Atoms for the Future 2014

Commissioning of Nuclear Power Plants
The AREVA approach

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October 14th 2014
Commissioning of NPPS

Agenda

- Commissioning in Project process
- Overview of Commissioning Phases and Tests
- General Commissioning organization / Interfaces
- Commissioning skills
Introduction

- Most of the Reactors started in the 70’s to 90’s
- ≈ 440 Reactors under operation
- ≈ 70 Reactors under construction

Power reactors by status worldwide (as June 2014 ref: IAEA PRIS)
Commissioning in Project Process

What is commissioning? Why is it such a special field of expertise?

- The commissioning, starting at the end of construction with tests and initial operation of components and systems, is the last phase of the project where all the preceding phases are verified & validated.

- Commissioning is on the critical path of a project and is considered a crucial phase of the project.
The commissioning approach of AREVA (organization, methods, principles, sequencing, criteria, completeness, documentation, …) is based on and in line with:

- improved principles and methods applied and recognized by Utilities and Authorities in different countries.
- the results and lesson learned of more than 40 years of experience in Nuclear Plants construction and commissioning through the startup and testing of around 100 nuclear power station units in France, Belgium, Germany, South Africa, Korea, China, Brazil,…
- the principles developed and applied now for commissioning of EPR™ Plants in Finland, France and China,
- the experience feedback analysis and recommendations from AIEA (such as new Safety guide SSG 28 for commissioning which replaced NS-G-2.9) and other international sources recommendations (such as EPRI, US Regulatory guides).
Commissioning in Project Process

1. Safety & Process Requirements → Systems Design
2. Systems Design → Equipment Specifications
3. Equipment Specifications → Equipment Design / Manufacturing
4. Equipment Design / Manufacturing → Equipment Qualification Tests / Factory Tests
5. Equipment Qualification Tests / Factory Tests → Equipment Installation
6. Equipment Installation → End of Installation Checks & Tests
7. End of Installation Checks & Tests → On-Site Commissioning
8. On-Site Commissioning → Plant Operation
9. Plant Operation → Transverse systems tests and Overall Tests
10. Transverse systems tests and Overall Tests → Functional Systems Tests
11. Functional Systems Tests → Components Tests
12. Components Tests → Transfer to Commissioning
13. Transfer to Commissioning → System test loop check & initial Reservations List

=> System test loop check & initial Reservations List
Commissioning in Project Process

What are its objectives?

The objectives of commissioning are to verify the fulfilment of Process and safety requirements and compliance of components and systems to Design intent.

They shall cover:

- Initial startup and operation of components and systems
- Checking and demonstration of systems and plant correct operation in all practicable design configurations including:
  - Verification of components and systems compliance with design intent and requirements
  - Verification of safety and operational requirements fulfillment
- Demonstration of Plant Operability and capability
- Demonstration of contractual performances fulfillment
- Familiarization of Operating staff with plant operation
- Contribution to the validation of Operating and Periodic Test procedures
Commissioning in Project Process

What are the requirements for its performance?

- Commissioning has to be organized and performed in the frame of proven, mastered and standardized principles and methods, continuously integrating experience feedback and optimization analysis results.

Commissioning Process:

1. Design and safety requirements
2. Commissioning specifications and objectives
3. Commissioning tests and procedures
4. Commissioning test results
5. Competent persons (Commissioning, Design & Operation)

- Design and safety requirements are translated into commissioning specifications and objectives, which are confirmed in the plant by commissioning tests and procedures, which are recorded in commissioning test results, which are evaluated by competent persons (Commissioning, Design & Operation) to confirm results meet commissioning specifications and objectives.
Commissioning in Project Process

What are the requirements for its definition?

