SMR design and technology development in Argentina and Status of the construction of CAREM25 prototype

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Background

• Since the 1950s Argentina has developed and constructed research reactors. This activity was very successful and research reactors were or are been exported to several countries.
Background

• Argentina has 3 pressurized heavy water reactors (PHWR) NPP in operation.

• Participation of the local industry in the constructions was very important.

• In the 1980s Argentina has designed pressurized heavy water SMRs.
Background

- Argentina produce nuclear fuels for the NPP in operation and research reactors.
- Many Nuclear Fuel Cycle Plants were built.
- In the early 1980s Argentina developed uranium enrichment capabilities.
CAREM Project

- CAREM project consists of the development, design and construction of small NPPs based on integrated pressurized water reactors (iPWRs).

- This project allows Argentina to sustain activities in the NPP design and construction area, assuring the availability of updated technology in the mid-term. The design basis is supported by the cumulative experience acquired in research reactors design, construction and operation, and pressurized heavy water reactors (PHWR) NPP operation, maintenance and improvement, as well as the finalization of the Atucha-2 and the development of advanced design solutions.

- Aimed to export NPPs in a competitive market, like previous experience with Research Reactors.
COMPARISON: CLASSIC PWR / CAREM

CLASSIC PWR

CAREM
OPERATION OF A CLASSIC PWR

- Core
- Reactor Vessel
- Control Drives
- Recirculation Pump
- Pressurizer
- Condensed
- Steam Generator
- To Turbine
TRANSFORMATION: INTEGRATION OF THE SGs

- Control Drives
- Pressurizer
- Reactor
- Vessel
- Steam Generators
- Core
- Feedwater
- To Turbine
- Condensed
- Steam Generator
PRESSURIZER ELIMINATION

- Control Drives
- Reactor Vessel
- Core
- Steam Generators
- Recirculation Pump
- Pressurizer
- Self-pressurized
- Feedwater
- To Turbine
PUMPS ELIMINATION

Control Drives

Self-pressurized

Reactor Vessel

Feedwater To Turbine

Core

Steam Generators

Recirculation Pump
CONTROL DRIVES INTEGRATION

- Core Steam Generators
- Reactor Vessel
- Self-pressurized
- Feedwater
- To Turbine
- Control Drives
  - Integrated
  - Hydraulic Control Drives

CAREM25
CAREM Distinctive Features

- Integrated primary cooling system
- Primary cooling by natural circulation
- Self-pressurized
- Safety systems relying on passive features (36 hours grace period)
- The grace period can be extended by simple systems supported by autonomous systems that provide core and containment cooling and RPV and spent fuel pool refilling.
Developments - Hydraulic CRD Tests
Developments - Thermal Limits and CHF Tests

LP Freon Loop Test (+250)
HP Water Loop Test (25)
TH LAB IPPE (Obninsk-Russia)
Developments - Natural Circulation and Self-pressurization Assessment

A High Pressure Natural Convection Loop (CAPCN) was constructed and operated to produce data in order to verify the thermal hydraulic tools used to design CAREM reactor, mainly its dynamical response.

This is accomplished by the validation of the calculation procedures and codes for the rig working in states that are very close to the operating states of CAREM reactor.
Developments - Fuel Element

LOW Pressure Test Rig
Others Developments

• Critical Facility
• Manufacturing Processes
• Fuel Maneuvering Device (Refueling)
• Use of Product Lifecycle Management and Collaborative Software (3D CAD Design, Integrated Digital Mock-up, 3D Simulation Software, FEA, etc.)
AIMS OF THE PROTOTYPE

• To provide the design basis for the commercial CAREM NPP

• To facilitate the licensing process of the commercial CAREM NPP

• To generate developing abilities within the CNEA, its associate companies and the private industry in Argentina (supplier development)

• To facilitate export of NPPs in a competitive market, like previous experience with Research Reactors.
CAREM25 – BASIC PARAMETERS

• PWR type
• 32 MWe gross
• 100 MW core thermal power
• Integrated Primary System
• Natural circulation
• Self-pressurized
• Enriched UO$_2$ fuel
• Passive safety systems
• Operating cycle length of 14 months
CAREM Prototype Licensing

• Several activities have been performed to obtain the Construction Permits for CAREM Prototype.

