Agenzia nazionale per le nuove tecnologie,
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MINISTERO DELLO SVILUPPO ECONOMICO

Ricerca di Sistema elettrico

Valutazione dei costi per la realizzazione della configurazione originale della Facility SPES-3 presso la SIET - parte A

Sara Boarin, Marco E. Ricotti

Report RdS/2013/069

VALUTAZIONE DEI COSTI PER LA REALIZZAZIONE DELLA CONFIGURAZIONE ORIGINALE DELLA FACILITY SPES-3 PRESSO LA SIET - PARTE A

Sara Boarin, Marco E. Ricotti (POLIMI)

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Report Ricerca di Sistema Elettrico

Accordo di Programma Ministero dello Sviluppo Economico - ENEA
Piano Annuale di Realizzazione 2012
Area: Produzione di energia elettrica e protezione dell'ambiente
Progetto: Sviluppo competenze scientifiche nel campo della sicurezza nucleare e collaborazione ai programmi internazionali per il nucleare di IV Generazione
Obiettivo: Sviluppo competenze scientifiche nel campo della sicurezza nucleare
Responsabile del Progetto: Felice De Rosa, ENEA

Il presente documento descrive le attività di ricerca svolte all'interno dell'Accordo di collaborazione "Sviluppo competenze scientifiche nel campo della sicurezza nucleare e collaborazione ai programmi internazionali per il nucleare di IV generazione"
Responsabile scientifico ENEA: Felice De Rosa.
Responsabile scientifico CIRTEN: Giuseppe Forasassi

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POLITECNICO DI MILANO

Department of Energy

Nuclear Reactors Group

Valutazione dei costi per la realizzazione della configurazione originale della Facility SPES-3 presso la SIET - parte A

Autori

Sara Boarin

Marco E. Ricotti

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Progetto B.3.1 "Sviluppo competenze scientifiche nel campo della sicurezza nucleare e collaborazione ai programmi internazionali per il nucleare di IV generazione

Indice

Summary

The aim of the present document is to inform about the realization status of a unique facility at SIET labs in Piacenza, and to report about its strategic potential value in the nuclear community, with reference to the Small-Medium Modular Reactors (SMRs) market segment. The latter is gaining increasing interest worldwide. The contributors to this document (hereafter, the "Contributors") are companies that are still active in the nuclear sector as international suppliers and service providers; in this panorama and through the SPES-3 project, the Italian industry might assume a significant role in this sector, as an integrated supply system, presenting and offering a comprehensive set of capabilities, from the experimental campaign to the industrial development and manufacturing. The completion of the SPES-3 facility would prove this organic set of competencies; the financial effort would be compensated by the sale of services open to the worldwide industry of the SMRs, concerning the experimental campaign on the thermo-hydraulics effects and accident simulation.

Introduction

A significant and worldwide recognised effort has been produced in the last years in the field of Small-Medium Modular Reactors (SMRs) by Italian companies and research institutions, with the support of the Italian Ministry of Economic Development, in the framework of the Research Agreement (Accordo di Programma) between the Ministry and ENEA.
In particular, the design and construction of a large scale testing facility (SPES-3) has been pursued, aiming at investigating and demonstrating the safety features and the dynamic behaviour of the of integral PWRs (iPWRs), i.e. the most advanced SMR concept, currently under development at industrial level in several countries, especially in US.
The completion of the construction and the operation of the SPES-3 facility by Italian industries, could offer a significant contribution to the understanding and demonstration of the iPWR concept, at international level. Most of all, it could offer a great visibility to Italian companies in the international SMR market that could develop in the next years.

1 International framework

Global activity supporting SMR design and technology development for near-term deployment has emerged as an important new paradigm. SMRs are under development for all principal reactor lines, i.e. water cooled reactors, liquid metal cooled reactors and gas cooled reactors. Worldwide, 131 SMR units are in operation in 26 Member States, with a capacity of 59 GWe. At present, 14 SMRs are under construction in 6 countries: Argentina, China, India, Pakistan, the Russian Federation and Slovakia. Research is being carried out on approximately 45 Advanced SMR concepts for electricity generation, process heat production, desalination, hydrogen generation and other applications in 10 Member States. These include Argentina, Canada, China, France, India, Italy, Japan, Republic of Korea, Russian Federation, South Africa, and United States of America.
In particular, light water cooled SMRs are being developed in Argentina, China, France, Republic of Korea, the Russian Federation and, last but not least, the USA where several SMRs are under development. The Department of Nuclear Energy announced a second round of competition for the SMR licensing technical support programme. According to the DOE, this solicitation would share the US$452 million funding allocation with a previous award made in November 2012. This competition targets SMR designs planned to be operable by 2025, three years later than last year's competition. These include the mPower, which envisages a deployment of twin 180 MW(e) modules in Clinch River, Tennessee; the NuScale that aims for one nuclear power plant made up of twelve 45 MW(e) modules; the W-SMR, a 225 MW(e) pressurized water reactor (PWR) that uses passive safety systems and components with proven performance from the AP1000 and the SMR-160. The first two are scheduled to be submitted to the US Nuclear Regulatory Commission (NRC) for design review in 2014. All four US reactors are integrated PWRs. The mPower has received an award in the first round of DOE solicitation in April 2013.
In Argentina the CAREM-25 reactor, a 27 MWe prototype for an eventual 150-300 MW(e) reactor, has been developed with all primary components located inside the reactor vessel. Civil works for the construction of the CAREM-25 prototype reactor started in 2012 at the Atucha site and the reactor is scheduled to be commissioned in 2016. The construction of a larger plant,

adopting the CAREM-25 design but with >150 MWe capacity, is envisioned for a site in Formosa Province. China has also developed pressurized light water cooled designs of 300 MW(e) and 600 MW(e) reactors. Three CNP-600 units are under construction while two CNP-300 units are under construction in Pakistan. Recently, China has also announced its own small PWR integral design, called ACP100, which is likely to be deployed at a site in Fujian Province within a few years. In July 2012, the Korean Nuclear Safety and Security Commission issued the Standard Design Approval for the 100 MWe SMART reactor design. SMART has a thermal capacity of 330 MW and is planned particularly for electric power and seawater desalination. The Russian Federation has deployed many VVER-440 units and is developing several VVER designs in the SMR category. In addition, two smaller units of the KLT-40S series are near completion and are to be mounted on a barge and used for the cogeneration of process heat and electricity. The development of the KLT-40S series was based on experience with reactors used to power icebreakers.

