DESIGNING OF MAIN COMPONENTS OF THE SECONDARY CIRCUIT OF ALFRED REACTOR

DIMENSIONAREA PRINCIPALELOR COMPONENTE DIN CIRCUITUL SECUNDAR AL REACTORULUI ALFRED

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Abstract: *The Advanced Lead Fast Reactor European Demonstrator is one of the main project to be built in Romania next to ELI-NP laser project. In order to be built, there are a great effort from Romanian and Italian researchers in order to design and built a new technology for Europe. In this paper we started from know data of steam generators feed water flowrate and main steam parameters and we obtained by iterative calculation all flowrates, pressure, thermal loads of all main equipment from secondary regenerative circuit of ALFRED. The main focus till this paper, research and design effort was focused on primary circuit, due to new provocations of using lead as cooling agent. Based on current research we can make big steps in procuring main components of secondary circuit of this important project who will be built in Romania at Mioveni.*

Keywords: ALFRED, Secondary Circuit, Heat balance

Rezumat: *Reactorul European de Demonstraţie Rapid Răcit cu Plumb va fi construit în România după construirea proiectului celui mai mare laser din lume proiectul ELI-NP. Pentru a putea fi construit, se face un efort considerabil din partea cercetătorilor români şi italieni pentru a proiecta şi construi o nouă tehnologie în Europa. In această lucrare am pornit de la datele cunoscute despre generatoarele de abur şi anume debitul şi temperatura apei de intrare şi temperatura şi presiunea aburului viu şi am obţinut, prin calcul iterativ, toate debitele presiunile, sarcinile termica ale principalelor echipamente din circuitul secundar al reactorului demonstrativ ALFRED. Principala ţintă până la această lucrare au fost cercetarea si proiectarea circuitului primar de răcire a reactorului, datorită noilor provocări datorate de folosirea plumbului ca agent de răcire. Pe baza cercetării curente putem face mari progrese în procurarea componentelor principale din circuitului secundar al acestui proiect important ce va fi construit în Romania at Mioveni.*

Cuvinte cheie: ALFERD, Circuit secundar, bilanţ termic

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1. Introduction

This paper has as main objectives indentifying and analysing of technical parameters in order to define a solution for secondary circuit diagram of ALFRED demonstrator reactor (Advanced Lead Fast Reactor European Demonstrator).

Nuclear energy based on fission reaction represent, in present, the main option of sustainable energy supply, clean and competitive to global scale.

Aware of the advantages and disadvantages of using nuclear energy, government and technical-scientific community problems related to nuclear safety, treatment and conditioning of radioactive waste, costs of investments in nuclear installations, physical protection of radioactive materials and nuclear facilities, resistance to proliferation.

Fast generation IV reactors are an acceptable and feasible solution with cleaner nuclear safety features that promise to prevent Fukushima-like consequences.

European Union and the major economic powers have set up a working group for the development of Generation IV reactors. Basic research on Generation IV reactors was conducted through a global collaboration effort coordinated by the Generation IV International Forum (GIF-Generation IV International Forum).

In order for Romania to adopt a modern generation of Generation IV nuclear reactors, it is imperative that we enter the club of countries that promote these branches in the research and experimental demonstration phase.

The design of the ALFRED demonstrator has so far been carried out under the 7th EURATOM Research Framework Program (European Atomic Energy Community) and Ansaldo Nucleare has been the leader of the ENEA integration in technological development.

The Nuclear Research Institute - I.C.N. Pitesti, participated in the design of ALFRED installation, starting with its first stages, contributing to the design of the core of the reactor and promoting the preliminary activities necessary for the approval of the project in Romania.

Reactors of IV generation are truly innovative technologies that combine maximum security with economic competitiveness. The technology is based on passive safety aspects that provide a "zero impact" outside the directly affected area, even for the worst accident scenarios.

Liquid-cooled reactors (sodium, lead and bismuth lead) are fast reactors, currently in the conceptual design stage in Europe.

The ALFRED (Advanced Lead Fast Reactor European Demonstrator) project is a reactor that is part of the Lead cooled Fast Reactor (LFR) line of the fourth generation nuclear reactor, a potential characterized pipeline to deliver efficient, simple and robust concepts. The LFR system is considered the first place in sustainable development because it uses a long-lived active area, has a closed fuel cycle and has a high resistance to proliferation and physical protection.

