections to the grid during (year) |
| Table 7. Reactor years experience up to December (year) |
| Table 8. Reactor units and net electrical power up to (year) |
| Table 9. Scheduled construction starts during (year) |
| Table 10. Reactors connected to the grid, 31 December (year) |
| Table 11. Reactors under construction, 31 December (year) |
| Table 12. Reactors shut down, 31 December (year) |
| Table 13. Annual construction starts and connections to the grid, 1955 to (year) |
| Table 14. Average construction time span |
| Table 15. Cumulative performance factors for non-prototype reactors up to (year) |
| Table 16. Average full outage statistics for non-prototype reactors during (year) |
| Table 17. Causes of unavailability during (year) for non-prototype reactors |
| Table 18. Causes of unavailability for non-prototype reactors (range of years) |
| Table 19. Countries: abbreviations and summary |
| Table 20. Reactor types: abbreviations and summary |
| Table 21. Operators: abbreviations and summary |
| Table 22. Nuclear steam supply system supplier: abbreviations and summary |
| **Statistics for non-electrical application units** |
| Number of non-electrical units (age is based on exploitation start date) |
| Shut down non-electrical units |
| List of non-electrical application units (NEAUs) in operation in a specified year |
| Number of NEAUs by age (age = 0 being the year of service start date) |
| Outage analysis |
| NEAU outage analysis: planned |
| NEAU outage analysis: unplanned external |
| NEAU outage analysis: unplanned internal |

## 4.3. PUBLICATIONS

Two main publications are produced from PRIS:

(a) Nuclear Power Reactors in the World, Reference Data Series No. 2 [1];
(b) Operating Experience with Nuclear Power Plants in Member States [2].

Nuclear Power Reactors in the World, Reference Data Series No. 2, contains general information as of the end of each year on nuclear power reactors operating, under construction and shut down, and contains performance data on reactors operating in Member States. It summarizes statistics on the status and trends of nuclear power plants by country.

Operating Experience with Nuclear Power Plants in Member States is also an annual publication. It contains records on operating experience of each nuclear power plant in operation or shut down during a certain year. The operating experience record includes monthly performance indicators, outages and yearly factors since the beginning of the commercial operation of nuclear power plants worldwide.

Both publications also include the most requested statistics in the form of charts and graphics.

PRIS also provides material for other IAEA publications and is widely used in-house. In addition, statistical analyses are carried out either for use within the IAEA or on request for Member States and outside organizations.

## 4.4. WEB SITE

Since 1995 PRIS has provided information to the public through its pages on the IAEA web site (http://www.iaea.or.at/programmes/a2/). The site currently contains the latest news on nuclear power, statistics on nuclear power plants and worldwide performance indicators in the form of charts, tables and figures. It also contains a search feature that provides summarized and public information on every nuclear power plant in the world.

In parallel, the IAEA is developing a web application with more detailed statistics and access to a major portion of the system, which should slowly replace PRIS-PC. The new tool will be accessible only to registered users of Member States.

### 4.5. EXAMPLES OF PRIS USAGE

PRIS serves to easily identify individual units by their main characteristics and to provide information on the status and performance of nuclear power plants worldwide, in regions or in individual countries. The IAEA also compiles information on plant design characteristics, which provides a better overview of a plant's design and mode of operation. This information covers items related to the mode of plant operation, safety characteristics, safety features, the existence of a safety analysis report and emergency plans, the plant environment, etc.

Outage analysis provides indications of reasons for unavailability. Statistical analyses as well as studies performed at the level of individual units or utilities provide indications of the usual problem areas and of what remedial actions and measures can be applied to achieve performance improvements. PRIS can help in providing a first level of indication in such an analysis.

PRIS can be used to assess nuclear power plant performance through different indicators and outage causes in a systematic and homogeneous manner.

PRIS covers the largest amount of worldwide statistical information on operating experience with nuclear power plants. The data contained in the system make it especially useful for identifying problem areas and overall trends, and the amount of operating experience data available permits statistical analyses to be made.

## REFERENCES


[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Power Reactors in the World, Reference Data Series No. 2, IAEA, Vienna (2003).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Operating Experience with Nuclear Power Plants in Member States, IAEA, Vienna (2003).

## Annex I

## REACTOR CHARACTERISTICS DATA FOR ALL NUCLEAR POWER PLANTS

### I–1. CORE AND REACTIVITY CONTROL

Fuel material.
Fuel inventory (t).
Moderator material.
Moderator weight (t).
Average core power density ($kW/dm^3$).
Average fuel power density (kW/kg U).
Average discharge burnup (MW·d/t).
Average linear core power density (kW/m).
Initial enrichment or enrichment range (wt%).
Reload enrichment at the equilibrium (for GCRs and AGRs) (wt%).
Refuelling frequency (month).
Type of refuelling (on/off-power).
Part of core withdrawn (%).
Active core height (m).
Core diameter (m).
Number of fuel assemblies.
Number of fissile fuel assemblies and fertile fuel assemblies (for FBRs).
Number of fuel rods per assembly.
Rod arrays in assembly.
Clad material.
Clad thickness.
Number of control rod assemblies.
Number of control rods (for GCRs and AGRs).
Number of control elements per assembly (for PWRs and BWRs).
Control rod neutron absorber material.
Soluble chemical neutron absorber.
Burnable poison.

### I–2. REACTOR COOLANT SYSTEM

Reactor core thermal power (for PWRs, BWRs and CANDUs) (MW).
Total thermal power (MW).

Coolant type.
Design coolant mass flow through core (kg/s or t/h).
Operating coolant pressure ($kg/cm^2$).
Inlet core temperature (°C).
Inlet reactor temperature (for GCRs) (°C).
Outlet core (or reactor) temperature (°C).
Outlet reactor temperature (for GCRs) (°C).

## I–3. REACTOR PRESSURE VESSEL

Overall length of assembled vessel and closure head (mm).
Inside shell diameter (mm).
Average shell thickness (mm).
Vessel material.
Cladding material.

For RBMKs, CANDUs and GCRs:

Number of channels.
Channel material.
Channel wall thickness (mm).

## I–4. STEAM GENERATOR (PWRs)

Number of steam generators.
Type.
Tube material.
Shell material.
Heat transfer surface per steam generator ($m^2$).
Thermal capacity per steam generator (MW).
Steam drums (RBMKs).
Number of steam drums.

## I–5. PRESSURIZER (PWRs AND CANDUs)

Pressurizer total volume ($m^3$).
Steam volume at full power ($m^3$).
Steam volume at zero power ($m^3$).

Design temperature (°C).
Design pressure (kg/cm$^2$).
Number of heaters.
Installed heat power (kW).

## I–6. MAIN COOLANT PUMPS

Number of primary cooling or recirculation pumps or gas circulators.
Type.
Pump mass flow rate (t/h or kg/s).
Pump design head or pressure (m of $H_2O$) (for all but AGRs and GCRs).
Pump nominal power (cold/hot for PWRs) (kW).
Pump nominal power (main/auxiliary for GCRs, AGRs and CANDUs) (kW).

## I–7. CONTAINMENT (PWRs, BWRs AND AGRs)

Type.

### I–7.1. Pressure suppression system

Free volume (m$^3$).
Total volume (m$^3$).
Design pressure (kg/cm$^2$).
Dry well design pressure (for BWRs) (kg/cm$^2$).
Design temperature (°C).
Design leakage rate (% per day).

## I–8. ACCIDENT LOCALIZATION SYSTEM OR CONFINEMENT (RBMKs AND WWERs)

Free volume (m$^3$).
Total volume (m$^3$).

## I–9. SAFETY AND SAFETY RELATED SYSTEMS

### I–9.1. Chemical volume control system

Number of extraction lines.
Number of pumps.
Number of feed and bleed connections.

## I–10. BORON INJECTION SYSTEM

Volume of boron tank ($m^3$).
Boron concentration (ppm).
Is there any boron system (GCRs and AGRs) (yes/no).

## I–11. EMERGENCY CORE COOLING SYSTEMS

High pressure (HP) injection: Number of pumps.
HP injection: Minimum number of pumps for coping with a design basis accident.
HP injection: Design head or pressure (m of $H_2O$).
HP injection: Design mass flow rate (kg/s or t/h).
Low pressure (LP) injection: Number of pumps.
LP injection: Minimum number of pumps for coping with a design basis accident.
LP injection: Design head or pressure (m of $H_2O$).
LP injection: Design mass flow rate (kg/s or t/h).
Accumulators: Number of accumulators.

## I–12. CORE SPRAY SYSTEM

Number of pumps.
Feed and bleed connections.

## I–13. COMPONENT COOLING SYSTEM UP TO THE ULTIMATE HEAT SINK

Number of trains.
Number of pumps.
Ultimate heat sink (river, lake or other).

## I–14. CONTAINMENT SYSTEM

### I–14.1. Spray systems

Number of trains.
Number of pumps.

## I–15. OTHER SAFETY SYSTEM

Hydrogen recombiner/ignitors (yes/no).
Countermeasures against core melting (yes/no).
Venting system (yes/no).
Inertiazation (yes/no).

## I–16. COOLING SYSTEM

Outside (yes/no).
Outside: Type.
Inside (yes/no).
Inside: Type.
Other.

## I–17. EMERGENCY FEEDWATER SYSTEM

Number of pumps.
Number of trains.
Type of energy supply (e.g. diesel or electric motor).

## I–18. FIRE PROTECTION SYSTEM

Fire hazard areas (nuclear safety and radiological protection) identified (yes/no).
Provisions to minimize fire loads in safety related areas (yes/no).
Storage of combustibles and/or flammable liquids or gases (yes/no).
Fire ignition sources (e.g. electrical equipment or special requirements) (yes/no).
Fire spread (e.g. fire retardant cable coatings) (yes/no).
Separation between independent trains (yes/no).

Fire detection systems available in all the building areas (yes/no) or only in selected rooms (yes/no).
List of detector types (e.g. optical, ionization chambers or temperature sensors).
Automatic fire suppression systems available in all buildings (yes/no).
List of fire extinguishing system types available for fire loads (yes/no).
List of fire extinguishing system types available for special areas (yes/no).
An on-site dedicated fire brigade (yes/no) or plant operators who are in charge of that duty (yes/no).

## I–19. SAFETY RELATED INSTRUMENTATION AND CONTROL SYSTEM

Reactor protection system physically and functionally separated and independent (yes/no).
Specify the hierarchy concept (e.g. two steps or three steps).
Reactor protection system (RPS): List of reactor trip signal parameters.
RPS: General protection logic.
RPS: Application of analog or digital reactor protection system.
RPS: Located in the main control room (yes/no).
RPS: Existence of centralized safety system panel different from the main operation panel (yes/no).
RPS: Existence of decentralized safety shutdown panel (yes/no).

## I–20. EMERGENCY POWER SUPPLY SYSTEM

Type (e.g. diesel, gas turbine or grid connections).
Number of trains.
Number of diesel generators per train.
Other uninterruptible AC emergency sources (e.g. motor generator).

## I–21. AC/DC SUPPLY SYSTEM

Type (e.g. rectifier, converter or battery).
Estimated time reserve (h).

## I–22. CONVENTIONAL THERMAL CYCLE

Turbine system.
Type (e.g. saturated steam condensing turbine, superheated condensing turbine).
Number of turbines per reactor.
Turbine rating (MW).
Number of turbine sections or cylinders per unit.
Turbine speed (rpm).
Steam conditions at HP turbine inlet: Temperature (°C).
Steam conditions at HP turbine inlet: Pressure (kg/cm$^2$).
Steam conditions at HP turbine inlet: Moisture content (%).
Steam conditions at HP turbine inlet: Flow (kg/s or t/h).

## I–23. CONDENSER

Type (e.g. box type surface condenser).
Number of condensers per turbine.
Condenser vacuum (kg/cm$^2$).
Type of condenser cooling (river, sea, lake or tower).

## I–24. MAIN GENERATOR

Type (e.g. three phase synchronous generator or DC generator).
Apparent power (VA).
Active power (MW).
Frequency (Hz).

## I–25. SPENT FUEL STORAGE

Number of pools.
Capacity (m$^3$).
Maximum number of fuel rods in storage.

# Annex II

# PRIS QUESTIONNAIRE

INTERNATIONAL ATOMIC ENERGY AGENCY

**POWER REACTOR INFORMATION SYSTEM**

**REPORTING QUESTIONNAIRE**

OPERATING EXPERIENCE WITH NUCLEAR POWER PLANTS

***DECEMBER 2002***

## PART 1: QUESTIONNAIRE FORM

This form provides:

I) **Production Data** (page 2) for calculating the following nuclear power plant performance indicators on monthly and annual basis:

Operation Factor (OF) and Load Factor (LF).

II) **Unavailability Data** (page 3) for calculating the following nuclear power plant performance indicators on monthly and annual basis:

Energy Availability Factor (EAF), Planned Energy Unavailability Factor (PUF), Unplanned Energy Unavailability Factor (UUF), Unit Capability Factor (UCF), Unplanned Capability Loss Factor (UCL), Forced Loss Rate (FLR)

III) **Operating Experience Data** (page 4) for brief information on the general performance and operational mode of the plant over the year and significant factors affecting energy generation over the year. Here information is also collected to calculate the Unplanned Automatic and Unplanned Manual Scram Indicators (UA7 and US7).

IV) **Outage Data** (page 5) to look at the plant operation history, to make various outage analyses, etc.

The record is given for all outages of the unit during the year containing the date and duration of the outage, total energy lost, type and cause of the outage and the system involved.

(V) **Heat Production Data** (page 6) to evaluate the amount of power delivered by the plant for non-electrical applications in the form of heat/steam.

This section is to be completed following closure of the related IAEA projects A2.06 and A2.04.

Contact Person at the plant for information on the completion of the questionnaire:

Name: ______________________________________________________
Address: ______________________________________________________
Telephone: _________________________ Fax: ________________________
E-mail: ______________________________________________________
Date of completion of questionnaire (yyyy/mm/dd): __ __ __ __/__ __/__ __
Reporting period: from __ __ __ __/__ __/__ __ to __ __ __ __/__ __/__ __
The recommended frequency of data reporting is twice a year (every six moths); however, the data must be reported at least once a year.
For any comments, and queries regarding the questionnaire please contact at the IAEA:
Ms. R. Spiegelberg-Planer
International Atomic Energy Agency
Division of Nuclear Power, IAEA
Tel: (+43 1) 2600 22788; Fax: (+43 1) 26007 22788; e-mail: r.spiegelberg-planer@iaea.org.

