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Research Article

Effect of Coolant Inventories and Parallel Loop Interconnections on the Natural Circulation in Various Heat Transport Systems of a Nuclear Power Plant during Station Blackout

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Provision of passive means to reactor core decay heat removal enhances the nuclear power plant (NPP) safety and availability. In the earlier Indian pressurised heavy water reactors (IPHWRs), like the 220 MWe and the 540 MWe, crash cooldown from the steam generators (SGs) is resorted to mitigate consequences of station blackout (SBO). In the 700 MWe PHWR currently being designed an additional passive decay heat removal (PDHR) system is also incorporated to condense the steam generated in the boilers during a SBO. The sustainability of natural circulation in the various heat transport systems (i.e., primary heat transport (PHT), SGs, and PDHRs) under station blackout depends on the corresponding system's coolant inventories and the coolant circuit configurations (i.e., parallel paths and interconnections). On the primary side, the interconnection between the two primary loops plays an important role to sustain the natural circulation heat removal. On the secondary side, the steam lines interconnections and the initial inventory in the SGs prior to cooldown, that is, hooking up of the PDHRs are very important. This paper attempts to open up discussions on the concept and the core issues associated with passive systems which can provide continued heat sink during such accident scenarios. The discussions would include the criteria for design, and performance of such concepts already implemented and proposes schemes to be implemented in the proposed 700 MWe IPHWR. The designer feedbacks generated, and critical examination of performance analysis results for the added passive system to the existing generation II & III reactors will help ascertaining that these safety systems/inventories in fact perform in sustaining decay heat removal and augmenting safety.

1. INTRODUCTION TO 700 MWe PRESSURISED HEAVY WATER REACTOR (PHWR)

In the 700 MWe PHWR, the primary coolant heavy water under pressure removes (with partial boiling at channel exit) the fission heat generated in the reactor core and transfers it to the secondary coolant (light water) in the steam generators (SGs). The primary heat transport (PHT) system consists of 392 fuel channels. The PHT system is divided into two identical loops. Each loop consists of two primary circulating pumps (PCPs) and two SGs in a figure of eight loop configuration as shown in Figure 1. There are two passes through the core for each loop. As the primary coolant flows over the fuel bundles placed inside the channels, it picks up the fission heat in four passes through the reactor core. In each pass, 98 channels are connected to a common header at each end of the reactor. After picking up heat from the reactor core, the coolant flows through the reactor outlet header (ROH) into the tube side of the SGs. After transferring heat in the SGs, the primary coolant is pumped (by the primary

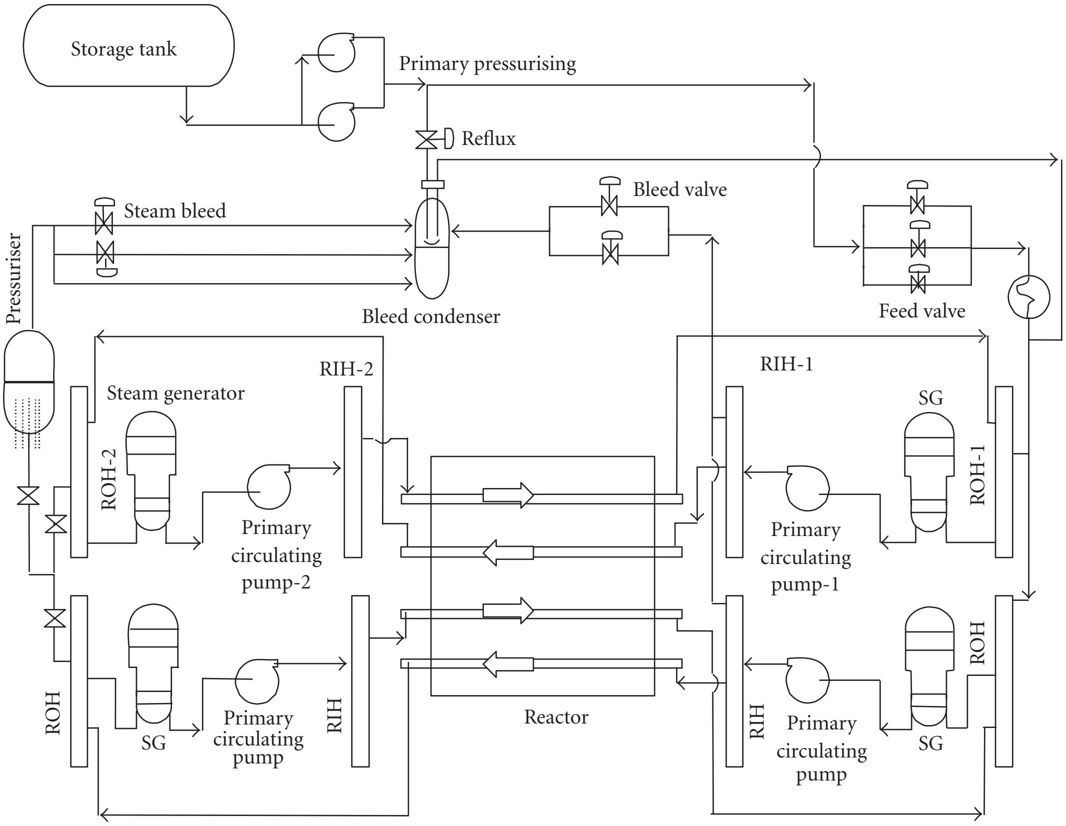

Figure 1: 700 MWe PHWR primary heat transport system.

circulating pumps (PCPs)) back to the reactor core through reactor inlet header (RIH).

The SG provides the thermal linkage between the PHT system and the secondary coolant system. The SGs deployed in the 700 MWe reactors are of the inverted U-tube type with integral drum. The secondary fluid flows in the shell side, and the hot primary coolant from the reactor core (ROH) flows inside the U tubes. The total boiler feed is given at the top of the downcomer. The recirculation flow from the steam drum, after mixing with the feed water, flows down the annulus (downcomer). Then, it rises up through the main boiling zone, as it picks up the heat. After extracting the heat, the secondary fluid (steam-water mixture) rises through the riser and then passes through the steam separator and dryers. Here, the two-phase mixture gets separated into saturated water and steam. The former is led downwards, after mixing with the feed water, to the annular downcomer of the SG, while the latter goes to the steam outlet and then to the turbine.

