Severe accident recriticality analyses (SARA)

Recriticality in a BWR during reflooding of an overheated partly degraded core, i.e. with relocated control rods, has been studied for a total loss of electric power accident scenario. In order to assess the impact of recriticality on reactor safety, including accident management strategies, the following issues have been investigated in the SARA project: (1) the energy deposition in the fuel during super-prompt power burst; (2) the quasi steady-state reactor power following the initial power burst; and (3) containment response to elevated quasi steady-state reactor power. The approach was to use three computer codes and to further develop and adapt them for the task. The codes were SIMULATE-3K, APROS and RECRIT. Recriticality analyses were carried out for a number of selected reflooding transients for the Oskarshamn 3 plant in Sweden with SIMULATE-3K and for the Olkiluoto I plant in Finland with all three codes. The core initial and boundary conditions prior to recriticality have been studied with the severe accident codes SCDAP/RELAP5, MELCOR and MAAP4.

The results of the analyses show that all three codes predict recriticality—both super-prompt power bursts and quasi steady-state power generation—for the range of parameters studied, i.e. with core uncovering and heat-up to maximum core temperatures of approximately 1800 K, and water flow rates of 45-2000 kg s\(^{-1}\) injected into the downcomer. Since recriticality takes place in a small fraction of the core, the power densities are high, which results in large energy deposition in the fuel during power burst in some accident scenarios. The highest value, 418 cal g\(^{-1}\), was obtained with SIMULATE-3K for an Oskarshamn 3 case with reflooding rate of 2000 kg s\(^{-1}\). In most cases, however, the predicted energy deposition was smaller, below the regulatory limits for fuel failure, but close to or above recently observed thresholds for fragmentation and dispersion of high burn-up fuel. The highest calculated quasi steady-state power following initial power excursion was in most cases approximately 20% of the nominal reactor power, according to SIMULATE-3K and APROS. However, in some RECRIT cases higher power levels, approaching 50% of the nominal power, were predicted leading to fuel temperatures exceeding the melting point, as a result of insufficient cooling of the fuel. Long-term containment response to recriticality was assessed through MELCOR calculations for the Olkiluoto I plant. At a stabilised reactor power of 19% of nominal power, the containment failure due to overpressurisation was predicted to occur 1.3 h after recriticality, if the accident is not mitigated. The SARA studies have clearly shown the sensitivity of recriticality phenomena to thermal-hydraulic modelling, the specifics of accident scenario, such as distribution of boron-carbide, and importance of multi-dimensional kinetics for determination of local power distribution in the core. The results of the project have pointed out the importance of adequate accident management strategies to be used by reactor operators and emergency staff during recovery actions. Recommendations in this area are given in the paper. (C) 2001 Elsevier Science B.V. All rights reserved.