In Europe, two years ago, France set up a national consortium grouping utilities (EdF), vendors (Areva, DCNS) and research bodies (CEA), to explore and evaluate the SMR potential market and the most suitable SMR technologies and concepts. After two years of work, a final report has been delivered to the Prime Minister for a strategic evaluation and possible political actions.

In particular, DCNS company is developing the FlexBlue design, which is a small subsea nuclear power plant with an output rating of 160 MW(e). Its development is based on extensive reactor operating experience in submarines.

Besides the French organisations, also UK is looking at the SMR option. Recently, Rolls Royce joined the US NuScale team, to support the development of the reactor.

Following the French example, also Italian organisations are discussing the possibility to create an "Italian SMR Working Group", to exploit the huge experience on SMRs, developed in the last decade around the IRIS project and to open possible European and international collaborations. The group could involve utilities, research bodies, universities, manufacturers and system integrators.

At international level, a strong and constant effort is provided by the International Atomic Energy Agency (IAEA), to support the sharing of knowledge about SMRs between the countries that are developing SMR designs and the several countries (especially the "newcomers", from South America to Africa to Middle East to Far East) that are interested in the SMR option for a possible deployment within the next decade.

Among the several activities of the IAEA in the field of advanced SMRs, it is worth citing:

- The organization of Workshop and Technical Meetings, such as the *Workshop on SMR Technology Assessment for Near-Term Deployment* conducted in December 2011 and the *Technical Meeting on Technology Assessment of Small and Medium-sized Reactors (SMRs) for Near Term Deployment* , hosted by China in September 2013;
- The dedication of a specific INPRO Dialogue Forum on Global Nuclear Energy Sustainability in July 2013 to *Licensing and Safety Issues for Small and Medium Sized Reactors (SMRs)*, with the participation of 97 delegates from 40 countries;
- The activity to incorporate lessons-learned from the Fukushima accident into an SMR technology assessment on the design of engineered safety features, started in June 2012;
- The preparation of a number of Nuclear Energy Series Reports like: i) *Approaches for Environmental Impact Assessments for Advanced SMRs,* in collaboration with nuclear regulatory authorities in leading nuclear countries; ii) *Options to Enhance Energy Supply Security using Hybrid Energy Systems based on SMRs – Synergizing Nuclear and Renewable Energies*, being developed in cooperation with the European Commission (EC-JRC) and INPRO; iii) *Options to Incorporate Intrinsic Proliferation Resistance*

Features into NPPs with Innovative SMRs and their Associated Fuel Cycle, aimed at harmonizing the methods developed by the INPRO and the GIF on proliferation resistance and physical protection;

- The development of a Toolkit for SMR Technology Assessment on the Reliability of Engineered Safety Features;
- A Coordinated Research Project (CRP) on the Development of Methodologies for the Assessment of Passive Safety System Performance in Advanced Reactors, completed in July 2012. The main objective of the CRP was to determine a common method to analyse and test the reliability of passive safety systems. It is worth mentioning that in the completed four-year CRP, **natural circulation tests were performed in Italy**. The test data were used to benchmark the capability of several thermal-hydraulic codes to simulate the flow behaviour in the test apparatus.

Finally, as a supplement to its Advanced Reactors Information System (ARIS), the IAEA published a booklet on *Status of Small and Medium Sized Reactor Designs* in September 2011 and November 2012.

In Europe, on February 2013, the new "Strategic Research Agenda" (SRA) was issued, that provides development and demonstration road maps to achieve the short (2015), medium (2020) and long term (2040-2050) goals of Strategic Energy Technology Plan, targeting Europe's transition to a low-carbon energy mix. In the SRA, SMR are mentioned as "*advanced reactors, sized for smaller generated thermal power and modular construction techniques, aimed at achieving long term operation, enhanced economics and safety*".

The reference made in the SRA, acknowledges for the first time in Europe, a specific role for the advanced SMR technology, particularly, but not limitedly, to the cogeneration applications.

The Strategic Research Agenda is the result of the contribution of nearly 100 scientists and engineers from the member organisations of SNETP, The interest of the SNETP stakeholders and in particular, members from the industry, suggests the possible involvement in specific activities in the SMR field.

2 Strategic issues and goal of the SPES-3 project

The SPES-3 (Simulatore Per Esperienze di Sicurezza) facility was originally conceived as an integral test facility, modeling the primary, secondary, containment and safety systems of the IRIS reactor (International Reactor Innovative & Secure). The IRIS is an integral modular medium-sized PWR, which has been under development by an international consortium with approximately 20 partners. The design of the SPES-3 was related to the licensing process by the U.S. Nuclear Regulatory Commission and the requirement of a series of experimental tests, to verify the behavior of the new plant and its safety system capabilities to cope with postulated accidents.

The building of the SPES-3 integral test facility started in 2007 at SIET (Società Informazioni Esperienze Termoidrauliche) laboratories in Piacenza, under the sponsorship of the Italian government and the coordination of ENEA.

Nowadays, the SPES-3 has reached an advanced completion state (chap.5). Further efforts would provide a valuable and unique asset in the worldwide panorama, with the capability to support the experimental campaign of GEN III+ passive safety based small-modular PWR.

Actually, beyond its original goal, the SPES-3 facility is suitable to reproduce and simulate the behavior of the primary, secondary and containment systems of generic integral PWR Small-Modular Reactors.

The SPES-3 represents an "open" facility, not bound to any specific reactor design, able to perform experimental campaigns on both integral and separate effect tests and investigate the thermal hydraulic interaction among the various systems. The SPES3 facility experimental data provide a qualified data-base for the accident analyses and simulation code assessment. This would provide early experimental evidence on the thermodynamic behavior of new reactor designs and consolidate the reliability of preliminary code-based simulations. Based on the experimental evidence, the Developer might apply the necessary design modifications, improvements and detailed engineering, before the eventual further investment effort in a dedicated simulation facility for the final design approval.