The average of the two ROH pressures is controlled around a set point of 101.0 kg/cm^2, to avoid excessive boiling and over-pressurisation in the PHT system. In the 700 MWe PHWR, for controlling the PHT system pressure, a pressuriser (surge tank) is also provided along with the Feed/Bleed system for maintaining the coolant inventory. The feed/bleed system is provided for controlling the water level in the pressuriser. Steam bleed valves (SBVs) are provided on top of the pressuriser vapor volume to control the increase in the PHT system pressure, by relieving the heavy water steam into the bleed condenser (BC) through the PHT system pressure controller. Electrical heaters are provided to take care of the low-pressure transient, by switching on the heater banks to increase the pressuriser pressure. The hot bleed from the RIH, and the relief from the south ROH flashes into a two-phase mixture inside the BC. The BC pressure is controlled at 34 Kg/cm^2. In the event of an increase in the PHT system pressure, the SBVs also start relieving heavy water steam into the BC. At 100% full power steady state, the reactor core inlet temperature is 266 C, the core outlet temperature at the ROH is 310 C, and the reactor core exit quality is around 3% only.

2. EXPERIENCE DURING 220 MWe PHWR NAPS FIRE INCIDENT

An incident of fire in the generator at one of the units of Narora Atomic Power Station had led to gradual loss of class-IV and class-III power supplies for all the plant loads such as primary coolant pumps, pressurising pumps, shutdown cooling pumps and main and auxiliary boiler feed pumps on secondary side resulting in a station blackout like scenario. Fire water had to be manually hooked up by going to boiler room. Thermosyphon in the primary and the secondary systems did work, and there were no fuel failures, with no activity release. Nuclear power plants have safety systems which are designed to be highly reliable. In spite of the various built-in provisions for very high reliability, requirement of analysis and suitable provisions for beyond design basis event (BDBE) scenario of station blackout, LOCA without ECCS actuation, and so forth, are necessary.

A debate on the concepts to be adopted for nuclear power plants to be built in the future has been underway with several different approaches being in vogue. One approach being the "evolutionary" approach which recommends that the plant design is similar to well proven design with some enhancements in safety. Other approach is to go for passive design. The "evolutionary" approach considers greater redundancy and diversity whereas latter relies on features such as lower-core power density, greater RB volumes, and greater reliance on thermosyphon. Broad lessons from Chernobyl, NAPS fire incident, and even recent Tsunami incident with respect to Kalpakkam show that continued availability of heat sink is the major issue to be addressed even if provision of this is done in somewhat "simple" manner.

3. PASSIVE DECAY HEAT REMOVAL SYSTEM (PDHRS) FOR 700 MWe PHWR

Long term removal of decay heat is essential to avoid fuel heat up even after reactor trip or shutdown. Different heat sinks are available for various states of reactor shutdown such as a normal shutdown with class IV available or accident conditions such as LOCA. During normal shutdown, initially the decay heat is removed by steam generators with steam being dumped to condenser and/or through atmospheric steam discharge valves (ASDVs). Feed water make up to steam generators is by main or auxiliary boiler feed pumps (MBFPs or ABFPS). Further primary cool down to room temperature is by shutdown cooling system with the heat getting transferred to active process water system (APW) and subsequently to service water loop and then to atmosphere.

In case of station blackout, the envisaged heat sink is the passive decay heat removal system (PDHRS) for recirculating the steam generator secondary side inventory through the U-tube condenser inside PDHRS tanks.

For removing the heat generated by the PHT, PDHRS is provided for condensing the steam and recirculating the steam generator inventory during station blackout scenario (see Figure 2). This system consists of a horizontal U-tube condenser inside a tank having inventory of 125 m^3 of water. The U-tube condenser is connected to a 150 mmNB line taken off from the main steam line, this steam gets condensed inside the 50 mmNB tubes of the condenser, and the condensate returns back to steam generator. During this process, the decay heat from primary side is given up to the tank inventory which would initially heat up, later starts boiling and the steam gets vented to the atmosphere. Four sets of such PDHR tanks, gets, and piping are provided one set connected to each of the four steam generators. The stored inventory in the tank is adequate to provide decay heat removal for more than 8 hours during which inventory make up to the tank can be initiated. During the normal operation of plant, periodic make up to this tank is envisaged by DM water connection. During the station black out scenario, the make up to this tank is envisaged from the firewater.

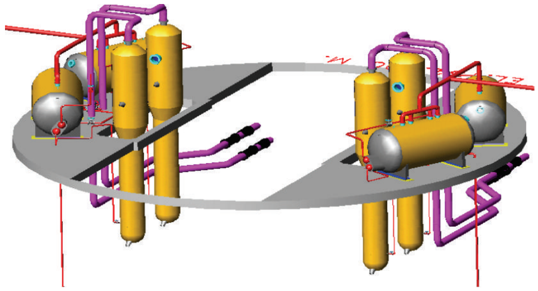

FIGURE 2: Layout for the four SGs and the 4 PDHRs.

As a design practice, it is always followed that the tested PHT system layouts (with multiple loops and parallel paths) of the earlier generation and operating power reactors are augmented with new concepts/systems such as the PDHRS and other passive systems. It is conveniently assumed that addition of these systems will enhance the NPP safety by continued removal of decay heat under adverse conditions. The performance analysis and the present studies point to another aspect which is very important, and it points out at the degradation/failure of heat removal in the presence of more than adequate coolant inventories in the primary, secondary, and the PDHRS. With detailed parametric studies and analysis of all the anticipated scenarios, this problem can be overcome and the effective use of all the available safety systems and coolant inventories can be achieved for the SBO case.

It has been reported in recent literature that RELAP5/MOD3.2 is capable of simulating natural circulation phenomena [1–4]. The SG boil-off and SBO response for a PWR are described in detail [5]. Reference [6] describes the incorporation of PDHRS, its design, and modeling. Reference [7] describes the application of RELAP5 for SBO analysis. The present study deals with boil-off in PDHRS connected to the secondary side of SGs and the effects of inter-loop connection leading to depletion of heat removal in the presence of large coolant inventories in the SGs and the PDHRS. Such study aims at analysing all the worst possible SBO scenarios and design verification to avoid severe accident conditions [8]. The thermal hydraulics modeling methodology and simulation philosophy of 700MWe PHWR for the present study are based on [9–16], though RELAP5/MOD3.2 code has been used here. Sensitivity studies were carried out to finalize the present nodalisation, which are not presented due to space limitation.

