The Jules Horowitz Reactor
Centralized Instrumentation &Control Overview
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1 ABSTRACT /INTRODUCTION

In this paper, we give a short overview of the Jules Horowitz Reactor I&C, AREVA TA being both the designer and the provider.

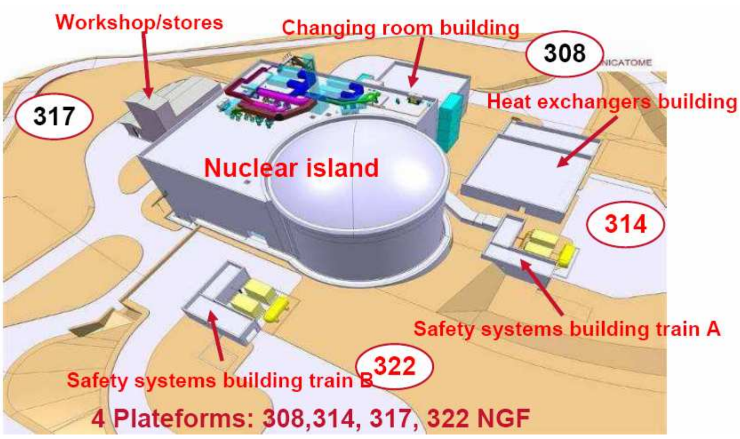
Before introducing the centralized I&C system itself, we will briefly explain the Jules Horowitz Reactor Project.

The second part gives an overview of the centralized I&C with explanations of the main functions this system has, the design drivers we have chosen, the automation and HMI sub systems included and a architectural diagram of the whole I&C system.

Finally, we will explain a few technical points such as the defence in depth, the architecture and technology of the reactor protection system, the ex-core flux measures and the problematic of qualification and durability.

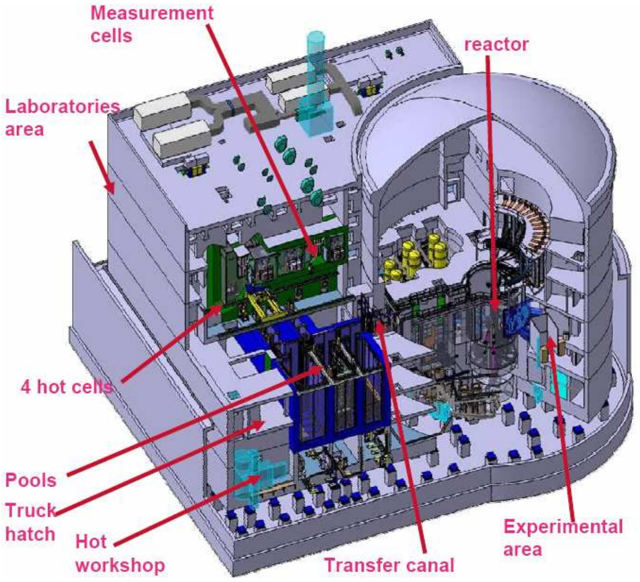
2 SHORT PRESENTATION OF THE JULES HOROWITZ REACTOR PROJECT

The Jules Horowitz Reactor is a nuclear experimental facility dedicated to irradiation experiments in support of generation II, III and IV technologies and may be even further with ITER.

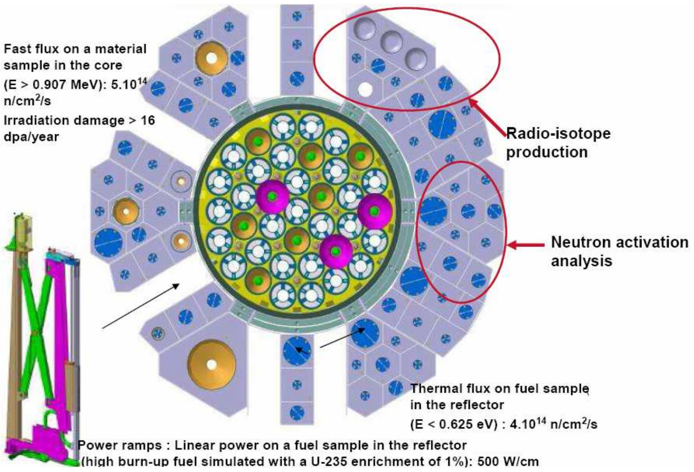


The JHR is also a reactor design to produce radioisotopes in the European area to replace the old Osiris reactor in France and to complete the HFR/Pallas reactor in Holland.

The reactor is a tank in a pool concept with a power of 100 MW with a large experimental area including an on line fission product laboratory, pool for intermediate storage and underwater benches. The nuclear auxiliaries building shelters hot cells, laboratories and various pools.