The facility configuration of the SPES-3 is suitable to investigate the natural circulation loops that allow removing the decay heat during the long-term accidental transients.

The test capabilities of the SPES-3 facility are summarized in Tab.1. Separate effect tests are devoted to investigate and characterize the heat transfer of innovative components like the helical coil SGs and the EHRS heat exchangers for long-term decay heat removal. Integral tests are devoted to investigate the general behavior of the system, the primary and containment dynamic interaction during accidental transients, the effectiveness of the Engineered Safety Features, the reactor capability to cope with postulated accidental transients.

Test type	Break	Purpose	Notes
Lower break	SBLOCA: DEG and SPLIT break of DVI	Verify the dynamic coupling between primary system and containment; the maximum containment pressure, the RPV mass and core temperature	All safety systems available except for a single failure on an ADS train
Upper break	SBLOCA: DEG break of EBT to RPV line		
ADS break	SBLOCA: DEG break of ADS single train		Maximum PRZ steam space break
FL break	DEG break of FL	Verify the plant response to non-LOCA events	Partial EHRS actuation
SL break	DEG break of SL		
Safe Shutdown sequence	Loss of all power	Verify the safe-shutdown sequences	Investigate the primary coolant shrinkage, natural circulation, EHRS HX cool-down capability

Tab.1 – Test matrix summary and main goals

All the worse LOCA cases may be simulated: 1 inch equivalent DVI split break; 2 inch equivalent DVI DEG break; 4 inch equivalent EBT to RPV balance line DEG break; 6 inch equivalent single train ADS DEG break. Secondary side line breaks such as the 12 inch equivalent FL DEG break and the 16 inch equivalent SL DEG break are also included in the test matrix.

The Design Basis cases verify the whole system response and mixture level in the core. The Beyond Design Basis cases assess the cooling capability of the plant with the contemporary failure of some emergency safety system.

The SPES-3 is conceived and equipped with modular components, dimensioned in a way to simulate different power sizes.

As an example, one of the three helical coil SGs has double power than the two others. During simulation one or two SGs can be isolated to investigate the behavior of the remaining ones. ADS as well, are simulated in SPES-3 by a single and a double train.

This gives flexibility to simulate different PWR power sizes and configurations, increasing its scope of application to different SMR designs under development.
The potential interest of SMR developers in such a valuable opportunity is undeniable.
On the other side, the SPES-3 facility may be the “Demo” project to show the capability of Italian manufacturers to fabricate qualified component and organize a comprehensive integrated supply system. The Italian industry would prove able to supply a comprehensive set of subsystems for the nuclear island, with the capability to run experimental campaign; this offer-package would represent a competitive edge against other international competitors of this industry.
This would enable the Italian industry to compete on an international level to the supply of the SMR technology, that undeniably will be assuming increasing relevance in the nuclear new build, worldwide.

3 Strategies for the valorization of SPES-3 facility

Once the SPES-3 facility will be completed and ready to be operational, different actions will be put in place to value that important effort:

- at IAEA level, the opportunities offered by the Agency on SMRs (technical and consultancy meetings, workshops, forums, etc.) will be fully exploited, to let the technology-holder countries as well as the newcomer countries to know about the possibility to use the SPES-3 facility for experimental campaigns, thus having access to the corresponding SMR knowledge development and sharing;
- at European level, specific contacts with the French consortium, the UK organisations and other organisations and companies of European countries interested in the SMRs will be carried out, possibly by means of the rising Italian Working Group on SMRs; the possibility to open an Euratom R&D programme devoted to SMRs will be proposed and discussed;
- at international and national level, the Italian Working Group will be involved, both to participate to and support the completion of the SPES-3 facility, and to exploit the facility as a key asset and a marketing sample of Italian competences and capabilities, in the exploration phase for possible collaborations with technology-holder companies, utilities and newcomer countries.

The main targets of the valorization actions will be:

- the newcomer countries, interested in SMR deployment and in developing and acquiring specific knowledge on the SMR-iPWR concept;
- the Nuclear Safety and Regulatory Authorities of the technology-holder countries, interested in developing knowledge and validating codes through experimental data, to support the licensing process of SMR-iPWRs;
- the technology-holder companies, interested in experimental data to support their design efforts.

An international scientific advisory board could be established to manage the SPES-3 facility, to select and prioritise the proposals of experimental campaigns.
A funding contribution to be asked to the organisations and countries interested in the SPES-3 facility could be in the range of 500K€ per experimental campaign, including typically a test preparation, a pre-test analysis, 3 experimental tests, a post-test analysis. In case of shared

experimental campaign hence shared contribution, the corresponding quote per participant would be affordable even for the newcomer countries.

4 SPES-3 facility description

The SPES-3 is an integral test facility that simulates the primary, secondary and containment systems of an integral PWR, as well as its safety/auxiliary systems.

(i) the primary system includes the Reactor Pressure Vessel with its power channel, circulation pump, pressurizer. The thermal power is provided by a 235 rod bundle, through Joule effect;

(ii) the secondary systems up to the Main Steam Line Isolation Valve, includes three Steam Generators with helical coils (loop A and B; loop C with double power as compared to A and B);

(iii) the containment system includes the Dry Well, the Quench Tank, the Reactor Cavity, the Pressure Suppression System;

(iv) the safety system includes the Emergency Heat Removal System with the Refueling Water Storage Tank, the Emergency Boration Tank, the Automatic Depressurization System, the Long-term Gravity Mitigation System e Direct Vessel Injection;

(v) the non-safety systems includes the Start-up Feed Water, steam lines and auxiliaries.

