**WER MOW 2022-0167**

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| **Category:** | **Noteworthy / Trending** |
| **Criteria:** | **N – criterion 10 / T – criteria 15, 16, 87** |
| **Note:** Not previously reported as Preliminary WER.  The event report is prepared based on the information provided by Bushehr NPP. | |
| **Station:** | Bushehr |
| **Event Date:** | 09.01.2022 |
| **Title:** | Disconnection of the plant from the 400kV power grid due to actuation of first differential protection of the unit transformers |
| **Reference Unit:** | Unit 1  Reactor Type: VVER 1000 / V-446 (PWR)  Plant Designer: AEP  Year Commercial: 2012  Capacity: 1,000MW(e) |
| **Station Event:** | **Single Unit Event** |
| **Summary:** | On 09.01.2022, the Unit 1 neutron power was at 50% of rated value.  The necessary operations were carrying out to connect the Unit 1 to the national power grid.  The Electrical Equipment Department (EED) personnel conducted electrical tests (no load, short circuit) of the Turbine Generator (TG).  At 11:10:14, at the initial attempt to connect to the grid, the first differential protection of the unit transformers (AT01, AT02) was triggered.  It led to the disconnection of the Unit from the 400kV power grid, followed by a reduction of the reactor power to a minimum controlled power level.  The stepwise start-up algorithm of diesel generators (DGs) of safety trains 2 and 3 was initiated, caused by the power loss of the internal power consumption buses 10BC and 10BB.  At 18:07:18, the personnel successfully reconnected Unit to the national power grid.  **Direct cause:** Incomplete connection of third arm of Unit transformers AT01, AT02 differential protection due to the operating personnel mistake.  **Root causes:**  - documentation deficiency,  - violation of procedures,  - inadequate inner team communication,  - system alignment/not verified,  - unsafe working practices applied.  **Contributing factor:** distractions due to the concurrency of test completion with the new shift handover. |
| **Event Units:** | Unit 1 |
| **References:** | - |
| **Description:** | On 09.01.2022, the Unit 1 neutron power was at 50% of rated value.  The necessary operations were carrying out to connect the Unit 1 to the national power grid.  The Electrical Equipment Department (EED) personnel was conducting electrical tests (no load, short circuit) of the Turbine Generator (TG).  At 11:10:14, the staff completed electrical tests.  The EED Shift Supervisor (SS) in the Main Control Room (MCR) connected the Unit to the national power grid through the unit transformer 10AT02 using corresponding TG circuit breaker switches No.1 (10AQ01Q01) and No.2 (10AQ02Q01).  At that moment, the Unit electrical power was 434.7MW with a reactive power of 83,304MVAR.  Then the differential and relay protection device of the unit transformers 10AT01 and 10AT02 suddenly actuated. As a result the following was disconnected:  - Circuit breakers 10AC10Q00 and 10AC11Q00 at the 400kV gas-insulated substation, which led to the Unit disconnection from the national power grid;  - TG circuit breakers No.2 and No.1, which led to the isolation of the unit transformer 10AT02;  - The main input circuit breaker of the normal operation 10kV busbars 10BA, 10BB, 10BC, 10BD, 10BE and 10BF.  The reactor power dropped to a minimum controlled power level.  After the internal power consumption transformers 10BT01 and 10BT02 were de-energised, a momentary voltage of the corresponding busbars 10BA, 10BB, 10BC, 10BD dropped to 8.714kV, 0.08kV, 0.058kV and 8.571kV (respectively). It led to the priority selection algorithm (ABP) of normal operation busbars of 10BA, 10BB, 10BC and 10BD actuation.  After the internal power consumption transformer 10BT03 loosed power, an instantaneous voltage at normal operation busbars 10BE and 10BF of plant common/general consumers dropped to 8.97kV and 9.127kV (respectively). It led to the priority selection algorithm (ABP) of normal operation busbars 10BF and 10BE of plant common power consumers’ actuation.  At 12:27:38, a momentary voltage of normal operation busbar 10BB decreased to the less than 0.25Un of the nominal voltage, which led to the circuit breaker connected to the normal operation busbar disconnection.  It resulted in disconnection of the circuit breaker connected to the safety train busbar, and actuation of stepwise start-up algorithm of safety train No.2 mechanisms.  Then the following occurred in the safety train No.2:  - stage 0 mechanisms connected simultaneously with the busbar 12BV was powered up;  - The complementary boric acid injection system pump 12TW20D001 was shut down in 11 seconds after being turned on at the Stage 0;  - corresponding stage 1 mechanisms connected in 10 seconds after the busbar 12BV powered up;  - corresponding stage 2 mechanisms connected in 20 seconds after the busbar 12BV powered up;  - corresponding stage 3 mechanisms connected in 30 seconds after the busbar 12BV powered up.  Then the diesel generator (DG) circuit breaker 13BW09G001 connected and the busbar 13 BW was powered up as a result of the system train No.3 mechanisms actuation. Then the following occurred:  - stage 0 mechanisms connected simultaneously with the busbar 13BV was powered up;  - stage 1 mechanisms connected in 10 seconds after the busbar 13BV was powered up;  - stage 2 mechanisms connected in 20 seconds after the busbar 13BV was powered up;  - stage 3 mechanisms connected in 30 seconds after the busbar 13BV was powered up.  After proper conditions restored as they were before the test the personnel performed the necessary steps to start up the Unit again:  - The power supply to consumers of the safety trains Nos.2 and 3 were switched to the normal operation busbars 10BB and 10BC (respectively);  - The power supply was switched to the backup normal operation busbars 10BN, 10BM of the unit backup transformer;  - The power supply of the Unit was connected to the energy exchange grid 10AL01 through circuit breaker 10AC01;  - Circuit breakers in the 400kV gas-insulated substation were turned on resulting in the internal consumption busbars 10BT01, 10BT02 and 10BT03 and the unit transformers 10AT01, 10AT02 being energised.  At 18:07:18, the personnel successfully reconnected Unit TG to the national power grid. |