4. MODELING & NODALISATION

Primary heat transport (PHT) system model has been developed with two loops connected to the pressuriser and four passes through the core (see Figures 3 and 4). In each pass, 98 channels are modeled using 10 axial volumes. 10 heat

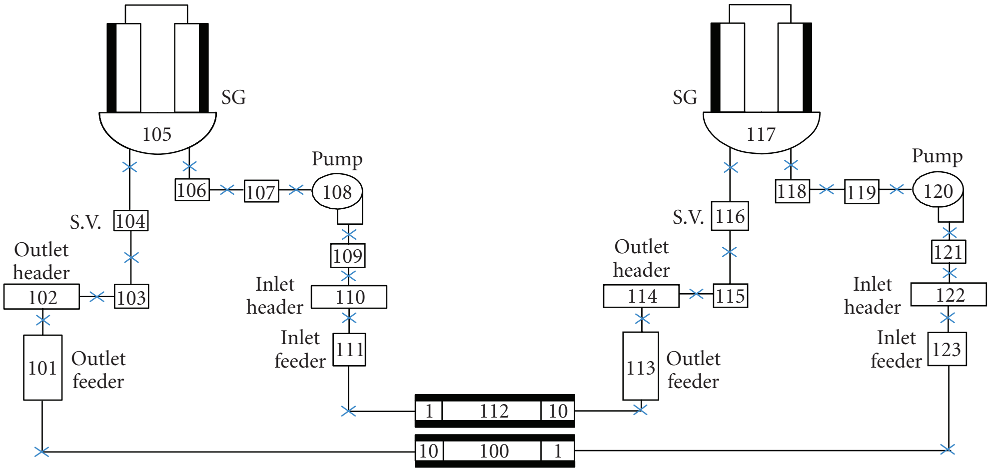

Figure 3: 700 MWe PHWR loop-1 nodalisation.

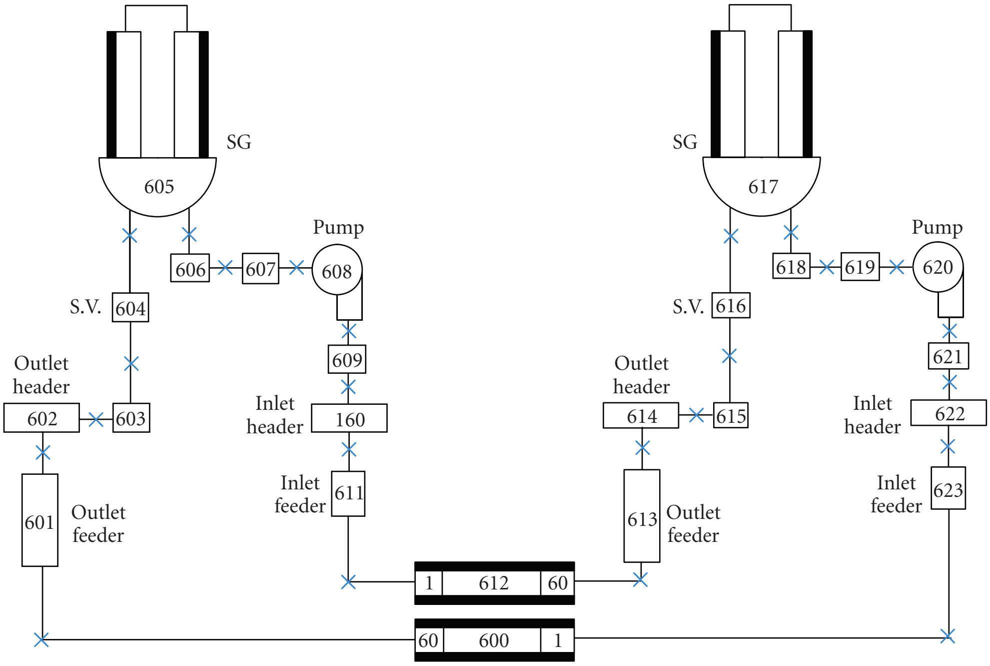

Figure 4: 700 MWe PHWR loop-2 nodalisation.

slabs are connected to the fuel in each pass of core. The feed and bleed systems are connected to the headers on one side of the reactor, and on the other side the pressuriser is connected to both outlet headers through the surge line. Surge line is modeled using two pipe volumes and a branch. All the headers are modeled as branches. The pressuriser is modeled using 12 control volumes with 1.5 MW electrical heaters and 10 heat slabs. The switching logic for pressuriser heaters has been developed based on the error in the PHT pressure, the steam bleed valves (SBVs) open following an increase in the PHT system pressure. The secondary system model (see Figure 5) includes simulation of the steam generator with pressure controller, level controller, and all the steam lines. The heated riser region is simulated with 10 control volumes; the unheated riser volume is also modeled. 20 heat slabs are used for connecting the primary and secondary systems thermally. The steam drum model includes 10 control volumes. The downcomer model also includes 10 control volumes. The PDHR system (see Figures 6 and 7) model is also integrated with all the 4 steam generators. All the steam lines up to governor, CSDV, and ASDV are simulated using several pipe and single volumes. Steady state conditions were

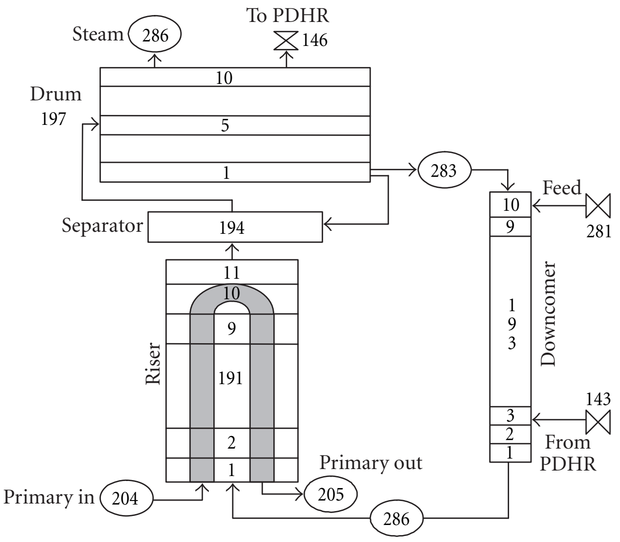

FIGURE 5: Steam generator nodalisation.

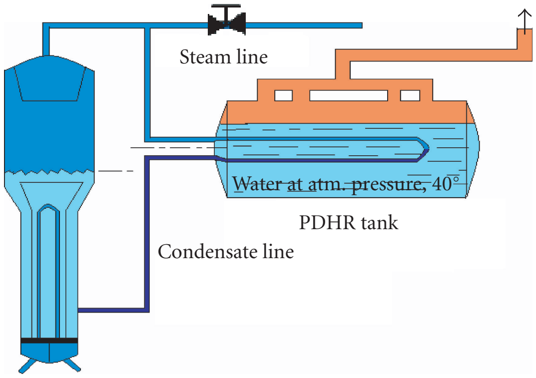

FIGURE 6: Schematic of a PDHR.