The ALFRED reactor uses a spectrum of fast neutrons and a closed fuel cycle for efficient uranium conversion and good management of minor actinides.

Data related to the ALFRED demonstration reactor were extracted from the existing specialized documents on the internet and used as input data for the calculation of the secondary circuit.

2. Secondary Circuit Description

ALFRED Secondary Circuit Operation is based on the second principle of thermodynamics, according to which a cyclic thermal machine can only produce mechanical work if it is in contact with two heat sources: hot and cold.

With help of all the parameters, a heat balance was made on the regenerative preheating line, determining the flows extracted from the turbine and the flows flowing through the regenerative preheaters.

For the ALFRED secondary circuit scheme design, the structure of the regenerative preheater circuit is the following:

- 3 low pressure heaters (LPH);
- 1 deaerator;
- 3 high pressure heaters (HPH);
- 1 Feed Water Temperature Control Heater (FWTCH).

Starting from the general scheme of an intermediate overheating condensation group (see figure 1), by calculating the decomposition in the steam turbine, the thermodynamic parameters of the steam were determined at the characteristic points of the thermal cycle, which are on the decomposition path between the exit from the steam generator and the entry into the steam condenser. Then the calculation for the main condensate for the supply water and condenser cooling circuit continued in three distinct situations: nominal mode (ambient temperature 18 °C); Severe winter (ambient temperature -25 °C) and severe summer (ambient temperature 37 °C).

To achieve the purpose of the paper, the input data characteristic of ALFRED project was set, establishing the steam generator parameters (≈300 MWt) of steam in the secondary circuit. A general scheme of an intermediate overheating condensation group was designed, calculating the power at the turbine generator terminals and the thermal cycle yield.

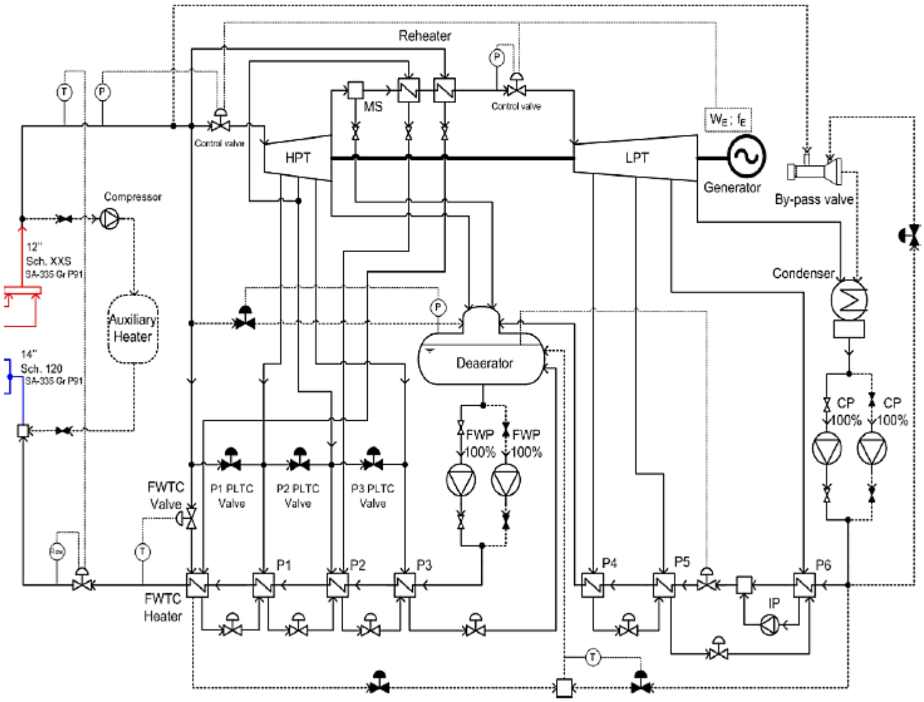

Figure 1. Secondary circuit diagram [ref. 1].

3. Obtained results

In the paper, the conceptual diagram of the secondary circuit for the ALFRED demonstration reactor [ref. 2 and 3] was drawn up and important parameters were calculated: pressure, flow, temperature, enthalpy at all characteristic points of the scheme. Interface with the requirements of the steam generator has been provided.

