Transient heat transfer in a 3D fuel rod, in a situation of unplanned shutdown of a PWR

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The study of heat transfer in fuel rods in situations involving accidents is of known importance, since it can be used to predict the temperature limits in designing a nuclear reactor, to assist in the making of more efficient fuel rods, and to increase knowledge about the behavior of the reactor's components, a crucial aspect for safety analysis. This study, presented at the International Nuclear Atlantic Conference – INAC [1], was conducted using the fuel rod that has the highest average power in a typical PWR reactor as parameter. For this purpose, a program (Fuel_Rod_3D) in Fortran language, using the Finite Elements Method (FEM) for the discretization of a fuel rod and coolant channel, was developed in order to study the temperature distribution in both the fuel rod and the coolant channel. Transient parameters were coupled to the heat transfer equations in order to obtain details of the behavior of the rod and the channel, which allowed the analysis of the temperature distribution and its change over time.

The study of an accident, where there is lack of energy in the reactor's coolant pumps and in the diesel engines, resulting in an unplanned shutdown of the reactor will be shown.

First, there was the verification/validation of the program based on the book Nuclear Systems [2]. This verification showed the proper functioning of the program, as in the case of the maximum temperature of the fuel, which had a relative percentage deviation of 0.03% compared with the analytical solution [1], as well as the coolant temperature, which had a relative percentage deviation of 0.08%. Other verifications also showed good results, such as the profiles of the distribution of temperatures in the center of the fuel and the coolant channel, both along the rod.

For shutdown study, Figure 1 illustrates the behavior of the power density and flow rate immediately after the start of reactor shutdown. The flow behavior shows that the pump does not stop immediately. This is due to the inertia of the pump, which features a safety factor making the coolant of the primary loop continue to circulate in the core for a period of time, cooling the fuel rods.

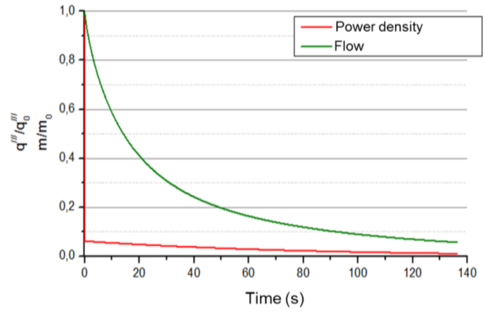

Figure 1. Power density and flow rate drop.

Figure 2 illustrates the behavior of some temperatures. The influence of inertia of the pump on these components can be observed, demonstrating that it would take some time for the rod components to be permanently damaged.

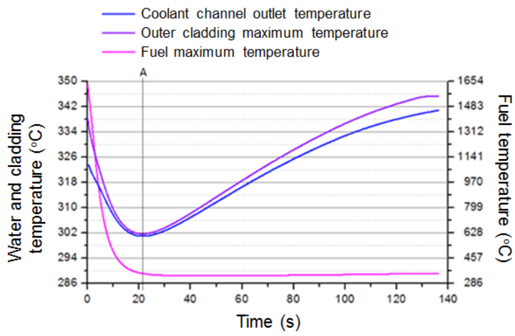

Figure 2. Temporal evolution of the maximum temperatures of the fuel, cladding and water in the channel's outlet.

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