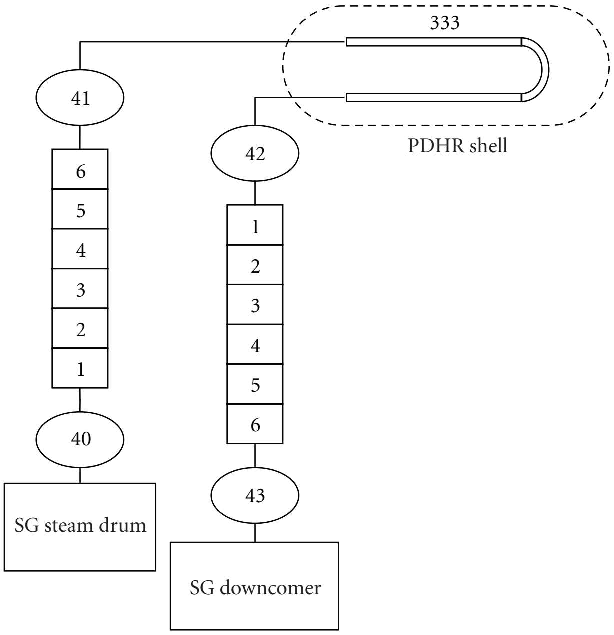

FIGURE 7: PDHR nodalisation.

achieved on both the PHT (ROH quality ~3.5%) and SG side integrated together for a plant simulation model.

5. RESULTS AND DISCUSSION

SBO scenario includes the loss of all the operating pumps, that is, 4 primary circulating pumps (PCPs), primary pressurising pumps (PPPs), and all the boiler feed pumps (BFPs). The reactor trip signal based on the loss of all the PCPs; is generated within one second. To study the effect of the various inventories and the parallel multiple loop interconnections, three case studies carried out, are is, (i) effect of initial coolant inventory in the SGs prior to cooldown, (ii) effect of the steam line interconnection, and (iii) effect of the PHT loop isolation.

5.1. *Effect of initial SG inventory*

Two cases are presented in this category, that is, (a) SBO analysis with PDHR valving in after 6 minutes. (b) SBO analysis with no delay in valving of the PDHR. Because of the delay in valving in of the PDHRS (which is a closed system), certain amount of SG inventory is lost through the ASDVs in the first case. In the second case, the initial inventory of the SG coolant is higher prior to the initiation of cooldown with the PDHRS.

5.1.1. *Station blackout analysis with PDHR valving in after 6 minutes*

Station blackout was initiated by tripping all the PCPs, PPPs, and the boiler feed pumps (BFPs) at $t = 0$ second. The reactor trip on no PCP available signal was delayed by one second. The actual reactor power reduction was further delayed by one second considering the delays for rod insertions on conservative side. Hot shutdown condition was maintained for initial six minutes with the help of atmospheric steam discharge valves (ASDVs) mounted on the SG steam lines, after this all the four PDHRs valves were opened to condense the steam from SGs, that is, at $t = 361$ seconds. Once the PCPs are tripped, the differential pressure across the headers/channel decreases, and all header pressures start falling together.

Following the reactor trip and the valving in of the PDHR, the PHT system pressure (see Figure 8) starts falling (80 bar at $t = 508$ seconds), and the pressuriser level falls below 1.7 m, which leads to isolation of the pressuriser. After this, the PHT system pressure falls rapidly to 8 bar at $t = 7000$ seconds, then it remains around this value approximately up to 27000 seconds. Later on the PHT system pressure, Pressure shows an increasing trend again following depletion of shell side inventory in the PDHRs. It comes down to about 43 ton from 121 ton. At $t = 47000$ seconds, it falls to 11 ton, and thereafter it remains almost constant as the liquid level in the PDHRS falls below the tube bundle.

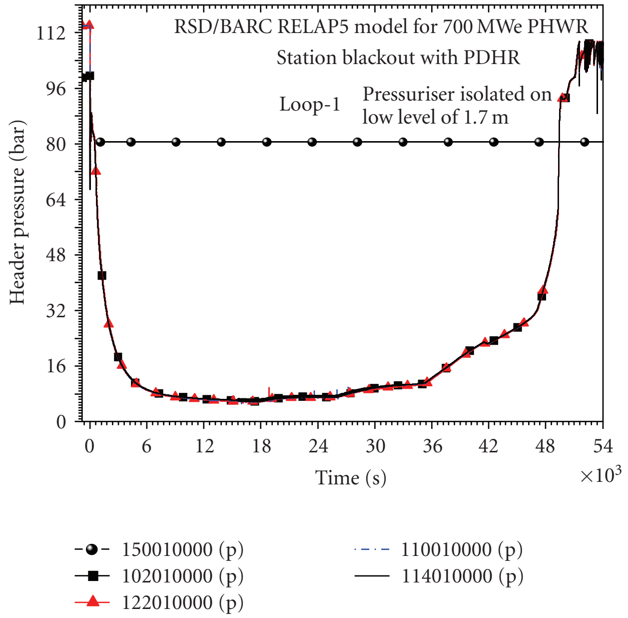

Figure 8: PHT system pressure case-6 minutes.

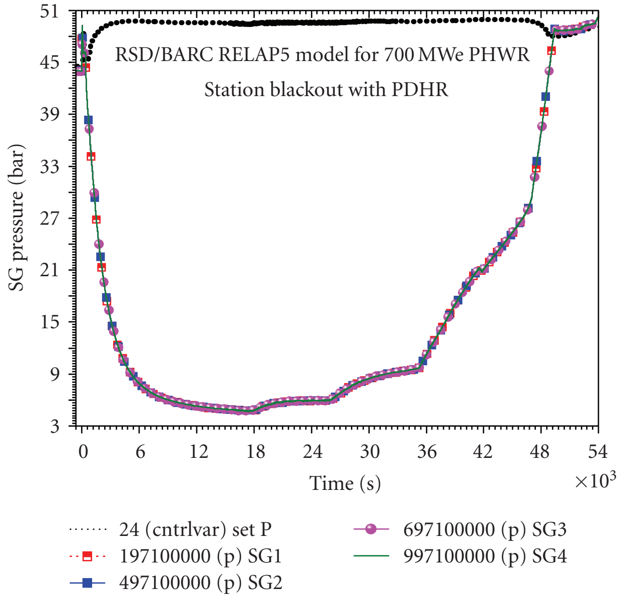

Figure 9: SG Pressure variation case-6 minutes delay in valving in PDHRS.

