Review of the Draft Report

KTH - Royal Institute of Technology
SH2702 Nuclear Reactor Technology
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Review of the Project Group:
Group Code: ABWR 22
Full title: ABWR Advanced Boiling Water Reactor

1 Collect information on General design specification of the nuclear power plant with selected reactor type (Task 1, ILO1, ILO2)

Grade: 1
The information provided about the reactor design are few and they are not presented in an appropriate way, moreover there are no numerical data (except for the reactor power).
In this section the expression “steam generators” is used a couple of times. This expression is not suitable for a ABWR description because ABWR has no steam generators, and the way it is used may be misleading, therefore I suggest to not use this term. As well as I suggest to not use the expression “secondary circuit” because an ABWR has only the internal circuit.
The control rod drive (CRD) system is described in a detailed way, but this is completely incoherent with respect to the whole section, because the other reactor components are not described. Control rods are not described at all, thus I suggest to describe control rods (where they are located, what are made of. . .) before giving so many specific details on CRD system.
I would recommend to improve this section adding more reactor information. For instance I suggest to add a detailed description of the core, providing data and schemes related to fuel rods, fuel assemblies distribution in the core and figures that show fuel assemblies characteristics. Even though some numerical data are presented in “Task 4” section, I suggest to add the data in this initial section. Moreover I suggest to describe in a proper way the steam separators and steam dryers elements located inside the vessel, with some images. I also recommend to provide information about the reactor pressure vessel (dimensions, materials. . .) as well as internal pumps characteristics. I suggest to describe the coolant flow at nominal operation conditions and provide details about recirculation.
I suggest to describe the reactor building and the containment features in this section. The balance of plant description is totally missing, I recommend to provide information about turbines and generators area of the plant.
The value of the reactor thermal power reported in this section is not coherent with the value reported in “Task 4” section.

2 Describe Operational principles of the power plant. (Task 2, ILO1, ILO2)

Grade: 1
This section related to plant operational principles is really poor and bad structured. In the last part of this section some reactor elements and concepts are presented, but these elements (basaltic concrete pad, containment, passive safety systems. . .) are not related to this section topic, therefore they should not be mentioned here. I suggest to keep all the elements related to reactor description in the first section about design.
The ABWR operational principles are presented in a poor way. The mechanisms used in order to control reactivity are mentioned, but there is not a description of these systems. I recommend to provide information on physical systems (like control rods) and explain how the other principles are actually used in order to operate the reactor. In particular I suggest to describe for which situation each system is used, for instance how xenon feedback is managed, which systems are used for instantaneous reactivity change or long term modulation and so on.
I suggest describing in detail how the startup and the shutdown of the reactor are performed. In particular I suggest to provide information about procedures used to avoid instabilities during these two processes (steps in coolant flow and power). I also recommend to improve the description of the ABWR load following capability providing data on the rate at which the reactor can modulate the power. I suggest to provide information about refuelling operations and give data on the fuel cycle duration in the core as well as the burnup.
As for the previous section, I recommend to not use the terms “steam generator” and “secondary loop”, as it is done in the sentence ”Steam generator, which is an heat exchanger that transfers the heat from the primary loop to the secondary loop”. These terms are not suitable for an ABWR description.

3 Explain Safety features of the power plant. (Task 3, ILO1, ILO2)

Grade: 3
The ABWR safety systems are described in an exhaustive and detailed way. In this section all the major safety systems are well described. For each safety system, the description includes a general description of the system structure with a scheme, then the authors provide information about the accidental scenarios in which the system is activated and they describe how the system operates. The descriptions include also numerical data.
Some descriptions may result even too much detailed. For instance descriptions of Reactor Core Isolation Cooling, Residual Heat removal and Emergency Diesel Generator might be shorter. A too detailed description is not suitable if the overall description of the reactor is rough, indeed sometimes is difficult to properly understand how a system works because the information about the general reactor design are poor.
I suggest to better explain the meaning of the sentence the “ABWR has at least 10 units higher calculated factor than BWR/5 and BWR/6 in avoidance of possible core damage from degraded events”. If it is possible, I would recommend to provide numerical values of probability safety assessment results about core damage frequency (CDF) and large release of radioactive material frequency (LRF).

