Methodology to account for load factor and availability during conceptual design phase of a gen IV nuclear power point

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METHODOLOGY TO ACCOUNT FOR LOAD FACTOR AND AVAILABILITY DURING CONCEPTUAL DESIGN PHASE OF A GEN IV NUCLEAR POWER POINT

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Increasing availability is a permanent objective of the nuclear plant designers and operators.

For ASTRID SFR project, this consideration was taken into account at the very beginning of the reactor conceptual design.

The parameters on which the plant designer can focus their action are :

- *The increase of the power production cycles duration,*
- *The reduce of the refueling & inspection outages,*
- *The increase of equipment reliability and parts availabilities.*

This overall work is conducted progressively and iteratively on all the ASTRID SFR reactor equipment and functions.

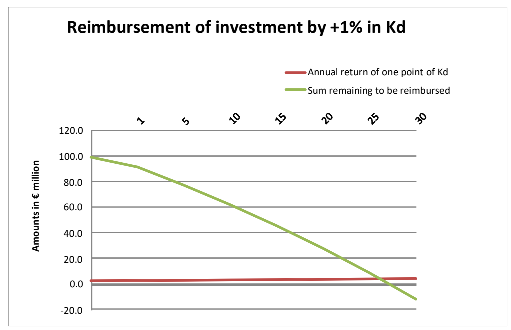
This original work has led to :

- *identify the functions or equipment on which it was necessary to focus in priority.*
- *Question on equipment or function failure consequences (and the solution to avoid being a "Driver").*
- *Set reliability targets by system or function and to assess gap between the target and the current design.*

I. INTRODUCTION

Increasing availability is a permanent objective of the nuclear plant designers and operators.

It is important to bear in mind that 100 M€ investment could be paid back in less than 25 years with an increase of 1% on the load factor.



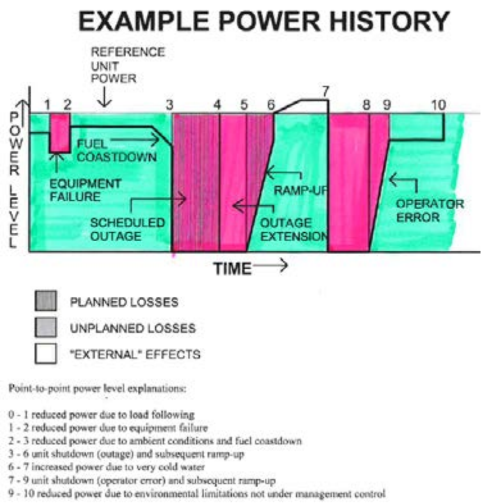
For ASTRID SFR project, this consideration was taken into account at the very beginning of the reactor conceptual design.

The topic was a particularly difficult one because:

- how to take action on the reliability of the entire plant while studies on the sub-systems are only in their early stages?

- How to challenge the design teams around an (ambitious) objective when we cannot know the discrepancy between the target value and the current state of the design?

The load factor is defined by WANO as the ratio of the available energy generation over a given time period to the reference energy generation over the same time period (expressed as a %).



In the example below, in simplified terms, the load factor is the following ratio:

Available energy generation
(Green part)

Reference energy generation
(Green part + Pink part)

As the GEN IV NPP are expected to be more expensive than PWR, it is important to improve their competitiveness with a high load factor.

The parameters on which the plant designer can focus their action are:

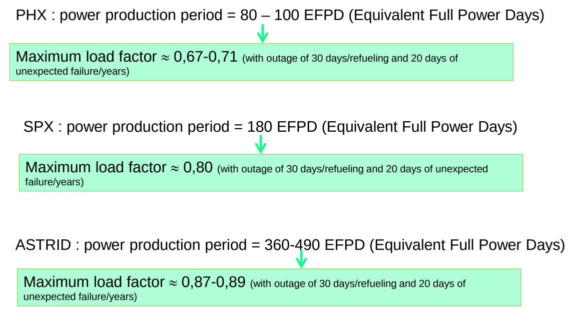
A. the increase of the power production cycles duration,
B. The reduce of the refueling & inspection outages,
C. The increase of equipment reliability and parts availabilities.