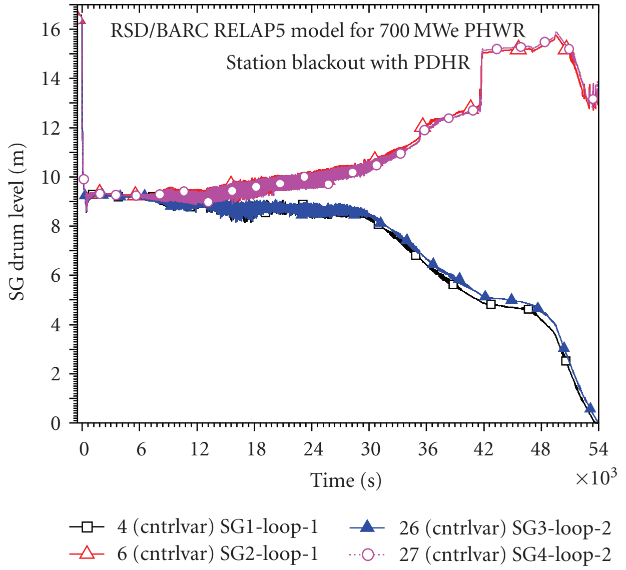

Figure 10: SG level variation case-6 minutes delay in valving in PDHRS.

The SG pressure (see Figure 9) shows a peak of 49.3 bar at $t = 45$ seconds initially following the turbine trip initiated due to reactor trip, it falls to 41.8 bar, at $t = 7000$ seconds, then it comes down to 7.03 bar at $t = 27000$ seconds.

All the four SGs are connected through the steam lines. Any PHDR through the steam lines can draw the steam from all the four SGs, but it sends back condensate only to the SG to which it is connected. Though the difference between the four SG pressures is very small, the SG with maximum SG pressure sends more steam to the other PDHR in addition to the PDHRs to which it is directly connected. The return flow to this SG is only equal to the steam flow which was going to the corresponding PDHR (directly connected), the steam flow to other PDHRs sends the condensate to the other SGs. This initiates an inventory transfer, beyond $t = 1800$ seconds, due to low-driving forces encountered during natural circulation at low pressure in the PHTs, SGs, and PDHR, it is observed that the SG level (see Figure 10) in two SGs goes down and the other two SGs, it shows an increasing trend. Inventory transfer through steam lines is observed but the total SGs inventory remains constant. Another initiation cause (for difference in the four SG pressures) is the difference in the PHT flow through all the four SGs during natural circulation.

The total primary core flow (see Figure 11) remains around 7% at $t = 7000$ seconds after this it shows a slow-decreasing trend. The PHT system core exit quality remains low up to 15000 seconds, then it shows lot of oscillation (also observed in the core flow), it even reaches values up to 50% and above, up to 30000 seconds, then it comes back to lower values (<2%). It can be concluded that the PDHRs can remove the decay heat safely up to 10 hours, during this period additional water inventories can be lined up.

5.1.2. SBO with no delay in valving in of the PDHRs

In the previous station blackout case, it was assumed that the PDHRs valves are opened after 6 minutes delay. In the present case, it is assumed that the PDHRs valves are opened without any delay immediately after sensing the station blackout at $t = 1$ second. The results obtained are similar to the earlier predictions (see Figures 12, 13, 14, 15, and 16) but the oscillation/fluctuation in the PHT and the SG flows are relatively dampened, and more stable flow conditions

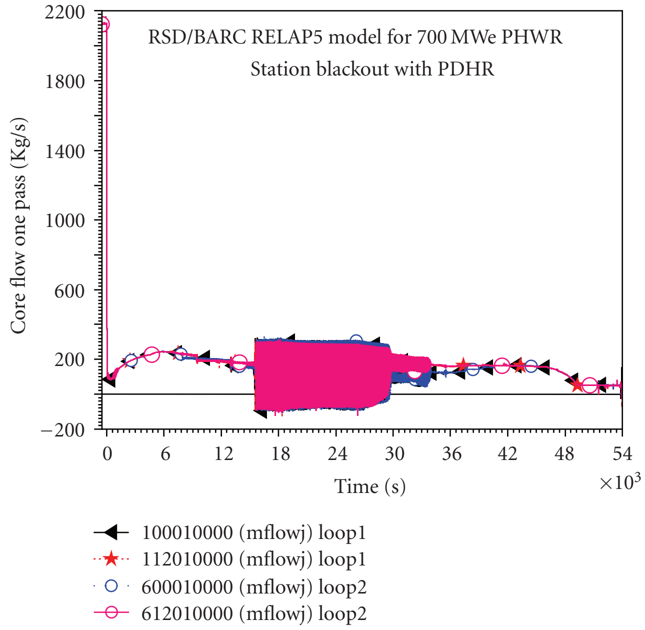

Figure 11: Core flow variation case-6 minutes delay in valving in PDHRS.

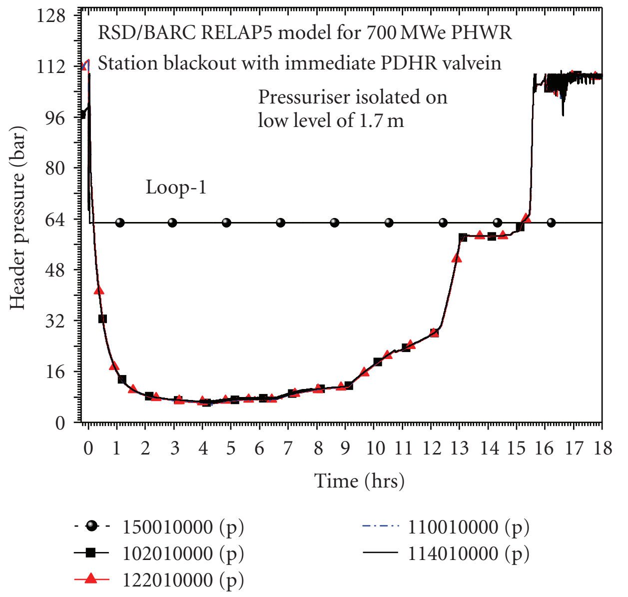

Figure 12: PHT pressure variation case-no delay in valving in PDHRS.

