Events at Russian VVER NPPs

December 11-13, 2013
India, Kanyakumari, Tamil Nadu, 20th Annual Meeting of the Forum of the State Nuclear Safety Authorities of the Countries Operating VVER Reactors (VVER Regulators Forum)

- **11.12.2012, Balakovo 4**

Exceeding of safe operation limits with reactor scram by actuation of reactor protection system caused by spontaneous opening and unfitting of steam generator (SG) main safety valve due to erosion of the disk and seat of the pilot operated safety valve

- **18.04.2013, Kalinin 4**

Occurrence related to safe operation conditions as a result of non-closure of the SG main safety valve during scheduled trial operation prior to unit start-up due to ingress of a mechanical particle (sized 5x3 mm) under the seat of the SG pilot operated safety valve

- **23.07.2013, Kalinin 3**

Failure of the safety system trains due to non-opening of the main safety valve of the pressurizer pilot operated safety relief valve (PORV) during scheduled trial operation during 2013 scheduled outage due to insufficient steam flow rate from the head-end cavity of the main safety valve of the pressurized PORV through the pilot valve as a result of non-conformance of the rated stroke of the slides of the pilot valve electrical solenoids with the requirements of the design documents

Operational Occurrence at Balakovo 4 (1/6)

Date: 11.12.2012

Plant: Balakovo

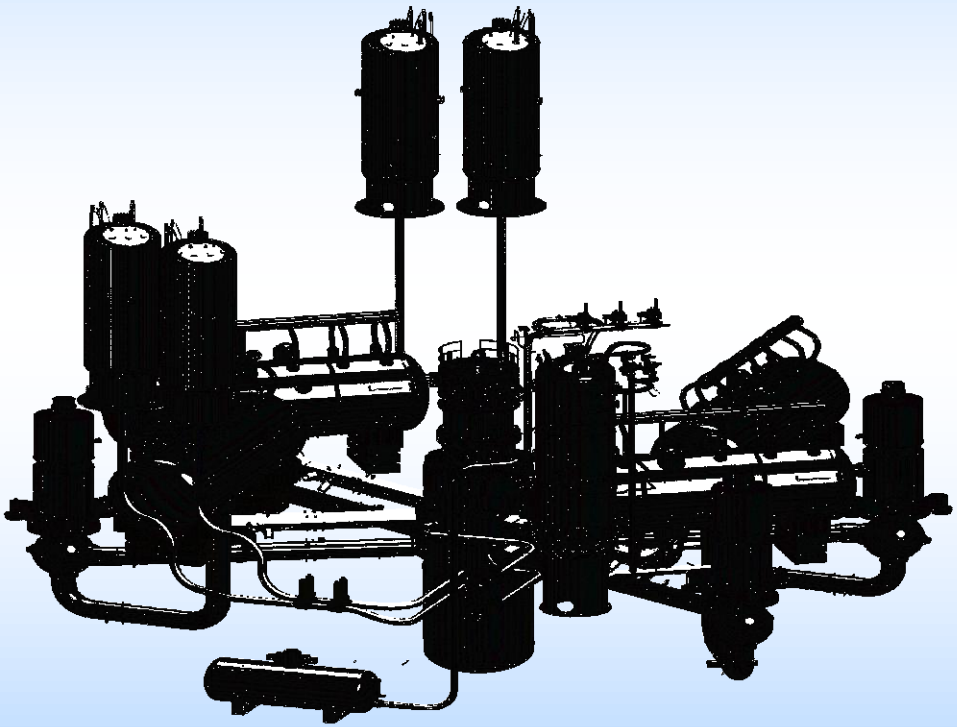
Unit No.: 4

Reactor: VVER-1000

Occurrence:

Exceeding safe operation limits with the reactor scram by actuation of the reactor protection system caused by spontaneous opening and non-seating of the SG main safety valve due to erosive washout of the disk and seat of the pilot operated safety valve

Operational Occurrence at Balakovo 4 (2/6)



<u>Parameters of the unit prior to occurrence</u>:

Unit at uprated power level

Ne=1070 MWe

Nt=3120 MWt

The state of all the normal operation systems important to safety, as well as that of the safety systems, complies with the requirements of the process regulations

Operational Occurrence at Balakovo 4 (3/6)

Disturbance description:

- December 11, 2012, 16:21 – spontaneous opening of the pilot valve of the SG PORV with subsequent opening of SG-4 main safety valve;
- Resultant level and pressure drop in SG-4. At 16:21:36, pilot valve closure initiated – non-closure of the valve;
- 16:21 to 16:32 – NPP personnel actions to eliminate consequences caused by spontaneous opening of pilot valve in compliance with the emergency response procedure;
- 16:32 – personnel managed to close SG-4 main safety valve;
- December 12, 08:15 – primary circuit cooled down; primary coolant temperature below 70ºC.

