**WANO EVENT REPORT-1BU-P08-001-02-19**

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| **\*\* Note:** |  |  |
| **\*\* Station:** | Bushehr Unit 1 |  |
| **\*\* Event Date:** | 04 February 2019 |  |
| **\*\*Title:** | Disconnection of the plant from the national power grid by closure of turbine stop valves resulting from increase in Steam Generator No.1 level due to the control valves and shut off valves not closing simultaneously |  |
| **\*\*Reference Unit:** | Unit, Year Commercial: Bushehr 1(2012)  Reactor Type (size): VVER 1000 / V-446 (PWR)  Plant Designer: AEP  Power: 1000 MW |  |
| **\*\*Station Event:** | Unit event |  |
| **Summary:** | On February 4th, 2019  When the plant was at “operation at power” state with 100% of the nominal power, one of Feedwater Pumps was shut down as a result of actuation of the Protection “Bearing Temperature Increase”. Later, by closure of turbine stop valves resulting from the increase in SG.1 level, due to the control valves and shut off valves not closing simultaneously, the plant was disconnected from the national power grid. | **Station Status -** 110- Steady power operation |
| **Event units:** | No others |  |
| **References:** | None |  |
| **Report Description:** | On February 4th,2019  When the plant was at “operation at power” state with 100% of the nominal power, one of the main Feedwater Pumps was shut down as a result of actuation of the protection “increase of the bearing temperature up to 75 0C”, and the backup pump was automatically put into operation. This backup pump was also shut down after 2 minutes due to actuation of the protection “Increase of Pump Axle Sealing System Water Temperature”, followed by automatic actuation of the load reduction algorithm and actuation of the Accelerated Preventive Protection (APP) of the PSL (power setback and limiting) equipment, the reactor power was reduced to 50% of the nominal power.  With the quick drop of the reactor power and shutdown of one of working main Feedwater Pumps, the level regulators of SGs start to change their status and to regulate the water level in the SGs, but this did not happen in the SG.1 due to malfunction in the performance of main regulator for level maintenance, and its stop at 100.5% status and not following the command to close. So, the water level in this SG started to rise, and by reaching 2.65 m, first the Reactor Coolant Pump No.1 shut down, later by increase of SG.1 level up to 2.7 m, the turbine protection was actuated and led to closure of turbine stop valves.  Later on, the Turbine Control Engineer (in a situation when the water level in the SG.1 was 3.628m) tries to close the shut off valve before the SG (valve located at the main route outlet and at the bypass for Feedwater going into the SG) in order to control the SG.1 level and to prevent water from entering the main steam collector, and this valve was also got an error signal (torque more than allowable limit on the valve stem) after getting closed.  Finally, the SG level was reduced and the process of reducing the reactor power in multiple stages, by pressing the PP1 button, to 23.4% of the nominal power was finished. The location of “group.9 control rods” was at 160 cm from the bottom of the reactor core, and the group.10 at 10 cm from the bottom of the reactor core (completely inside the reactor core). | **Station Activity -** 05-Normal equipment operations  **Component(s(-**  210- Pumps  230- Valves (including safety, check, relief & solenoid)  **Consequence(s)-** 04- Degradation of safety systems, such as shutdown cooling, safeguard, emergency power |
| **\*\*Consequences:** | Plant shutdown time due to occurrence of the event: 17 hours  Amount of loss of power generation: 23152 MWh |  |
| **Report Analysis and Comments:** | In order to identify the defect of the Radial Bearing No.8 of the Main Feedwater Pump, first a sample was taken from the oil of bearing lubrication system of the said pump, and sample was sent to the central laboratory of the Chemistry Management to be analyzed, which results showed no external particles in the oil.  After disassembling the bearing by the repair team, it was specified that the babbitt layer of the bearing has suffered from mechanical abrasion in two sections: 1-lower cap (9-6 o’clock position) and 2-upper cap (12-3 o’clock position).  After reading the Met Lab report and the Rotary Equipment Repair Management report by the Event Investigation Committee, the following conclusions were arrived at:  From the Event Investigation Committee point of view, the cause of the abovementioned defect was assessed to be the ingress of very small external object inside the oil into the space between the pump axle and the internal section of the bearing, which caused the radial displacement of the axle in opposite direction of the external object and its collision with bearing opposite point. This process has continued with more intensity because of ingress of particles resulting from the initial abrasion into the space between the axle and the bearing surface, and caused the destruction of oil film in these locations. In addition, the disruption in supplying oil to the space between the axle and the bearing led to generation of heat resulting from friction, and as a result softening and shrinking of babbitt resulting from the weight force and the rotational torque of the axle. Investigations has also specified that the main feedwater pumps do not have weekly or monthly vibration measurement schedule, and the vibration condition of the pumps is not continuously controlled and monitored by the Turbine Management.  