

International Atomic Energy Agency

L13-Plant Operability and manoeuvrability, Inspectability and maintainability

Pierre BERBEY, EDF/SEPTEN

**Technical Cooperation Workshop on
Nuclear Power Plant Technology Assessment
Vienna, November 17-20, 2008**

Plant Operability and manoeuvrability, Inspectability and maintainability

- **Key design requirements related to operation**
 - **Manoeuvrability**
 - **Operability**
 - **Inspectability**
 - **Maintainability**
- **Real owner requirements, not a simple guidance to the designer**
- **Two questions: why? what to require?**



Why?

Why manoeuvrability?

- **HV grid regulator requirement to allow the plant to be connected to the grid**
- **An Owner/Operator requirement**
 - continuity of supply during daily or weekly variation of the power called by the grid
 - management of the output of a plant in a market-driven environment
 - the prices of electricity vary a lot in a year
 - generation to be available when the reselling prices are high
 - fleet management where there is a large proportion of nuclear generation
 - not all the plants can always keep operating in base load
 - some plants of the fleet must contribute to weekly or seasonal power variation



Why operability?

- **An Owner/Operator requirement to keep the plant capable of producing the power called by the grid and generate revenue**
- **Reducing the risk of plant unavailability**
 - **Acceptable failure rate of the critical components and systems**
 - **Redundancy/diversity of the critical components**
 - **Capability to identify the failure and to repair in a short time**



Why inspectability and maintainability?

- **safety requirements**

- **Some equipment is necessary to protect individuals, society and environment from the consequences of accidents**
- **Unavailability of the critical safety functions is limited or forbidden**
- **periodic inspection and testing requested**
- **capability to identify the failure and to repair in the time allowed by the plant tech specs**



Why inspectability and maintainability? (2)

- **Owner/Operator requirements**

- **Some equipment necessary to guarantee plant availability**
- **Investment protection: avoid large or irreversible damages to the plant that would preclude further operation**
- **Capacity to detect and repair the failures without jeopardizing the plant availability design objective (> 90% over 20 years in EUR)**



What?

What? A few key requirements related to manoeuvrability

- **HV transmission grid requirements**
- **Capability for transients**
- **Capability for operation in upset conditions**

HV transmission grid requirements

- **Primary control and secondary control**
- **Voltage frequency diagram**
- **Remote control of the active power of the plant**
 - typical range: 5 to 10% of rated power
- **capability to (full or partial) load rejection without reactor or turbine trip**
 - ability to continue stable operation with on house loads (typically 5-10% of the rated power)
 - steam bypass system capacity
- **Capability to keep operating during and after grid faults**



