A REVIEW OF FAST REACTOR ACTIVITIES IN ITALY

Edited by:  F. Pierantoni
           R. Tavoni

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1. **Energy consumption in Italy**

In 1991, Italy's total primary energy demand increased by 1.5% (see table 1) more than the GNP increase in real terms, causing a slight increase of the energy intensity and this is an opposite trend in comparison with the 1983-1990 performance (-0.6%/year).

Net electricity import is at about the same level as in 1990 (~5%).

National energy production reaching 31.2 Mtep, represents about the 19% of the total energy consumption; one third of it comes from the primary electric energy (hydroelectric + geoelectric) that was particularly good for last year's favorable water conditions.

<table>
<thead>
<tr>
<th>Table 1 - Primary energy requirements(^1)/ in Italy during 1990 and 1991(^2)/</th>
<th>1990 Mtep %</th>
<th>1991 Mtep %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil derivatives</td>
<td>92.5 56.6</td>
<td>91.8 55.3</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>39.2 24.0</td>
<td>41.5 25.0</td>
</tr>
<tr>
<td>Solid fuels</td>
<td>15.8 9.7</td>
<td>14.3 8.6</td>
</tr>
<tr>
<td>Primary electricity(^3)/</td>
<td>8.4 5.1</td>
<td>10.7 6.5</td>
</tr>
<tr>
<td>-Hydro</td>
<td>(7.7) (4.7)</td>
<td>(10.0) (6.0)</td>
</tr>
<tr>
<td>-Geo</td>
<td>(0.7) (0.4)</td>
<td>(0.7) (0.4)</td>
</tr>
<tr>
<td>-Nuclear</td>
<td>- -</td>
<td>- -</td>
</tr>
<tr>
<td>Net electricity import</td>
<td>7.6 4.6</td>
<td>7.7 4.6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>163.5 100.0</td>
<td>166.0 100.0</td>
</tr>
</tbody>
</table>

In 1991, the electrical demand increased by 2.1% (see table 2) and the electric intensity by 1.0%, in agreement with last years trend that was about +0.9% during the years 1983-1990, representing an electricity penetration of 33%.

\(^1\)/ Including storage reserves
\(^2\)/ Provisional data
\(^3\)/ 0.22kgep/kwh
Net electricity import represents 15% of the total electric demand. The major contribution to the electricity increase production has been supplied by the hydroelectric sector allowing a 3% reduction in the thermoelectric production.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Electricity production and demand in Italy during 1990 and 1991/1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1990</td>
</tr>
<tr>
<td></td>
<td>TWh</td>
</tr>
<tr>
<td>Thermoelectric Energy</td>
<td>178.6</td>
</tr>
<tr>
<td>-Oil derivatives</td>
<td>102.7</td>
</tr>
<tr>
<td>-Natural gas</td>
<td>39.3</td>
</tr>
<tr>
<td>-Solid fuels/2/</td>
<td>36.6</td>
</tr>
<tr>
<td>Primary Electricity</td>
<td>38.3</td>
</tr>
<tr>
<td>-Hydro</td>
<td>35.1</td>
</tr>
<tr>
<td>-Geo</td>
<td>3.2</td>
</tr>
<tr>
<td>-Nuclear</td>
<td>-</td>
</tr>
<tr>
<td>Total Gross Production</td>
<td>216.9</td>
</tr>
<tr>
<td>Net Electricity Import</td>
<td>+34.7</td>
</tr>
<tr>
<td>Total Availability</td>
<td>251.6</td>
</tr>
<tr>
<td>Energy used by auxiliary production services and by pumping</td>
<td>-16.5</td>
</tr>
<tr>
<td>Network demand</td>
<td>235.1</td>
</tr>
</tbody>
</table>

2. Nuclear research and development in Italy

In August 1991, a new reform law of ENEA was issued, containing some changes in its attribution. ENEA is now the Italian National Agency for New Technology, Energy and the Environment. Its principal areas of activity are:

/1/ Provisional data
/2/ Coal, lignite and others
- the development and promotion of renewable energy sources and other alternatives to hydrocarbon fuels;
- energy conservation;
- research into innovative nuclear fission reactors and into the development of nuclear fusion;
- assessment, monitoring and protection of the environment and human health;
- development, diffusion and transfer of innovative technologies into productive systems, in Italy and abroad;
- licensing and control of peaceful uses of nuclear energy.