Compared to the design reference (an integral PWR, 300-350MWe and 1,000 MWth), the facility has a full height scale (30 m) and 1:100 volume scaling factor. The following ratios were also preserved as in the original reactor design: power-to-mass flow of the coolant, power-to-volume, transit time of the coolant, average thermal flows and pressure, temperature, enthalpy of coolant.
The coolant fluid is water. The design pressure of the primary and secondary systems up to the main isolation valves is 17.25MPa with its corresponding saturation temperature of 353◦C. The primary and secondary side operating pressure is 15.5MPa and 5.8MPa, respectively. The containment design pressure is 1.5MPa with its corresponding saturation temperature of 198°C.
The SPES-3 is equipped with more than 600 control instruments and a data acquisition system to elaborate the incoming signals from the process and tests; it has a specific-designed regulation & control system.
Figure 1 and 2 show the SPES-3 layout and general view; a detailed view of the Reactor Vessel is given in Fig.3. A full and detailed description of the facility is provided in (1), (2), (3), (4), (5).

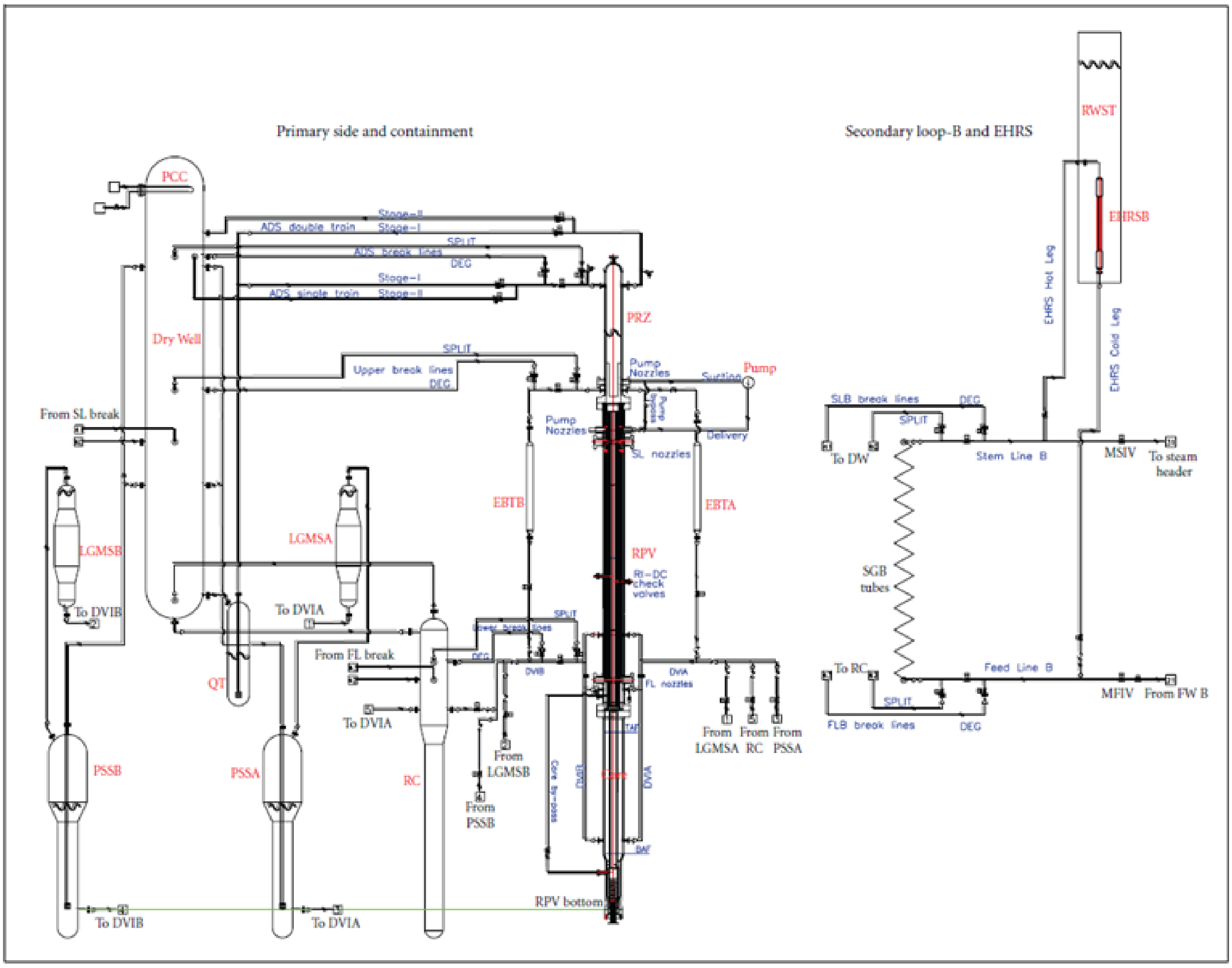


Fig.1 – SPES-3 Layout

Nomenclature:

ADS: Automatic Depressurization System
DC: Downcomer
DEG: Double Ended Guillotine
DVI: Direct Vessel Injection
DW: Dry-Well
EBT: Emergency Boration Tank
EHRS: Emergency Heat Removal System
FL: Feed Line
FW: Feed Water
LGMS: Long-term Gravity Make-up System
LOCA: Loss Of Coolant Accident
LP: Lower Plenum
MFIV: Main Feed Isolation Valve
MSIV: Main Steam Isolation Valve

PCCS: Passive Containment Cooling System
PRZ: Pressurizer
PSS: Pressure Suppression System
PWR: Pressurized Water Reactor
QT: Quench Tank
RC: Reactor Cavity
RCCA: Rod Cluster Control Assembly
RCS: Reactor Coolant System
RI: Riser
RPV: Reactor Pressure Vessel
RV: Reactor Vessel
RWST: Refueling Water Storage Tank
SL: Steam Line
SG: Steam Generator