Voltage frequency field in normal operation

EUR chapter 2.3

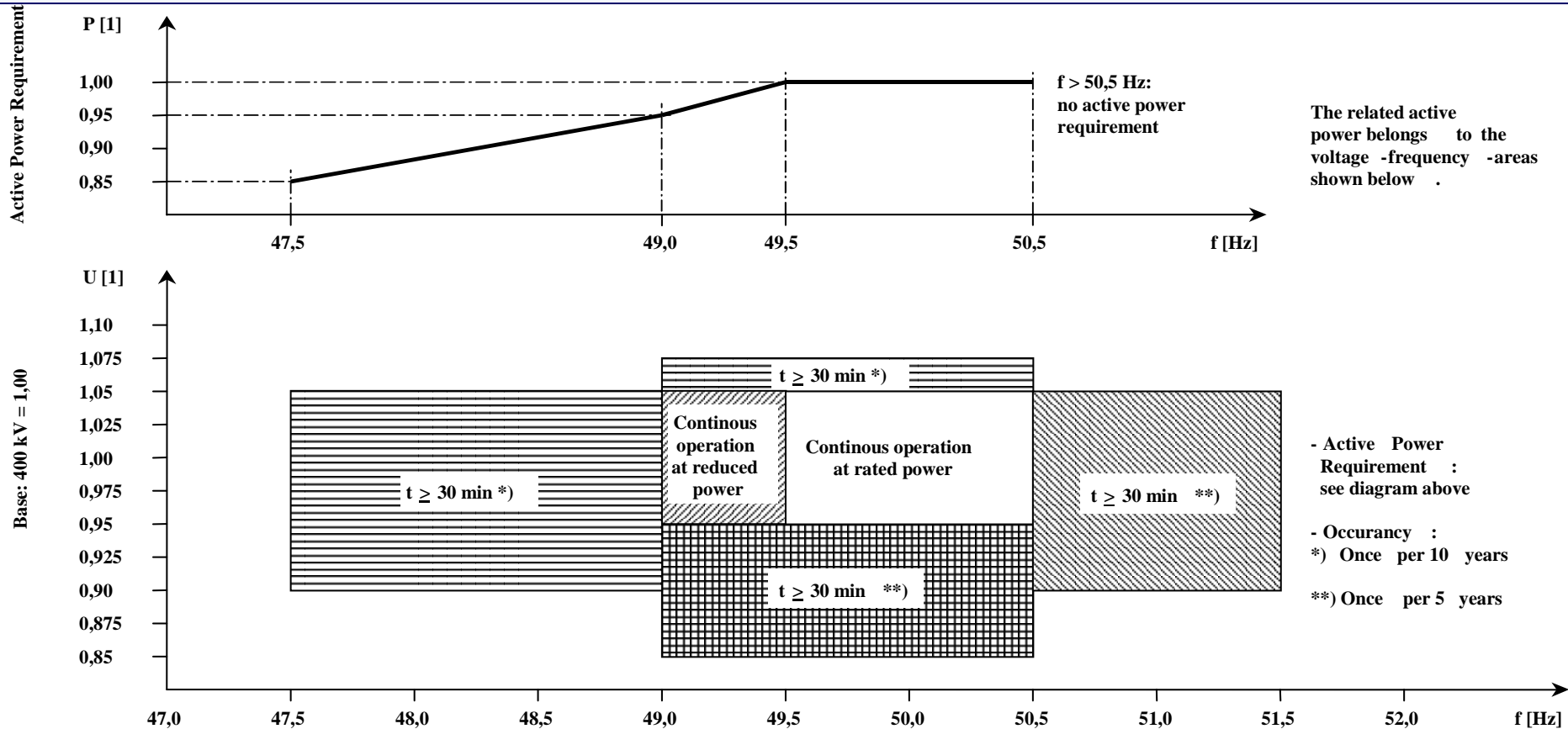
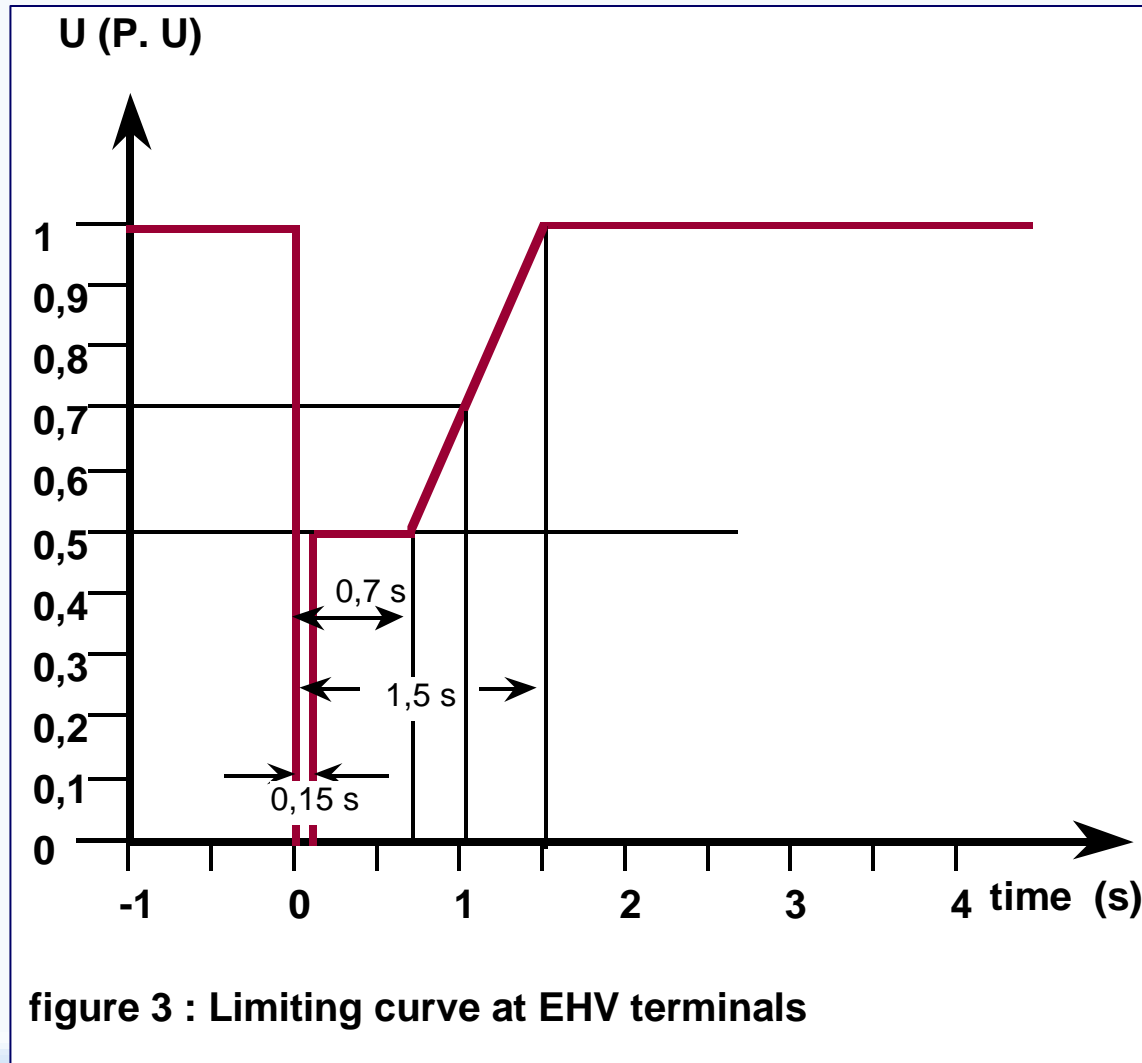


