System Engineering Approach for EPR NM Nuclear Power Plant Basic Design Project

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EPR NM BASIC DESIGN PROJECT
CONTEXT AND OBJECTIVES

- **Beginning of 2015, in view of the future French fleet renewal, EDF and AREVA NP have launched the Basic Design of an optimized EPR from the cost and construction duration perspective, relying on 3 pillars**
  - Standardization and early involvement of industrial suppliers to secure constructability.
  - Simplification of the design on specific buildings and systems.
  - Engineering efficiency improvement through mastery of product design sequence and configuration.

- **To improve engineering efficiency, it was decided to switch from a discipline centric engineering approach to a product centric one, through the deployment of System Engineering principles, tooled by a PLM Technical Information System.**

- **Therefore, besides carrying the Basic Design of an optimized EPR, the EPRNM project is also a transformation project, at the scale of a Nuclear Power Plant (NPP) design project, involving more than 500 people located on 5 sites in France and Germany.**

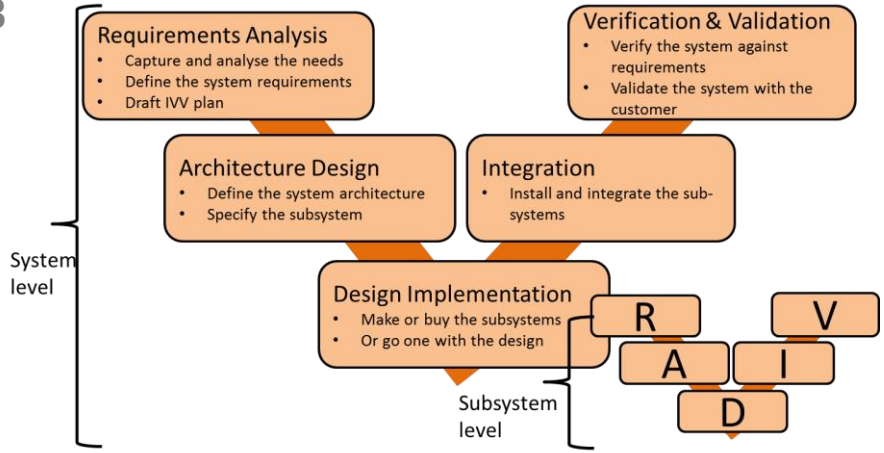
FUNDAMENTALS OF SYSTEM ENGINEERING
KEY CONCEPTS IMPLEMENTED ON EPR NM PROJECT

- **NPP product described by a PBS(*) and Basic Design Project described by a WBS (*)**
  - Technical data organized according to the PBS (meaningful across the product lifecycle, about 100 yrs dismantling included ; versus project WBS meaningful during the project lifecycle only, about 10 yrs).
- **Engineering process based on ISO15288 technical process, aiming at mastering the NPP as a product, its constituents, their requirements and interfaces, called RADIV.**
- **SE oriented Project organization involving**
  - Architects accountable for the design of one (or several) PBS node(s), according to the RADIV process.
  - Roles supporting the Architects to ensure that transverse stakes are taken into account consistently in the relevant PBS nodes, both in terms of requirements on the product and design methods, rules or guidelines to implement :
    - Transverse Specialties : safety, radio protection, fire protection, human factor ...
    - Product lifecycle : procurement, construction and commissioning, operation and maintenance, deconstruction.
  - Design Integration & Control entity to develop methods, and to support and ensure its application.
- **A Set of methods and tools to enable Architects to manage requirements and interfaces, ensure their implementation in the design and check their fulfilment**

(*) PBS=Product Breakdown Structure ; WBS=Work Breakdown Structure

ENGINEERING PROCESS (RADIV)

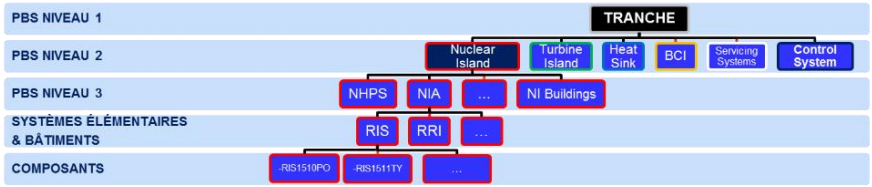
- **Engineering process (based on ISO15288 technical processes), involving 5 steps named RADIV,**
  - **R**equirements
  - **A**rchitecture design
  - **D**esign implementation
  - **I**ntegration
  - **V**erification and Validation