The secondary circuit diagram was calculated for three operating modes. Thus, in addition to the nominal exploitation regime (100% of the nominal load), the severe summer and severe winter regimes were also calculated. These calculations were made to determine the performance of the projected secondary circuit throughout the calendar year [ref. 4].

Following the calculation, the following results were obtained:

- For normal operation, the turbine generator output is 130.78 MW at a secondary circuit output of 43.92%;

- For the "extreme summer" operating mode, the turbine generator output is 126.6 MW at a secondary circuit efficiency of 42.52%- the computational diagram is showed in figure 2;

- For the "severe winter" operation, the turbine generator output is 132.1 MW at a secondary circuit efficiency of 44.38%- the computational diagram is showed in figure 3.

The internal report presents the results of the secondary circuit diagram parameters for all ALFRED thermal circuit components.

The results of steam expansion in turbine and the distribution of thermal loads for the regenerative circuit allow the dimensioning of these equipment in the next stage of the technical project.

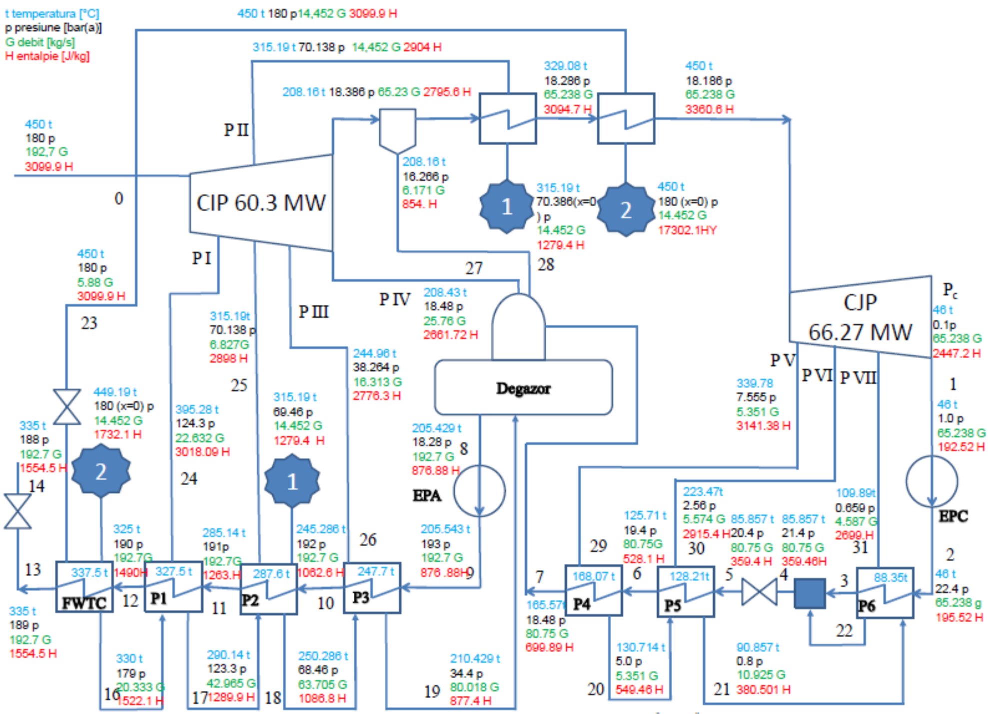

Figure 2. Heat Balance Diagram for one severe summer conditions

Because the ALFRED site does not allow cooling of the condenser in open circuit, closed-loop cooling solution is selected by means of a cooling towers battery that will discharge a thermal load of 147.1 MW in severe summer mode.