• The use of the land is under the jurisdiction of the provinces. To concede this permit, the application authority of Provincia de Buenos Aires (OPDS) requires an Environmental Impact Assessment performed and signed by registered professionals. On the 11th October 2013 the OPDS issued a “Certificado de Aptitud Ambiental”.

• In December 2014, the Regulatory Body (ARN) has given authorization to start construction of safety-related buildings and containment structures (Stage 2 approval).
Feedback from Fukushima for CAREM -25

• Seismic requirements were reviewed

• Provisions were added to allow the extension of the grace period by simple systems, supported by the fire extinguishing system or an autonomous system (self-powered), that provide core and containment cooling and RPV and spent fuel pool refilling.

• Provisions were added for RPV lower head external cooling for in-vessel corium retention and for pressure suppression pool venting.
Defence in Depth and Safety Classification

• A methodology to address Safety Classification of Structures, Systems and Components (SSCs), in harmony with IAEA (SSG-30) and IEC 61226 was developed.

• Safety classification of SSCs is based on identification of low level safety functions (LLSF) –derived from the Fundamental Safety Functions (FSFs)- and safety functional groups of SSCs that fulfill those functions.

• Criteria for safety categories assignation to LLSF and classes to SSC are obtained from the way the principle of Defence in Depth (DinD) is internalized in the design to cope and mitigate the initiating events.
Strategy for implementing the DinD principle

- **DinD Level**
  - L2 (AOO)
  - L3A (PSiE)
  - L3B (PMFE)
  - L4 (PCMA)

- **Enhanced Process Systems**
  - Initial stage (grace period)
  - Final stage

- **Safety Systems**
  - Main Line of Protection (MLP: passive)
  - Diverse Line of Protection (DLP: passive)

- **Final Safe State Systems**
  - Systems (active)
  - Autonomous systems to extend the Plant Safe State

- **Plant Safe State**

- **Additional safety features to mitigate the SA**

- **Severe accident management**

**Time**

**Postulated Initiating Event (PIE)**
CAREM Prototype construction

- The hardware and software for the control system (SPPA-T3000) has been purchased.

- Local suppliers have been developed for CAREM.
CAREM Prototype RPV construction
CAREM Prototype turbine
CAREM Prototype site
CAREM Prototype construction
CAREM Prototype construction
CAREM Prototype construction
CAREM Prototype construction
CAREM commercial units

• Based on the prototype CAREM 25.

• Lessons learned.

• NA-SA has created a working group for SMR evaluation and is planning to join CNEA in future developments.

• Economies of Scale (the power of each reactor can be increased up to approximately 400 MWt each).

• Economies of multiple units (learning curve, costs reduction in owner’s cost, engineering, equipment and construction).

• Construction and commissioning in stages.
CAREM commercial units

• Early revenues due to electricity sales as the first unit starts
• Easier to meet the growing energy demand
• More flexibility to complement renewables energy sources.
• More flexibility to be adapted to site requirements
• Systems and components sharing.
• Flow assistance for higher power modules is also considered
CAREM 480 NPP

• Based on the prototype CAREM 25.
• Multi-reactor NPP.
• It is comprised of 4 reactors of about 400 MWt each.
• Each reactor has its own containment.
• The lay-out for each containment will be based on the CAREM 25 but it will have some differences due to improvements in the design of systems related to nuclear safety.
• Increased power of each reactor (economy of size).
• Shared systems and components.
• Construction and commissioning in stages.
• Optimization of the safety design.
CAREM 480 NPP

- Two parallel nuclear buildings.
- Each of them will house two reactors with their corresponding containments, a spent fuel pool between them and the nuclear systems of both reactors.
- The auxiliary building will be located between both nuclear buildings. It will house shared systems and services, the main control room, the auxiliary control room and the administrative offices.
- One BOP with two turbine-generators, each with the capability of processing the steam coming from two reactors.
- More flexibility to complement renewables energy sources.
Financial aspects of CAREM 480 NPP

Fuel Cycle Cost from 7 to 10 U$S/MWh

LCOE from 70 to 90 U$S/MWh

The overnight cost per installed kW shall not be higher than USD 5000, approximately like a PWR.

The above mentioned values in the table correspond to a FR of 10% during a period of 30 years.

We are currently working on the calculations models to analyze the financial benefits of some changes based on the experience gained from the prototype.

Simultaneously, the financial database is being updated by gathering the prototype construction real values and optimized construction costs.
THANK YOU FOR YOUR ATTENTION

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