Main principles and requirements for the commissioning program development can be summarized as follows:

► **Completeness** = Program should cover
  - All systems and functions
  - All systems and plant operating modes - normal and as possible abnormal operating situations

► **Progressiveness** =
  - Commissioning by steps
  - Allowing safe fallback states in case of troubles

► **Respect of Operating limits and specifications**

► **Limitation of Equipment and plant loading situations during commissioning**

► **Respect of environment**
  - Limitation of wastes

► **Anticipation**
  - Detection of problems the earlier possible
  - Risk analysis – Mitigation measures

► **Optimization** = consideration of checks and tests performed
  - In Factory
  - On Test benches, platform
  - During and at the end of construction / installation
The commissioning is performed according to a commissioning plan ensuring that succession of tests is such that plant safety is never dependent on the performances or availability of structures, systems or equipment that have not yet been tested.
Overview of Commissioning Phases & Tests

- Commissioning Activities range from erection to Commercial Operation Date and include two test categories:
  - Pre-operational Tests (before fuel loading), corresponding to Non-Nuclear Testing of the Plant
  - Operational Tests – Called Commissioning Tests (after Fuel Loading), corresponding to Nuclear Testing of the Plant

Pre-Operational Test Phases

Operational Test Phases
Overview of Commissioning Phases & Tests

Main Commissioning Phases:

▶ PRE-OPERATIONNAL TESTS

◆ PHASE A: Pre-Operational Systems Tests
  ● System Transfer Process (Erection/Commissioning)
  ● Component Commissioning (Tests of individual components)
  ● System Commissioning Tests
  ● Nuclear Circuit Cleaning (NCC) and Cleaning of TI circuit

◆ PHASE B: Pre-Operational Overall systems Tests
  ● Cold Functional Tests (CFT) including Pressure Testing of Primary Circuit
  ● Hot Functional Tests Phase I (HFT) Pre-Core

▶ OPERATIONAL TESTS

◆ PHASE C: First Core Loading and Hot Functional Tests II (Post-Core)
  ● First Core Loading (FLG)
  ● Hot Functional Tests Phase II Post-Core (Pre-critical Tests)

◆ PHASE D: First Criticality and Power Escalation
  ● First Criticality and Zero-power Tests
  ● Turbine-Generator Set Tests and First Connection to the Grid
  ● Power Escalation (Typically 30%, 50%, 80%, 100%)
  ● Performance Test (at the Rated Thermal Output)
Overview of Commissioning Phases & Tests

Commissioning phases overview (Typical sequence)

- **PHASE A** (Phase 1)
  - Mechanical system completion tests
  - HVAC systems completion tests
  - I&C systems completion tests
  - Electrical systems completion tests
  - Nuclear circuit cleaning
  - Cold functional tests, reactor vessel open
  - ... Cold functional tests preparation

- **PHASE B** (Phase 2)
  - Cold functional test
  - Hot functional tests preparation
  - Hot functional tests
  - Preparation for fuel loading

- **PHASE C** (Phase 3.1 & 3.2)
  - Fuel loading
  - Precritical tests

- **PHASE D** (Phase 3.3 & 3.4)
  - First criticality
  - Low power tests
  - Power escalation tests
  - Full power tests
  - Performance Run & tests
Overview of Commissioning Phases & Tests

**PRE-OPERATIONNALL TESTS – Overall Tests Phase**

- Cold Functional Tests (CFT) including Pressure Testing of Primary Circuit
- HFT Phase I Preparation
- Hot Functional Tests Phase I (HFT) Pre-Core
- Preparation for Fuel Loading
Main generic organization / responsibilities

Regulator

Owner Operation Organization / License holder

Owner Construction Group

Owner Commissioning Group

Owner NPP Director / Operating Staff

Project Director

Commissioning leader

Contractual Contractors obligations fulfillment and assessment of commissioning process

Interface with Regulator

Construction group

Commissioning group

Ensure that construction and installation of SSCs has been completed in accordance with design requirements and specifications

Ensure proper preparation, coordination, performance and assessment of commissioning activities for its scope, with respect to overall plant program and schedule

Commissioning group

Operating group

Overall responsibility for nuclear and radiation safety and active participation to permit to work process and systems / plant operation and maintenance from beginning

Responsible of plant operation in compliance with Operating Technical Specifications from fuel delivery on site (Limited area) and from fuel loading for the whole plant.