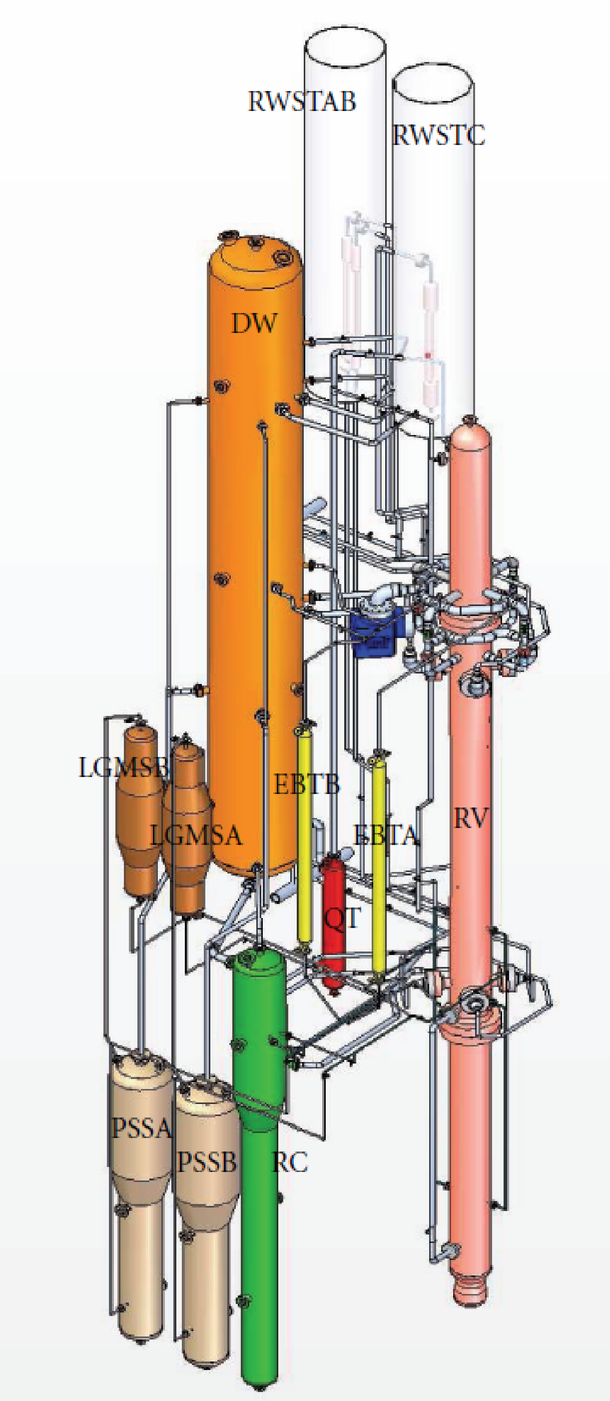


Fig. 2 SPES-3 general view

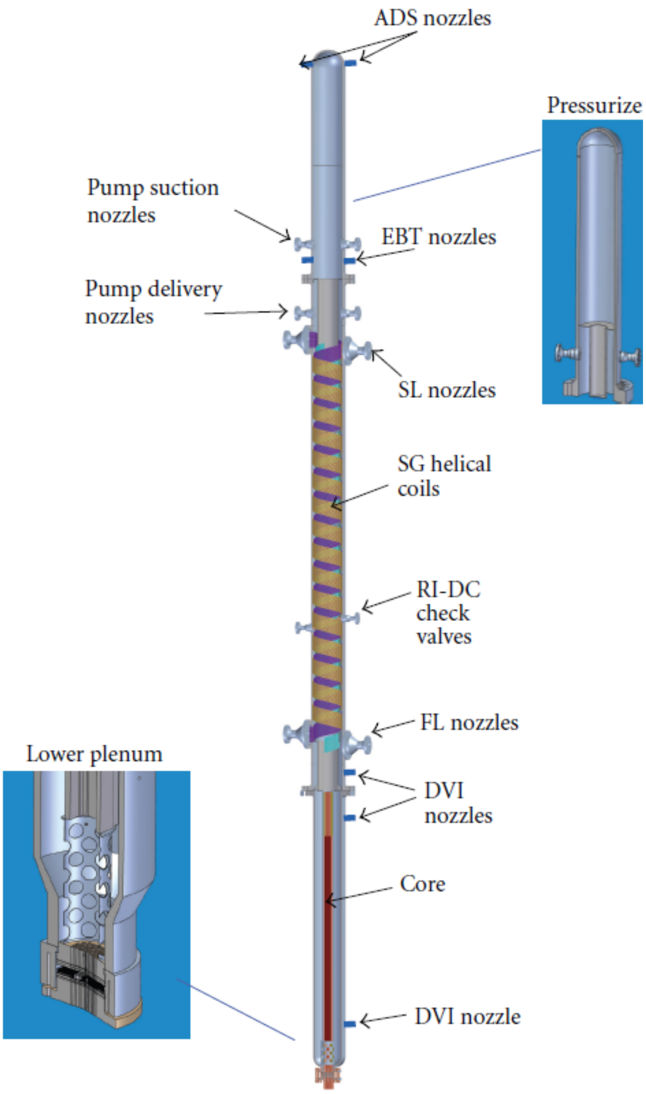


Fig.3 Detailed view of the RV

5 Status of SPES-3 facility and completion level achieved

As of today, the SPES-3 facility is in advanced state of completion. The following activities have been accomplished:

(i) design of all the systems ;
(ii) site preparation;
(iii) arrangement of the retaining structure and handling equipment (crane)
(iv) fabrication and installation of the containment equipment
(v) fabrication and installation of the pools and the Emergency Heat Removal System (EHRS);
(vi) fabrication and installation of the Emergency Boration Tank (EBT);
(vii) supply and installation of the electric equipment for the power channel (switches 130 kV, transformers 130/3 kV, switches 3 kV);
(viii) revamping of two power units (4 MW and 8 MW) used as direct-current generators for the power channel rod bundle;
(ix) supply and installation of components of the control system (PLC);
(x) qualification tests of prototypes for the heating rods used in the power channel,
(xi) performed in a test plant designed and built on-purpose;
(xii) special instrumentation developement tests for the measurement of the two-phase flows.