This Material Testing Reactor will be able to receive 25 simultaneous experiments with up to 10 incore ones.



The owner of this facility is CEA. The reactor is being erected on the Cadarache CEA site, near Aix en Provence in the south of France after the construction license was granted last year.

A prime contractor consortium with AREVA NP, EDF and AREVA TA, leaded by TA is supporting the CEA.

In 2009 the civil works package was awarded. By the end of 2010 most of the procurement packages will be notified for a first criticality at the end of 2014.

AREVA TA will be the supplier of the reactor unit package including the centralized instrumentation & control system.

3 OVERVIEW OF JHR CENTRALIZED I&C SYSTEM

Regarding the processes to control and monitor, the 4 main functions to perform are:

- A whole Reactor Control & Monitoring including the primary, secondary and tertiary cooling systems, plus various pool systems, the reactivity control system and safety systems.

- A Complete Centralized Monitoring for processes supplied with their own dedicated I&C Systems (Electricity and HVAC Utilities)

- A Synthetic Monitoring in the Main Control Room (MCR) & the emergency Control Room (ECR) for processes with their own dedicated control and local monitoring systems (Laboratories and Other Utilities (Radioprotection, Fire Detection, Handling, Effluents))

- A set of Standardized Interlock Functions between Experimental Devices and Reactor I&C for
    - The Safe Shutdown Orders from Experimental Devices (x25) to Reactor or from Reactor to each Experimental Device
    - The Preventive Reactor Shutdown due to incident on Exp Devices or Cutoff of Exp Devices Displacement Systems (x6)
    - The Transmission of Analogical Parameters from Reactor to Experimental Devices to give contextual data

Based on 25 years of experience in digital I&C Systems for nuclear reactors, AREVA TA designed JHR Centralized I&C with 3 main items in mind : **licensability, cost-effectiveness and durability**.

For a Material Testing Reactor, we took also into account the necessity of **evolutivity** regarding interfaces between the multiple and evolutional experiments and the reactor I&C system.

- For the first item, to make it easier to be **licensable**, which is in our point of view the fundamental item, we chose to :
    - Be fully compliant with international nuclear IEC standards (45A serie)
    - Re-use « Precertified » architecture and technology for Category A Automation Systems (referring to IEC 61226)
    - Implement a clear separation between Safety and Non safety systems with unidirectional links

- For the second item, we have based our approach of the **cost effectiveness** upon :

* a good balance between our own safety products and the best available Commercial Off The Shelf (COTS) ones.
* The use of only 2 safety categories rather than 3 (A & C regarding IEC 61226) to simplify and reduce the cost of qualification of the safety equipment.

- The third item, **durability** leans on 2 complementary pillars :
  * AREVA TA is the owner of the safety calculators' technology. We secure the durability of this solution by re-using the same standardized products for all the reactors we design. Of course we have strong commitment from our different customers including the JHR one to maintain these safety calculators for a long term.
  * We also improve durability using well established industrial Products (Sensors, PLC & SCADA) to take advantage of proven solutions in other industries when there is no specific nuclear requirement.

- The last item is essential for a Material Testing Reactor as JHR. We decided to improve **evolutivity** with :
  * A set of decentralized Remote Input/Output modules and large margin in racks and in cabinets for the Reactor I&C
  * Generic and Standardized Interfaces between Reactor and Experimental Devices to facilitate the implementation of these various experimental devices

To carry out all the functions with respect to these 4 design drivers, we have broken down the centralized I&C system into 5 automations and 3 HMI sub systems.

The tables in appendix 1 give a synthesis of the functionalities, the sizing and the technologies of these 8 sub systems.

The main point we'd like to underline is the strict separation between safety subsystems, used in accidental and post accidental situations, and the operational ones.

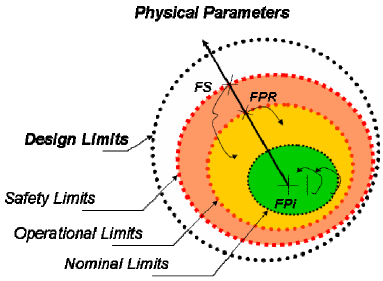
The appendix 2 shows the global architecture of the centralized I&C system.

4 FOCUS ON A FEW TECHNICAL POINTS

4.1 DEFENCE IN DEPTH FOCUS

Defence in depth is implemented to avoid a domino effect with a clear hierarchy of functions and systems.