Operational Occurrence at Balakovo 4 (4/6)

Direct cause:

- erosive washout of the disk and seat of the pilot operated safety valve. The amount of leakage in that case achieved the value, which was sufficient to actuate the operating valve and, hence, opening of the main safety valve of the steam generator pilot operated relief valve.

Root causes:

- manufacturing shortage in terms of obtaining the required carbonitride layer in accordance with the requirements of the manufacturing documentation;
- sealing surface of the valve gate did not allow precluding erosive washout and growth of leak in the course of operation up to a value sufficient for actuation of the pilot operated relief valve.

Operational Occurrence at Balakovo 4 (5/6)

Assessment with regard to safety:

In the course of the transient period after actuation of the reactor protection system, the following limits of safe operation were exceeded:

- pressure in 4SG-4 < 45 kg/cm2;
- pressurizer level < 400 cm;
- 4SG-4 level – 110 cm lower than the rated value

All the safety systems and equipment envisaged in the design and aimed at managing the consequences of spontaneous opening and unfitting of the main safety valve of steam generator pilot operated relief valve were completely operable. The safety systems designed to perform their functions were in place.
The event did not cause any radiological consequences.
The disturbance was ranked level “1” on INES scale.

Operational Occurrence at Balakovo 4 (6/6)

Corrective Actions:

- replacement of the faulty parts of the pilot valve with the factory components;
- analysis of the transient mode of the reactor operation in case of a spontaneous opening and unfitting of the steam generator steam relief valves with the purpose of clarifying the limits of safe operation;
- development of documentation for debugging of the pilot valve design in order to preclude erosive and corrosive washout of the sealing surfaces of the seats and disks, which cause opening of the safety valve due to leaks in the gates of the pilot valve;
- introduction of a debugged design of the pilot valve;
- introduction of changes to the operating documentation in terms of specification of the amount, procedure and frequency of supervision of the technical state of the steam generator pilot operated relief valve performed by the operating personnel when the unit operates on power.

Operational Occurrence at Kalinin 4 (1/6)

Date: 18.04.2013

Plant: Kalinin

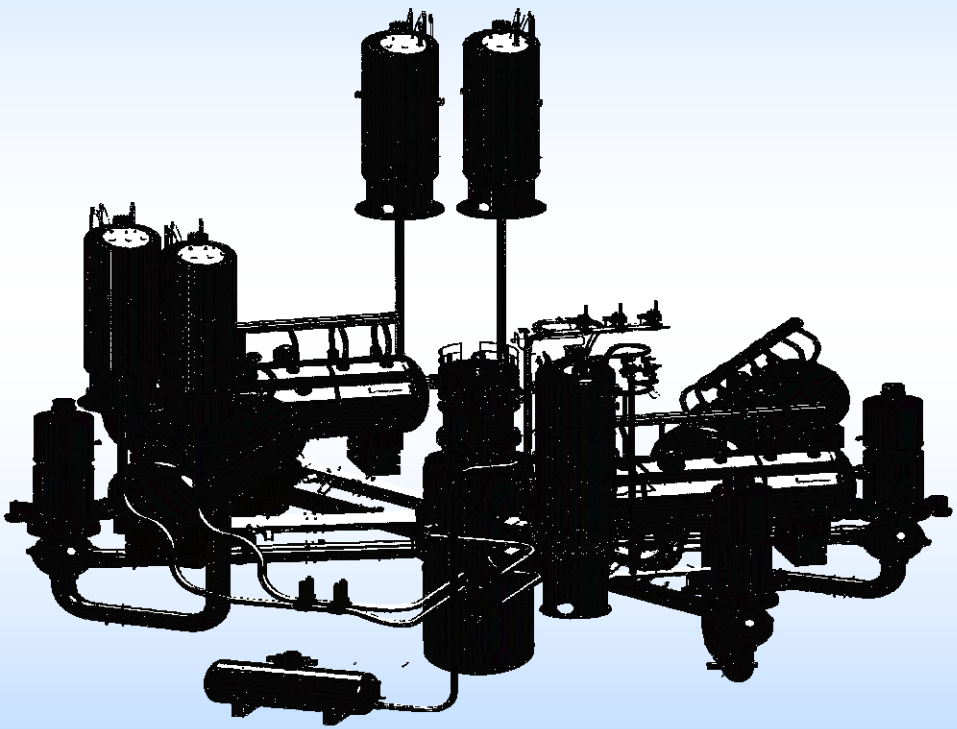
Unit No.: 4

Reactor: VVER-1000

Occurrence:

Violation of safe operation conditions as a result of non-closure of the steam generator-2 main safety valve during the scheduled trial operation prior to the start-up of the unit due to the ingress of a mechanical particle (5x3 mm) under the seat of the steam generator-2 pilot operated safety valve.