A summary of the total cost incurred during the period 2006-2012 is provided in Tab. 2 and amounts to 8.4 M€. The cost of "Design, quality, analysis and calculations" represents 2.8 M€.
In the experimental development phase, the testing of the heating rod bundle has to be highlighted as a critical activity: the sensitivity of this component in the whole project requires high reliability. The rod bundle are a special component designed and fabricated on purpose. Experimental campaign revealed some criticalities from the point of view of the electrical isolation and provided data and information for proper design requirements; its total cost was 498,340 €. Supply, assembly and plant installation represent 42% of total cost (i.e.3.5 M€; Fig. 4). The realization of the support structures for the facility represented a significant cost item, due to the relevant weights and volumes concerned.

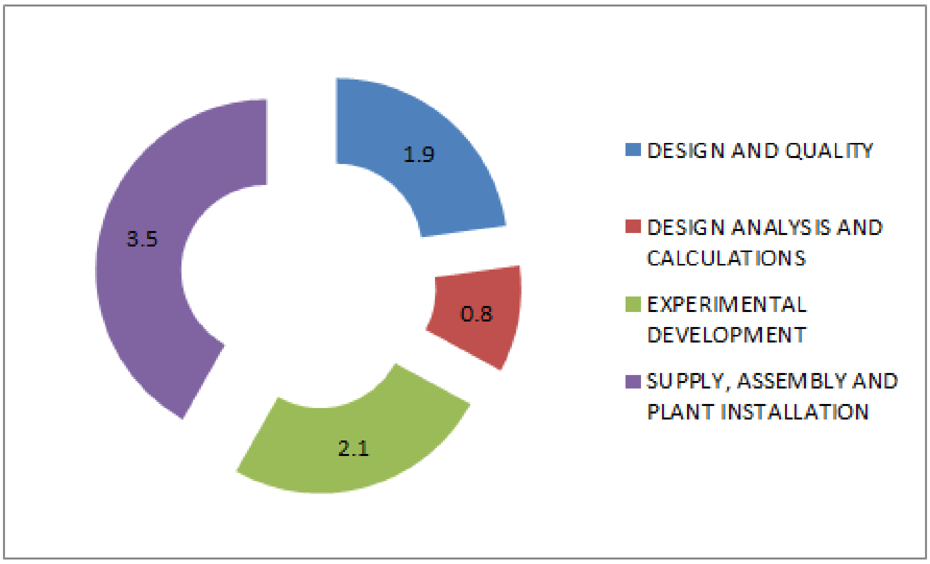


Fig. 4 – Breakdown of total cost of the SPES-3 facility (M€)

Activity	cost (€)
DESIGN AND QUALITY	
conceptual design of plant	455,000
quality plan	76,000
engineering design of plant	577,000
engineering design of power channel	357,900
design review of plant	223,080
design review of piping	102,000
studies for completion of SPES-3 facility	119,090
sub-total 1	**1,910,070**
DESIGN ANALYSIS AND CALCULATIONS	
test specifications and experimental matrix	31,000
pre-test analysis as support to design	327,000
IRIS project follow-up	149,120
analysis and validation activities related to the IRIS project	138,896
analysis and validation activities related to the SPES-3	200,000
sub-total 2	**846,016**
EXPERIMENTAL DEVELOPMENT	
design and realization of heated thermocouple probe for speed measurement	30,000
identification and qualification of instrumentation for thermo-fluidodynamic measurements	60,000
selection of special instrumentation	171,760
design and realization of test circuit for the heated rod bundle	575,000
design of capacity probe for bi-phase fluid	84,000
experimental campaign of rod bundle 1st step	288,340
development of special instrumentation	261,244
experimental campaign of rod bundle 2nd step	210,000
realization and test of capacity probe	265,000
realization and test of spool piece	170,910
sub-total 3	**2,116,254**
SUPPLY, ASSEMBLY AND PLANT INSTALLATION	
auxiliary systems: 1st phase	341,600
removal of existing equipments and site preparation	188,000
support structure realization	841,662
auxiliary systems technological up-date	301,120
supply, installation and setup of tanks	917,326
supply, installation and setup of power station's transformer	711,721
supply of auxiliary equipment and miscellaneous instrumentation	77,000
installation of auxiliary equipment and miscellaneous instrumentation	123,000
sub-total 4	**3,501,428**
TOTAL (including VAT)	**8,373,768**

Tab. 2 – Summary of total cost incurred up to date for the realization of the SPES-3 facility

6 Budget estimation for SPES-3 completion

The completion of the SPES-3 facility requires the following main activities:

(i) supply of the heating rod bundle for the simulation of the reactor core;
(ii) fabrication and installation of the power channel, including the internals and the coil Steam Generators;
(iii) supply and installation of the primary loop pump;
(iv) supply and installation of the piping and valves;
(v) supply, installation and wiring of the instrumentation and of the data acquisition/processing system.

This chapter summarizes the financial effort necessary to complete the SPES-3 facility which is estimated in terms of "commercial value" of the equipment and activities.
The budget perimeter excludes the calibration of the instrumentation, that is considered as an activity specific to the commissioning phase, and the eventual special instrumentation for bi-phase flow measurements. Table 3 shows the estimated value of the equipment and activities necessary for the SPES-3 completion.

Sub-system/component	value (€)
power channel	3,500,000
heating rod bundle	2,645,000
primary pumps	313,000
piping & fittings	159,000
valves	461,000
piping & valves installation	252,000
instrumentation	926,702
data acquisition system	278,522
TOTAL (excluding VAT)	**8,535,224**

Tab. 3 – Summary of total budget for the completion of the SPES-3 facility

The equipment supply is detailed as follows:

Power channel. It is a pressure vessel in stainless steel with 23 m height and 0.76 m maximum external diameter. It is made of three parts: the lower part houses the heating rod bundle; the intermediate hosts the steam generators and the upper part represents the pressurizer. The supply includes: includes pressure vessel, steam generators, pressurizer, internals (excluding heating rod bundle), sealing and spacing grid for the rod bundle, primary pump piping)

Heating rod bundle. The supply includes 235 rods + 15 spare with total power of 6,500 kW; rods have lengths of about 7.8 m and are made of Inconel with heating electric wire in Monel/Inconel and boron nitride as insulator; 120 thermocouples are mounted on 30 rods

Primary pumps. Two pumps in series, working at high temperature (~ 330 °C) and suction pressure (~ 155 bar).