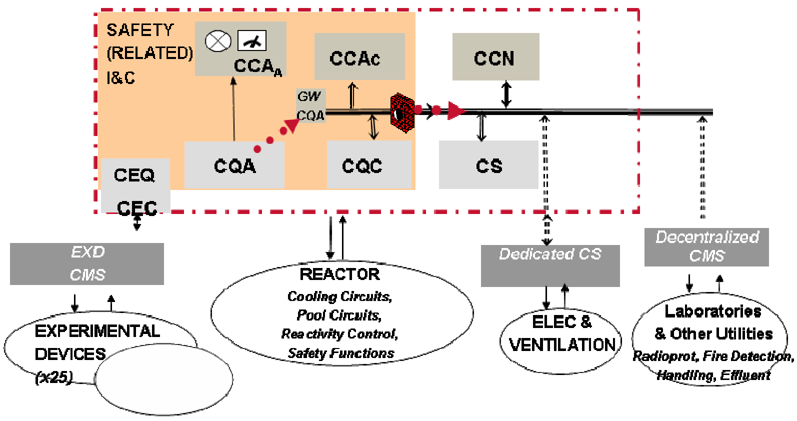
For automation we have 3 classes of graduated functions regarding the entropy from nominal situations.



The Pilot Functions (FPI) & the Preventive Function (FPR) are implemented inside the operational I&C systems (mostly CS automation system) to maintain the reactor within operational limits.
The Safety Functions (FS) are implemented in the safety systems (mostly the CQA one) to maintain the system within safety limits.

To improve this Defence in Depth, we have also decided to use only unidirectional Communication from higher to lower safety level Syst to limit stresses from lower safety systems to higher ones.

Note : In our point of view, it should also be easier, with this approach, to dialog with the safety authorities.



4.2 FOCUS ON CQA DESIGN OPTIONS AND TECHNOLOGIES

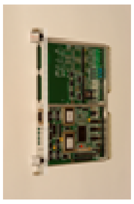
The CQA system is a **Category A** Safety system regarding IEC 61226 standard. To respect requirements of a system of such category we have designed the CQA :

- respecting the Single Failure Criteria with a Redundant 2 out of 3 architecture to allow a high level of safety and availability
- with Safety Oriented Failure Calculators to have a very high reliability level per channel
- with an evaluation of Common Cause Failure required by IEC 61226

With those design bases, we reach a probability of failure per demand for each safety function of 10^{-4} and 10^{-5} with functional diversity.

Based on our experience in digital safety systems, we've developed *PEGASUS**TM* *NR-S*, a System/HardWare/SoftWare mastered by TA and using commercial components (FreeScale -ex Motorola - processors, VME 6U format, rack EUROFER, FPGA ACTEL)

Each channel is organised around a CPU card called CSG organised in a dual software architecture.



As we have done for all the nuclear reactors we have designed recently, we propose this technology and architecture for JHR CQA.

4.3 FOCUS ON EX CORE FLUX MEASURES

To control Reactivity, we will use 3 groups of excore sensors :

- Triple redundant Starting Neutron Flux Channels – ND
  - To Monitor Reactivity and Protect Reactor from refuelling to Long Term Post Accidental Situations
  - To Start Reactor and Monitor Criticality (up to 1 kw)

- Triple redundant Power Neutron Flux Channels – NF
  - To Monitor Reactivity and Protect Reactor in power operations

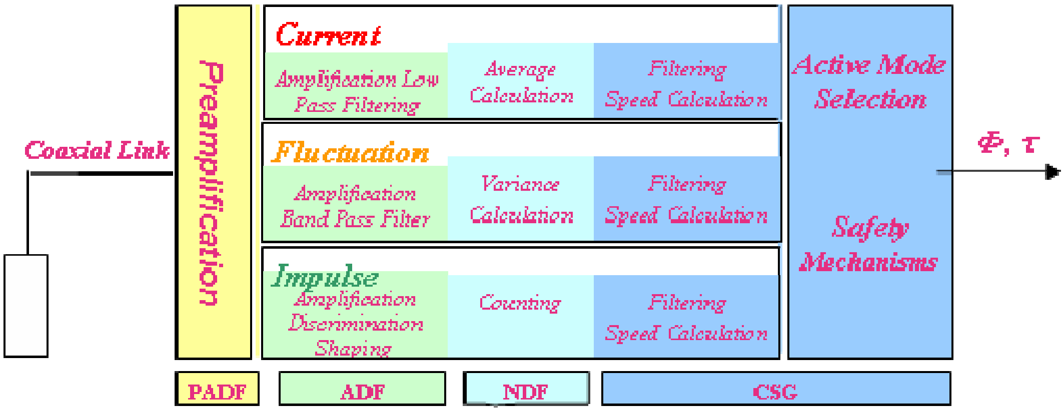
- Duplex Gamma Chains for Reactor Power Regulation to control Power Reactor with a set point from 10 % to full Power

To have wide range Neutron Channels we use :

- 4,5 decades Boron lined proportional Counter in pulse mode (CPNB64) for Starting Channels

- 10 decades fission Chamber (CFUL08) in 3 alternative modes : impulsion, fluctuation & current for Power Channels NF

- And Our own High Dynamic Digital Electronic with 12 decades range and automatic switching modes between current, fluctuation and impulse ones



4.4 FOCUS ON QUALIFICATION AND DURABILITY

Here, we look for a good balance between the nuclear requirements for safety functions and the well established Commercial Off The Shelf (COTS) solutions.