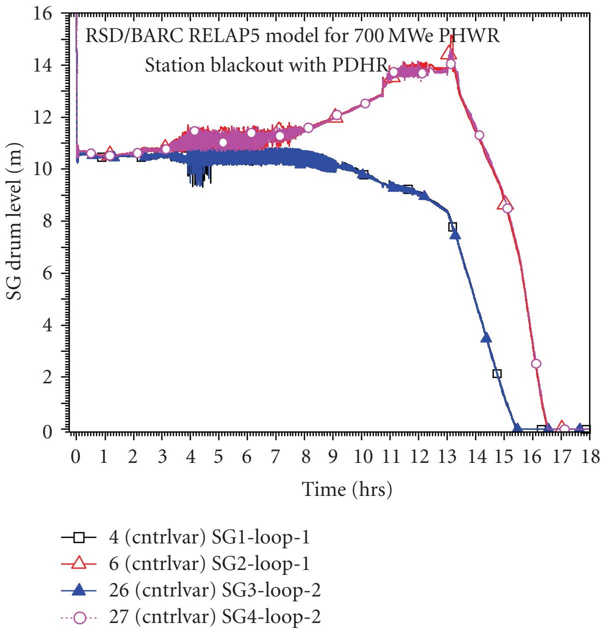

Figure 13: SG level variation case-no delay in valving in PDHRS.

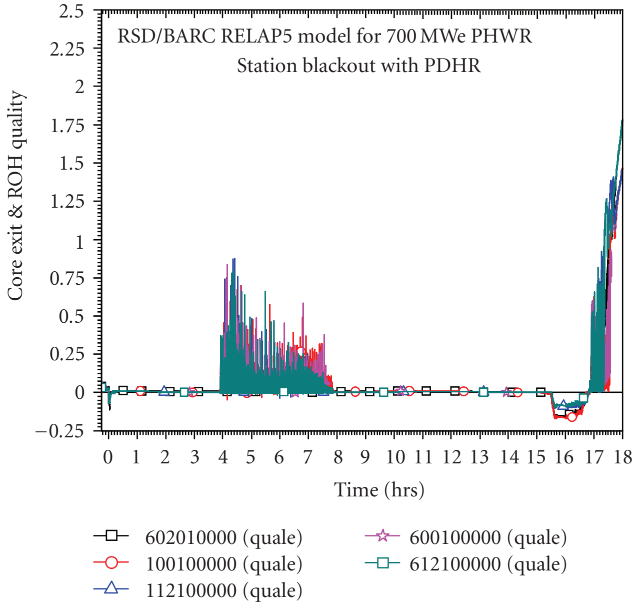

Figure 14: Core exit quality variation case-no delay in valving in PDHRS.

are observed due to higher SG inventories. In the 6 minutes PDHR valving delay cases, the SG inventories go down from 32 ton to almost 27 ton, a loss of 5 ton through atmospheric steam discharge valves (ASDVs) in the initial 6 minutes. For the no delay case, the ASDVs open only for a short period, and the SG inventory remains around 32 ton with negligible loss. As the steam lines were not isolated, diverging trend was observed for SG levels (see Figure 13). It can be concluded that valving in of the PDHR should not be delayed if a SBO is confirmed.

5.2. *SBO with steam line isolation*

All the steam lines interconnections were isolated to avoid any inter loop inventory transfer through the parallel paths available in the steam lines. Each of the SGs is connected only

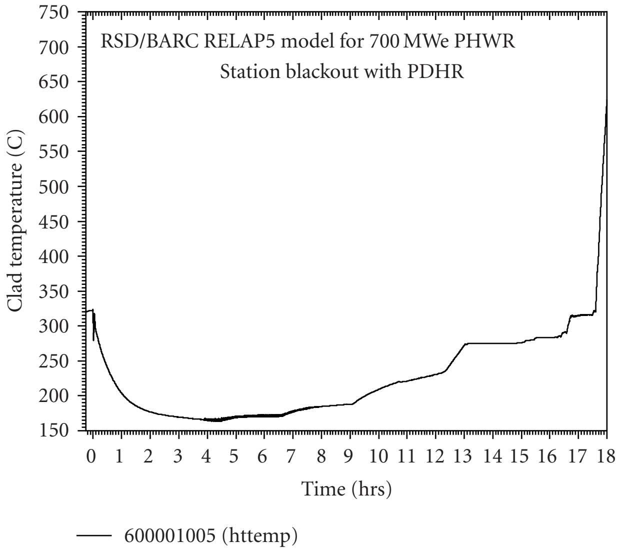

Figure 15: Clad temperature variation case-no delay in valving in PDHRS.

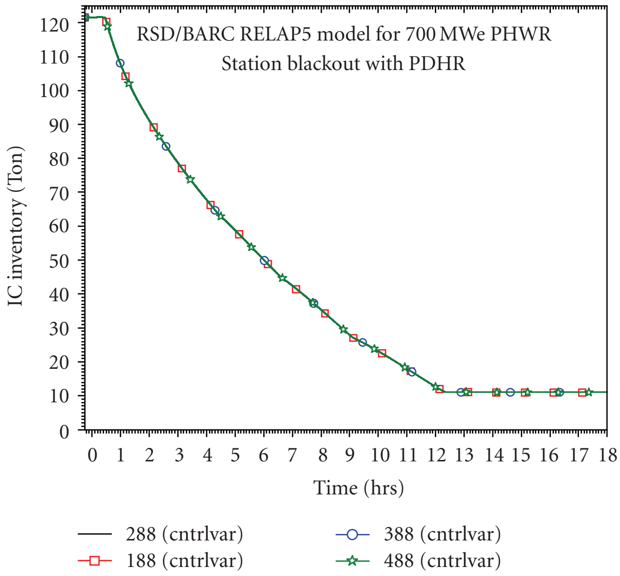

Figure 16: PDHR shell inventory variation case-no delay in valving in PDHRS.

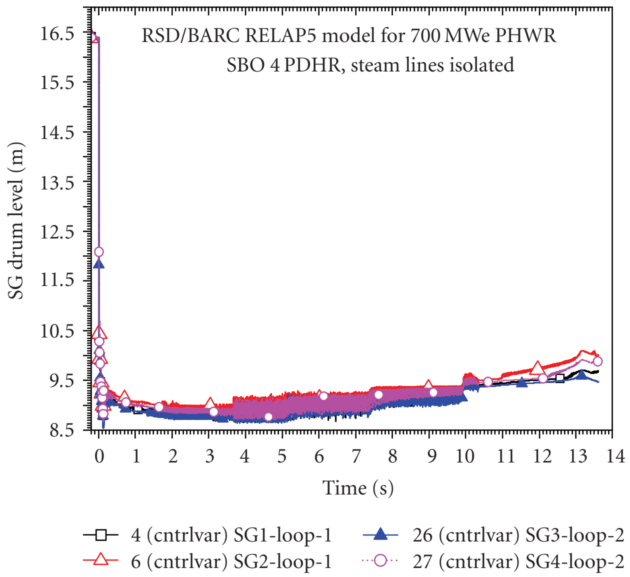

Figure 17: SG level case-steam line isolation.

to the corresponding PDHR, and all other connections are snapped.