Piping & fittings. Stainless steel piping (452 m) with 3/8" ÷ 8", sch. 40-80-160. Fittings: num. 756 flanges, tees, bends, ecc. with 1/2" ÷ 8", ANSI 300-600-2500, sch.40-80-160. the piping of primary pump is accounted in the "power channel" item
Valves. Stainless steel, num. 136 valves: taping, regulation, safety, non-return. Size 1/2" ÷ 4". Rating: ANSI 300-2500

Instrumentation and data acquisition system. It provides the measurement of 601 parameters: pressure (182), temperature (255), mass flow (58), electric parameters (13), angular and linear displacements (93). The data saving and elaboration requires the capability of managing 768 channels.

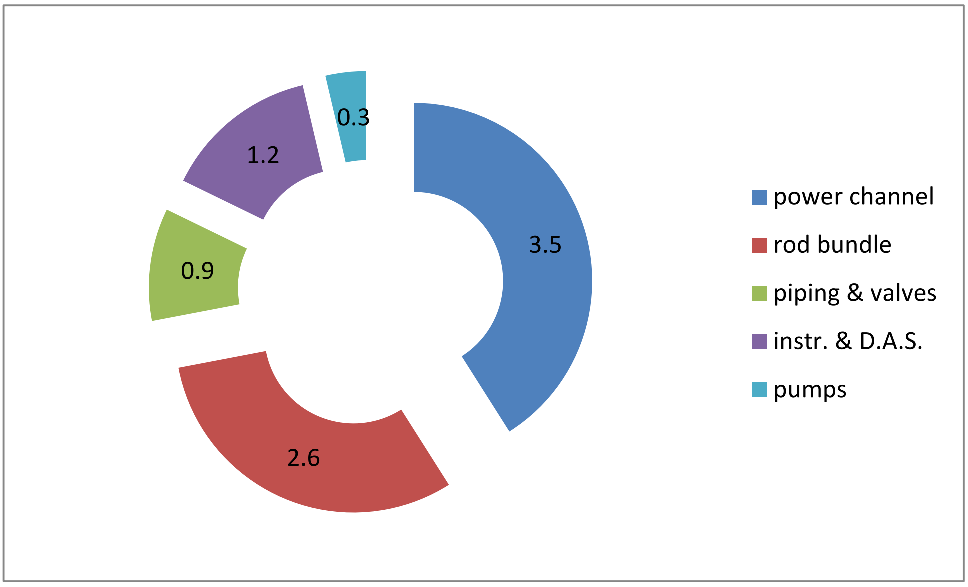


Fig. 5 – Breakdown of total budget for the SPES-3 completion (M€)

The heating rod bundle represents a major cost item whose estimate is based on a very recent offer (May 2013) made by a Canadian supplier of consolidated experience in this type of components: STERN Laboratories inc. based in Hamilton, Ontario, Canada. The value of the supply is 2,645,000 (excluding VAT) and includes all the procurement, test, transport activities as well as the collaboration with the supplier in every phase of the design and realization. The assembly is not included in the supply value, since it is accounted in the Power Channel cost item.
The value of the power channel supply includes its realization, test, transport, assembling and installation in the SIET site.ATB Riva Calzoni is in charge of this supply, in collaboration with Morandini and Officine Resta.

Some components or subsystems considered in the budget list may be manufactured by the Contributors (e.g. power channel); others have to be supplied by a third party (e.g. the heating rod bundle). In the first case, the estimate figure encompasses fabrication, transport and installation; in the latter it includes to the procurement activity performed by the Contributors

and the "price" paid by the Contributors to the third parties for the supply and installation service.
Commercial value covers manpower, materials and processes related to the procurement, fabrication, transport and installation of the generic item/component, as well as fixed costs compensation and normal profit for the enterprise.
As stated in a letter to the Italian Ministry of the Economic Development, sent in May 18, 2012, Contributors are available and willing to support the realization of the SPES-3 facility that they view as a strategic asset for the Italian industry development in international nuclear supply market. Because of this interest, the Contributors are available to provide major equipment and design, general contractor activities, accounting and covering the mere variable costs, such as personnel, material and process expenses of the supply.
The difference between these "values" and "costs" has to be considered as a co-financing of the facility by the Contributors for the completion of the SPES-3.
Total co-financing allowed by the Contributors amounts to **2,650,000 €** and is summarized as follows:

(i) **Heating rod bundle.** Alternative suppliers to the Canadian STERN Labs. have been considered (Thermocoax, FR and Rotfil, Torino-IT), but experimental tests highlighted the need of further technological development. Nevertheless, would the Italian Rotfil be considered as a supplier, a potential saving in the supply value could be estimated in 800,000. A collaboration with SIET would be necessary to set up an experimental campaign for the Rotfil rod prototypes, on an existing test circuit already used at this purpose. Under this option, the additional benefit could be attained of qualifying an Italian company for this kind of technical equipment supply.