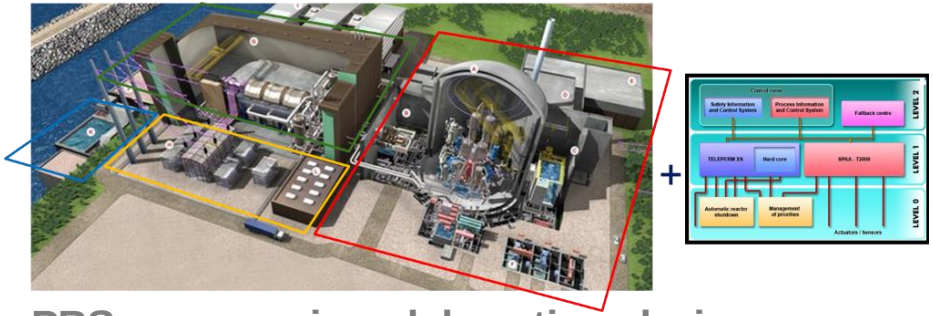


- **RADIV is applicable recursively to all PBS nodes, starting from the NPP unit.**
- **RADIV is monitored by 3 Gate Reviews (R, A, V) to check that expected data and documents have been delivered and validated by stakeholders.**
- **Project WBS and Time Schedule are structured according to PBS and RADIV steps.**

PRODUCT BREAKDOWN STRUCTURE (PBS)

- **EPRNM PBS elaboration criteria**
  - Clear identification of boundaries and interfaces,
  - A disciplined path from the global to the detail,
  - All engineering information, including specifications, attached at the PBS right level,
  - Each node should be functionally meaningful: can be specified, can be implemented (designed or procured), can be verified,
  - Consistency with EDF legacy Coding System (ECS) at the Elementary System level (buildings and systems: fluid, mechanical, electrical, automation …).

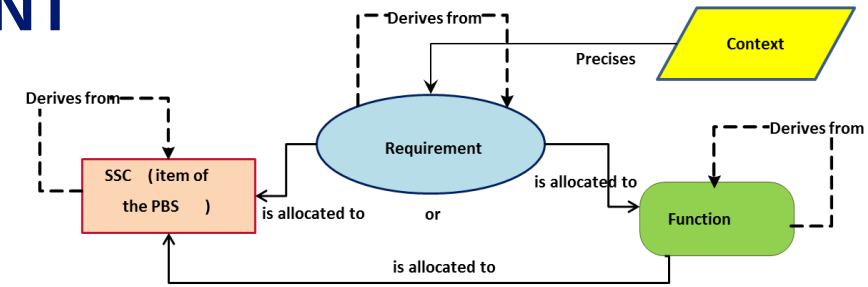




- **PBS progressive elaboration during engineering process (RADIV)**
  - PBS nodes of level N are created during RADIV A step of level N-1.
  - Level 5 PBS nodes (components) are created via authoring tools (2D or 3D) into PLM.

REQUIREMENTS MANAGEMENT

- Organization of requirements around Product and functions



- Derivation of functions and requirements going down the PBS to build traceability

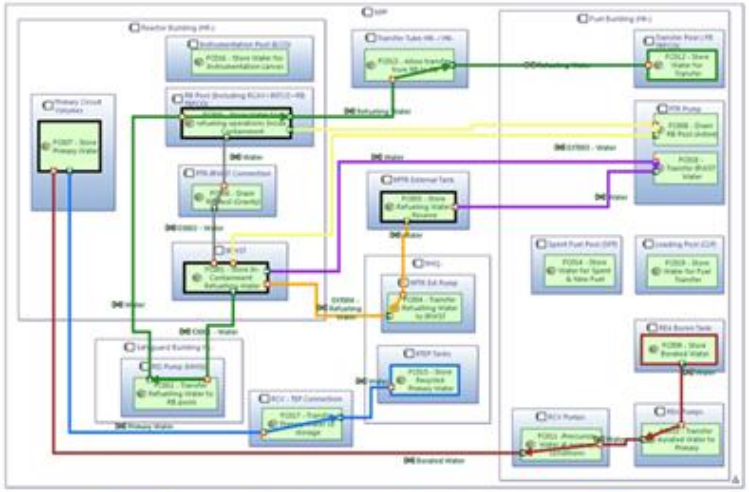
- Anticipation of IVV (defined in Requirement object itself for Basic Design)

Extract from PLM

Statement:	DCL shall be able to operate in case of AC voltage deviation during the time specified below: - [0,90 Un - 1,05 Un] : unlimited time - [0,85 Un - 0,90 Un] : => 60 minutes
IVV Approach:	Analysis (sizing calculation shall consider voltage deviation or justification shall be done) Inspection (document review) of specification and P8
IVV Proof:	System sizing P3 shall demonstrate or justify that the voltage deviations has no impact on required system performance and air ambient condition requirement are met. SDM P8 and component specification document for electrical consumers shall contain the range of voltage deviations.