II. INCREASE OF THE POWER PRODUCTION CYCLES DURATION

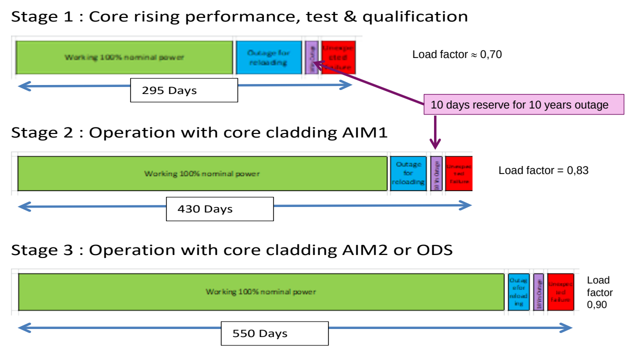
The power production cycle duration is link with the time in core for the fuel subassembly. This time in core depends on the cladding and the fuel.

Presently, cladding life time limits the duration of the fuel assembly in core to 1440 Equivalent Full Power Days (about 4 cycles of 360 EFPD and one outage for refueling each year).

The increased cycle duration has an immediate effect on the load factor. The compared results of the lengths of cycles and load factor of fast neutron reactor plants are indicated in the diagram below:



In the ASTRID project, we plan to increase the duration of the cycles (and hence the load factor) in 3 stages, represented in the diagram below:

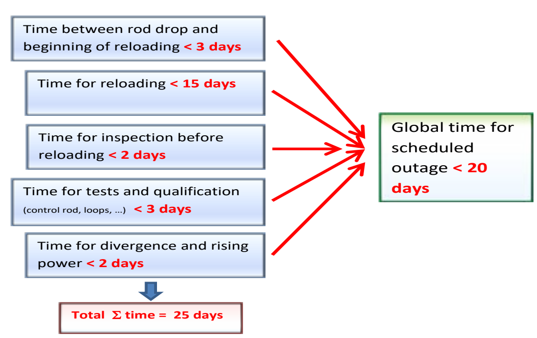


III. REDUCE OF THE REFUELING & INSPECTION OUTAGES

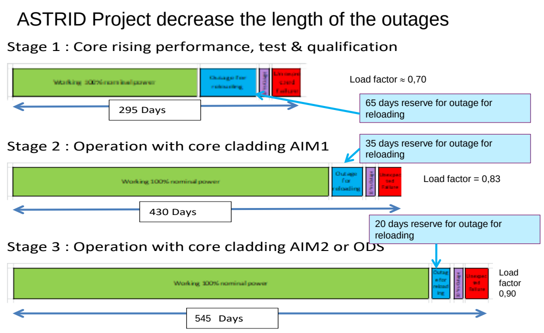
The refueling outage duration is linked to the technology used for replacement of spent fuel by fresh fuel. In addition, the power plants design should be such that inspection and maintenance operations are avoided during outages.

The fuel handling route is designed to achieve a high level of performance that is compatible with the ambitious program objectives mentioned below:

ASTRID Project scheduled outage :



All of the equipment is designed to achieve this objective after a learning phase, an operating phase on power, and a fuel and cladding performance ramp-up phase.



IV. INCREASE OF EQUIPMENT RELIABILITY & PARTS AVAILABILITY

Equipment availability must be integrated as soon as possible in the NPP design studies. For that, innovative methodologies are needed, with the aim of addressing the following issues:

- how to set goals when the NPP design is not completely defined?
- How to identify the "equipment with poor availability record" in a conceptual design phase?