After the initial investigations, it was specified that the cause of increase of water temperature in the mechanical sealing of axle of the backup pump was a leak in the mechanical sealing of axle of the pump on the Bearing No.7 side, and after inspection and conducting the necessary investigations in the planned preventive maintenance of the year 2019 (PPM-2019), the following was concluded:  The results of investigations showed that considering the fact that the secondary sealing on the fixed part (stator casing) is made of resin non-resistant against petroleum materials and resin O-ring is in contact with water on one side and with oil steam on the other side, contact with oil steam leads to asymmetrical swelling of resinated O-ring (i.e. the increase of diameter and cross section area). This led to asymmetrical abrasion of resinated O-ring on one side and sticking of the moving part of mechanical seal in the stator casing on the other side, which has the duty of providing necessary force to the back of resinated O-ring in order to create complete sealing. Therefore the radial movement of mechanical sealing has been halted and led to leak of feedwater toward sealing water and increase of temperature of sealing water.  Therefore, in order to remove the problem, it was decided that in the PPM-2019 the mechanical sealing be completely replaced and resinated O-rings of secondary sealing be replaced with the type resistant to petroleum material.  The field investigations carried out together with analysis of the diagrams of SGs level, the percentage of the openness of main regulators of SG level, feedwater flow rate of 4 SGs and archive of top level system unit (TLSU) indicated that the defect of control valve of the main regulator for level maintenance was due to the defect in the I&C circuits of this equipment.  Also, in order to detect the cause of the defect, the control circuits of the main regulator for level maintenance were completely investigated. The results indicated ground connection of feed of circuits of micro-switches of this regulator (from the route related to open micro-switch) due to rupture of the feed circuit cable insulation at the inlet into the socket, which led to the occurrence of error signal, and resulted in the control valve of the main regulator for level maintenance going out of control and not following any command. Also the cause of rupture of cable insulation was overstretching of the mentioned cable because of changing of thermal insulation of regulator and its thickening in PPM-2018 which led to the overstretching of control cable. Turbine field operator not paying attention during operational investigations and also turbine system engineer not paying attention to the overstretching of mentioned cable at the time of hand-over of the equipment after the PPM-2018 led to the gradual rupture of control cables insulation and consequently its ground connection.  After the occurrence of the error in the control valve of the main regulator for level maintenance, the electrical valve (secondary shut off valve before the regulator) starts to close according to the protection signal but electrical valve was stopped mid-way and was not fully closed because of occurrence of error signal (torque more than allowable limit to valve stem during closure). Field investigations specified that the valve did not have I&C and control defect and it should undergo internal investigation and inspection in PPM-2019. Therefore, the following results were obtained after opening the valve in PPM-2019 and after the investigations made in the presence of the representative of the manufacturer:  After opening the valve, it was observed that supporting parts of valve discs were deformed 11mm in length and 7mm in width, which led to slight displacement of discs in their place and can be the cause of valve being stuck in opening and closing stages. The following are recommended for removal of this problem:  1) At the time of preheating the Unit or when performing hydraulic tests of feedwater line system, abovementioned type of valves should be placed in open position.  2) During overhaul of the abovementioned type of valves, and based on the operating experience obtained from recommendation.1 and if necessary, make a small hole in the disc part of the valve inlet in order to free the water trapped between discs.  Operator tried to manually close the electrical shut off valve before the steam generator. 32 seconds later and after the closure of the valve, the error signal (torque more than allowable limit to valve stem during closure) occurred in the mentioned valve.  Investigations showed that, considering the complete closure of the aforementioned valve, occurrence of the error signal “torque more than allowable limit” was due to defect of mechanical part of torque transfer of the gearbox of the electrical shut off valve before the SG, in a way that its failure to properly function at the end of the closure route of the valve led to the occurrence of the error signal “torque more than allowable limit to the valve stem during closure”.  Turbine Control Engineer not paying attention to the trend of increase of the temperature of the bearing No.8 of the main feedwater pump, which has increased from 67.30C to 750C, and cause the actuation of shutdown protection of this pump.  After the control valve of the main regulator for level maintenance was stuck in “open” state and was not closed, and also when the main shut off valve before the regulator was not closed by the protection signal command, the Main Control Room (MCR) operators of turbine section should have issued the command for manual closure of the mentioned valves at their installation location for the turbine field operators, but this command has not been issued by the Turbine Shift Supervisor, Consequently , 39 minutes after the closure of the shut off valve before the SG, as level of the SG.1 goes lower than 2.48m , the mentioned valve was opened again and the level of SG.1 has been increased by 1220 mm in 85 seconds.  