INTERNATIONAL ATOMIC ENERGY AGENCY

# POWER REACTOR INFORMATION SYSTEM

## REPORTING QUESTIONNAIRE

(I) PRODUCTION DATA

**Year:** |_|_|_|_|

**IAEA plant unit code:** |_|_| - |_|_|_|

**Station name and unit number:** _________ |_|_|_|_|

_______**Reference unit power (net) at the beginning of the year *[MWe]*:**

**Reference unit power revisions during the year:**

| Date (yyyymmdd): | Reference unit power (net) *[MWe]*: |
|---|---|
| |_|_|_|_|_|_|_|_| | |_|_|_|_| |
| |_|_|_|_|_|_|_|_| | |_|_|_|_| |

**Does your plant supply heat for non-electrical applications?** ☐ Yes[1] ☐ No

**Monthly energy generation (net) during the year:**

<table>
<tr><th></th><th>Electricity Generated (net)<br>EG<br>[MWe·h]</th><th>On-line Hours<br>t<br>[hours]</th><th>Reference Period<br>T<br>[hours]</th></tr>
<tr><td>January</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>February</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>March</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>April</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>May</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>June</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>July</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>August</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>September</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>October</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>November</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>December</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>TOTAL</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
</table>

**Lifetime Cumulative Energy Generation (net) *[GWe·h]*:** |_|_|_|_|_|_|_|_|

[1] Please refer to section V

INTERNATIONAL ATOMIC ENERGY AGENCY

# POWER REACTOR INFORMATION SYSTEM

## REPORTING QUESTIONNAIRE

## (II) UNAVAILABILITY DATA

<table>
<tr><th rowspan="2">Month</th><th>Planned Energy Losses (net)</th><th colspan="2">Unplanned Energy Losses (net) (due to causes under the plant management control)<br>UEL</th><th>External Energy Losses (net) (due to causes beyond the plant management control)</th></tr>
<tr><th>PEL<br>[Mwe·h]</th><th>FEL<br>Forced energy losses<br>[MWe·h]</th><th>EPL Extensions of planned energy losses<br>[MWe·h]</th><th>XEL<br>[MWe·h]</th></tr>
<tr><td>January</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>February</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>March</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>April</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>May</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>June</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>July</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
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<tr><td>September</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
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<tr><td>December</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
<tr><td>TOTAL</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|</td></tr>
</table>

INTERNATIONAL ATOMIC ENERGY AGENCY
POWER REACTOR INFORMATION SYSTEM
REPORTING QUESTIONNAIRE

PRIS

## (III) OPERATING EXPERIENCE DATA

**Highlights of Operation:**

| | |
|---|---|
| **Number of critical hours in the reporting period [hrs]:** | \|_\|_\|_\|_\|_\| |

| | |
|---|---|
| **Number of unplanned automatic scrams in the reporting period:** | \|_\|_\| |
| **Number of unplanned manual scrams in the reporting period:** | \|_\|_\| |

INTERNATIONAL ATOMIC ENERGY AGENCY
**POWER REACTOR INFORMATION SYSTEM**
**REPORTING QUESTIONNAIRE**

## (IV) OUTAGE DATA

<table>
<tr><td>Start Date:<br>[yyyymmdd]</td><td>Duration:<br>[hours]</td><td>Energy Loss (net):<br>[MWe·h]</td><td>Type Code:</td><td>Cause Code:</td></tr>
<tr><td>|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|/|_|</td><td>|_|/|_|_|.|_|_|</td></tr>
</table>

**Description of the outage (cause and mode):**

<table>
<tr><td>Start Date:<br>[yyyymmdd]</td><td>Duration:<br>[hours]</td><td>Energy Loss (net):<br>[MWe·h]</td><td>Type Code:</td><td>Cause Code:</td></tr>
<tr><td>|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|/|_|</td><td>|_|/|_|_|.|_|_|</td></tr>
</table>

**Description of the outage (cause and mode):**

<table>
<tr><td>Start Date:<br>[yyyymmdd]</td><td>Duration:<br>[hours]</td><td>Energy Loss (net):<br>[Mwe·h]</td><td>Type Code:</td><td>Cause Code:</td></tr>
<tr><td>|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|</td><td>|_|_|_|_|_|_|</td><td>|_|_|/|_|</td><td>|_|/|_|_|.|_|_|</td></tr>
</table>

**Description of the outage (cause and mode):**

## (V) HEAT PRODUCTION DATA

*Section to be added after completion of two related IAEA projects:*

***A2.06 - Co-generation and heat application***

***A2.04 - Nuclear desalination***

*One of possible data elements:*

| | |
|---|---|
| **Equivalent non-electrical energy generated (NEG) (net)** ***[MWe·h]*** | \|_\|_\|_\|_\|_\|_\|_\| |

## II–2. PART 2: REPORTING INSTRUCTIONS

### II–2.1. Production data

*Year*: The year of operation in the form of yyyy should be entered.

*IAEA plant unit code*: The PRIS reactor code should be entered.

*Station name and unit number*: The station name and unit number for which the data are being reported should be entered.

*Reference unit power (net) (MW(e))*: The reference unit power (net), expressed in units of MW(e), should be entered. The reference unit power is the maximum (electrical) power that could be maintained continuously throughout a prolonged period of operation under reference ambient conditions. The power value is measured at the unit outlet terminals (i.e. after deducting the power taken by unit auxiliaries and the losses in the transformers considered integral parts of the unit). The reference unit power value should also include the electrical equivalent of the portion of energy delivered in the form of steam and/or heat that might have been used for non-electrical applications. However, this applies only to units in which heat production may reduce the unit electrical power below its maximum value. If a maximum power capability has been determined by a formal test, the reference unit power is determined by correcting the test results to reference ambient conditions. If a formal test has not been performed, the reference power should be based on design values, adjusted for reference ambient conditions. The reference unit power is expected to remain constant unless, following design changes, or a new permanent authorization, the management of the plant decides to amend the original value. (It is recognized that the reference unit power may be based upon an authorized maximum unit thermal power, and in these cases the reference unit power (net) corresponding to the authorized maximum unit thermal power should be used for simplicity in the calculations.)

*Reference unit power revisions and dates of revisions*: Any changes in the reference unit power (net) that are foreseen to be permanent and which occurred during the year should be entered. Note that regulatory limitations for the net reference unit power of a non-permanent nature should not be reported here but should be reported as a partial outage due to regulatory limitation.

*Does the plant supply heat for non-electrical applications?* The appropriate box according to the actual conditions at the plant should be ticked. If the answer is yes (i.e. if the plant produces a part of its power in the form of heat (supplies steam for non-electrical applications to off-site consumers)), the amount of thermal energy should also be reported using the Heat Production Data Sheet (see Section II–2.5). This applies, however, only to plants for which heat production may reduce the unit electrical power below the reference unit power.

*Monthly energy generation (net) during the year:*

(a) *Energy generation (net), EG (MW(e)·h)*: The net electrical energy produced during the reference period as measured at the unit outlet terminals (i.e. after deducting the electrical energy taken by unit auxiliaries and the losses in the transformers considered integral parts of the unit) should be entered.
(b) *On-line hours, t (h)*: The total clock hours in the month during which the unit operated with at least one main generator connected to the grid should be entered.
(c) *Reference period, T (h)*: Generally, the total number of hours in the calendar month should be entered.

For units being commissioned during the month, the clock hours from the beginning of the month or the first connection to the grid, whichever comes last, to the end of the month should be entered. For units in commercial operation at the beginning of the month, the clock hours from the beginning of the month to the end of the month or to the last disconnection from the grid before permanent shutdown, whichever comes first, should be entered.

*Lifetime cumulative energy generation (net) (GW(e)·h)*: The net energy generated since the first connection to the grid, including the electrical equivalent of thermal energy used for non-electrical applications, should be entered. For its actual value, the total energy generated during the current reporting period should be added to the last reported lifetime cumulative energy generation value.

### II–2.2. Unavailability data

For the purpose of the outage coding system, unit unavailability is defined as the status when the plant is not able to operate at its reference power. This condition, which may be under or beyond the control of the management of the plant, should only reflect lack of availability of the plant itself, regardless of the energy demand, transmission grid condition or political situation in the country. It follows from the definition that the term ‘outage’ is more general and does not always imply unit unavailability. In other words, some outages may occur even though the unit is fully available.

In the Unit Unavailability Data Form only those energy losses caused by plant unavailability (full or partial) as defined above should be entered. If the power plant was operated at a power lower than the reference unit power, although it would be able to operate at the reference unit power, the energy loss incurred should not be entered in the Unit Unavailability Data Form. Such energy losses that may be due to grid failure, load following operation, a government or court decision or stretch-out operation do not constitute other energy losses for the purpose of energy availability factor calculations. For completeness of information on lost energy, however, these energy losses should be reported in the Outage Data Form. (See the outage cause codes J, K, M, R, S, T and U in Section II–2.4.)

The calculation of energy losses due to reduced unit availability is always related to the reference unit power. If the unit availability is reduced for two or more concurrent reasons (e.g. an unplanned equipment failure during a planned power reduction for maintenance), the energy loss due to the equipment failure is calculated as if the unit were operated at the reference power at the moment of the failure.

Three types of energy loss caused by unit unavailability are defined in PRIS: planned energy losses, unplanned energy losses due to causes within the control of the management of the plant and other energy losses due to constraints beyond the control of the management of the plant.

*Planned energy loss (net), PEL (MW(e)·h)*: The energy, expressed in MW(e)·h, that was not delivered during the month because of planned shutdowns or planned load reductions due to causes under the control of the management of the plant should be entered. Shutdowns or load reductions are considered to be planned if they are scheduled at least four weeks in advance (generally at the time the annual overhaul, refuelling or maintenance programme is established) and if the beginning of the unavailability period can be largely controlled and deferred by the management of the plant.

*Unplanned energy loss (net), UEL (MW(e)·h)*: The energy, expressed in MW(e)·h, that was not delivered during the month because of unplanned shutdowns, unplanned load reductions or outage extensions due to causes under the control of the management of the plant should be entered. Shutdowns or load reductions due to causes under the control of the management of the plant are considered to be unplanned if they are not scheduled at least four weeks in advance. When evaluating unplanned energy losses, the unit is supposed to be running under reference ambient conditions.

*Forced energy loss, FEL (MW(e)·h)*: The energy, expressed in MW(e)·h, that was not delivered during the month because of unplanned shutdowns or unplanned load reductions due to causes under the control of the management of the plant should be entered.

*Extensions of planned energy loss, EPL (MW(e)·h)*: The energy, expressed in MW(e)·h, that was not delivered during the month due to unplanned extensions of planned load reductions or shutdowns, if the causes of these extensions were under the control of the management of the plant, should be entered.

Additional information on planned and unplanned energy losses is provided in Section II–2.4 and Annex V.

*External energy losses (net), XEL (MW(e)·h)*: The energy, expressed in MW(e)·h, that was not delivered during the month due to constraints reducing plant availability and being beyond the control of the management of the plant should be entered. Energy losses caused by the following conditions should be reported here:

(a) Environmental conditions (seasonal variations in cooling water temperature, flood, storm, lightning and lack of cooling water due to drought, tidal valves and high sea or water intake restrictions that could not be prevented by operator action);
(b) Fuel coastdown (power reduction at the end of the fuel cycle resulting in a release of positive reactivity to compensate for high fuel burnup);
(c) Restrictions on supply and services due to external constraints (lack of funds due to delayed payments from customers, disputes in fuel industries, fuel rationing, a labour strike outside the plant, spare part procurement difficulties, etc.).

### II–2.3. Operating experience data

*Highlights of operation*: The general performance and operational mode of the plant over the reporting period should be briefly stated; for example:

(a) Operation at full power in the base load mode;
(b) Load following for a period;
(c) Shutdown for a period;
(d) Major achievements leading to increased availability.

The significant factors affecting energy generation over the reporting period should be described; for example:

(i) Limitations introduced by regulatory bodies;
(ii) Limitations due to fuel management;
(iii) Shortage of consumables;
(iv) Personnel factors;
(v) Equipment performance;
(vi) Environmental conditions.

*Number of critical hours in the reporting period*: The number of hours during the reporting period when the reactor was critical should be entered.

*Number of unplanned automatic scrams in the reporting period*: The number of unplanned automatic scrams that occurred during the reporting period while the reactor was critical should be entered.

*Number of unplanned manual scrams in the reporting period*: The number of unplanned manual scrams that occurred during the reporting period while the reactor was critical should be entered.

### II–2.4. Outage data

For the purposes of PRIS coding, an outage is defined as any status of a reactor unit when its actual output power is lower than the reference unit power for a period of time. By this definition, outage includes both power reduction and unit shutdown; however, it is recognized that by common understanding it may mean the shutdown only.

All significant outages, including outage extensions and reactor scrams, should be reported. The outage is considered significant if the loss in energy production corresponds to at least 10 h of continuous operation at the reference unit power, or if it has been caused by an unplanned reactor scram (even if the unit was shut down for less than 10 h). It is desirable also to report smaller than significant outages. If more than one outage occurred at the same time, they should be considered to be separate outages and reported as if the unit were operating at the reference power.

A reactor scram is defined as a reactor shutdown achieved by a rapid insertion of negative reactivity into the reactor core, which can be performed either manually or automatically. All unplanned reactor scrams must be reported, even if they occurred after the unit was disconnected from the grid (when the reactor remained at power, for example on the main output breaker trip). Planned scrams performed as a part of planned tests are not reported.

An outage extension is defined as the unplanned portion of a planned outage causing prolongation of the planned outage beyond its originally planned completion date. An outage extension must always be reported as unplanned unless it is announced at least four weeks in advance. Planned outage extensions are considered to be part of planned outages and are not reported separately.

*Start date*: The first day of the outage in the form of “yyyymmdd” (e.g. 20001228 for 28 December 2000) should be entered. If no start date can be specified (e.g. for a continuous load following operation), the first day of the reporting period should be entered. The same applies if an outage extends from the previous reporting period.

*Duration (h)*: The total time of the outage measured in full clock hours (rounded) from the beginning of the reporting period or outage, whichever comes last, to the end of the reporting period or outage, whichever comes first, should be entered. The time includes both the power decrease and power rise period. If a part of the outage extends to the next reporting period, the corresponding outage duration is coded for each reporting period separately. For intermittent outages (e.g. due to a load following operation), cumulative data for the reporting period should be entered. For reactor scrams after disconnection of the unit from the grid, no outage duration should be reported (the field should be left blank).

*Energy loss (net) (MW(e)·h)*: The total energy, expressed in MW(e)·h, that has not been delivered to the grid or to other consumers[1] because of the outage should be entered. Energy losses are calculated separately for each outage. If several outages are concurrent for a period of time, the energy loss for each outage should be reported as if the unit had been operated at the reference power at the beginning of the outage. For reactor scrams after disconnection of the unit from the grid, no energy loss should be reported (the field is left blank). For intermittent outages (e.g. due to a load following operation), cumulative data for the reporting period should be entered.