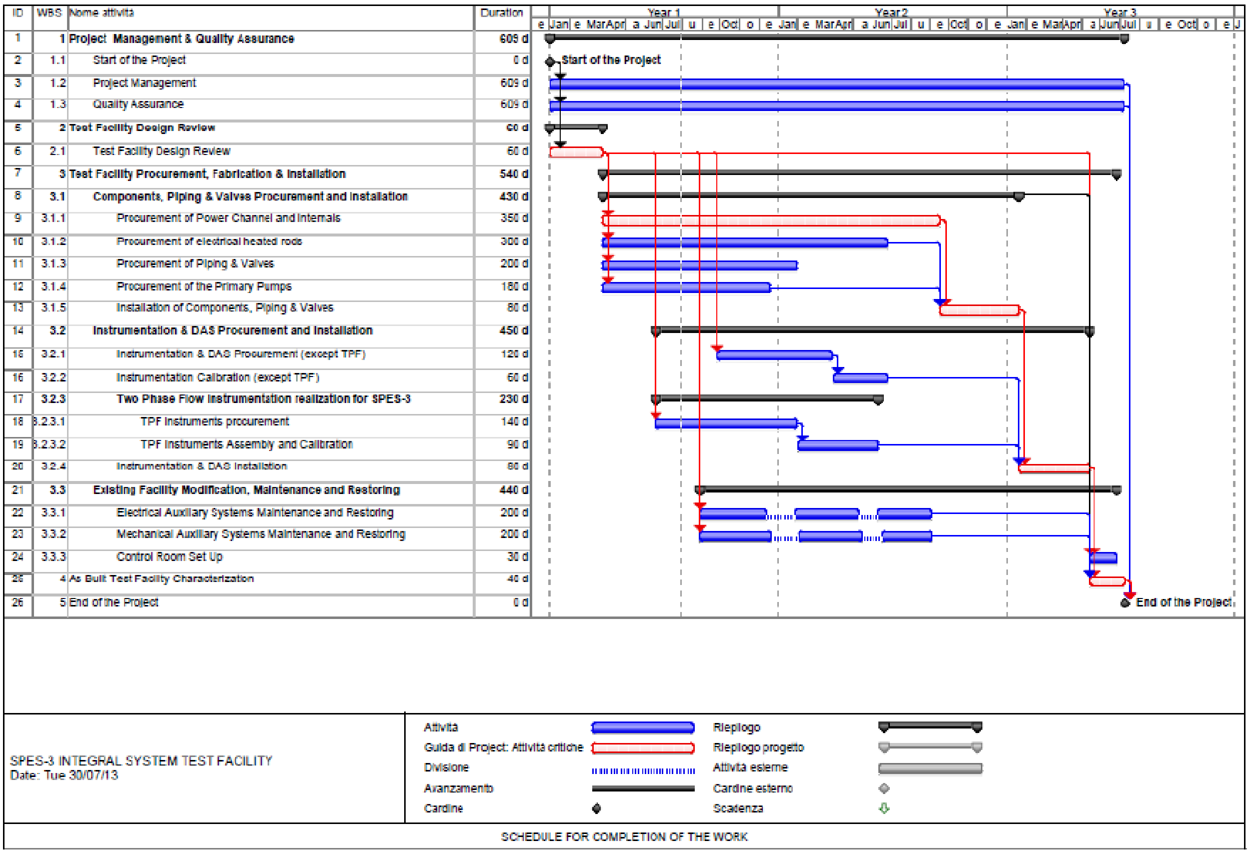
(ii) **Power channel.** The total saving allowed by the contribution of ATB Riva Calzoni, Morandini and Officine Resta is 1.3 M€. The cost of the power channel would then amount to 2.2 M€, significantly below its commercial value.

(iii) **General contracting.** SIET has been entitled by ENEA of the following activities: project management, quality assurance, design review, safety, procurement and technical collaboration with the supplier in the special supplies, supervisory of sub-contractors, installation and test of instrumentation, development of the software, data acquisition/elaboration, maintenance reporting. Previous authorization of the Advisory Board, could be performed with a reduction of the manpower value up to 550,000 €.

Including the savings allowed by the Contributors' partnership, the total investment effort for the completion of the SPES-3 facility would amount to about 5,885,000 € (excluding VAT).

7 Completion time-schedule

The completion of the SPES-3 facility will require 2.5 years, excluding possible delay in the availability of funds. The critical path is highlighted in red and the procurement of the power channel represent the main technological effort.



8 Contributors

The Contributors involved in the SPES-3 design and cost evaluation are:

- SIET (Società Informazioni Esperienze Termoidrauliche);
- ATB Riva Calzoni;
- Officine Resta;
- Morandini.
-

Other companies could be involved in the completion of the SPES-3 facility, potentially interested in sharing the efforts and the following benefits.
Today, only the Contributors have been involved, confirming their interest in the endeavour.
Other potential suppliers of components, systems and services needed to complete the facility will be contacted in the very next future, also by means of the present document.

9 References

1. **Achilli A., Congiu C., Ferri R., Bianchi F., Meloni P., Grgić D., Dzodzo M.** *SPES3 Facility RELAP5 Sensitivity Analyses on the Containment System for Design Review.* Science and Technology of Nuclear Installations, Hindawi Publishing Corporation, Article ID 173637, 2012.

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5. **Ferri R., Achilli A., Congiu C., Cattadori G., Bianchi F., Meloni P., Monti S., Luce A., Ricotti M.E., Papini D., Grgić D.** *The SPES3 facility for testing an integral layout SMR: BDBE simulation analysis*. Proceedings of the ASME 2011 Small Modular Reactors Symposium. September 28-30, 2011, Washington, DC, USA.

CURRICULUM SCIENTIFICO DEL GRUPPO DI LAVORO

Il gruppo di lavoro impegnato nell’attività è costituito da un professore ordinario di Impianti Nucleari del Politecnico di Milano (Dipartimento Energia), Marco Enrico Ricotti, e da una Assegnista di Ricerca, Sara Boarin.
Il prof. Ricotti svolge attività di ricerca da più di 20 anni al Politecnico nel campo della Ingegneria Nucleare, con particolare riferimento alla termoidraulica, alla sicurezza, agli aspetti economici dell’energia nucleare ed ha svolto o coordinato ricerche teorico-modellistiche e sperimentali nel gruppo Reattori Nucleari del Dipartimento di Energia del Politecnico di Milano, che attualmente guida, pubblicando i risultati su rivista e in atti di Congresso, quasi esclusivamente internazionali. Insieme all’ing. Boarin è anche autore di diversi rapporti nell'ambito dei PAR trascorsi.
L’ing. Boarin ha una esperienza pluriennale di collaborazione di ricerca con il Politecnico sulle tematiche economico-finanziarie dei reattori nucleari, nonché una esperienza lavorativa presso banche di affari internazionali. E’ coautrice di paper scientifici e report per organizzazioni internazionali (OECD, IAEA).
Maggiori dettagli sulle attività di ricerca nonché l’elenco delle pubblicazioni più recenti si possono trovare sul sito Web del gruppo di ricerca del Politecnico di Milano (http://www.nuclearenergy.polimi.it).