Operational Occurrence at Kalinin 4 (2/6)



<u>Unit parameters prior to occurrence</u>:

Unit under hot shutdown

N_{NFME}= 0%

$P_{1circuit}$= 15.61 MPa

$T_{1circuit}$= 275ºC

C_{H3BO3}= 18.41 g/dm^3

$P_{II\ circuit}$= 6.25 MPa

CPS control rods on bottom limit switch

Operational Occurrence at Kalinin 4 (3/6)

Occurrence description:

- April 18, 2013, 01:47 – NPP personnel started tests of the SG safety valve. At 04:41, when the pressure value in the SG-2 was 8.49 MPa, testing of the SG-2 main safety valve took place. The valve opened;
- 04:42 – pressure value in the SG-2 dropped to 6.81 MPa, the valve failed to close automatically. Forced closure of the pilot valve initiated;
- 04:42 – pilot valve closed, but the main safety valve remained opened. Within the next minute the pressure value in the SG-2 dropped to 5.89 MPa. The NPP personnel acted in accordance with the emergency response procedure in terms of opening and non-closure of the SG safety valve;
- 05:30 – reactor parameters became stable. The NPP personnel started to cool down the unit and brought it to cold state.

Operational Occurrence at Kalinin 4 (4/6)

Direct cause:

- A particle sized 5x3 mm had been carried over from the dead zones of the secondary circuit equipment and entered the area under the seat of the pilot valve.

Root causes:

- Insufficiently effective corrective actions for blowdown of the dead zones developed by the Kalinin personnel;
- Failure to take the needed action or an untimely action aimed at eliminating the detected drawbacks;
- Shortcomings of the adjustment activities resulted in poor quality of flushing of the makeup system pipelines of the unit SGs caused by imperfection of the methodologies and criteria for completion of installation cleaning of the makeup water pipelines and steam generator housings.

Operational Occurrence at Kalinin 4 (5/6)

Assessment with regard to safety:

The operational occurrence at Kalinin 4 is considered to be potentially important to safety. The opening and subsequent non-closure of the steam generator main safety valve are assumed to constitute an initiating event that might cause a design-basis accident.

The occurrence was assigned to Category P03 (abnormal safety operation conditions as per the rate of change in the primary pressure and temperature) under the “Provision on Investigation and Accounting of Occurrences in NPP Operation”.

The event caused no radiological consequences.

The event shall be level “1” on INES scale.

Operational Occurrence at Kalinin 4 (6/6)

Corrective actions:

- recovery repair of the steam generator pilot operated relief valves;
- analysis of the sufficiency of actions aimed at removing any foreign objects from the inner cavities of the equipment and pipelines during installation and upgrading. Based on the analysis results, the programs for equipment and pipelines flushing–blowdown will be revised to increase the number of cycles and improve quality control;
- inclusion of the topic of opening and non-closure of the steam generator safety valve during testing into the operating personnel training programs on a full-scale simulator prior to unit start-up;
- arrangement and conduct of targeted training for the Kalinin maintenance personnel with regard for repairs of the main steam valve unit.

Operational Occurrence at Kalinin 3 (1/6)