*Type code*: A two or three character code for the outage type should be entered. The individual outage types should be coded as follows: first character, see Table II–1; second character, see Table II–2; third character (for unplanned outages only), see Table II–3. Thus the outage type may have one of the following codes: PF or PP, UF1–5 or UP1–3, XF or XP, XF1–5 or XP1–3.

*Cause code*: For each outage type a one to five character code describing the outage cause and the system primarily involved or affected in the outage should be entered. The first character represents a direct cause of the outage. The direct cause is defined as an immediate action or condition that has directly resulted in the outage; for example, if a minor equipment failure, such as an oil leak dropping on to a hot pipeline or a short circuit in a non-vital switchgear cabinet, results in an extensive fire that directly causes an outage, the fire is considered to be the direct cause of the outage. For a particular outage (full or partial), only one cause may be selected. If outages occur successively, they must be reported as separate outages due to different causes; for example, if unit power was first reduced due to an equipment failure, but the unit subsequently tripped due to human error when responding to the failure, these incidents should be reported as two

[1] For non-electrical applications.

TABLE II–1. FIRST CHARACTER FOR THE OUTAGE TYPE CODE

| Code | Description |
|---|---|
| P | Planned outage due to causes under the control of the management of the plant |
| U | Unplanned outage due to causes under the control of the management of the plant |
| X | Outage due to causes beyond the control of the management of the plant (external) |

**Notes:** An outage is considered to be planned if it has been scheduled at least four weeks in advance.
An outage is considered to be unplanned if it has not been scheduled at least four weeks in advance.
External outages may also be considered to be planned or unplanned. Although this aspect is not explicitly coded, adding the third character (see below) to the external outage code will imply an unplanned external outage.
In general, any change in the planned outage start date is considered to be unplanned unless it is announced at least four weeks in advance. If the start date is anticipated, the outage is considered to be unplanned until the originally scheduled start date. If the start date is postponed, the outage is still considered to be planned until the originally scheduled completion date. Any extension of the planned outage beyond the original completion date is considered to be unplanned unless it is announced at least four weeks in advance. The unplanned portions of planned outages due to changes in the outage start date should be coded as separate outages.
Exceptions to this rule are provided in Annex V.

separate outages caused by equipment failure and human error, respectively. Similarly, a partial and full outage following immediately one upon the other and having the same direct cause must be reported separately.

In the first character position, one letter should be entered from Table II–4.

The second to fifth characters represent the plant system primarily involved and/or affected in the outage. In the second to fifth character

TABLE II–2. SECOND CHARACTER FOR THE OUTAGE TYPE CODE

| Code | Description |
|---|---|
| F | Full outage |
| P | Partial outage |

**Note:** An outage is considered to be full if the actual unit output power has been reduced to 0% (unit disconnected from all off-site power supply lines). An outage is considered to be partial if the actual unit output power is lower than its reference value but is greater than 0%.

TABLE II–3. THIRD CHARACTER (FOR UNPLANNED OUTAGES ONLY) FOR THE OUTAGE TYPE CODE

| Code | Description |
|---|---|
| 1 | Controlled shutdown or load reduction that could have been deferred but had to be performed earlier than four weeks after the cause occurred or before the next refuelling outage, whichever comes first |
| 2 | Controlled shutdown or load reduction that had to be performed in the next 24 h after the cause occurred |
| 3 | Outage extension |
| 4 | Reactor scram, automatic |
| 5 | Reactor scram, manual |

**Note:** The third character should be assigned also to outages due to causes beyond the control of the management of the plant (external) that can be considered to be unplanned (e.g. cause codes J, M, N, R, T and U).

positions, the code for the particular system should be chosen from Table II–5. For a single outage (full or partial), only one system may be selected. If two or more systems were involved in the outage, either the system directly causing the outage or the one being most significantly affected should be selected. If no particular system can be specified from the general system group, the general system code ‘xx.00’ should be entered. If a particular system was involved in the outage, but no suitable code can be found on the list, the appropriate general system group should be chosen and the ‘other’ code ‘xx.99’ should be entered.

If no system was involved or affected in the outage, the second to fifth characters in the outage cause code should be left blank.

*Description of the outage*: the direct cause of the outage and the operational mode of the plant at the time of the outage should be briefly described and the systems involved, including their components, should be specified. This field should provide at least a name describing the nature of the outage. In the cause description, the general causes should be specified in more detail: the type of human factor (e.g. operator mistake, omission or failure to monitor plant processes), the type of equipment failure (e.g. spurious actuation of a system, component trip, damage or malfunction), the type of adverse environmental condition (e.g. frost, lightning or high sea), the type of load following operation (e.g. frequency control or reserve shutdown), the cause of fire, etc. If applicable, the cause and system should be described for causes coded 2 (others), systems coded xx.99 and other systems involved but not coded.

TABLE II–4. DIRECT CAUSES OF OUTAGES

| Code[a] | Description |
|---|---|
| A | Plant equipment failure |
| B | Refuelling without maintenance |
| C | Inspection, maintenance or repair with refuelling |
| D | Inspection, maintenance or repair without refuelling |
| E | Testing of plant systems or components |
| F | Major backfitting, refurbishment or upgrading activities with refuelling |
| G | Major backfitting, refurbishment or upgrading activities without refuelling |
| H | Nuclear regulatory requirements |
| J | Grid failure or grid unavailability |
| K | Load following (frequency control, reserve shutdown due to reduced energy demand) |
| L | Human factor related |
| M | Governmental requirement or court decision |
| N | Environmental conditions (flood, storm, lightning, lack of cooling water due to dry weather, cooling water temperature limits, etc.) |
| P | Fire |
| R | External restrictions on supply and services (lack of funds due to delayed payments from customers, disputes in fuel industries, fuel rationing, labour strike outside the plant[b], spare part delivery problems, etc.) |
| S | Fuel management limitation (including high flux tilt, stretch out or coastdown operation) |
| T | Off-site heat distribution system unavailability |
| U | Security and access control and other preventive shutdown due to external threats |
| Z | Others |

**Note:** Planned outages may be due to causes coded B, C, D, E, F or G; unplanned outages may be due to causes coded A, H, L or P; external outages may be due to causes coded J, K, M, N, R, T or U. The cause code S can apply to planned, unplanned and external outages.

Causes related to equipment (A), repair (D), testing (E), backfitting (F and G), nuclear regulatory requirements (H), human actions (L), environmental conditions (N), fire (P), fuel management (S) and others (Z) should, whenever possible, be followed by the numerical code of the plant system affected.

[a] The letters I, O and Q have been deliberately omitted to avoid confusion with digits 0 and 1.

[b] Outages caused by plant personnel strikes should be coded L, human factor related.

TABLE II–5. PLANT SYSTEMS POSSIBLY INVOLVED IN AN OUTAGE

| Code | System description |
|---|---|
| | **Nuclear systems** |
| *11.00* | *Reactor and accessories* |
| 11.01 | Reactor vessel and main shielding (including penetrations and nozzles) |
| 11.02 | Reactor core (including fuel assemblies) |
| 11.03 | Reactor internals (including steam separators and dryers of BWRs, and graphite and pressure tubes) |
| 11.04 | Auxiliary shielding and heat insulation |
| 11.05 | Moderator and auxiliaries (PHWRs) |
| 11.06 | Annulus gas system (PHWRs and RBMKs) |
| 11.99 | None of the above systems |
| *12.00* | *Reactor instrumentation and control (I&C) systems* |
| 12.01 | Control and safety rods (including drives and special power supply) |
| 12.02 | Neutron monitoring (in-core and ex-core) |
| 12.03 | Reactor instrumentation (except neutron instrumentation) |
| 12.04 | Reactor control system |
| 12.05 | Reactor protection system |
| 12.06 | Process computer |
| 12.07 | Reactor recirculation control (BWRs) |
| 12.99 | None of the above systems |
| *13.00* | *Reactor auxiliary systems* |
| 13.01 | Primary coolant treatment and cleanup system |
| 13.02 | Chemical and volume control system |
| 13.03 | Residual heat removal system (including heat exchangers) |
| 13.04 | Component cooling system |
| 13.05 | Gaseous, liquid and solid radioactive waste treatment systems |
| 13.06 | Nuclear building ventilation and containment inerting systems |
| 13.07 | Nuclear equipment venting and drainage systems (including room floor drainage) |
| 13.08 | Borated or refuelling water storage system |
| 13.09 | $CO_2$ injection and storage system (GCRs) |

TABLE II–5. PLANT SYSTEMS POSSIBLY INVOLVED IN AN OUTAGE (cont.)

| Code | System description |
|---|---|
| 13.10 | Sodium heating system (FBRs) |
| 13.11 | Primary pump oil system (including the reactor coolant pump or make-up pump oil) |
| 13.12 | $D_2O$ leakage collection and dryer system (PHWRs) |
| 13.13 | Essential auxiliary systems (GCRs) |
| 13.99 | None of the above systems |
| *14.00* | *Safety systems* |
| 14.01 | Emergency core cooling systems (including accumulators and the core spray system) |
| 14.02 | High pressure safety injection and emergency poisoning system |
| 14.03 | Auxiliary and emergency feedwater system |
| 14.04 | Containment spray system (active) |
| 14.05 | Containment pressure suppression system (passive) |
| 14.06 | Containment isolation system (isolation valves, doors, locks and penetrations) |
| 14.07 | Containment structures |
| 14.08 | Fire protection system |
| 14.99 | None of the above systems |
| *15.00* | *Reactor cooling systems* |
| 15.01 | Reactor coolant pumps and blowers and drives |
| 15.02 | Reactor coolant piping (including associated valves) |
| 15.03 | Reactor coolant safety and relief valves (including the relief tank) |
| 15.04 | Reactor coolant pressure control system |
| 15.05 | Main steam piping and isolation valves (BWRs) |
| 15.99 | None of the above systems |
| *16.00* | *Steam generation systems* |
| 16.01 | Steam generator (PWRs), boiler (PHWRs and AGRs) and steam drum vessel (RBMKs and BWRs) |
| 16.02 | Steam generator blowdown system |
| 16.03 | Steam drum level control system (RBMKs and BWRs) |
| 16.99 | None of the above systems |

TABLE II–5. PLANT SYSTEMS POSSIBLY INVOLVED IN AN OUTAGE (cont.)

| Code | System description |
|---|---|
| *17.00* | *Safety I&C systems (excluding reactor I&C)* |
| 17.01 | Engineered safeguard feature actuation system |
| 17.02 | Fire detection system |
| 17.03 | Containment isolation function |
| 17.04 | Main steam and/or feedwater isolation function |
| 17.05 | Main steam pressure emergency control system (turbine bypass and steam dump valve control) |
| 17.06 | Failed fuel detection system (DN monitoring system for PHWRs) |
| 17.07 | Reactor coolant system integrity monitoring system (RBMKs) |
| 17.99 | None of the above systems |
| | **Fuel and refuelling systems** |
| *21.00* | *Fuel handling and storage facilities* |
| 21.01 | On-power refuelling machine |
| 21.02 | Fuel transfer system |
| 21.03 | Storage facilities, including treatment plant and final loading and cask handling facilities |
| 21.99 | None of the above systems |
| | **Secondary plant systems** |
| *31.00* | *Turbine and auxiliaries* |
| 31.01 | Turbine |
| 31.02 | Moisture separator and reheater |
| 31.03 | Turbine control valves and stop valves |
| 31.04 | Main condenser (including the vacuum system) |
| 31.05 | Turbine bypass valves |
| 31.06 | Turbine auxiliaries (lubricating oil, gland steam and steam extraction) |
| 31.07 | Turbine control and protection system |
| 31.99 | None of the above systems |
| *32.00* | *Feedwater and main steam system* |
| 32.01 | Main steam piping and valves |

TABLE II–5. PLANT SYSTEMS POSSIBLY INVOLVED IN AN OUTAGE (cont.)

| Code | System description |
|---|---|
| 32.02 | Main steam safety and relief valves |
| 32.03 | Feedwater system (including the feedwater tank, piping, pumps and heaters) |
| 32.04 | Condensate system (including the condensate pumps, piping and heaters) |
| 32.05 | Condensate treatment system |
| 32.99 | None of the above systems |
| *33.00* | *Circulating water system* |
| 33.01 | Circulating water system (including the pumps, piping and ducts, excluding the heat sink system) |
| 33.02 | Cooling towers and/or heat sink system |
| 33.03 | Emergency ultimate heat sink system |
| 33.99 | None of the above systems |
| *34.00* | *Miscellaneous systems* |
| 34.01 | Compressed air (essential and non-essential, high pressure and low pressure) |
| 34.02 | Gas storage, supply and cleanup systems (nitrogen, hydrogen, carbon dioxide, etc.) |
| 34.03 | Service water and/or process water supply system (including water treatment) |
| 34.04 | Demineralized water supply system (including water treatment) |
| 34.05 | Auxiliary steam supply system (including the boilers and pressure control equipment) |
| 34.06 | Non-nuclear area ventilation (including the main control room) |
| 34.07 | Chilled water supply system |
| 34.08 | Chemical additive injection and makeup systems |
| 34.09 | Non-nuclear equipment venting and drainage system |
| 34.10 | Communications system |
| 34.99 | None of the above systems |
| *35.00* | *All other I&C systems* |
| 35.01 | Plant process monitoring systems (excluding the process computer) |
| 35.02 | Leak monitoring systems |
| 35.03 | Alarm annunciation system |

TABLE II–5. PLANT SYSTEMS POSSIBLY INVOLVED IN AN OUTAGE (cont.)

| Code | System description |
|---|---|
| 35.04 | Plant radiation monitoring system |
| 35.05 | Plant process control systems |
| 35.99 | None of the above systems |
| | **Electrical systems** |
| *41.00* | *Main generator systems* |
| 41.01 | Generator and exciter (including the generator output breaker) |
| 41.02 | Sealing oil system |
| 41.03 | Rotor cooling gas system |
| 41.04 | Stator cooling water system |
| 41.05 | Main generator control and protection system |
| 41.99 | None of the above systems |
| *42.00* | *Electrical power supply systems* |
| 42.01 | Main transformers |
| 42.02 | Unit self-consumption transformers (station, auxiliary, house reserve, etc.) |
| 42.03 | Vital AC and DC plant power supply systems (medium and low voltage) |
| 42.04 | Non-vital AC plant power supply system (medium and low voltage) |
| 42.05 | Emergency power generation system (e.g. emergency diesel generator and auxiliaries) |
| 42.06 | Power supply system logics (including load shed logic, emergency bus transfer logic, load sequencer logic, breaker trip logic, etc.) |
| 42.07 | Plant switchyard equipment |
| 42.99 | None of the above systems |

For the operational mode description, one of the following operational modes describing the status of the unit immediately before the outage should be chosen:

(a) Power operation;
(b) Startup or shutdown operation;
(c) Hot standby (reactor subcritical);

(d) Hot shutdown (reactor subcritical);
(e) Cold shutdown (reactor subcritical);
(f) Reactor pressure vessel open.