4 Calculate Selected core parameters (Task 4, ILO3)

Grade: 2
It is not clear whether the analysis performed in Task 4 is performed on an entire fuel assembly or it is about a single fuel channel. I recommend to provide better description of the channel analysed, with a scheme that shows the fuel rods lattice. The power normalization procedure is not clear, I suggest to explain better how the power for the averaged channel is normalized, in particular explaining what q''_{av} is.
It is not clear how the effective coolant flow rate is computed in the analysis, in particular it is not clear what "total mass flow" and "bypass flow" mean. If you are dealing with a BWR, the total coolant that flows in the core should be the sum of the feedwater and the recirculation flows (neglecting control rods and cleanup flows). I also suggest to express units of measure related to coolant flow in kg/s instead of t/h.
I recommend to provide more information about the axial discretization, in particular reporting the number of cells in which the core height is divided.
I suggest to better organize the paragraph related to pressure drop calculations, maybe creating sub paragraphs for each pressure drop contribution. I also suggest to provide information about the calculation of the local pressure drop coefficient for the orifice pressure drop. Moreover I recommend to explain how the local coolant properties are calculated at each cell, indeed local properties like density and viscosity depend on local enthalpy and pressure values, which are not constant along the channel.
I have some doubts about core flow characteristic plot. When the coolant flow is close to zero, I expect a larger pressure drop associated to zero power condition compared to the pressure drop related to higher power (due to the gravitational pressure drop contribution). I suggest to provide another plot that shows in detail the region with low flow rate. Moreover I expect that the coolant reaches single phase vapour condition when the core power is high and the coolant flow rate is low. Thus, I recommend implementing correlations for pressure drop in the single phase vapour flow as, based on the process description, these correlations do not appear to have been used.
The overall procedures adopted in order to solve Task 4 seem correct (even though they are not extremely precise) and they are quite well explained. The correlations used in order to evaluate pressure drops are reported. With the except of the core flow characteristic plot, the results seem reasonable.

5 Calculate CHF margins in a hot channel (Task 5, ILO4a)

Grade: 2
As for the section related to Task 4, it is not clear whether the authors are performing an analysis related to an entire fuel assembly or a single hot channel. The authors correctly take into account the radial peak factor in order to evaluate the power distribution in the hot channel.
The procedure applied in order to analyse the channel is quite well explained and seems correct. The correlation used in order to evaluate the critical heat flux (Reddy and Fighetti) seems valid for the actual coolant properties, but I suggest to explicitly show whether this specific analysis is in the applicability range of the correlation or not.
The results related to enthalpy, void fraction, pressure drop and temperature profiles seem reasonable. The profile of the CPR seems quite strange, the power has a cosine shape, thus I do not expect a monotonic decreasing CPR (see course handouts). I recommend to check the calculations and to improve the plot adding the flux profile in the hot channel and the profile of the critical heat flux.

6 Calculate Maximum cladding and fuel pellet temperature (Task 6, ILO4b)

Grade: 2
The procedure used in order to calculate the cladding surface temperature is well explained, and correctly the heat transfer coefficient is calculated differently for the single phase liquid regime and for the two phase regime.
The procedure used in order to compute the cladding temperature is not clear. First of all I recommend to explain which cladding temperatures are computed and whether the cladding radial direction is discretized or not. I suggest to provide references about the correlation used for the cladding thermal conductivity as well as I suggest to describe the cladding material. It is not clear how the equation for the cladding temperature is computed (Eq. 50), thus I recommend to provide the derivation (at least the major steps) starting from the Fourier equation. Moreover it is not clear which temperature is used in order to evaluate the cladding thermal conductivity.
I suggest to improve the paragraph related to the outer fuel temperature calculation because it is not clear where the equation used (Eq. 51) comes from. In addition I suggest to provide a reference for the gas thermal conductivity used. I also recommend to improve the paragraph related to the inner fuel temperature computation, explaining how the equation used to calculate the temperature (Eq. 52) is derived. Moreover it is not clear how this equation (Eq. 52) it is solved and it is not clear whether the analysis discretizes the radial direction of the fuel, providing a radial temperature profile, or it just calculates the fuel temperature at the centre.
The results related to the heat transfer coefficient (HTC) between the coolant and the cladding seem not correct. I expected a sharp increase in the heat transfer coefficient when the coolant enters in two phase flow, then the HTC should monotonically decrease as the vapour quality increases. I recommend to check the calculations, because a wrong HTC value affects all the other results.
I suggest to explain how the plot related to the radial temperature profile is obtained, because from the previous procedure description seems that the authors only calculated temperature values at surfaces, it is not clear whether the authors have calculated a radial temperature profile. In addition I suggest to improve the plot adding on the curves marks related to the specific computed values.

7 General comments

I would suggest to double check the text because there are some grammar and lexical errors. I also suggest to improve the general text layout with a better management of sub sections and paragraphs, especially in the first two sections.
I recommend to improve the image location, adding all the images at end of each section, avoiding in this way to break the text.
I also recommend to write mathematical expressions in a proper way, using the correct scientific notation (1×10^2 instead of $1E2$).