As far as the budget allocation is concerned, programme agreements with the proper Ministries have to be concluded in order to get the necessary financial resources.

ENEA activity on severe accidents have concerned the study of the phenomenologies, the development or validation of adequate calculation methods and the study of the radiological source term.

A relevant part of the activity concerning component and system studies has been performed in the framework of a contract between ENEA and the Genesi Consortium (Ansaldo & Fiat).

ENEL has contracts going on with EPRI, GE, Westinghouse, Edf, with the essential purpose of setting up sound design specifications, while the contract between ENEL and the Genesi Consortium has the aim of the development of the designs themselves and their adaptation to peculiar Italian criteria.

Experimental tests on innovative components of new reactors are an important step towards the demonstration of attractiveness of the plants themselves. In this respect the principal experimental activities going on, are the following:

- Automatic Depressurization System (ADS) test for Westinghouse AP-600 reactor. The test will be performed at ENEA's VAPORÉ facility in Casaccia, Italy, by ENEA personnel and Ansaldo is providing engineering and construction support. The first phase of the programme, to be completed in autumn 1992, will allow the experimental determination of the dynamic loads that follow the discharge of the steam into a pool.

- Tests on a prototype of the Isolation Condenser (I.C.) and on two modules in full scale of the Passive Containment Cooler System (PCCS) for the General Electric SBWR reactor. At Siet, under an ENEA contract, the
realization of two test loops is being completed; Ansaldo is now proceeding under an ENEL contract, to the construction of the two prototypes to be tested and the tests will be terminated at the beginning of 1993.

3. Modular systems studies

- Oxide core studies
The cooperation between ENEA and GE concerning the study of an oxide version of the PRISM core, has continued. A detailed description of the work going on, has been written out in two papers presented at the Kyoto conference in October 1991. A study on the characterization of the oxide fueled PRISM reactor, as an actinide burner has been done. It is common knowledge that the minor actinides time evolution shape results in an exponential function toward an asymptotical equilibrium concentration, different from zero. Therefore the typical figures, able to characterize the facility as burner are: the time constants, the equilibrium concentrations and the facility capacity, as maximum possibility of housing minor actinides without any significant negative impact on the operational and safety aspects. Two options were examined: the homogeneous and the heterogeneous. In the homogeneous solution, the minor actinides can be dispersed either in the fuel assemblies worsening all the safety parameters, or in the blanket assemblies with a general improvement on safety parameters. In the blanket dispersion the relative transmutation rates are rather low, but there is the possibility of reaching high absolute rates by "over loading" the blanket assemblies with minor actinides. In the heterogeneous option, all the minor actinides associated to the PRISM inventory fuel, have been concentrated in six special housing assemblies having the fuel geometry, in a depleted uranium matrix. This solution is safe and effective, in case a suitable overloading is provided.

- PRISM component development
The activity on PRISM component design has been performed mainly by Ansaldo, partly under a contract with ENEA. The main activity performed by Ansaldo in 1991 concerned the fuel in-vessel transfer machine (IVTM). The structural/seismic design evaluation
has been completed and detailed design layout drawings have been produced based on the latest structural analysis results. Materials have been identified for the IVTM components.

Moreover, the Ansaldo activity continued on the following areas:
- safety: a preliminary set of the design criteria and requirements for the containment and the decay heat removal system has been defined; these criteria are considered to be suitable for the PRISM in the Italian/European context.
- RVACS (Reactor Vessel Auxiliary Cooling System): an alternative design solution, where the heat is removed from the containment vessel by an U-tube air exchanger has been proposed. The layout drawing and the preliminary thermal-hydraulic performance analysis of the air exchanger have been produced.
- reactor block analysis: activity has continued with the cost estimates for the reactor internal structure and the IHX.
- IHX: a review of the PRISM IHX based on the Italian/European design, fabrication and operating experience has been performed.