If applicable, the actual type of operation or activity in the particular mode (e.g. power ascension after an outage, steady power operation at rated or reduced power upon the grid dispatcher's request) should be described in more detail.

### II–2.5. Heat production data

Some power plant units produce a portion of their output energy in the form of heat and/or steam for non-electrical applications (desalination, district heating and industrial heat). This energy should also be reported, provided that the production of heat and/or steam reduces the actual output electrical power below the reference unit power as defined in Section II–2.1.

*Monthly energy provision during the year to off-site heat application systems*: Thermal energy provided for district heating (PDH), process heat (PPH) and desalination (PDS), PDH + PPH + PDS (Gcal). Enter the thermal energy provided during the reference period to the off-site heat application systems (district heating, industrial process heat delivery and/or distillation type desalination) in the form of heat (steam or hot water), measured as the difference between the plant feed (outlet) and return (inlet) headers. If it is difficult to provide individual data for PDH, PPH and PDS, the total delivery data for PDH + PPH + PDS are acceptable. If monthly data are difficult to provide, the annual total data are acceptable.

*Equivalent energy generated for off-site non-electrical applications during the reporting period, NE1 (MW(e)·h).* Enter the sum of electrical equivalent energy supplied to off-site non-electrical application systems during the reporting period in the form of steam expressed in MW(e)·h. This should be equal to the sum of heat energy delivered to heat application systems (total PDH + PPH + PDS).

To calculate the equivalent energy, the following formula may be applied:

$$\text{NE1 (MW(e)·h)} = 1.16 \times \text{Total (PDH + PPH + PDS) (Gcal)} \times \text{Average thermal efficiency of the unit}$$

where 'average' is the thermal efficiency of the unit over the reporting period. If the average value is not available for each unit, the overall average of the plant or the 'default' value may be used. The default value is 0.30, estimated from the designed capacity of all cogenerating plants in the PRIS database. If no value is given, PRIS calculates the value using this default value.

*Lifetime accumulated equivalent energy generated for non-electrical applications, LE1 (MW(e)·h)*: PRIS calculates the sum of NE1 over the whole life of the unit automatically. When all the historical data are not available, it will be so mentioned.

*Backup source*: A non-nuclear backup heat source may be installed at a nuclear power plant with multiple units in order to secure heat delivery capability from the plant, under the control of the plant, in order to compensate for an insufficient availability of heat from the nuclear reactor.

*Monthly energy delivery to, and water production of, on-site desalination systems during the year*: Thermal energy provided for distillation, PDI (Gcal). Enter the thermal energy provided during the reference period to the desalination systems of distillation type MSF or MED or in the form of heat, measured as the difference between at the plant feed (outlet) and return (inlet) headers, or between at the heat extraction points and return points in the case of in-plant facilities. If it is difficult to provide monthly data, the annual total data are acceptable.

*Electrical energy provided for RO process, PRO (MW(e)·h).* Enter the electrical energy provided during the reference period to the desalination systems of RO processes. By definition this electrical energy is a part of on-site power. If it is difficult to provide monthly data, the annual total data are acceptable.

*Water production, WPR ($m^3$), and its fraction delivered to off-site consumers, WDL ($m^3$).* Enter the water production and its fraction delivered to off-site consumers during the reference period by the desalination systems. If it is difficult to provide monthly data, the annual total data are acceptable.

*Equivalent energy consumed by on-site desalination for off-site delivery during the reporting period, NE2 (MW(e)·h).* Enter the sum of electrical equivalent energy used for desalination for off-site delivery (fraction of total PDI + PRO for off-site delivery). The equivalent energy is calculated on the assumption that the fraction of energy consumed for off-site delivered water is equal to the fraction of the water delivered off the site.

To calculate the equivalent energy, the following formula may be applied:

$$\text{NE2 (MW(e)·h)} = 1.16 \times \text{Total PDI (Gcal)} \times \text{Average thermal efficiency of the unit} \times \text{Total WDL/Total WPR} + \text{Total PRO (MW(e)·h)} \times \text{Total WDL/Total WPR}$$

where ‘average’ is the thermal efficiency of the unit over the reporting period. If the average value is not available for each unit, the overall average of the plant or the 'default' value may be used. The default value is 0.30, estimated from the designed capacity of all cogenerating plants in the PRIS database. If no value is given here, PRIS calculates the value using this default value.

*Lifetime accumulated equivalent energy generated for non-electrical applications, LE2 (MW(e)·h)*: PRIS calculates the sum of NE2 over the whole life of the unit automatically. When all the historical data are not available, it will be so mentioned.

*Equivalent total energy generated for non-electrical applications during the reporting period, NEG (MW(e)·h)*: PRIS calculates the sum of NE1 and NE2 as NE1 (MW(e)·h) + NE2 (MW(e)·h).

*Lifetime accumulated equivalent energy generated for non-electrical applications, LEG (MW(e)·h)*: PRIS calculates the sum of LE1 and LE2 over the whole life of the unit automatically. When all the historical data are not available, it will be so mentioned.

If the operation of non-electric application systems is limited by insufficient heat delivery from the nuclear heat sources, this should be explained. Descriptive explanations of what caused this, what countermeasures were taken, etc., should be given.

*Highlights of energy delivery to non-electric application systems*: Any relevant information may be entered.

## Annex III

## DECOMMISSIONING INFORMATION ON NUCLEAR POWER PLANTS

PRIS contains information on nuclear power plants that dates from their construction to their final shutdown. A significant number of these nuclear power plants have been operating for more than 30 years, while many others have been shut down and their operating organizations have started the decommissioning process. Details on decommissioning stages and activities are not at present included in PRIS.

Activities such as characterization, decontamination, dismantling and demolition of installations are performed during particular periods in the decommissioning process.

In order to complement the existing databases on nuclear power plants, collect experience on decommissioning, compile information on techniques used in decommissioning activities and disseminate decommissioning references to Member States, the IAEA is developing a computerized database on decommissioning.

In addition to the details of nuclear power plants already included in PRIS, it is necessary to collect information on the different phases and activities of the decommissioning process. This information will eventually complement PRIS.

To assist in developing this decommissioning database, the information outlined below will be collected, based either on current or planned activities. If the PRIS national correspondents and liaison officers wish to supply the information as published in routine reports of their organizations, they will be asked that the information requested in the questionnaire also be included. In addition, if they have a historical overview of work carried out in the decommissioning of their installation (or other installations shut down in their country), they will be asked to send it, in order to update existing information.

The information requested will be updated at least annually, and will comprise:

(a) The name of the country.
(b) The name of the nuclear power plant (PRIS identification).
(c) The unit or units (if several are on the same site) currently or formerly involved in a decommissioning project.
(d) The name (identification) of the licensee (responsible entity).
(e) The reason for shutdown. One or more of the following:
    (i) The technology or process being used became obsolete;
    (ii) The process was no longer profitable;

(iii) There were changes in licensing requirements;
(iv) After an operating incident;
(v) Other technological reasons (to be specified);
(vi) Other economic reasons (to be specified);
(vii) Public acceptance reasons;
(viii) Other (to be specified).

(f) Decommissioning strategy. One or more of the following:
(i) Immediate dismantling and removal of all radioactive material;
(ii) Deferred dismantling, placing all radiological areas into safe enclosure;
(iii) Deferred dismantling, including partial dismantling and placing of the remaining radiological areas into safe enclosure;
(iv) In situ disposal, involving encapsulation of radioactive material and subsequent restriction of access;
(v) Other (to be specified).

(g) Current status of decommissioning and foreseen objectives.

(h) Scheduled decommissioning phases. To be provided in the form of Table III–1; other specific decommissioning phases not listed may be added.

(i) Management of fuel removal. To be provided in the form of Table III–2; other specific instances not listed may be added.

(j) The names (identification) of the main decommissioning contractors.

(k) Decommissioning milestones.

TABLE III–1. SCHEDULED DECOMMISSIONING PHASES

| Decommissioning phase | Dates | |
|---|---|---|
| | From | To |
| Drawing up the final decommissioning plan | | |
| Reactor core defuelling (see also item (i)) | | |
| Waste conditioning on the site | | |
| Waste shipment off the site | | |
| Safe enclosure preparation | | |
| Partial dismantling | | |
| Active safe enclosure period (e.g. manned controls) | | |
| Passive safe enclosure period (e.g. remote controls) | | |
| Final dismantling | | |
| Final survey | | |
| Licence termination | | |

TABLE III–2. MANAGEMENT OF FUEL REMOVAL

| Fuel management | Dates | |
|---|---|---|
| | From | To |
| Transfer to a reactor facility | | |
| Transfer away from a reactor facility | | |
| Storage in an on-site facility | | |
| Storage in an off-site facility | | |
| Shipment to a reprocessing plant | | |
| Underwater storage | | |
| Dry storage | | |
| Encapsulation | | |

## Annex IV

## INFORMATION RELATED TO DELAYED NUCLEAR POWER PLANT PROJECTS

### IV–1. INTRODUCTION

PRIS contains information on nuclear power plant projects that dates from their construction to their final shutdown. A number of projects while under construction experience delays of five years or more with respect to their original scheduled operation (grid connection) date. In 1997 the IAEA initiated a programme to provide assistance in the management of such delayed plants directed at implementing measures to maintain readiness for resuming the project implementation schedule when conditions permit. The implementation of this programme allowed the collation of information specific to delayed nuclear power plants, which was provided by participants at meetings organized by the IAEA between February 1997 and October 2001. The information collected at these meetings, which contains preliminary data on the subject of delayed nuclear power plants, has been summarized; the latest version of this summary, Rev. 3, October 2001, is presented in this annex.

The information gathered on delayed nuclear power plants shows a wide range of issues reflecting various situations in Member States. Some significant issues in several States are sometimes not relevant to, or have only limited effect on, other States. In spite of these differences, the subject of delayed nuclear power plants is progressively perceived in a wider context and is not regarded as an isolated problem for one State but as a significant subject involving difficulties shared by several States. Along with this recognition, the collection of preliminary data on delayed nuclear power plants by the IAEA was regarded as an initial step that could be built upon through a more precise definition of inputs, regular updating and dissemination of specific information. It has been recommended that the IAEA consider integrating data on delayed nuclear power plants into PRIS.

An IAEA Consultants Meeting held in March 2002 discussed delayed nuclear power plant related information and recommended that a questionnaire including corresponding definitions be developed to collate data.

### IV–2. INFORMATION ON DELAYED NUCLEAR POWER PLANTS

The following information will be collected:

(a) The name of the country.
(b) The name of the delayed nuclear power plant project or unit (PRIS identification). A nuclear power plant project is considered to be delayed if it experiences a delay of more than five years with respect to the originally scheduled date of commercial operation.
(c) General information:
  (i) Reactor type;
  (ii) Capacity (MW(e));
  (iii) Original main contractor;
  (iv) Current main contractor;
  (v) Original general designer;
  (vi) Current general designer.
(d) The name (identification) of the licensee (the owner or responsible entity).
(e) Current status:
  (i) Date construction started.
  (ii) Original date foreseen for commercial operation.
  (iii) Current date foreseen for commercial operation.
  (iv) Physical progress (%): engineering, construction, supplies and global.
  (v) Physical progress over the past five years (global) (%).
  (vi) Physical progress over the past year (global) (%).
  (vii) Current dedicated staff: project management, design, construction and operation.
(f) The main reasons for the delay. To be provided in the form of Table IV–1, ranked with a number between 0 and 5 indicating the impact of each

TABLE IV–1. MAIN REASONS FOR THE DELAY

| Reason for delay | Impact |
|---|---|
| Lack of national funds | |
| Lack of foreign funds | |
| Competitiveness | |
| Decreasing energy demand | |
| Technological changes, upgrading and increased safety requirements | |
| Institutional and/or organizational changes (privatization and/or external) | |
| Ecological | |
| Declining human resources | |

reason upon the delay of the nuclear power plant. 0: no importance at all; 1: minor contributor to the delay, but hidden by other causes; 2: minor contributor, with some influence on the delay; 3: contributor to the delay, among others, with no major importance; 4: important contributor to the delay, in association with others; 5: major importance, main or unique reason for the delay.

(g) The main problems areas. To be provided in the form of Table IV–2, with the degree of difficulty experienced at present ranked with a number between 0 and 5. 0: no difficulty; 5: highest difficulty.

TABLE IV–2. MAIN PROBLEM AREAS

| Problem area | Degree of difficulty |
|---|---|
| Setting a finance scheme | |
| Identification of possible financial support | |
| Upgrading to technological and regulatory requirements | |
| Retention of human resources | |
| Public opinion and the environment | |
| Preservation and maintenance of equipment and facilities | |
| Preservation and/or availability of project data (documentation) | |
| Renegotiation with suppliers and/or contractors | |
| Project management and/or organization | |
| Maintenance of main contractor's guarantees and warranties | |
| Lack of support from external contractor | |
| Delay in governmental decisions | |

## Annex V

## DETAILED DESCRIPTIONS OF THE PERFORMANCE INDICATORS USED IN PRIS

### V–1. INTRODUCTION

This annex provides descriptions of the international performance indicators reported in PRIS.

The load factor, operation factor and energy availability factor indicators have been used in PRIS since the beginning of its operation. In 1990 two performance indicators of the International Union of Producers and Distributors of Electrical Energy (UNIPEDE)/World Association of Nuclear Operators (WANO), the unit capability factor and the unplanned capability loss factor, were included in PRIS.

The other three indicators presented, the planned capability loss factor, the external capability loss factor and the energy unavailability factor, can easily be calculated from those given above.

The Advisory Group Meeting on Performance Analysis of Nuclear Power Plants recommended to harmonize the definitions of PRIS and UNIPEDE/WANO. An effort has been made to use, where adequate, the definitions and descriptions of performance indicators as used by these organizations.

Accordingly, the definitions of three additional indicators, the operating period forced loss rate (a new proposed WANO indicator), unplanned automatic scrams (a WANO indicator) and unplanned manual scrams, have been included.

In preparing this annex the following information sources were consulted:

(a) The PRIS Annual Questionnaire (September 1990 revision);
(b) The Conclusions and Recommendations of the Advisory Group Meetings on Performance Analysis of Nuclear Power Plants;
(c) Descriptions of PRIS Performance Indicators (November 1990);
(d) International Nuclear Power Plant Performance Indicator Definitions (WANO, 2000);
(e) UNIPEDE Terminology (June 1991).

## V–2. LOAD FACTOR (LF)

### V–2.1. Purpose

The purpose of the LF indicator is to provide the ratio of actual unit energy production to reference energy generation over a certain period of time. This indicator reflects the actual energy utilization of the unit for electricity and heat production.

### V–2.2. Definition

The LF for a given period is the ratio of the energy that the power unit has produced over that period divided by the energy it would have produced at its reference power capacity over that period.