Based upon IEC 61226 Classification, for the JHR, we have decided to implement only 2 classes to limit the number of technologies to be qualified and to be maintained :

- Classes A : with integrated packages for harsh environment requirements
  - *PEGASUS TM NR-S,* System/HW/SW mastered by TA using commercial components (FreeScale, ex-Motorola processor, VME 6U format, rack EUROFER, FPGA ACTEL, etc.)
  - TA guarantees to maintain for a long time this critical technology and associated certification with a reasonable level of dependency from providers of components

- Classes C & NC : using good COTS technologies and solutions
  - Using the best of the market for PLC & SCADA
  - Keeping under control the strategic reactor application software

5 CONCLUSION

Based on 25 years of experience in digital I&C Systems for nuclear reactors, AREVA TA designed JHR Centralized I&C with 3 main items in mind : licensability, cost-effectiveness and durability.

Concerning the specific purposes of a Material Testing Reactor, we also took into account the necessity of the evolutivity of this class of reactor.

Finally, the solution we offer to our CEA customer is an efficient alliance between our own qualified safety digital solutions and good COST products.

We think it’s important to keep in mind that for a nuclear I&C system, safety licensing is still a main issue. Moreover, for an adaptable facility like a Material Testing Reactor, it will also be difficult to maintain the safety level during its whole life.

6 APPENDIX 1 : AUTOMATION & HMI SUB SYSTEMS

Sub system	Functions	Safety Cat	Sizing						Technologies
			DI	AI	DO	AO	Sensors	Actuat.	
CQA **Protection System**	Short Term Automatic Safety Actions and Monitoring of the Emergency Shut Down	A	120x3	15x3	60	20	**80x3**	**120**	Safety Calculator from AREVA TA in a 2oo3 Architecture. Each channel is organised around a CPU card called CSG organised in a dual software architecture.
CQC **Safety Related System**	Complementary automatisms for MT/LT accidental situations Complementary post accidental monitoring system including safety automatic actions monitoring, mitigation of hazards (seism) and availability of safety systems	C	1400x2	150x2	72	0	**180x2**	**130**	Industrial PLCs with RIO (Quantum from Schneider) with a strong separation from CS and unidirectional communication. 2 separate files to guarantee Single Failure Criteria
CEQ **Safety Interfaces with Exp Devices**	Safe Shutdown Orders from Exp Devices (x25) to Reactor or from Reactor to each Exp Devices	A							HW Relay Logic
CS **Operational System**	Automatisms in the normal and incidental situations	C & NC	1600	1000	500	30	**500**	**400**	Industrial PLCs with RIO (Quantum PLCs from Schneider in a HSBy architecture)
CEC **Operational Interfaces with Exp Devices**	Preventive Reactor Shutdown or Cutoff of Exp Devices Displacement Systems Trans of Analog Parameters from Reactor to Exp Devices	C							RIO modules with wired links between CEC and CS except for the transmission of parameters by a digital link from the reactor to the Exp Dev

Sub system	Functions	Safety Cat	Sizing	Technologies
CCA_A **Accidental HMI**	HW HMI for Monitoring the Safety Limits Thresholds and the Main Safety Parameters	A	20 to 30 Galvanometers 30 to 40 indicators lights 80 operator commands for CCA_A & CCAc	HW approach with Indicators, Galvanometers and a mediator module MIA to connect digital output of the triplex redundant CQA to these HW Galvanometers and Indicators
CCAc **Post Accidental HMI**	Digital Monitoring HMI & HW Commands Complementary to CCA_A for monitoring post accidental situations	C	2 VDU in MCR + 1 in ECR 60 accidental views	Digital Monitoring HMI and HW Operator Commands Developed by TA to improve digital HMI capabilities regarding safety requirements Based on VME HW for calculator and QNX OS with a set of graphical level C objects for SW application
CCN **Operational HMI**	Digital HMI in the normal and incidental situations	NC	11 VDU in MCR + 2 VDU in ECR + 1 Large Wall Screen 120 operational views	Industrial SCADA Panorama E^2 from CODRA with HSBy OPC Servers

7 APPENDIX 2 : JHR CENTRALIZED I&C ARCHITECTURE