After the shutdown of the working main feedwater and turning on the backup feedwater pump by the signal followed by its shutdown by the signal of increase of temperature of sealing water, the signal of the pump itself and the signal of operation of two pumps out of three main feedwater pumps should have been deactivated in this stage or at most at the next stage of turning on the mentioned pump so that the pump would not be turned on by the signal. Taking into account the first time of turning on the pump by the signal, the mentioned 10-KV pump has been turned on and off from the cold mode three times, which violates the standard of main regulation of nuclear power plants operation.  The Turbine Control Engineer, in addition to switching the working mode of turbine deaerator level regulator from automatic mode to manual mode, fully closed it but later on, the negligence of operator in reopening the mentioned regulator and not switching it back to automatic mode led to the significant drop in deaerator level. This reduction in the condensate water flow rate and deaerator level led to condensate water pumps being turned off and on two times.  Direct causes:   * Mechanical abrasion of the bearing babbitt layer in two upper and lower areas due to ingress of very small external particle into the space between the axle and the bearing, which caused the reduction of oil film in these areas and increase of oil temperature in the bearing. * Existence of leak in the mechanical sealing of the pump axle due to mechanical sealing moving part getting stuck, as a result of swelling of secondary sealing resinated O-rings, which caused the increase of water temperature of sealing system of the pump axle. * Ground connection of feed of circuits of micro-switches of the control valve of the main regulator for level maintenance (through the route related to the open micro-switch) as a result of rupture of insulation of feed circuit cable at the entry point into the junction box, due to overstretching of the cable. * Mechanical stuckness of the main shut off valve before the actuator regulator which led to the occurrence of error signal of torque more than allowable limit and the valve stopping mid-way. * Malfunction of the mechanical part for torques transfer of the gearbox of the shut off valve before the SG, which at the point of closure caused the occurrence of the error signal “torque more than allowable limit on the valve stem”. * Mistake in performing technical operation due to not complying with the requirements by Turbine Control Engineer.  |  | | --- | | Root causes:   * The cause of existence of external particle is not specified. * Not taking into consideration the operation conditions of equipment when designing the internal parts of the pump during the integration of the feedwater pumps. * inattention of the following people to the problem of overstretching of the control cables*:*1.Turbine Field Operator when conducting operator visits of the equipment2. Turbine Systems Engineer when taking delivery of the equipment after PPM-2018 * Defect in the structural design of the valve, which leads to water being trapped in the space between discs and stuffing box of the valve. * Not performing technical service of gearbox and mechanical part which transfers the valve torque in a timely manner, because there is no schedule developed for periodical repairs of the moving part of valves and regulators according to the requirements of factory documents. * The operator not being prepared for conducting the technical processes correctly and not being prepared for the correct switching at the time of occurrence of an event. | | **System(s)-**  215-Auxiliary and emergency feedwater  345-Main steam/feedwater isolation function  **Direct cause** –  0107-Blockage, restriction, obstruction, binding, foreign material, loose parts  0108- Wear, fretting, lubrication problem  0105- Leak  0208-Ground fault  **Category-**03- Major equipment damage  **Group(s)-**  140- Mechanical  120-Electrical  301-System engineering  340-Mechanical |
| **Corrective Actions:** | 1. Repairing the main feedwater pump (complete replacement of the radial bearing of the main pump- bearing No.8 of the electric pump)  1. Washing the pipelines of the lubrication system of the bearings of feedwater pumps after conducting technical services and repairs for removing the possible external particles.  3. Complete replacement of the mechanical sealing of the axle of the main feedwater pumps and, replacing the resinated O-rings with a type resistant to water, hot steam and petroleum products.  4. Trying to make a hole in the disc part of the inlet of shut off valves before the SGs and the valves with the same type during the overhaul of the aforementioned valves  5. Developing weekly or monthly schedules for vibration measurement by the Turbine Management for continuously controlling and monitoring the vibration condition of the feedwater pumps. |  |
| **Note:** |  |  |
| **INES Level:** | 0 |  |
| **Station Status:** | 110- Steady power operation |  |
| **Station Activity:** | 05-Normal equipment operations |  |
| **Direct cause:** | 0107-Blockage, restriction, obstruction, binding, foreign material, loose parts  0108- Wear, fretting, lubrication problem  0105- Leak  0208-Ground fault |  |
| **Category:** | 07-Deficiencies of design, analysis, fabrication, construction, installation, operation, configuration management, man-machine interface, testing, maintenance, procedure or training |  |
| **Consequence(s)\*:** | 04- Degradation of safety systems, such as shutdown cooling, safeguard, emergency power |  |
| **System(s)\*:** | 215-Auxiliary and emergency feedwater  345-Main steam/feedwater isolation function |  |
| **Component(s)\*:** | 210- Pumps  230- Valves (including safety, check, relief & solenoid) |  |
| **Group(s)\*:** | 140- Mechanical  120-Electrical  301-System engineering  340-Mechanical |  |
| **Root cause(s)\*:** | temporarily not specified |  |
| **Causal factor(s)\*:** | ***-*** |  |
| **List Attachments:** | \_ |  |