The energy generation (net) is the electrical and non-electrical energy produced during a given time period as measured at the unit outlet terminals (i.e. after deducting the energy taken by unit auxiliaries and the losses in the transformers and heat exchangers considered integral parts of the unit).

The reference energy generation (REG) (net) is the energy that could be produced during a given time period if the unit were operated continuously at reference unit power (net).

### V–2.3. Data elements

The following data are required to calculate this indicator for each unit:

(a) The energy generation (net), expressed in units of MW(e)·h;
(b) The reference energy generation (net), expressed in units of MW(e)·h.

### V–2.4. Calculations

The unit LF is calculated for each period as:

$$\text{LF}\ (\%) = \frac{\text{EG} \times 100\%}{\text{REG}}$$

where

LF is the value for a unit;
EG is the energy generation (net) (MW·h) for the period;
REG is the reference energy generation (net) (MW·h) for the period.

### V–2.5. Clarifying notes

(a) The REG (net) is the product of the reference unit power (net) and the reference period in hours.

(b) The reference unit power is the maximum (electrical) power that could be maintained continuously throughout a prolonged period of operation under reference ambient conditions. The power value is measured at the unit outlet terminals (i.e. after deducting the power taken by unit auxiliaries and the losses in the transformers considered integral parts of the unit). The reference unit power value should also include the electrical equivalent of the portion of energy delivered in the form of steam or heat that might have been used for non-electrical applications. However, this applies only to units in which heat production may reduce the unit electrical power below its maximum value. If a maximum power capability has been determined by a formal test, the reference unit power is determined by correcting the test results to reference ambient conditions. If a formal test has not been performed, the reference power should be based on design values adjusted for reference ambient conditions. The reference unit power is expected to remain constant unless, following design changes or a new permanent authorization, the management of the plant decides to amend the original value. (It is recognized that the reference unit power may be based upon an authorized maximum unit thermal power, and in these cases the reference unit power (net) corresponding to the authorized maximum unit thermal power should be used for simplicity in the calculations.)

(c) Although the LF refers to the energy production provided to the grid, implying the use of net values, it is possible to calculate this indicator using gross values. In this case the two energy figures (production and REG) must be of the same kind.

(d) Nuclear thermal power is the nuclear thermal power output of the unit as derived from the most accurate heat balance measurement.

(e) The reference ambient conditions are environmental conditions representative of the annual mean (or typical) conditions of the unit. It is expected that historical heat sink temperatures will be used to determine the reference ambient conditions. The same reference ambient conditions will generally apply for the lifetime of the unit. Periodic review of these reference conditions is not required. The reference period hours are the total number of hours in the predefined calendar time. For units in power ascension at the end of the period, it is the clock hours from the beginning of the period or the first energy production, whichever comes last, to the end of the period. For units in commercial operation at the end of the period, it is the clock hours from the beginning of the period or of commercial operation, whichever comes last, to the end of the period or permanent shutdown, whichever comes first.

### V–2.6. Example indicator calculation

(a) Reference unit power: 985 MW(e).
(b) Actual energy production (EG) during the year (8760 h): 5 950 000 MW(e)·h.
(c) REG (1 year):

$$REG = (985\ MW(e)) \times (8760\ h) = 8\,628\,600\ MW(e)\cdot h$$

$$LF = \frac{5\,950\,000 \times 100}{8\,628\,600} = 69\%$$

## V–3. OPERATION FACTOR (OF)

### V–3.1. Purpose

The purpose of the OF indicator is to monitor the actual time utilization of the unit with the turbogenerator set synchronized to the grid, whatever the power produced, over a certain period of time.

### V–3.2. Definition

The OF is defined as the ratio of the number of hours that the unit was on-line to the total number of hours in the reference period, expressed as a percentage. It is a measure of the unit time availability on the grid and does not depend on the operating power level (UNIPEDE denotes it as a time utilization factor).

On-line hours are the total clock hours in the reference period during which the unit operated with breakers closed to the unit bus.

Reference period hours are the total number of hours in the predefined calendar time.

For units in power ascension at the end of the period, it is the clock hours from the beginning of the period or the first electrical production, whichever comes last, to the end of the period.

For units in commercial operation at the end of the period, it is the clock hours from the beginning of the period or of commercial operation, whichever comes last, to the end of the period or permanent shutdown, whichever comes first.

### V–3.3. Data elements

The following data are required to calculate this indicator for each unit:

(a) The unit on-line hours in the reference period;
(b) The reference period, in hours.

### V–3.4. Calculations

The unit OF is calculated as:

$$\text{OF}\ (\%) = \frac{t}{T} \times 100\%$$

where

OF is the value of a unit;
$t$ is the number of hours on-line (h);
$T$ is the reference period (h).

### V–3.5. Example indicator calculation

(a) Number of hours on line: $t = 5320$ h.
(b) Reference period hours: $T = 8760$ h (1 year).

$$\text{OF} = \frac{5320 \times 100}{8760} = 60.7\%$$

## V–4. UNIT CAPABILITY FACTOR (UCF)

### V–4.1. Purpose

The purpose of the UCF indicator is to monitor progress in attaining high unit and industry energy production reliability. This indicator reflects the effectiveness of plant programmes and practices in maximizing available electrical generation, and provides an overall indication of how well a plant is being operated and maintained.

### V–4.2. Definition

The UCF is defined as the ratio of the available energy generation over a given time period to the REG over the same time period, expressed as a percentage. Both of these energy generation terms are determined relative to reference ambient conditions.

The available energy generation is the energy that could have been produced under reference ambient conditions considering only limitations within the control of the management of the plant (i.e. plant equipment, personnel performance and work control).

The REG is the energy that could be produced if the unit were operated continuously at full power under reference ambient conditions.

Reference ambient conditions are environmental conditions representative of the annual mean (or typical) ambient conditions of the unit.

### V–4.3. Data elements

The following data are required to determine each unit's value for this indicator:

(a) The REG, expressed in units of MW(e)·h.
(b) The planned energy loss (PEL): the energy that was not produced during the period because of planned shutdowns or load reductions due to causes under the control of the management of the plant. Energy losses are considered to be planned if they are scheduled at least four weeks in advance. Energy losses considered to be under the control of the management of the plant are further defined in the clarifying notes. The PEL is expressed in units of MW·h.
(c) The unplanned energy loss (UEL): the energy that was not produced during the period because of unplanned shutdowns, outage extensions or load reductions due to causes under the control of the management of the plant. Energy losses are considered to be unplanned if they are not scheduled at least four weeks in advance. Energy losses considered to be under the control of the management of the plant are further defined in the clarifying notes. The UEL is expressed in units of MW·h.

### V–4.4. Calculations

The UCF is determined for each period as:

$$\text{UCF } (\%) = \frac{(\text{REG} - \text{PEL} - \text{UEL}) \times 100\%}{\text{REG}}$$

where

UCF is the value for a unit;
REG is the reference energy generation for the period;
PEL is the total planned energy loss for the period;
UEL is the total unplanned energy loss for the period.

PEL:

$$\text{PEL} = \sum(\text{PPL} \times \text{HRP})$$

where

PPL is the planned power loss: the power decrease in MW due to a planned event.
HRP is the hours operated at reduced power (or shutdown) due to the planned event.

Note: The total PEL for the period is the sum of the losses from all planned events.

UEL:

$$\text{UEL} = \sum(\text{UPL} \times \text{HRU})$$

where

UPL is the unplanned power loss: the power decrease in MW due to an unplanned event;
HRU is the hours operated at reduced power (or shutdown) due to the unplanned event.

Note: The total UEL for the period is the sum of the losses from all unplanned events.

Value for the industry = median of the unit values

### V–4.5. Data qualification requirements

Data for new units are included in the calculation of industry values beginning 1 January of the first calendar year following commercial operation.

### V–4.6. Clarifying notes

(a) The REG is determined by multiplying the reference unit power by the period hours.

(b) The reference unit power is the maximum power capability of the unit under reference ambient conditions. If a maximum power capability has been determined by a formal test, the reference unit power is determined by correcting the test results to reference ambient conditions. If a formal test has not been performed, the reference unit power should be based on design values adjusted for reference ambient conditions. The reference unit power is expected to remain constant unless design changes that affect the capacity are made to the unit.

(c) The reference ambient conditions are environmental conditions representative of the annual mean (or typical) conditions of the unit. It is expected that historical heat sink temperatures will be used to determine the reference ambient conditions. The same reference ambient conditions will generally apply for the lifetime of the unit. Periodic review of these reference conditions is not required.

(d) The PEL (those scheduled at least four weeks in advance) caused by the following conditions should be included when computing the UCF, since they are considered to be under the control of the management of the plant:
   - (i) Refuelling or planned maintenance outages;
   - (ii) Planned outages or load reductions for testing or repair, or for other plant equipment or personnel related reasons.

(e) Energy losses due to tests may be considered to be planned if they are identified at least four weeks in advance and are part of a regular programme, even if the precise time of the test is not decided upon four weeks in advance.

(f) The UEL caused by the following conditions should be included when computing the UCF, since they are considered to be under the control of the management of the plant:
   - (i) Unplanned maintenance outages;
   - (ii) Unplanned outages or load reductions for testing or repair, or for other plant equipment or personnel related reasons;
   - (iii) Unplanned outage extensions;

(iv) Unplanned outages or load reductions that are caused or prolonged by regulatory actions taken as a result of plant equipment or personnel performance, or regulatory actions applied on a generic basis to all like plants.

(g) Energy losses due to the following causes should not be considered when computing the UCF, since these losses are not considered to be under the control of the management of the plant:

(i) Grid instability or failure;

(ii) Lack of demand (reserve shutdown, economic shutdown or load following);

(iii) Environmental limitations (such as a low cooling pond level, water intake restrictions, earthquakes or deluges that could not be prevented by operator action);

(iv) Labour strikes (see clarifying note (k));

(v) Fuel coastdowns;

(vi) Seasonal variations in gross dependable capacity due to cooling water temperature variations.

(h) The values of planned or unplanned power losses to be used in computing energy losses due to a particular event are the losses that would have occurred if the unit were operating at the reference power level at the time of the event. The power losses relative to the reference power may be determined by one of the following techniques:

(i) Subtracting the actual power level during the event from the power level immediately prior to the event when the power was at or near the reference power level.

(ii) Computing the power level reduction that would have occurred with the unit at the reference power level.

(iii) Using historical data from similar events that have occurred at the reference power level. For example, if a unit experiences a 10 MW power loss due to an equipment problem while operating at 75% of the reference power, and it is determined from calculations or from similar events that have occurred at the reference power that the same equipment problem would have resulted in a 20 MW power loss at the reference power level, then 20 MW should be used when computing the energy loss.

(i) For events involving planned or unplanned outages and startup following these outages, the reference unit power should be used as the basis for computing power losses.

(j) If energy losses during an event occur due to a combination of causes under and outside of the control of the management, the portion of the total losses caused by factors under the control of the management should be identified and included when computing the UCF.

(k) Outages or load reductions caused by labour strikes that occur while the unit is operating are normally not included as PEL or UEL, since these energy losses are not under the direct control of the management of the plant. However, if during the strike the unit becomes incapable of starting or operating because of equipment failures, maintenance, overhauls or other activities such as refuelling, then the energy losses during the time when the unit is inoperable are included. If a labour strike occurs during an outage, any outage extensions are included as energy losses as long as the unit is incapable of being restarted because of equipment failures, maintenance, overhauls or other activities such as refuelling.

(l) In general, changes in an outage or load reduction start date must be announced at least four weeks in advance to be considered planned. However, if the grid dispatcher requests a change in the start date less than four weeks in advance, the outage or load reduction is considered to be planned. The same rule may be used if the change in the start date is decided upon by the management of the plant, assuming that this decision is covered by all of the following reasons or circumstances:
  (i) The unit is operating in a deregulated environment, and the management decision to modify the planned outage start date is solely to take advantage of economic situations to maximize, on a short term basis, the economic benefit coming from selling the plant's electricity output. This economic benefit can be applied to the entire production system of the utility, not only to the specific unit under consideration.
  (ii) The unit is considered to be able to run at maximum power during the four week period prior to the initial planned outage start date.
  (iii) Any forced or unplanned outage occurring during this four week period (or before the new start date) shall not become the reason for putting forward the planned outage.

(m) If a unit begins an outage or load reduction before the scheduled start date, the energy loss from the beginning of the outage or load reduction to the scheduled start date is a UEL.

(n) If an outage extends beyond the scheduled startup date, either to complete originally scheduled work or to complete corrective maintenance work on equipment required for startup, all energy losses associated with the outage extension should be considered to be unplanned. However, outage extensions to complete discretionary work (i.e. preventive maintenance and modifications) not originally scheduled for completion during the outage should be considered to be planned if the work is scheduled at least four weeks in advance. Extended outages can be reclassified from unplanned to planned once the corrective maintenance activities required for startup are completed, if any remaining planned activities were scheduled at least four weeks in advance. This clarification also applies to load reductions.

(o) The scheduled start and end dates of planned outages and load reductions are those dates negotiated with and agreed to by the network and/or grid dispatcher. These dates may differ from those shown on the detailed schedule of activities used at the unit for directing the outage.

(p) Energy losses related to load reductions preceding a shutdown and load increases following the shutdown should be categorized as planned or unplanned depending on whether the shutdown is planned or unplanned. For example, energy losses while entering and recovering from a planned outage will be considered to be planned losses. If an outage extension (unplanned outage) occurs at the end of a planned outage, the energy loss during recovery from the outage will still be considered to be a planned loss because the shutdown was originally caused by a planned outage. Energy losses due to required tests following refuelling are considered to be planned losses.

(q) A unit that is in reserve shutdown will be considered to be available if it can be restarted within the normal time required for unit startup. If work on plant equipment is undertaken that would prevent a restart, the energy that potentially could have been produced while the plant was unavailable should be computed and used when determining the UCF, even if the plant was not actually required to start up during the period.

(r) Either net or gross energy may be used; however, consistency must be maintained for all energy terms. The use of gross energy is more meaningful in certain situations; for example, it is less confusing for multiunit stations that may power the station electrical loads from another unit.

(s) As a point of interest, the sum of the UCF, the unplanned capability loss factor (UCL) and the planned capability loss factor (PCL) equals 100% over a specific time period. The PCL can be calculated from this relationship.