- **Passive Monitoring device**

Current devices of the fission gas monitoring are based on active components (pumps, filters and so on) and significantly extend the reactor primary boundary.

The Passive Monitoring Device (PMD) is a static column and relies on the molecular diffusion, providing the necessary delay time for Ne-23 decay. It will be mounted on the PRISM reactor head, where it will determine the presence of radioactive fission gases (Kr, Xe, and so on) released from the failed fuel pins into the cover gas region.

The prototype construction was completed in July 1991 and after the device assembling at ENEA Brasimone center, test activities started in October 1991.

Diffusion tests with Xe-133 tracer in Helium at atmospheric pressure and various temperatures were performed.

Until now, the following measures have been accomplished:
- PMD subsystems calibration (temperature and pressure detection chains, metering valves, control panels).
- Energy calibration and efficiency calibration of the nuclear chains at room temperature (diffusion column at 20°C).
- Room temperature diffusion pre-trials with the aim of testing all PMD components and procedures.
- Room temperature diffusion test.
- Nuclear chain efficiency calibration in refueling conditions.
- Refueling conditions diffusion tests (diffusion column at 205°C).
- Efficiency calibration in operating conditions.
- Operating conditions diffusion test (diffusion column at 495°C).
- Small thermal gradient diffusion test (top of diffusion column at 495°C and bottom at 485°C).
- Large thermal gradient diffusion test (top of diffusion column at 220°C and bottom at 70°C).

Test results were excellent, with good agreement between theoretical diffusion curves and experimental data (Fig. 1 shows the operating temperature test results, where C2/C1 is the ratio between top and bottom concentrations in the diffusion column).

The next step will be the test with sodium to evaluate the potential for sodium condensation and plugging in the column: these phenomena could interfere with, or impede the gas diffusion. The test will be performed at the same temperatures as in reactor.

Figure 1: Operating Conditions Diffusion Test (Jan. 27-28, 1992)

C2/C1
time (s)
4. Seismic Isolation

- Generalities
A complete description of the Italian activities was presented at the SM on Seismic Isolation Technology, San José, California, USA, 18-22 March 1992.
At present, the R&D work on seismic isolation is mainly being performed in Italy by ENEA, ENEL, ISMES and ALGA: these were the main promoters (in 1989) of the National Working Group in Seismic Isolation (GLIS) which already includes representatives of all the organizations, universities, companies and designers who are dealing with the new technique.
A first version of the document for design guidelines for nuclear power plants using HDLBRs (high damping steel-laminated rubber bearings) is being prepared and will be soon published: it accounts both for comments received and the first results of R&D studies in progress in Italy and the USA.
These activities have been recently extended - as part of a cooperation with the Italian Standard Authority (UNI) - to other anti-seismic devices, for application to civil buildings and non-nuclear plants. A cooperation has also been started by ENEA, ENEL and ISMES with the National Seismic Service.
Furthermore, the guidelines document will also be extended to nuclear reactors using bearings different from the HDLRB, under the sponsorship of the Commission of the European Communities (CEC): this work will be performed by ENEA, with the cooperation of ALGA, ISMES, Ansaldo and the Nuclear Engineering Laboratory (LIN) of the Bologna University.