Station blackout analysis with isolation of steam lines

In the previous station blackout transient analysis, it was observed that the level in two SGs was increasing significantly after 30000 seconds, and in the other two SGs, it was going down correspondingly, keeping the total inventory of all the four SGs constant. This was attributed to low-driving forces encountered during natural circulation at low pressure in the PHTs, SGs, and PDHR, resulting in an inventory transfer through steam lines. To support these explanations, another hypothetical station blackout with complete isolation of the steam lines was carried out. Here, it was observed that the SG levels (see Figure 17) do not diverge and remain almost at the same value for all the four SGs, though the levels are not exactly same, but they follow a similar trend (variation around 9 m). For most of the other parameters, the trend is almost similar as compared to the previous blackout analysis without isolation of the steam lines. It can be concluded that the alternative parallel path provided by the steam lines leads to inventory transfer. This leads to drying out of one SG in each loop, but the decay heat removal is unaffected as the other SG in the loop with its own inventory and the transferred coolant inventory can carry on the decay heat removal effectively for the complete loop.

5.3. 3 PDHRs with/without primay loop isolation

In these cases, one PDHR connected to one of the SG in loop-1 was kept isolated during the transient. As there is no heat removal from one of the bank, the primary coolant at higher temperature enters in the core through the return pass. After some time as the two phases appear in the return pass, there is a drastic reduction in core flow leading to a stagnation phase at $t > 4200$ seconds (see Figure 18). Since the affected loop pressure was slightly higher as compared to healthy loop (cooling unaffected), there is a continuous transfer of primary inventory from loop-1 to loop-2 through the ROH connection though the pressuriser is isolated, but the PHT loops are connected.

To avoid this inter-loop PHT inventory transfer, a case study with the isolation of these two primary loops was also carried out. With the arrest of primary inventory removal from the affected loop-1 (with one working and another

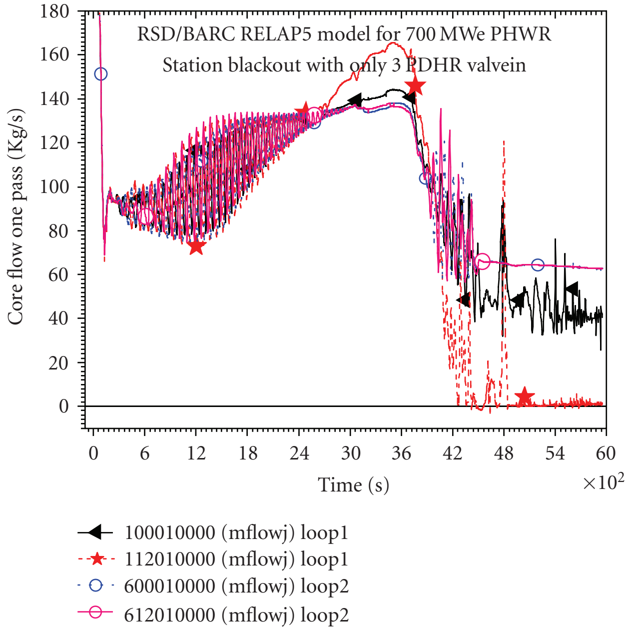

FIGURE 18: Core flow case-3PDHRs with no loop isolation.

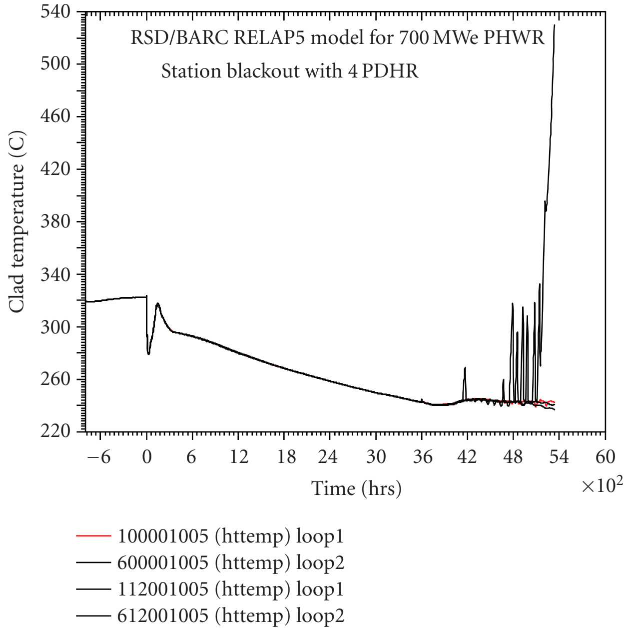

FIGURE 19: Clad temperature case-3PDHRs with no loop isolation.

nonworking PDHR), the core flow (see Figure 20) through the two passes of both affected loop-1 and healthy loop-2 remains at a higher-positive value for a considerable period of time (∼21 000 seconds), and core cool ability is maintained. The PDHR isolation valve failure leads to the failure of the corresponding PDHR, probability of this event cannot be neglected. Based on this study, it is highly recommended that the two primary loops should be isolated when there is an unsymmetrical mode of PDHR operation.

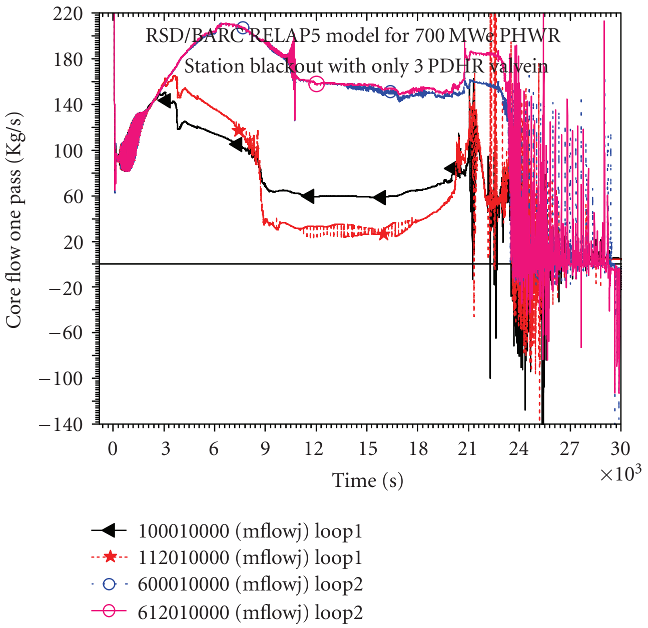

FIGURE 20: Core flow case-3PDHRs with loop isolation.