### V–4.7. Example of a UCF calculation

The following examples and the accompanying power history plot in Fig. V–1 are provided to illustrate methods used in calculating the UCF and the

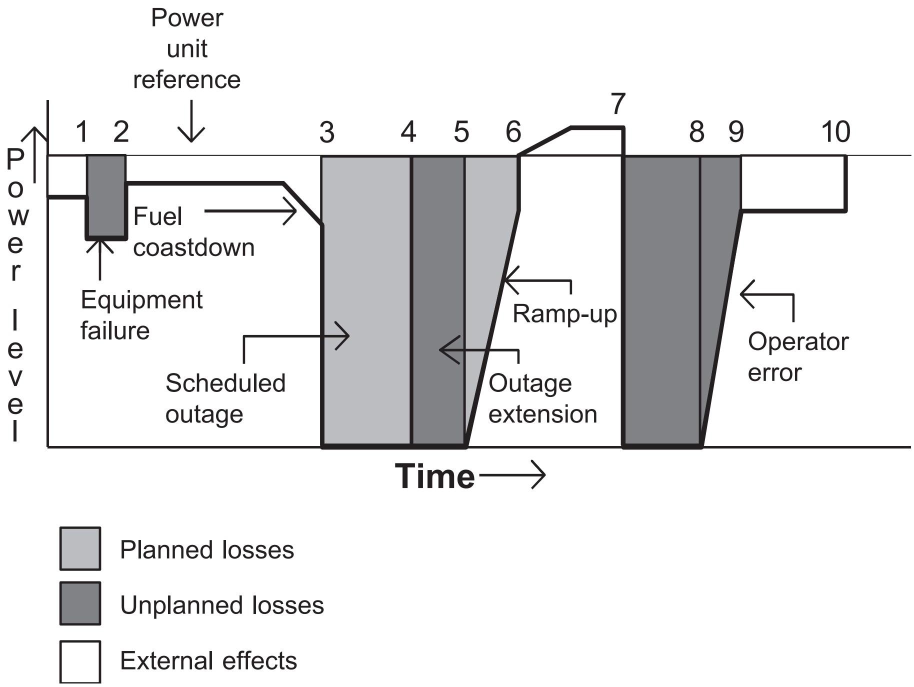


*FIG. V–1. Power example history. Point to point power level explanations: 0–1: reduced power due to load following; 1–2: reduced power due to equipment failure; 2–3: reduced power due to ambient conditions and fuel coastdown; 3–6: unit shutdown (outage) and subsequent ramp-up; 6–7: increased power due to very cold water; 7–9: unit shutdown (operator error) and subsequent ramp-up; 9–10: reduced power due to environmental limitations not under management control.*

UCL for a plant under a variety of common situations. The time periods referenced in this example refer to points labelled in Fig. V–1.

*V–4.7.1. Initial conditions*

Reference unit power: 985 MW(e).

It is assumed that this unit has a maximum power output of 1000 MW(e) under optimum ambient conditions (determined by a formal test). Correction of test results to reference ambient conditions resulted in the reference capacity value of 985 MW(e).

Time period being considered: one year (8760 h).

The REG for the period:

$$REG = (985 \text{ MW(e)}) \times (8760 \text{ h}) = 8\,628\,600 \text{ MW(e)·h}$$

*V–4.7.2. Energy loss examples*

Time period 1–2: Power reduction of 100 MW(e) for 12 h due to a circulating water pump failure. The unit was operating at reduced power due to a load following at the time of the pump failure. The power reduction caused by this failure would have been 201 MW(e) if the failure had occurred at the reference power level:

$$UEL = 201 \times 12 = 2412 \text{ MW(e)·h unplanned}$$

Time period 2–3: Reduced power operation due to ambient conditions and fuel coastdown. The lost energy generation is not used in calculations.

Time period 3–4: Planned refuelling outage. Scheduled length was 45 days (1080 h). The outage begins on the scheduled date:

$$PEL = 985 \times 1080 = 1\,063\,800 \text{ MW(e)·h planned}$$

Time period 4–5: Outage extension of 10 days (240 h) beyond scheduled length to complete all work scheduled for the outage:

$$UEL = 985 \times 240 = 236\,400 \text{ MW(e)·h unplanned}$$

Time period 5–6: Power ramp-up following outage. Average power level of 495 MW(e) for three days (72 h):

$$PEL = (985 - 495) \times 72 = 35\,280 \text{ MW(e)·h planned}$$

Time period 6–7: Operation above reference unit capacity due to very cold cooling water. The additional energy generation is not used in calculations.

Time period 7–8: Shutdown for 32 h due to reactor scram caused by personnel error:

$$UEL = 985 \times 32 = 31\,520 \text{ MW(e)·h unplanned}$$

Time period 8–9: Power ramp-up following the scram. Average power level of 490 MW(e) for 8 h.

Time period 9–10: Operation below reference unit capacity due to environmental limitations only. The lost energy generation is not used in calculations.

*V–4.7.3. Calculations for the UCF*

Total PEL:

Time period: 3–4; energy loss: 1 063 800 MW(e)·h.
Time period: 5–6; energy loss: 35 280 MW(e)·h.
Total energy loss: 1 099 080 MW(e)·h.

Total UEL:

Time period: 1–2; energy loss: 2412 MW(e)·h.
Time period: 4–5; energy loss: 236 400 MW(e)·h.
Time period: 7–8; energy loss: 31 520 MW(e)·h.
Time period: 8–9; energy loss: 3960 MW(e)·h.
Total energy loss: 274 292 MW(e)·h.

$$\text{UCF (\%)} = \frac{(\text{REG} - \text{PEL} - \text{UEL}) \times 100\%}{\text{REG}}$$

$$= \frac{(8\,628\,600 - 1\,099\,080 - 274\,292) \times 100\%}{8\,628\,600}$$

$$= 84.1\%$$

*V–4.7.4. Calculations for the UCL*[1]

$$\text{UCL (\%)} = \frac{\text{UEL} \times 100\%}{\text{REG}}$$

$$= \frac{274\,292 \times 100\%}{8\,628\,600}$$

$$= 3.2\%$$

[1] This calculation is provided for use with the UCL detailed description.

## V–5. UNPLANNED CAPABILITY LOSS FACTOR (UCL)

### V–5.1. Purpose

The purpose of the UCL indicator is to monitor industry progress in minimizing outage times and power reductions that result from unplanned equipment failures or other conditions. This indicator reflects the effectiveness of plant programmes and practices in maintaining systems available for the safe generation of electricity.

### V–5.2. Definition

The UCL is defined as the ratio of the UEL during a given period of time to the REG, expressed as a percentage.

The UEL is the energy that was not produced during the period because of unplanned shutdowns, outage extensions or unplanned load reductions due to causes under the control of the management of the plant. Causes of energy losses are considered to be unplanned if they are not scheduled at least four weeks in advance. Causes considered to be under the control of the management of the plant are defined in the clarifying notes.

The REG is the energy that could be produced if the unit were operated continuously at full power under reference ambient conditions throughout the period. Reference ambient conditions are environmental conditions representative of the annual mean (or typical) ambient conditions of the unit.

### V–5.3. Data elements

The following data are required to determine each unit's value for this indicator:

(a) The UEL, expressed in MW(e)·h. The definition of the UEL is included as part of the UCF indicator description.
(b) The REG, expressed in MW(e)·h.

### V–5.4. Calculations

The UCL is determined for each period as shown below.

Value for a unit:

$$\text{UCL }(\%) = \frac{\text{UEL} \times 100\%}{\text{REG}}$$

where

UEL is the total unplanned energy loss for the period;
REG is the reference energy generation for the period.

Note: The total UEL for the period is the sum of the losses from all unplanned events.

UEL:

$$UEL = \Sigma(UPL \times HRU)$$

where

UPL is the unplanned power loss: the power decrease in MW due to an unplanned event.
HRU is the hours operated at reduced power (or shutdown) due to the unplanned event.

Value for the industry = the median of the unit values

The UCLs for individual units are presented for a three year period, in order to maintain consistency with the three year UCF.

### V–5.5. Data qualification requirements

Data for new units are included in the calculation of industry values beginning on 1 January of the first calendar year following commercial operation.

### V–5.6. Clarifying notes

(a) The REG is determined by multiplying the reference unit power by the period hours.
(b) The reference unit power is the maximum power capability of the unit under reference ambient conditions. If a maximum power capability has been determined by a formal test, the reference unit power is determined by correcting the test results to reference ambient conditions. If a formal test has not been performed, the reference unit power should be based on design values adjusted for reference ambient conditions. The reference unit power is expected to remain constant unless design changes that affect the capacity are made to the unit.

(c) The reference ambient conditions are environmental conditions representative of the annual mean (or typical) ambient conditions of the unit. It is expected that historical heat sink temperatures will be used to determine the reference ambient conditions. The same reference ambient conditions will generally apply for the lifetime of the unit. Periodic review of these reference conditions is not required.

(d) The UEL caused by the following conditions should be included when computing the UCL, since they are considered to be under the control of the management of the plant:
  - (i) Unplanned maintenance outages;
  - (ii) Unplanned outages or load reductions for testing or repair, or for other plant equipment or personnel related reasons;
  - (iii) Unplanned outage extensions;
  - (iv) Unplanned outages or load reductions that are caused or prolonged by regulatory actions taken as a result of plant equipment or personnel performance, or regulatory actions applied on a generic basis to all like plants.

(e) The UEL due to the following causes should not be included when computing the UCL, since these losses are not considered to be under the control of the management of the plant:
  - (i) Grid instability or failure;
  - (ii) Lack of demand (reserve shutdown, economic shutdown or load following);
  - (iii) Environmental limitations (such as low cooling pond level, water intake restrictions, earthquakes or deluges that could not be prevented by operator action);
  - (iv) Labour strikes (see clarifying note (i));
  - (v) Fuel coastdowns;
  - (vi) Seasonal variations in gross dependable capacity due to cooling water temperature variations.

(f) The values of planned or unplanned power losses to be used in computing energy losses due to a particular event are the losses that would have occurred if the unit were operating at the reference power level at the time of the event. The power losses relative to the reference power may be determined by one of the following techniques:
  - (i) Subtracting the actual power level during the event from the power level immediately prior to the event when the power was at or near the reference power level.
  - (ii) Computing the power level reduction that would have occurred with the unit at the reference power level.

(iii) Using historical data from similar events that have occurred at the reference power level. For example, if a unit experiences a 10 MW power loss due to an equipment problem while operating at 75% of the reference power, and it is determined from calculations or from similar events that have occurred at the reference power that the same equipment problem would have resulted in a 20 MW power loss at the reference power level, then 20 MW should be used when computing the energy loss.

(g) For events involving unplanned outages and startup following these outages, the reference unit power should be used as the basis for computing power losses.

(h) If energy losses during an event occur due to a combination of causes under and outside of the control of the management, the portion of the total losses that is unplanned and under management control should be identified and used when computing the UCL.

(i) Outages or load reductions caused by labour strikes that occur while the unit is operating are normally not included as UEL, since these energy losses are not under the direct control of the management of the plant. However, if during the strike the unit becomes incapable of starting or operating because of equipment failures, maintenance, overhauls or other activities such as refuelling, then the energy losses during the time when the unit is inoperable are included. If a labour strike occurs during an outage, any outage extensions are included as energy losses as long as the unit is incapable of being restarted because of equipment failures, maintenance, overhauls or other activities such as refuelling.

(j) In general, changes in an outage or load reduction start date must be announced at least four weeks in advance to be considered planned. However, if the grid dispatcher requests a change in the start date less than four weeks in advance, the outage or load reduction is considered to be planned. The same rule may be used if the change in the start date is decided upon by the management of the plant, assuming that this decision is covered by all of the following reasons or circumstances:

(i) The unit is operating in a deregulated environment, and the management decision to modify the planned outage start date is solely to take advantage of economic situations to maximize, on a short term basis, the economic benefit coming from selling the plant's electricity output. This economic benefit can be applied to the entire production system of the utility, not only to the specific unit under consideration.

(ii) The unit is considered to be able to run at maximum power during the four week period prior to the initial planned outage start date.

(iii) Any forced or unplanned outage occurring during this four week period (or before the new start date) shall not become the reason for putting forward the planned outage.

(k) If a unit begins an outage or load reduction before the scheduled start date, the energy loss from the beginning of the outage or load reduction to the scheduled start date is a UEL.

(l) If an outage extends beyond the scheduled startup date, either to complete originally scheduled work or to complete corrective maintenance work on equipment required for startup, all energy losses associated with the outage extension should be considered to be unplanned. However, outage extensions to complete discretionary work (i.e. preventive maintenance and modifications) not originally scheduled for completion during the outage should be considered to be planned if the work is scheduled at least four weeks in advance. Extended outages can be reclassified from unplanned to planned once the corrective maintenance activities required for startup are completed, if any remaining planned activities were scheduled at least four weeks in advance. This clarification also applies to load reductions.

(m) The scheduled start and end dates of planned outages and load reductions are those dates negotiated with and agreed to by the network and/or grid dispatcher. These dates may differ from those shown on the detailed schedule of activities used at the unit for directing the outage.

(n) Energy losses that occur while entering and recovering from an unplanned outage will be considered to be unplanned losses. If an outage extension (unplanned outage) occurs at the end of a planned outage, the energy loss during recovery from the outage will still be considered to be a planned loss because the shutdown was originally caused by a planned outage. Energy losses due to required tests following refuelling are considered to be planned losses.

(o) Either net or gross energy may be used; however, consistency must be maintained for all energy terms. The use of gross energy is more meaningful in certain situations; for example, it is less confusing for multiunit stations that may power the station electrical loads from another unit.

### V–5.7. Planned capability loss factor (PCL)

The PCL can be calculated from the relationship:

UCF + UCL + PCL = 100% over a specific time period

where

UCF is the unit capability factor (%);
UCL is the unplanned capability loss factor (%).

Note: The PCL replaces the formerly used planned energy unavailability factor (PUF).

## V–6. OPERATING PERIOD FORCED LOSS RATE (FLR)

### V–6.1. Purpose

The purpose of the FLR indicator is to monitor industry progress in minimizing outage times and power reductions that result from unplanned equipment failures, human factors or other conditions during the operating period (excluding planned outages and their possible unplanned extensions). This indicator reflects the effectiveness of plant programmes and practices in maintaining systems available for safe electrical generation when the plant is expected to be at the disposal of the grid dispatcher.

### V–6.2. Definition

The FLR is defined as the ratio of the UEL during a given period of time, considering only the operating period, to the REG minus energy losses corresponding to planned outages and their possible unplanned extensions, during the same period, expressed as a percentage.

The unplanned forced energy loss (FEL) during the operating period is the energy that was not produced during that period because of unplanned shutdowns or unplanned load reductions due to causes under the control of the management of the plant. Causes of energy losses are considered to be unplanned if they are not scheduled at least four weeks in advance. Causes considered to be under the control of the management of the plant are further defined in the clarifying notes.

The REG is the energy that could be produced if the unit were operated continuously at full power under reference ambient conditions throughout the whole period. Reference ambient conditions are environmental conditions representative of the annual mean (or typical) ambient conditions of the unit. Energy losses corresponding to planned outages and their possible unplanned extensions are energy losses that are not produced due to these specific reasons.