MODEL BASED SYSTEM ENGINEERING (MBSE)

- **Capella (open source)**
  - Consolidate architecture (functional analysis and allocation to systems)
  - Check completeness and consistency of interfaces between systems
  - Use of state machines to describe some sequences of operation of the plant
- **3D model**
  - De-risk system integration in buildings
- **Engineering simulator**
  - Best estimate approach centered on Nuclear Island during Basic Design to study normal operation sequences (Startup and shutdown of the plant)

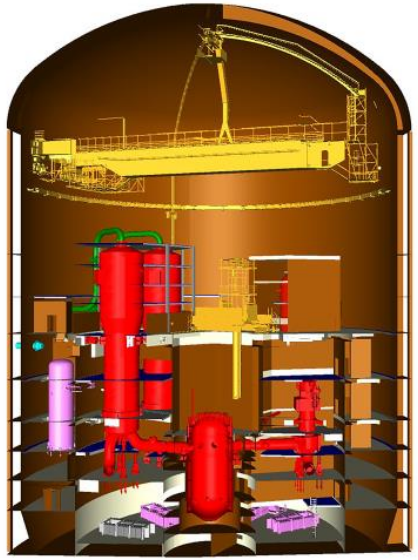


V&V STRATEGY – IVV METHODS AND TOOLS

- **In Basic Design IVV of a system is based on numerical models and documents, according to IVV plan issued during R phase**

- **Stepped IVV approach going upstream the PBS:**
  - Integration between components at elementary system level : managed by consistency checks in CAO tools and in PLM.
  - Integration between process systems and buildings: 2D/3D reviews between system architects and buildings architects
  - Plant IVV through safety studies and normal operation studies and simulation.

- **Verification through check lists that guidelines from transverse specialties are applied**



INTERFACE MANAGEMENT

Interface folder SSC1-SSC2

IF_0000138_[SSC1 hosts SSC2 equipment]

Interface Folder created by SSC_Leader

Interface folder designation
= refers to the type of interaction btw SSC1 and SSC2, either functional or non-functional
(ex: « SSC1 hosts SSC2 equipment», « SSC1 provides electrical Power supply to SSC2 », « SSC1 provides cooling water to SSC2", ...)

Architects involved :
- SSC1 : Server system
- SSC2 : Served system
- SSC_leader : super system common to SSC1 & SSC2

Content of interface folder IF :
- SSC1 Function involved (when existing)
- List of Interface Sheets (IS)
- IS validation schedule

IF_00039

SSC_Leader (Super-System)

… subsequently documented and validated by SSC1 and SSC2 Architects

SSC1 Architect SSC2 Architect

Interface Sheets
Interface specification data jointly produced and signed by involved architects

IS_0000172/A IS_0000491/A IS_0000514/A IS_0000826/A

avr.-16 juil.-16 oct.-16 janv.-17 avr.-17 juil.-17 oct.-17 janv.-18 avr.-18

Size & weights of SSC2 main equipment
Heat dissipations of SSC2 main equipment
Safety classifications of SSC2 main equipment
Size & weights of SSC2 secundary equipment

Increasing details of interface specification

Validation by Architects « Transaction » traced by a PLM workflow

SSC1 Architect SSC2 Architect

SSC1 Architect SSC2 Architect

IS derived in requirements applicable to SSC1 and SSC2 (or directly to impacted sub-systems if appropriate)

1NID 1NTI 1NBI 1NPP 1NHS 1NSR 1NOT

RQ_0001941 SSC1 Architect

Requirements on SSC1 and SSC2 derived from Interface_Sheet

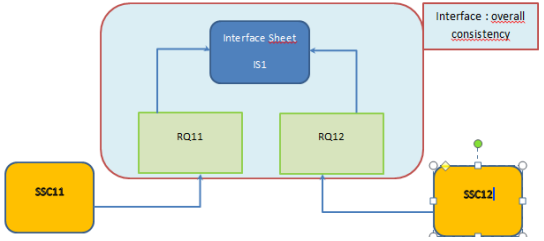
RQ_0002029 SSC2 Architect

.....