Figure 1, Voltage frequency field

Reference grid fault EUR chapter 2.3



Capability for transients

- **Automatic power control capability of the plant**
 - Minimum load in automatic control (typically 15-30 % rated power)
- **Plant start and cooldown capability**
 - Time required to go from cold shutdown condition to hot standby
 - time required from reactor critical at full pressure and temperature to the beginning of refuelling operations
- **Load change response**
 - ramps (typically 2-5% rated power per minute)
 - steps (typically 10% rated power)
- **Plant load cycling capability**
 - list & number of the transients for which the plant is designed over its design life.



Number of transients

EUR chapter 2.2

2.2 2.1.3 Number of startups during lifetime

- A** The number of start-ups depends on the planned operating mode of the plant and shall be defined by the operator of the plant.
- B** The plant shall be designed for a number of transients which cannot exceed :
- 2000 hot start-ups (equivalent to one start-up every week-end for a lifetime of 40 years,
 - 200 cold start-ups

Capability for operation in upset conditions

- **Plant operating capability following the failure of an auxiliary equipment item.**
 - Percentage of rated power at which the plant can continue operation following auxiliary equipment failures (eg, loss of feedwater pump, loss of condenser circulating water pump, etc.)
- **Maintenance during operation**
 - Safety related equipment & systems
 - Equipment and systems critical for availability

What? A few key requirements related to operability

- **Man-machine interface**
- **fuel management flexibility**
- **Waste & spent fuel storage**
- **Operating and maintenance staff**

Man-machine interface

- Main control room design and technology
- Operating staff
- Operating and maintenance interfaces

2.10 3.2.1.1 Interfaces dedicated to plant operation

- A** The number of different types of **M-MI** dedicated to operation shall be minimised independently from the location: centralised or localised facilities.
- B** In the **Main Control Room*** (MCR), one single interface shall be used in all plant conditions. Exception or deviation may be allowed for safety or availability reasons when backup operating facilities are needed. In such cases, benefits shall be taken from the advantage of diversity of **M-MI** technology. Justification for this exception or deviation shall be given.
- C** The operating facilities used by the **Operators*** shall be exclusively dedicated to plant operation and shall not be used for any other purpose such as maintenance or analytical tools for technical specialists outside the operating staff.



fuel management flexibility

- **Capability to accommodate UO₂ and MOX**
- **Capability to use fuel from different suppliers**
- **Adaptation of fuel cycle length**
 - **stretch out**
 - **adaptation of campaign length of a unit in a fleet**
 - **adaptation following fuel damage**

Waste & spent fuel storage

- **Storage capacity in the unit, in the station, in common facilities elsewhere**
- **spent fuel: taking in consideration different operating options**
 - **Sufficient capacity for spent fuel cooling (UO₂ and MOX)**
 - Typically 10 years of production for UO₂, 15 for MOX
 - **Interface with the back end of the fuel cycle**
 - reprocessing, interim storage, ...
 - **Extra capacity to allow freedom and flexibility**
 - **interim radioactive waste storage on the plant**

Operating and maintenance staff

- **Expected staff occupational exposure**
- **Expected maintenance tasks**
 - choosing adapted design lifespan for the critical components
 - staff organisation
- **Expected operating staff and staff organisation**



What? A few key requirements related to inspectability & maintainability

- **Easy maintenance**
- **Easy replacement of the faulted equipment**
- **Miscellaneous**

Easy maintenance and replacement of the faulted components

- **easy maintenance.**
 - reduces operating and maintenance costs,
 - reduces occupational exposure of plant personnel
 - facilitates equipment repair or replacement.

Factors that favour inspectability & maintainability

- **standardized equipment**
- **clear identification**
- **low-maintenance designs**
- **satisfactory work conditions**
 - reduced occupational exposure
 - layout that facilitates access to equipment (pull-out and laydown space)
 - available rigging equipment and tooling to support inspections, testing, repairs and replacements
 - automated maintenance and inspection machines
- **maintenance during outages**
 - inspection and maintenance schedules consistent with the expected campaign length

To conclude

- **Critical factors to good operation records**
- **Can make a plant profitable or not**
- **Specific care shall be given by the potential owner to the assessment of efficiency of the design provisions contributing to these objectives**
 - **Redundancy/diversity**
 - **High-reliability equipment**
 - **Possible replacement and repair**
- **A preliminary assessment of the expected availability of the plant during a long period of time (typically 15-20 years, to include all the proposed maintenance programmes) may be useful to check the performance claimed by the vendor**