- Tests on rubber specimens
The tests have been performed by ENEA in cooperation with ALGA and Ansaldo with the aim of improving fabrication processes, controlling bearing quality and determining rubber properties. As an example, one of these tests, consisted in defining an accelerated ageing method for the analysis of ageing effects with the result that a relaxation of pressure equal to 50% of the initial value after 142 years at nominal temperature (30°C) was obtained.
**Tests on bearings**

A modification of the SYSTEM test machine, to allow for tension on bearings and to better guide vertical loads, has been accomplished. New types of bearings have been fabricated: among them some with dowelled and bolted attachment systems and a central hole which enables a better centering of steel plates and better bonding. The first results of the tests in progress on the modified bearings have showed a reduction of vertical stiffness of about 20%, due to the combined effects of lower values of shape factor, cross-section area and total rubber thickness. The results have confirmed the validity of simplified formulas to compute bearing vertical stiffness and stressed the adequacy of the single-dowel attachment system for minimizing the deformations of bearing end-plates.

**Test on isolated structure mock-ups or buildings**

Dynamic experiments of structures concerned both full-scale and scaled isolated structure mock-ups and actual isolated buildings (one of those forming the SIP Administration Center at Ancona). Both snap-back tests and forced excitation experiments were performed, to large displacements (85 mm for the full scale mock-up, 36 mm for the 1/4 scale mock-up, 107 mm for the SIP building). Forced excitation tests were both sinusoidal and seismic, with one and multi-directional simultaneous excitations. Test results have already demonstrated the adequacy of seismic isolation and have provided data useful for the comparison with single bearing test results and validation of numerical models for the analysis of isolated structures. By applying Italian seismic records that are peculiar to rigid, medium and soft soils, significant reduction on the motion amplitude has been obtained (from 60% to 90%).

**Numerical activities**

The numerical activities mainly concern the definition of models for bearings and isolated structures, and their use for test design and the analysis of experimental results. Simple bearing models have been set up, and the development of finite-element (f.e.) three-dimensional (3D) and 2D axisymmetric models is in progress. Simple models have been based on the results of single bearing tests: models formed by a spring in parallel to a viscous damper, where
both horizontal stiffness and viscous damping vary with displacements, have been developed by ENEA. Models based on hysteretic damping have also been developed by DISP and ISMES.

Detailed bearing models (Fig. 2) include separate elements for the rubber and steel plates. A 3D model has been implemented by ENEA in the ABAQUS computer code. Linear elastic calculations have been performed with this model. The implementation of an elastic-plastic model for steel is also being completed, together with that of a hyperelastic model of the rubber, based on tests on specimens.

Finite-elements models with constant viscous damping have been implemented by ENEA in the ABAQUS program, and have been used for the analysis of the previously tested isolated structures. For buildings, ABAQUS analysis concerns both models where a very large stiffness is assumed also for the structure and sophisticated 3D f.e. models of the superstructure (Fig. 3). The first have been found sufficient to describe the overall motion of the SIP isolated buildings at Ancona.

![Figure 2: 3D model of SIP-type bearings; first mode of the unloaded bearing.](image1)

![Figure 3: 3D model of the SIP building; first vibration mode of the superstructure.](image2)
5. Other activities

- **Methods**
  In the reactor physics field, ENEA has continued to collaborate in the production of the Jef-2 cross-section file and in the implementation of the data processing code chain. As far as Monte Carlo development is concerned, a large programme is in progress to make different codes, more independent of the users' input choices. Presently, the comparison between the Direct Statistical Approach method developed at ENEA and the automatic generation of window weight of the Los Alamos Laboratory, is in progress. As for the integrity of structures, ENEA, under contract with CEA, has continued the promotion towards universities and research institutes of the Castem 2000 and Trio Systems. An application, verification and validation of the modules to study the structural behaviour of concrete containment buildings has been started.

- **EFR**
  Ansaldo has supported the EFR design as contributing partner to EFRA (European Fast Reactor Associates), by participating in some working group such as the design and construction rules committee. Specific involvement on design process has been related to the definition of a sodium/sodium heat exchanger for the decay heat removal system with reduced pressure loss on primary and secondary sides.

- **SPX-1**
  Activities of modification of the auxiliary circuits for the barillet, have been continued at Ansaldo. Design activities for a ISI machine for the Steam Generator have also been started in collaboration with CEA and FRAMATOME. Assistance to the plant operator for service activities has been supplied.