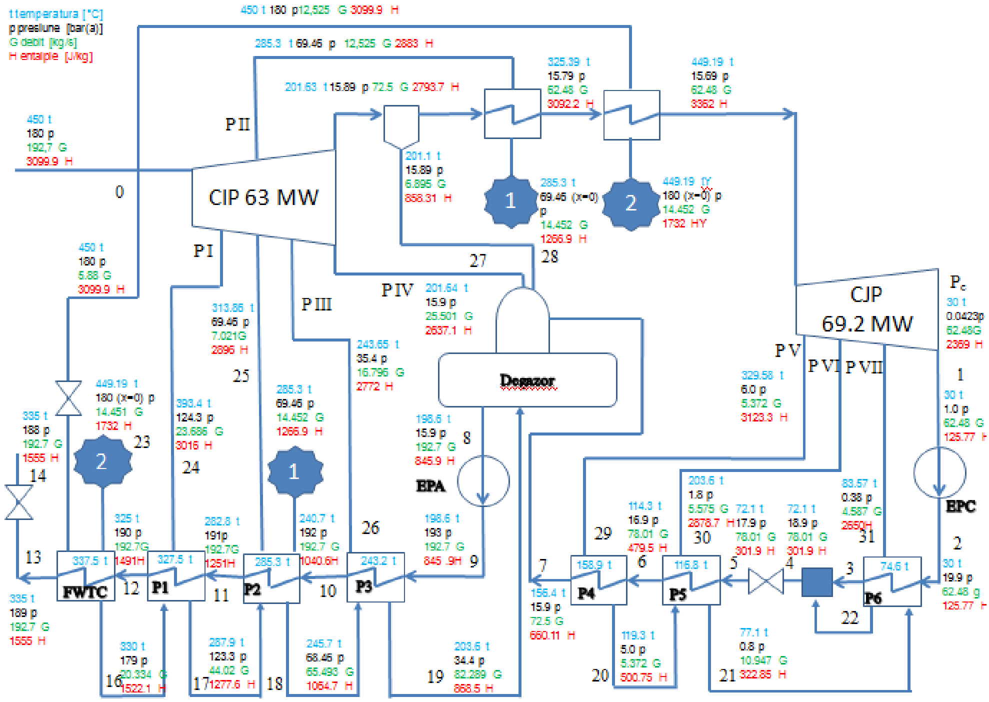

Figure 3. Heat Balance Diagram for one severe winter conditions

4. Conclusions

Nuclear power is the only energy source capable of meeting decarbonisation targets at the same time as supply security, being stable and not dependent on price fluctuations in fossil fuels. Nuclear power ensures the energy needs of mankind, it is a source of energy security because it brings a diversification of the energy mix; Through its carbon-free character, is part of the current decarbonisation trend in electricity production, fully responding to climate change prevention concerns.

The recent Communication on a new European Strategic Energy Technology Plan also states that the priority for nuclear energy is to support the development of the most advanced technologies in order to maintain the highest level of nuclear reactor security and to improve the efficiency of the operation, Processes from the final stage of the fuel cycle and decommissioning.

In this respect, the current EURATOM research initiative is to implement the European Industrial Initiative for Sustainable Nuclear Energy, which aims to prepare for the future deployment of the fourth generation nuclear power system, based on fast neutron fuel cycle technology . A number of reactors are in the research stage. These are: ALFRED; ALLEGRO; MYRRHA and ASTRID.

Fast generation IV reactors are an acceptable and feasible solution with clearly superior nuclear safety features that promise to prevent Fukushima-like consequences.

Generation IV reactors were designed to achieve a high level of security, proliferation resistance, low fuel consumption, high technical and economic performance, and to reduce the amount of radioactive waste generated.

The Russian experience with the deployment of LBE cooling systems for propulsion of submarines has provided excellent evidence that LFR reactors can be produced and operated on an industrial scale.

Fast lead-cooled reactors offer a great promise in terms of simplification of the boiler scheme, performance and safety response, while offering advantages over other fast reactors.

As a result of the calculation, good yields were obtained for the three studied operating regimes (nominal, severe summer, severe winter), which justifies the sizing of the secondary circuit of the ALFRED demonstration reactor.

The results obtained will be used to sizing all the main components of the ALFRED secondary circuit diagram, a big step forward in order to put in implementation a great project of generation IV reactor in Romania.

This paper is in the strategic direction of support activities for the development of its capability, competence and expertise in the field of LFR in order to strengthen the contribution to the ALFRED demonstration reactor.

In conclusion, Romania is the reference option for hosting the ALFRED demonstration plant of the fast-cooled lead reactor (LFR), based on the benefits of accessing structural funds, existing technical capabilities and nuclear expertise. At European level, the idea of building the ALFRED demonstrator (LFR) in the new Member States is agreed to reduce the imbalances in the development of the technological infrastructure.

R E F E R E N C E S

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