### V–6.3. Data elements

The following data are required to determine each unit's value for this indicator:

(a) The REG, expressed in MW(e)·h.
(b) The PEL, expressed in MW(e)·h.
(c) The UEL (see definition of the UCF and the UCL), which contains two terms: operating period unplanned forced energy loss (FEL) and unplanned extension of a planned outage energy loss (EPL):

UEL = FEL + EPL (see note below)

(d) The FEL: that occurring during the operating period, when the unit is considered to be at the disposal of the grid dispatcher (see note below).
(e) The EPL, expressed in MW(e)·h.

Note: Only two out of the UEL, FEL and EPL are required to be reported.

### V–6.4. Calculations

The FLR is determined for each period as shown below.
Value for a unit:

$$\text{FLR}\ (\%) = \frac{\text{FEL} \times 100\%}{\text{REG} - (\text{PEL} + \text{EPL})}$$

where

FEL is the operating period unplanned forced energy loss for one year;
REG is the reference energy generation for one year;
PEL is the planned energy loss for one year;
EPL is the unplanned extensions of planned outages energy loss for one year.

Note: The total operating period FEL for one year is the sum of the losses from all unplanned forced events:

$$\text{FEL} = \Sigma(\text{FPL} \times \text{HRU})$$

where

FPL is the operating cycle unplanned forced power loss: the power decreases in MW due to an unplanned event during the operating period (excluding possible extensions of planned outages).

HRU is the hours operated at reduced power (or shutdown) due to the unplanned forced event.

Value for the industry = median of the unit values

### V–6.5. Data qualification requirements

Data for new units are included in the calculation of industry values beginning on 1 January of the first calendar year following commercial operation.

### V–6.6. Clarifying notes

(a) The REG is determined by multiplying the reference unit power by the period hours.

(b) The reference unit power is the maximum power capability of the unit under reference ambient conditions. If a maximum power capability has been determined by a formal test, the reference unit power is determined by correcting the test results to reference ambient conditions. If a formal test has not been performed, the reference unit power should be based on design values adjusted for reference ambient conditions. The reference unit power is expected to remain constant unless design changes that affect capacity are made to the unit.

(c) The reference ambient conditions are environmental conditions representative of the annual mean (or typical) ambient conditions of the unit. It is expected that historical heat sink temperatures will be used to determine the reference ambient conditions. The same reference ambient conditions will generally apply for the unit. Periodic review of these reference conditions is not required.

(d) The FEL caused by the following conditions should be included when computing the FLR, since they are considered to be under the control of the management of the plant:

   (i) Unplanned maintenance outages, excluding extensions of planned outages;

   (ii) Unplanned outages or load reductions for unplanned testing or repair, or for other plant equipment or personnel related reasons;

(iii) Unplanned outages or load reductions that are caused or prolonged by regulatory actions taken as a result of plant equipment or personnel performance, or regulatory actions applied on a generic basis to all like plants, excluding those associated with extensions of planned outages.

(e) The UEL due to the following causes should not be included when computing the FLR, since these losses are not considered to be under the control of the management of the plant:
   (i) Grid instability or failure;
   (ii) Lack of demand (reserve shutdown, economic shutdown or load following);
   (iii) Environmental limitations (such as low cooling pond level, water intake restrictions, earthquakes or deluges that could not be prevented by operator action);
   (iv) Industrial action (labour strikes) (see clarifying note (i));
   (v) Fuel coastdowns;
   (vi) Seasonal variations in gross dependable capacity due to cooling water temperature variations.

(f) The values of planned or unplanned power losses to be used in computing energy losses due to a particular event are the losses that would have occurred if the unit were operating at the reference power level at the time of the event. The power losses relative to the reference power can be determined by one of the following techniques:
   (i) Subtracting the actual power level during the event from the power level immediately prior to the event when the power was at or near the reference power level.
   (ii) Computing the power level reduction that would have occurred with the unit at the reference power level.
   (iii) Using historical data from similar events that have occurred at the reference power level. For example, if a unit experiences a 10 MW power loss due to an equipment problem while operating at 75% of the reference power, and it is determined from calculations or from similar events that have occurred at the reference power that the same equipment problem would have resulted in a 20 MW power loss at the reference power level, then 20 MW should be used when computing the energy loss.

(g) For events involving unplanned outages and startup following these outages, the reference unit power should be used as the basis for computing power losses.

(h) If energy losses during an event occur due to a combination of causes under and outside of the control of the management, the portion of the total losses that is unplanned and under management control should be identified and used when computing the FLR.

(i) Outages or load reductions caused by labour strikes that occur while the unit is operating are normally not included as UEL, since these energy losses are not under the direct control of the management of the plant. However, if during the strike the unit becomes incapable of starting or operating because of equipment failures, maintenance or other unplanned activities, then the energy losses during the time when the unit is inoperable are included.

(j) In general, changes in an outage or load reduction start date must be announced at least four weeks in advance to be considered to be planned. However, if the grid dispatcher requests a change in the start date less than four weeks in advance, the outage or load reduction is considered to be planned. The same rule may be used if the change in the start date is decided upon by the management of the plant, assuming that this decision is covered by all of the following reasons or circumstances:
   (i) The unit is operating in a deregulated environment, and the management decision to modify the planned outage start date is solely to take advantage of economic situations to maximize, on a short term basis, the economic benefit coming from selling the plant's electricity output. This economic benefit can be applied to the entire production system of the utility, not only to the specific unit under consideration.
   (ii) The unit is considered to be able to run at maximum power during the four week period prior to the initial planned outage start date.
   (iii) Any forced or unplanned outage occurring during this four week period (or before the new start date) shall not become the reason for putting forward the planned outage.

(k) If a unit begins an outage or load reduction before the scheduled start date, the energy loss from the beginning of the outage or load reduction to the scheduled start date is a UEL.

(l) If an outage extends beyond the scheduled startup date, either to complete originally scheduled work or to complete corrective maintenance work on equipment required for startup, all energy losses associated with the outage extension should be considered to be unplanned but not 'forced'.

(m) The scheduled start and end dates of planned outages and load reductions are those dates negotiated with and agreed to by the network and/or grid dispatcher. These dates may differ from those shown on the detailed schedule of activities used at the unit for directing the outage.

(n) Energy losses that occur while entering and recovering from an unplanned outage will be considered to be unplanned losses. If an outage extension (unplanned outage) occurs at the end of a planned outage, the energy loss during recovery from the outage will still be considered to be a planned loss because the shutdown was originally caused by a planned outage. Energy losses due to required tests following refuelling are considered to be planned losses.
(o) Either net or gross energy may be used; however, consistency must be maintained for all energy terms. The use of gross energy is more meaningful in certain situations; for example, it is less confusing for multiunit stations that may power the station electrical loads from one unit.
(p) The in-cycle unit capability rate is equal to 100% minus the FLR.

### V–6.7. Example of an FLR calculation

The following examples and Figs 10 and 11 are provided to illustrate methods used in calculating the UCF, UCL and FLR for a plant under a variety of common situations. The time periods referenced in the example refer to points labelled in Fig. V–1.

#### *V–6.7.1. Initial conditions*

Reference capacity: 985 MW(e). It is assumed that this unit has a maximum power output of 1000 MW(e) under optimum ambient conditions (determined by a formal test). Correction of test results to reference ambient conditions resulted in the reference capacity value of 985 MW(e).

Time period being considered: one year (8760 h).

The REG for the period:

$$\text{REG} = (985\ \text{MW(e)}) \times (8760\ \text{h}) = 8\,628\,600\ \text{MW(e)}\cdot\text{h}$$

#### *V–6.7.2. Energy loss examples*

Time period 1–2: Power reduction of 100 MW(e) for 12 h due to a circulating water pump failure. The unit was operating at reduced power due to a load following at the time of the pump failure. The power reduction caused by this failure would have been 201 MW(e) if the failure had occurred at the reference power level:

$$\text{FEL} = 201 \times 12 = 2412\ \text{MW(e)}\cdot\text{h (unplanned, forced)}$$

Time period 2–3: Reduced power operation due to ambient conditions and fuel coastdown. The lost energy generation is not used in calculations.

Time period 3–4: Planned refuelling outage. Scheduled length was 45 days (1080 h). The outage begins on the scheduled date:

PEL = 985 × 1080 = 1 063 800 MW(e)·h (planned)

Time period 4–5: Outage extension of 10 days (240 h) beyond the scheduled length to complete all work scheduled for the outage:

EPL = 985 × 240 = 236 400 MW(e)·h (unplanned extension)

Time period 5–6: Power ramp-up following outage. Average power level of 495 MW(e) for three days (72 h):

PEL = (985 – 495) × 72 = 35 280 MW(e)·h (planned)

Time period 6–7: Operation above reference unit capacity due to very cold cooling water. The additional energy generation is not used in calculations.

Time period 7–8: Shutdown for 32 h due to reactor scram caused by personnel error:

FEL = 985 × 32 = 31 520 MW(e)·h (unplanned, forced)

Time period 8–9: Power ramp-up following the scram. Average power level of 490 MW(e) for 8 h:

FEL = (985 – 490) × 8 = 3960 MW(e)·h (unplanned, forced)

Time period 9–10: Operation below reference unit capacity due to environmental limitations only. The lost energy generation is not used in calculations.

Total PEL:

Time period: 3–4; energy loss: 1 063 800 MW(e)·h.
Time period: 5–6; energy loss: 35 280 MW(e)·h.
Total energy loss: 1 099 080 MW(e)·h.

Total UEL:

Time period: 1–2; energy loss: 2412 MW(e)·h (forced).
Time period: 4–5; energy loss: 236 400 MW(e)·h (see note below).
Time period: 7–8; energy loss: 31 520 MW(e)·h (forced).
Time period: 8–9; energy loss: 3960 MW(e)·h (forced).
Total energy loss: 274 292 MW(e)·h.

Note: The 236 400 MW(e)·h is an unplanned extension of a planned outage.

$$\text{UCF } (\%) = \frac{(\text{REG} - \text{PEL} - \text{UEL}) \times 100\%}{\text{REG}}$$

$$= \frac{(8\,628\,600 - 1\,099\,080 - 274\,292) \times 100\%}{8\,628\,600}$$

$$= 84.1\%$$

*V–6.7.3. Calculations for the FLR*

Total unplanned FEL:

Time period: 1–2; energy loss: 2412 MW(e)·h.
Time period: 7–8; energy loss: 31 520 MW(e)·h.
Time period: 8–9; energy loss: 3960 MW(e)·h.
Total energy loss: 37 892 MW(e)·h.

$$\text{FLR } (\%) = \frac{\text{FEL} \times 100\%}{\text{REG} - (\text{PEL} + \text{EPL})}$$

$$= \frac{(2412 + 31\,520 + 3960) \times 100\%}{8\,628\,600 - (1\,099\,080 + 236\,400)}$$

$$= 5.2\%$$

*V–6.7.4. Calculations for the UCL*

$$\text{UCL } (\%) = \frac{\text{UEL} \times 100\%}{\text{REG}}$$

$$= \frac{274\,292 \times 100\%}{8\,628\,600}$$

$$= 3.2\%$$

*V–6.7.5. Calculations for the PCL*

(UCF) + (UCL) + (PCL) = 100%
PCL = 100 – (84.1 + 3.2)
PCL = 12.7%

## V–7. ENERGY AVAILABILITY FACTOR (EAF)

### V–7.1. Definition

The EAF over a specified period is the ratio of the energy that the available capacity could have produced during this period to the energy that the reference unit power could have produced during the same period.

The energy that the available capacity could have produced is equal to:

REG – PEL – UEL – XEL

where

REG is the reference energy generation (net) (MW(e)·h) during the period;
PEL is the total planned energy loss (MW(e)·h);
UEL is the total unplanned energy loss (MW(e)·h);
XEL is the total external energy loss (beyond the control of the management of the plant).

### V–7.2. Data elements

The following data are required to determine each unit's value for this indicator:

(a) The REG (net), expressed in MW(e)·h.
(b) The PEL: the energy that was not produced during the period because of planned shutdowns or load reductions due to causes under the control of the management of the plant. Energy losses are considered to be planned if they are scheduled at least four weeks in advance, generally at the time when the annual overhaul, refuelling or maintenance programme is established. Energy losses considered to be under the control of the management of the plant are further defined in the clarifying notes. The PEL is expressed in MW·h.

(c) The UEL: the energy that was not produced during the period because of unplanned shutdowns, outage extensions or load reductions due to causes under the control of the management of the plant. Energy losses are considered to be unplanned if they are not scheduled at least four weeks in advance. Energy losses considered to be under the control of the management of the plant are further defined in the clarifying notes. The UEL is expressed in MW·h.

(d) The XEL: the energy that was not produced during the period due to constraints considered to be beyond the control of the management of the plant. Energy losses considered to be beyond the control of the management of the plant are further defined in the clarifying notes.

### V–7.3. Calculations

The EAF is determined for each period as:

$$\text{EAF (\%)} = \frac{(\text{REG} - \text{PEL} - \text{UEL} - \text{XEL}) \times 100\%}{\text{REG}}$$

where

REG is the reference energy generation (net) for the period (MW(e)·h);
PEL is the total planned energy loss (MW(e)·h);
UEL is the total unplanned energy loss (MW(e)·h);
XEL is the total external energy loss (beyond the control of the management of the plant) (MW(e)·h).

Note: The total planned and unplanned energy losses and energy loss due to causes external to the plant for the period is the sum of the losses from all planned, unplanned and external events.

### V–7.4. Data qualification requirements

Data for new units are included in the calculation of annual values beginning on 1 January of the first calendar year following commercial operation. Data for units in commercial operation at the end of the commercial operation period are included in the calculation of annual values ending on 31 December of the last calendar year preceding shutdown.

### V–7.5. Clarifying notes

(a) The REG (net) is determined by multiplying the reference unit power (net) by the reference period hours.

(b) The reference unit power is the maximum power capability of the unit under reference ambient conditions (i.e. the maximum power that could be maintained or is authorized to be maintained throughout a period of continuous operation, in practice 15 h or longer). If a maximum power capability has been determined by a formal test, the reference unit power is determined by correcting the test results to reference ambient conditions. If a formal test has not been performed, the reference unit power should be based on design values adjusted for reference ambient conditions. The reference unit power is expected to remain constant unless, following design changes or a new permanent authorization, the management decides to amend the original value.

(c) The reference unit power (net) is the maximum power that can be supplied, measured at the unit outlet terminals (i.e. after deducting the power taken by unit auxiliaries and the losses in the transformers considered integral parts of the unit).

(d) The nuclear thermal power is the unit nuclear thermal power as derived from whatever is the most accurate heat balance measurement.

(e) The reference ambient conditions are environmental conditions representative of the annual mean (or typical) conditions of the unit. It is expected that historical heat sink temperatures will be used to determine the reference ambient conditions. The same reference ambient conditions will generally apply for the lifetime of the unit. Periodic review of these reference conditions is not required.