Date: 23.07.2013

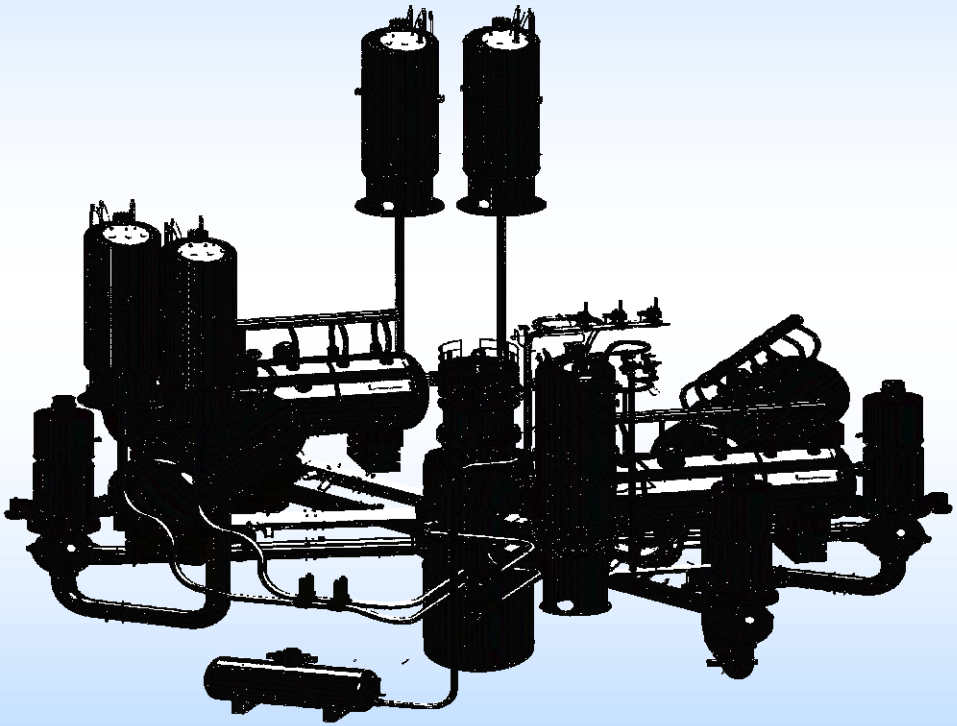
Plant: Kalinin

Unit No.: 3

Reactor: VVER-1000

Occurrence: Failure of the safety system trains due to non-opening of the main safety valve of the pressurizer PORV in the course of scheduled trial operation during the 2013 scheduled outage due to an insufficient steam flow rate from the head-end cavity of the main safety valve of the pressurizer PORV through the pilot valve as a result of non-conformance of the rated stroke of the slides of the pilot valve electric solenoids with requirements of design documents.

Operational Occurrence at Kalinin 3 (2/6)



Unit parameters prior to occurrence:

Unit under maintenance

Reactor in heat-up state

N_{NFME}= 0%

$P_{1circuit}$= 13.75 MPa

$T_{1circuit}$= 280 °C

C_{H3BO3}= 18 g/dm^3

$P_{II\ circuit}$= 6.25 MPa

Operational Occurrence at Kalinin 3 (3/6)

Occurrence description:

July 23, 19:00 to 19:39 – testing on the main safety valves of the pressurizer pilot operated safety relief valve was in progress. Two valves out of three failed to open. The test was stopped, and the reactor was brought to cold state.

After examination of the main safety valves of the pressurizer PORV which failed to open, re-testing was successfully carried out on August 1.

Operational Occurrence at Kalinin 3 (4/6)

Direct cause:

- insufficient steam flow rate from the head-end cavity of the main safety valve through the pilot valve as a result of non-conformance of the rated stroke of the slides of the pilot valve electrical solenoids with the requirements of the design documents.

Root causes:

- shortcomings of the manufacturer's design and engineering documents;
- drawbacks in the management and arrangement of NPP operation, namely:
  - shortcomings in the operating technical documents, including the maintenance and repair documents;
  - shortcomings in the maintenance and repair procedures to be performed by the NPP personnel, including supervision.

Operational Occurrence at Kalinin 3 (5/6)

Assessment with regard to safety:

The subsequent investigation revealed that the event was caused by exceeding the safe operation limits and conditions of the unit in terms of the pressurizer level.

The occurrence caused no radiological consequences.

The event was ranked level “1” on INES scale.

Operational Occurrence at Kalinin 3 (6/6)

Corrective actions:

- examination of the pressurizer PORV;
- introduction of changes to the supervisory procedure when maintaining the pressurizer PORV to make sure that the pilot valve rated slide stroke complies with the requirements of the manufacturer's documents (drawing);
- review of the test program for the pressurizer PORV in terms of the requirements to prohibition of work under the program when defects or faults of the system are detected;
- training of the NPP maintenance personnel who perform maintenance and repairs of the pressurizer PORV;
- consideration of a possibility of inviting the manufacturer’s representatives to examine the pressurizer PORV when it is under maintenance.

Conclusions

the operating organization has been taking actions on improving the robustness of the PORVs:

- the operator is considering the issue of using an optimal type of safety valves at the Russian NPPs;
- in 2013, corrective actions proposed by the manufacturers of the valves and approved by the operating organization and aimed at improving the robustness of the safety valves were implemented during the scheduled outage;
- the possibility for use of direct-operated safety relief valves at the Russian NPPs is analyzed
- a possibility of using direct-operated safety relief valves at the Russian NPPs is being considered.

Rostechnadzor follows the progress of these activities.

Thank you for attention!