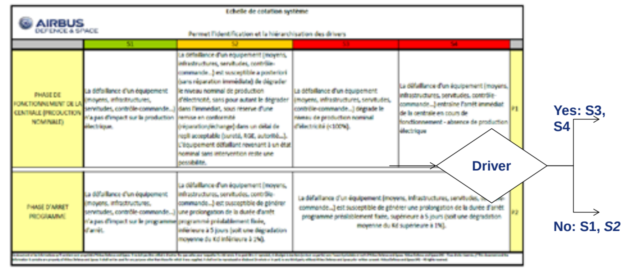
On the SFR ASTRID project, CEA and AIRBUS Defence and Space deployed a system engineering approach in order to develop a methodology that focuses on the equipment and functions that contribute to non-operability.

These are called "drivers" and the aim is to optimize them. These "drivers" cover RAM (Reliability, Availability and Maintainability) and ILS (Integrated Logistic Support).

The deployment of this methodology is based on the Products Breakdown Structure produced by ASTRID and on the interview with the plant designers.

It is a qualitative method that replaces the RAM studies which are not available at the conceptual design type studies stage.

Firstly, it involves assessing each item of equipment (or sub-units) through a grid that has 4 levels. The lowest level (S1 in green) identifies the equipment the failure of which has no consequences on electricity production by the plant. The higher levels (S3 & S4 in red) identify the equipment the failure of which leads to an outage of the plant, or a drop in power. These items of equipment are called "Drivers" of operability in the operating phase.



It is applied an equivalent assessment grid to identify the equipment the failure of which leads to the duration of the unit outage being increased by more than 5 days. These items of equipment are called "Drivers" of operability in the scheduled outages phase.

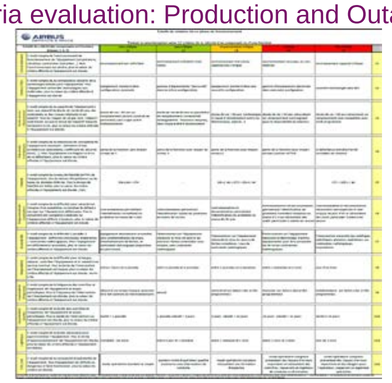
The primary duty of the designers is hence to have as few "Drivers" as possible within the perimeter of their package.

For this, architectures of functional unit have been proposed to the ASTRID project, and have or have not been adopted according to technical-economic criteria.

Each "Driver" is then subject to a grid of 12 criteria that allow the following to be assessed over 5 levels:

- Reliability and lifetime
- Maintainability - accessibility - inspectionability
- Supply and logistical support
- Operational availability

3. If driver:
12 criteria evaluation: Production and Outage phases



The entire grid, once completed, gives a characteristic of each "Driver" and an image of the level of operability of the package.

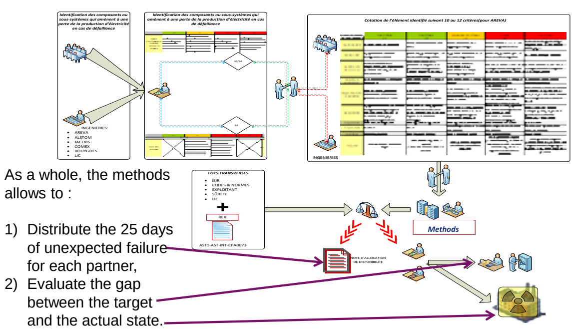
4. System Data Base

Interpretation of these grids allows each package or perimeter of the facility to be assigned a load factor allocation value.

A package that has many "Drivers" and high criticalities will have a higher allocation than one that has few “Drivers” and low criticality.

The allocation assigned to each package of the tree structure produced allows an objective to be set for each designer.

The information gathered during working meetings has also allowed an assessment of the level of operability achieved by the packages and the sub-units, by converting qualitative information into qualitative values. It is hence possible to outline the discrepancy between the target and the state of progress of the design studies.



V. CONCLUSIONS

Deploying this kind of methodology requires holding meetings with all the engineering units involved in the project, participating in working groups and mathematical modeling of the operability function. This overall work is conducted progressively and iteratively on all the reactor equipment and functions.

This original work has led to:

- identify the functions or equipment on which it was necessary to focus in priority.
- Question on equipment or function failure consequences (and the solution to avoid being a “Driver”).
- Set reliability targets by system or function and to assess gap between the target and the current design.

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