(f) The reference period hours are the total number of hours in the predefined calendar time. For units in power ascension at the end of the period, it is the clock hours from the beginning of the period or the first electrical production, whichever comes last, to the end of the period. For units in commercial operation at the end of the period, it is the clock hours from the beginning of the period or of commercial operation, whichever comes last, to the end of the period or permanent shutdown, whichever comes first.

(g) The PEL (those scheduled at least four weeks in advance) caused by the following conditions should be included when computing the EAF, since they are considered to be under the control of the management of the plant:
   (i) Refuelling or planned maintenance outages;
   (ii) Planned outages or load reductions for testing or repair, or for other plant equipment or personnel related reasons.

(h) Energy losses due to tests may be considered to be planned if they are identified at least four weeks in advance and are part of a regular programme, even if the precise time of the test was not decided upon four weeks in advance.

(i) The UEL caused by the following conditions should be included when computing the EAF, since they are considered to be under the control of the management of the plant:
   (i) Unplanned maintenance outages;
   (ii) Unplanned outages or load reductions for testing or repair, or for other plant equipment or personnel related reasons;
   (iii) Unplanned outage extensions;
   (iv) Unplanned outages or load reductions that are caused or prolonged by regulatory actions taken as a result of plant equipment or personnel performance, or regulatory actions applied on a generic basis to all like plants.

(j) External energy losses caused by the following conditions should be included when computing the EAF:
   (i) Environmental limitations (such as a low cooling pond level or water intake restrictions that could not be prevented by operator action);
   (ii) Labour strikes (see clarifying note (m));
   (iii) Fuel coastdowns;
   (iv) Seasonal variations in net dependable capacity due to cooling water temperature variations, low rivers or tidal waves;
   (v) Restrictions on fuel supply as a result of external constraints, for example disputes in fuel industries or fuel rationing.

(k) The values of planned, unplanned or external power losses to be used in computing energy losses due to a particular event are the losses that would have occurred if the unit were operating at the reference power level at the time of the event. The power losses relative to the reference power may be determined by one of the following techniques:
   (i) Subtracting the actual power level during the event from the power level immediately prior to the event when the power was at or near the reference power level.
   (ii) Computing the power level reduction that would have occurred with the unit at the reference power level.
   (iii) Using historical data from similar events that have occurred at the reference power level. For example, if a unit experiences a 10 MW power loss due to an equipment problem while operating at 75% of the reference power, and it is determined from calculations or from similar events that have occurred at the reference power that the same equipment problem would have resulted in a 20 MW power

loss at the reference power level, then 20 MW should be used when computing the energy loss.

(l) For events involving planned, unplanned or external outages and startup following these outages, the reference unit power should be used as the basis for computing power losses.

(m) Outages or load reductions caused by labour strikes that occur while the unit is operating are normally included as external energy losses, since these energy losses are not under the direct control of the management of the plant. However, if during the strike the unit becomes incapable of starting or operating because of equipment failures, maintenance, overhauls or other activities such as refuelling, then the energy losses during the time when the unit is inoperable are included as planned or unplanned. If a labour strike occurs during an outage, any outage extensions are included as energy losses (planned or unplanned) as long as the unit is incapable of being restarted because of equipment failures, maintenance, overhauls or other activities such as refuelling.

(n) In general, changes in an outage or load reduction start date must be announced at least four weeks in advance to be considered planned. However, if the grid dispatcher requests a change in the start date less than four weeks in advance, the outage or load reduction is considered to be planned. The same rule may be used if the change in the start date is decided upon by the management of the plant, assuming that this decision is covered by all of the following reasons or circumstances:

  (i) The unit is operating in a deregulated environment, and the management decision to modify the planned outage start date is solely to take advantage of economic situations to maximize, on a short term basis, the economic benefit coming from selling the plant's electricity output. This economic benefit can be applied to the entire production system of the utility, not only to the specific unit under consideration.

  (ii) The unit is considered to be able to run at maximum power during the four week period prior to the initial planned outage start date.

  (iii) Any forced or unplanned outage occurring during this four week period (or before the new start date) shall not become the reason for putting forward the planned outage.

(o) If a unit begins an outage or load reduction before the scheduled start date, the energy loss from the beginning of the outage or load reduction to the scheduled start date is a UEL.

(p) If an outage extends beyond the scheduled startup date, either to complete originally scheduled work or to complete corrective maintenance work on equipment required for startup, all energy losses associated with the outage extension should be considered to be unplanned. However, outage extensions to complete discretionary work (i.e. preventive maintenance and modifications) not originally scheduled for completion during the outage should be considered to be planned if the work is scheduled at least four weeks in advance. Extended outages can be reclassified from unplanned to planned once the corrective maintenance activities required for startup are completed if any remaining planned activities were scheduled at least four weeks in advance. This classification also applies to load reductions.

(q) The scheduled start and end dates of planned outages and load reductions are those dates negotiated with and agreed to by the network and/or grid dispatcher. These dates may differ from those shown on the detailed schedule of activities used at the unit for directing the outage.

(r) Energy losses related to load reductions preceding a shutdown and load increases following the shutdown should be categorized as planned or unplanned, depending on whether the shutdown is planned or unplanned. For example, energy losses while entering and recovering from a planned outage will be considered to be planned losses. If an outage extension (unplanned outage) occurs at the end of a planned outage, the energy loss during recovery from the outage will still be considered to be a planned loss because the shutdown was originally caused by a planned outage. Energy losses due to required tests following refuelling are considered to be planned losses.

(s) A unit that is in reserve shutdown will be considered to be available if it can be restarted within the normal time required for unit startup. If work on plant equipment is undertaken that would prevent a restart, the energy that potentially could have been produced while the plant was unavailable should be computed and used when determining the EAF, even if the plant was not actually required to start up during the period.

### V–7.6. Energy unavailability factor (EUF)

The EUF can be calculated from:

EUF = 100 – EAF over a specific time period

where EAF is the energy availability factor.

Note: Formerly, the EUF was defined as:

EUF = PUF + UUF + XUF

where

PUF is the planned energy unavailability factor;
UUF is the unplanned energy unavailability factor due to causes in the plant;
XUF is the unplanned unavailability factor due to causes external to the plant.

## V–8. UNPLANNED AUTOMATIC SCRAMS PER 7000 HOURS CRITICAL (UA7) AND UNPLANNED SCRAMS PER 7000 HOURS CRITICAL (US7)

### V–8.1. Purpose

The purpose of the unplanned automatic and/or total unplanned scrams per 7000 h critical indicator is to monitor performance in reducing the number of unplanned automatic and/or total reactor shutdowns. The indicator provides an indication of success in improving plant safety by reducing the number of undesirable and unplanned thermohydraulic and reactivity transients requiring reactor scrams. It also provides an indication of how well a plant is being operated and maintained.

Taking into account the number of hours that a plant was critical provides an indication of the effectiveness of scram reduction efforts while a unit is in an operating condition. In addition, normalizing individual unit scram data to a common standard (7000 h critical) provides a uniform basis for comparisons between individual units and with industry values.

### V–8.2. Definition

The indicator is defined as the number of unplanned automatic and/or total number of scrams (reactor protection system logic actuations) that occur per 7000 h of critical operation. The indicator is further defined as follows:

(a) ‘Unplanned’ means that the scram was not an anticipated part of a planned test.
(b) ‘Scram’ means the shutdown of the reactor by a rapid insertion of negative reactivity (e.g. by control rods or a liquid injection shutdown system) that is caused by actuation of the reactor protection system. The scram signal may have resulted from exceeding a set point or may have been spurious.
(c) ‘Automatic’ means that the initial signal that caused actuation of the reactor protection system logic was provided from one of the sensors

monitoring the plant's parameters and conditions, rather than from the manual scram switches or, in certain cases described in the clarifying notes, manual turbine trip switches (or push buttons) provided in the main control room.

(d) 'Manual' means that the scram was initiated by a manual action of the operator.

(e) 'Critical' means that during the steady state condition of the reactor prior to the scram, the effective multiplication factor ($k_{eff}$) was essentially equal to 1.

(f) The value of 7000 h is representative of the critical hours of operation during a year for most plants and provides an indicator value that typically approximates the actual number of scrams occurring during the year.

### V–8.3. Data elements

The following data are required to determine each unit's value for this indicator:

(a) The number of unplanned automatic and/or manual scrams while critical;
(b) The number of hours of critical operation.

The total number of unplanned scrams is the sum of the automatic and manual scrams.

### V–8.4. Calculations

The unit and industry values for this indicator are determined for a period as:

Value for a unit:

$$\text{UA7} = \frac{(\text{number of unplanned automatic scrams while critical}) \times 7000}{\text{total number of hours critical}}$$

$$\text{US7} = \frac{(\text{total unplanned scrams while critical}) \times 7000}{\text{total number of hours critical}}$$

Worldwide value = median of the unit values

Since these calculations are based on the number of scrams occurring per 7000 h critical, the typical result for both an individual unit and worldwide will not be an integer. For comparisons of individual units (e.g. histograms), unplanned automatic and/or manual scrams per 7000 h critical will be presented for a three year period, in order to minimize the effects of variations in the indicator value during shorter time periods due to the low number of scrams at most plants. Units must average at least 1000 h critical per year to be included in the worldwide (median) value.

### V–8.5. Data qualification requirements

Data for new units are included in the calculation of industry values beginning on 1 January of the first calendar year following commercial operation. However, in order to be included in the industry values, the unit must be critical for at least 1000 h per year. Requiring this minimum number of critical hours reduces the effects of plants that are shut down for long periods of time and whose limited data may not be statistically valid.

### V–8.6. Clarifying notes

(a) Scrams that are planned to occur as part of a test (e.g. a reactor protection system actuation test) or scrams that are part of a normal operation or evolution and are covered by controlled procedures are not included.
(b) Reactor protection system actuation signals that occur while all control rods are inserted are not counted, since no control rod movement occurs as a result of the signals.
(c) During a startup, shutdown or change of power condition, reactivity transients may cause the reactor to go subcritical or supercritical for a short period of time. However, the plant is considered critical for the purposes of this indicator if the reactor was critical prior to the reactivity transient and may be assumed to return to a critical condition after the transient is completed (e.g. a plant is considered to remain critical after initial criticality is declared on a reactor startup and to be critical until taken permanently subcritical on a reactor shutdown).
(d) Each scram caused by an intentional manual trip of the turbine should be analysed in order to determine those that clearly involve a conscious decision by the operator to manually trip the turbine to protect important equipment or to minimize the effects of a transient. Scrams that involve such a decision are considered manual scrams and are not counted for the UA7 indicator, but are counted for the US7 indicator.

### V–8.7. Example of a UA7/US7 calculation

The following examples are provided to illustrate which reactor protection system actuations are counted or not counted for the number of unplanned scrams per 7000 h critical indicator.

Reactor protection system actuations:

(a) While shutting down the reactor, sufficient control rods had been inserted to make the reactor subcritical. A spurious scram signal then caused the remaining control rods to be inserted into the core. (This scram is not counted for the performance indicator because the reactor was not critical.)

(b) A reactor scram occurred while a special test was conducted on the turbine. The plant procedure used for this test indicated that a scram would occur while performing the test. (This scram is not counted for the performance indicator because the scram is part of a planned operation and is covered by plant procedures.)

(c) While a routine surveillance test was conducted of the reactor protection system at 100% power, a reactor scram occurred when a spurious signal was received on one protection system channel while another channel was being tested. (This scram is counted for the UA7 and US7 performance indicators.)

(d) While at full power, a main feedwater pump tripped. Operators attempted to restart the pump and to reduce reactor power, but actions to maintain the steam generator (PWRs) or reactor (BWRs) levels were unsuccessful. Operators then initiated a manual reactor scram before the set point for an automatic scram was reached. (This scram does not count for the UA7 performance indicator because the scram did not result from an automatic actuation of the reactor protection system, but it counts for the US7 indicator, as it is an unplanned manual scram.)

(e) While at 75% power, operators tripped the main turbine to prevent overspeed caused by a malfunction in the turbine control system. The turbine trip caused an automatic reactor scram. (This scram does not count for the UA7 performance indicator because the scram was caused by operators manually tripping the turbine to prevent equipment damage, but it counts for the US7 indicator, as it is an unplanned manual scram.)

Sample data (see Table V–1) and a calculation of the indicator value for a particular plant are as follows:

(i) Unplanned scrams while critical — data for one quarter:

Number of unplanned automatic scrams: 1
Number of unplanned manual scrams: 2
Number of hours critical during the quarter = 1856

(ii) Unplanned automatic scrams per 7000 h critical for the period (one year):

$$\text{Value for unit} = \frac{(\text{total unplanned automatic scrams while critical}) \times 7000}{\text{total number of hours critical}}$$

$$= \frac{2 \times 7000}{6566}$$

$$= 2.1$$

(iii) Total unplanned scrams per 7000 h critical for the period (one year):

$$\text{Value for unit} = \frac{(2 + 4) \times 7000}{6566}$$

$$= 6.3$$

TABLE V–1. UNPLANNED AUTOMATIC AND/OR MANUAL SCRAMS WHILE CRITICAL — DATA FOR ONE YEAR

| | Number of unplanned automatic scrams while critical | Number of hours critical | Number of unplanned manual scrams while critical |
|---|---|---|---|
| Previous three quarters | 1 | 4710 | 2 |
| Current quarter | 1 | 1856 | 2 |
| Total for year | 2 | 6566 | 4 |

# ABBREVIATIONS

| | |
|---|---|
| EAF | energy availability factor |
| EG | energy generation |
| EPL | extension of planned energy loss |
| EUF | energy unavailability factor |
| FEL | forced energy loss |
| FLR | operating period forced loss rate |
| FPL | forced power loss, power decrease due to failure at power |
| HRP | hours operated at reduced power due to planned outage |
| HRU | hours operated at reduced power due to unplanned outage |
| LF | load factor |
| MED | multieffect distillation |
| MSF | multistage flash |
| OF | operation factor |
| PCL | planned capability loss factor |
| PEL | planned energy loss |
| PRIS | Power Reactor Information System |
| PUF | planned energy unavailability factor |
| REG | reference energy generation |
| RO | reverse osmosis |
| UA7 | unplanned automatic scrams per 7000 h critical |
| UCF | unit capability factor |
| UCL | unplanned capability loss factor |
| UEL | unplanned energy loss |
| UNIPEDE | International Union of Producers and Distributors of Electrical Energy |
| UPL | unplanned power loss, power decrease in MW due to an unplanned outage |
| US7 | unplanned scrams per 7000 h critical |
| UUF | unplanned energy unavailability factor (due to internal causes) |
| WANO | World Association of Nuclear Operators |
| XEL | external energy loss (beyond the control of the management of the plant) |
| XUF | unplanned unavailability factor (due to external causes) |

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