Responsible of the Emergency plan implementation, the fire protection and radiation protection in the Plant, including the management of area access control.
Commissioning Interfaces

Gradual approach of safety oversight from classical to nuclear

Construction group
- Take-over for commissioning
- Take-over for Blocking/tagging

Commissioning group: in charge of tests and reports
- Perform the commissioning tests
- System test management and performance
- Leading performance of tests
- Technical assistance for system operation
- Technical assistance for plant operation and nuclear safety

Operation group: in charge of pre-operation (following start-up program instructions) and operation
- System operation, monitoring and maintenance
- Plant operation and maintenance

Mechanical: Hydro tests
Electrical: Continuity and insulation

Erection
System Tests
Overall tests
Operation

Pre-Operational Tests Phase
Operational Tests Phase

Fuel Loading
COD

Commissioning organization
Operating organization

Support to Commissioning organization
System operation, monitoring and maintenance
Plant operation and maintenance

Take-over for Temporary Operation
Plant take-over for Nuclear Operation

Take-over for

Commissioning organization
Operating organization

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Commissioning skills

- Commissioning requires qualified, experimented and operational resources
  - With a strong Safety culture
  - With a Team spirit
  - With strong reactivity in case of problems or particular requests from Customers or Safety Authority.

- Commissioning can not be learned only at school.
  - Commissioning requires a great variety of skills in all main project fields: mechanics, instrumentation & control, electricity, chemistry, process, safety, neutronics,
  - but most of all with the global practical approach of the systems functioning and plant operation.
Commissioning skills

A Commissioning engineer should have a global and practical view covering activities that can only be mastered by working on the project construction site, such as:

- **Technical activities**: Follow-up of construction, Commissioning preparation and implementation in compliance with specific site conditions, Commissioning Lessons learned, …

- **Project activities**: operational interfaces and scheduling management, contractual follow-up of suppliers, contractual interfaces with customer and partners

This explains why it is considered sometimes as a “special profession”, offering a real carrier opportunity for people seeking an operational and challenging job.
Conclusion

- **Commissioning = Challenging Phase in a Project**
  - Last phase of the Project,
  - On the critical path of the Project,
  - Considered as a crucial phase of the Project

- **Commissioning Success depends on:**
  - Quality, completeness and sequencing of the commissioning programs and methods:
    - with consideration of experience and lessons learned from previous Projects and from benchmark with other nuclear facility projects
    - With early involvement of commissioning in the design phase
    - with respect of internal and external interfaces (from and to commissioning)
  - Availability of qualified, experimented and operational resources, with a Team Spirit and support of young generation by experienced engineers.

- **Commissioning = Attractive and enhancing job**
  - Both theoretical and practical
  - Multidiscipline, both technical and managerial
  - Key experience in an engineer career development
Questions ?

Thanks for your Attention
General site commissioning organization

- **Main generic Functions vs. relevant commissioning aspects:**
  - **Contractual supervision and follow-up of plant commissioning**
    - **Owner Project Commissioning Group:** Contractual Contractors obligations fulfillment and assessment of commissioning process
    - **Contractor’s Site Representative Team:** Handling of deviations to Contractual obligations; Commissioning process and performances assessment

- **Commissioning organization and implementation:**
  - **Commissioning Leader:** Overall coordination and management of commissioning activities and interfaces; Ensuring satisfactory organization, planning, execution and assessment of commissioning process.
  - **Commissioning Groups:** Organization and implementation of the Commissioning for its scope of supply and services; With respect to overall plant program and schedule
  - **Operating Group:** Overall responsibility for nuclear and radiation safety and active participation to permit to work process and systems / plant operation and maintenance from beginning
  - **Test Leader:** Responsible for a system tests implementation through test permit process
  - **Suppliers in technical assistance:** Participation to the Commissioning for its scope of supply and services, under Commissioning Group coordination and supervision.