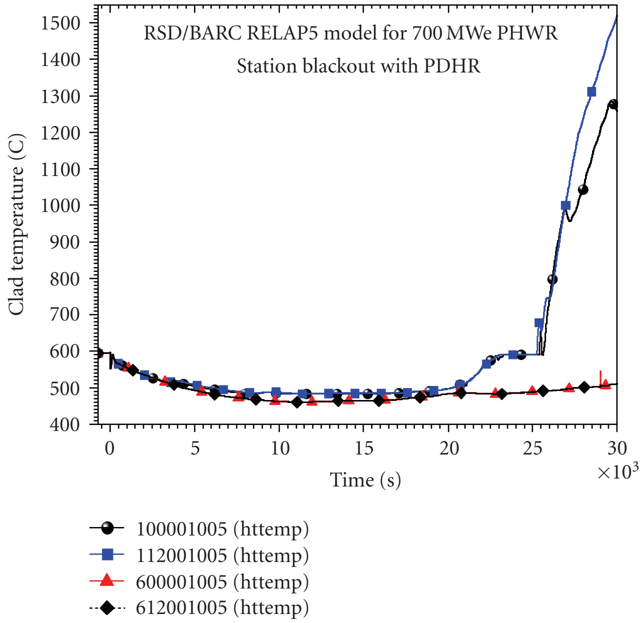

FIGURE 21: Clad temperature case-3PDHRs with loop isolation.

5.3.1. *Station blackout (SBO) analysis with only 3 PDHRs available and with PHT loops isolation*

In this SBO transient analysis, it is assumed that, one passive decay heat removal (PDHR) heat exchanger fails, as a result only 3 PDHRs are available to cool the steam from all the four SGs. It was also assumed that the pressuriser and the 2 PHT loops are isolated from each other on pressuriser low level. The results obtained are similar to the all PDHRs available case for the initial period, but the decay heat removal is hampered within 7 hours, whereas for SBO with all PDHRs available case, the decay heat removal is not affected for more than 17 hours.

For the PHT loop isolation case, the nonfunctional PDHR inventory remains at 121 ton throughout. For the other only working PDHR, in the affected PHT loop-1, the PDHR inventory falls to 26.7 ton in 8.3 hours, whereas in the healthy PHT loop-2, with both PDHRs working, the PDHR inventory falls to 16.5 ton in the corresponding period. After 7 hours, the affected loop clad temperature (see Figure 21) shoots up sharply following core flow (see Figure 20) reduction and exposure of the PDHR heat exchanger tubes in the only working PDHR in that loop. For the SG without a working PDHR, the SG-inventory falls to almost one ton within 1.1 hour, after this it remains around this value and does not fall to zero. For the SG in the affected PHT loop-1 with only working PDHR, the SG-inventory comes down below one ton after 5.8 hours, that is, both the SGs in the affected PHT loop-1 dryout due to inventory transfer to the SGs in healthy PHT loop-2.

This unfavorable situation is caused by inventory transfer from the SGs of the affected loops to the other loops where both PDHRs are operational. Steam flow from all the four SGs to 4 PDHRs is guided based on the differential pressure between these components. More steam flow goes from the SG drum with the highest pressure (i.e., low-PHT flow) to the PDHRs, based on the pressure, all the SGs send steam to the PDHRs. The SG receiving maximum steam/condensate will accumulate more inventory. This phenomenon was observed for all the SBO cases analysed (except for the SBO without steam lines). It leads to total SG inventory transfer from loop with one PDHRs working to the SGs of the loop with 2 PDHRs working, as a result both the SGs in the one PDHR available loop-1 dryout after 5.8 hours for the PHT loop isolation case, and the clad temperature (see Figure 20) increases rapidly.

5.3.2. *SBO analysis with only 3 PDHRs available and without PHT loops isolation*

Here, only 3 PDHRs are available following SBO, and it was also assumed that only the pressuriser isolates from the 2 PHT loops, and the 2 PHT loops remain hydraulically connected through the surge lines as the pressuriser level falls below 1.7 m. For this case, the primary flow reduces to almost zero in the one of the core passes in the affected loop, leading to an increase in clad surface temperature (see Figure 19, more than 1000 C) after ~1.5 hours. The primary coolant flow (see Figure 18) in this core path is hampered by the inter-loop inventory transfer, as the affected loop which is at higher pressure and temperature tries to equalise pressure, forcing flow out from this core path. As the flow reduces and stagnates (see Figure 18), the core exit quality increases sharply (>1.0). Though a lot of coolant inventory is available in the SGs and also in the PDHRs (89 ton), the clad temperature (see Figure 19)shoots up due to core flow stagnation. For the SG without PDHR working, the SG level comes down almost to zero, in one hour. For the other SG in the healthy loop-2 with working PDHRs, it shows an inventory corresponding to 12 m level at about 1.5 hours. Here, also the phenomenon of SGs inventory transfer from the affected loop to the healthy loop is observed, but the clad temperature shoots up far ahead of dryout due to PHT flow stagnation following PHT inventory transfer from affected loop to healthy loop.

The results obtained with RELAP5 model show a similar behavior for natural circulation as reported in the literature [1–4]. It can be concluded that the 2 PHT loops should be isolated following an SBO to avoid inter-loop inventory transfer through the surge lines, which leads to stagnation of core flow in the affected loop due to unfavorable pressure distribution. This undesirable situation is further aggravated by the inventory transfer from the SGs of the affected loops to another loop with both PDHRs operational.

CONCLUDING REMARKS

(1) It can be concluded that the 4 PDHRs, with an initial inventory of 121 ton each at 40 C, can remove the core decay heat without any increase in the clad temperature for about 17 hours without the help of make up system, if all the 4 PDHRs are available.

(2) No delay in valving in of the PDHRs is recommended after confirmation of a station blackout situation, as a higher inventory in the SG leads to more stable natural circulation in the secondary and the primary heat transport system. The rate of change of primary and secondary coolants structure temperature is also moderate.

(3) The secondary inventory transfer from SGs in one loop to SGs in another occurs due to parallel paths interconnected steam lines. Following the SBO and cooldown with natural circulation at low pressure and low-driving forces in the PHT, SGs, and PDHRS, this phenomenon cannot be avoided.

(4) For the SBO with three PDHRs available case, the PHT system inventory transfer takes place from the affected loop (cooling affected due to inventory transfer to other loop) to healthy loop (cooling unhindered), due to pressure imbalance and parallel paths inter-connected surge lines available. In this case, the isolation of the two PHT system loops is helpful in mitigating the consequences of failure of one of the 4 PDHRs, and without the loop interconnection the decay heat removal is not hampered for 7 hours.

(5) The designer feedbacks generated from the analysis, and critical examination of performance analysis results for the added passive system to existing generation II and III reactors will help ascertaining that the these safety systems/inventories in fact perform in sustaining decay heat removal and augmenting safety.

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