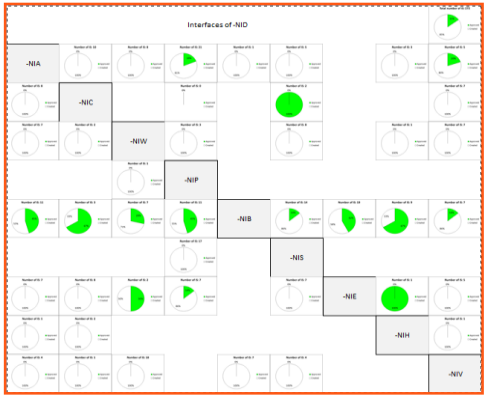
1NID 1NTI 1NBI 1NPP 1NHS 1NSR 1NOT

RQ_0003914

RQ_0003872



From Interface Sheet (IS) to Requirements (RQ) Derivation principles



Interface Matrix → Architect Dashboard
Progress status of interface specification (PLM report)

LARGE SCALE DEPLOYMENT OF SYSTEM ENGINEERING
LESSONS LEARNED, KEY SUCCESS FACTORS

A dedicated team **(Design Integration and Control)** empowered to support deployment of System Engineering :

- SE methodological framework documented by 40 + project instructions, engineering procedures and practical guidelines
- Coaching and field support to system Architects
- Supervision and sanity checks of requirements baselines
- Specification & testing of SE functionalities implemented in PLM platform

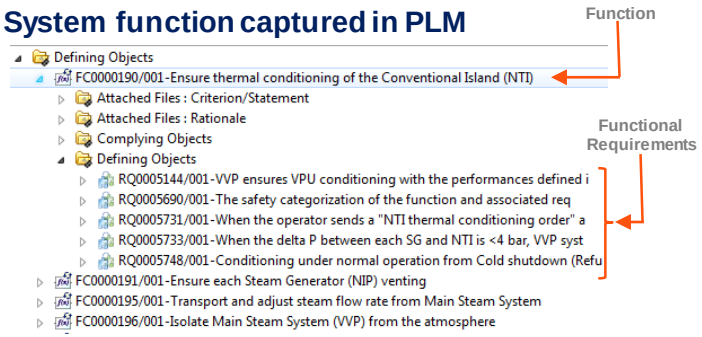
System Engineering Management Plan (SEMP)
Configuration Management Plan (CMP)
Interface Management Plan (IMP)
Documentation Management Plan (DMP)
Architecture guideline
Gate Reviews guidelines
3D Model Management procedures
IVV guideline
…

Engineering Manual - SE methodological framework

Key success factors :

- Training is essential to appropriation of SE methods and tools → more than 160 training sessions delivered to project contributors
- Network of “SE key users” to promote good practices at working level
- Gate Reviews (R, A, V) captured as progress milestones in project time schedule → powerful driver to align all stakeholders on common objectives
- PLM platform : SE-oriented functionalities including Gate Review management services, SRS (*) publication, SE dashboards, KPI and metrics, …

System function captured in PLM

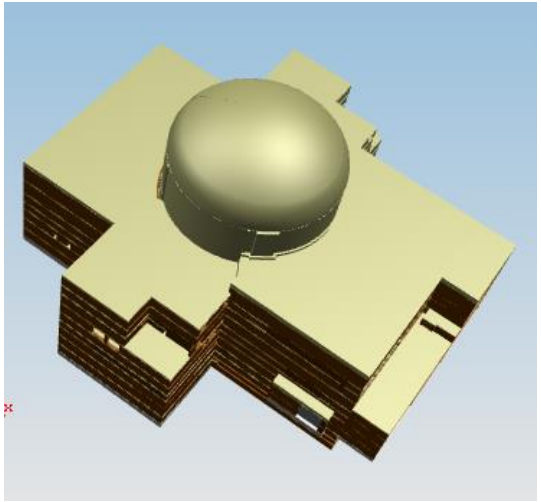


(*) Acronym for System Requirement Specification

UPCOMING CHALLENGES FACING EPR NM PROJECT
NEXT STEPS OF SE DEPLOYMENT

- **Transition from Basic Design to Detailed Design will require further developments of SE Methods and Tools**

- **New frontiers of SE deployment :**
  - Integrate multiple suppliers in SE methodological framework (design offices, equipment manufacturers, EPC contractors, …)
  - Complete RADIV process to address contracting, manufacturing, site construction and commissioning activities
  - Massive utilization of models/simulations to reinforce IVV capabilities
  - Sanity checks and quality improvement of functions and requirements baselines implemented in PLM
  - Transition to Detailed Design will mobilize approx. 2000 additional project contributors → large scale training and coaching program to enable appropriation of SE methods and tools



Nuclear Island Buildings
3D model at Basic Design stage