| **Revision:** | 00 |
| **Consequences:** | The Unit downtime lasted 5.5 hours, during which the electrical power supply was provided by the emergency diesel generators.  Energy production loss: 1,826 MWh. |
| **Analysis and Comments:** | As described above, the starting point of the event was the occurrence of an imbalance phenomenon in unit transformers 10AT01 and 10AT02, which led to the activation of their differential and relay protection devices.  The main function of differential protection devices and relays of unit transformers is to compare the electric currents entering and exiting the transformer by calculating the conversion coefficient. It actuates by following factors:  - Short circuit inside the transformer (phase to casing, phase to phase, Ring Contact short circuit, and contact between primary and secondary coils);  - Short circuits outside the transformer due to external reasons within the relay protection zone i.e. between the current transformers (CTs) at the sides;  - Spurious signals caused by defects in current transformers or connected circuits.  Based on the Protection and Relay Group reports and on the field visit to the location of unit main relays, it was found that the **direct cause** of the event was a failure in completing the connections (**defect in the connected circuits**).  The defect in protection zones circuits 10AE01, 10AP10 and 10AP02 appeared due to 4 test blocks inserted during the electrical test conducting, which resulted in spurious signals (states) formation.  It was revealed that the TG initial preparation stages for its connection to the national power grid were carried out for two shifts before the event using switching form:  - evening shift started 08.01.2022 up to row No.65,  - and the rest were made depending on the rotation of the turbine and conducting short circuit and no load tests of the generator.  Due to the some technical problems (not power-related) during the Unit preparation to the turbine rotating, the proper conditions for conducting the no-load and short circuit tests of the generator were not provided.  By observing these conditions, the matter was communicated to personnel of the Protection and Relay Group who were conducting short circuit test on the panels adjacent to these panels few hours ago. Then they put these test blocks in their dock places by going to that panel.  The workgroup was comprised of Shift Supervisor (SS) and Shift Operator (SO) of the EED, and day-work personnel of the Protection And Relay Group:  - EED the personnel were responsible for preparing and organizing the conditions for the short circuit test and for restoring them to the condition preceding the test;  - The Protection and Relay Group the personnel was only responsible for conducting the short circuit test itself.  **Conclusion:**  The personnel did not use the human errors prevention tools, ensuring that no detail of any activity will not be forgotten and will be performed in a standard manner and a logical order, such as:  - use of approved checklists and the program to accurately plan the Unit start-up works and activities (getting parallel with the grid, short circuit and no load tests) instead of relying on individuals’ memory and knowledge,  - effective interpersonal communication during a work,  - lessons learned from similar events occurrence, which could prevent their recurrence.  **Direct cause:** Incomplete connection of third arm of unit transformers AT01 and AT02 differential protection due to the operating personnel mistake.  **Root causes:**  1. Documentation deficiency – It was not assumed in the generator short circuit test program that personnel would perform operational switching (removal of the test blocks), and the purpose of test blocks was not clearly stated.  2. Violation of procedures – The EED night Shift Supervisor performed switching that was not included in the generator testing program. He thought he would return these switches to their original position immediately after completing the test.  3. Inadequate inner team communication – The EED night Shift Supervisor did not inform other members of the working team about switching he performed.  4. System alignment not verified – the EED night Shift Supervisor did not check the accuracy of the performed switching after returning them to the state prior the short circuit test.  5. Violation of procedures – After the completion of the tests, the EED Shift Supervisor and the Protection and Relay Group personnel did not fully fulfil their duties specified in the generator short circuit testing program due to the simultaneous shift handover.  6. Unsafe working practices applied – The EED morning Shift Supervisor did not use the checklist, which led to the fact that inaccurate switching performed during the night shift was not detected in a timely manner.  **Contributing factor:** distractions due to the concurrency of test completion with the new shift handover. |
| **Corrective Actions:** | 1. The influence of the switches considered in the short circuit test program and the open circuit state of the generator on the switches made using the switching form No. 2130 will be analyzed.  2. The cause of the incomplete execution of the switching function will be analyzed to determine the priority of the three-phase selectors S04 on panel 10BA14 and to implement the appropriate solution.  3. All managements and shift supervisors will be additionally briefed to avoid important tests and switches during the last hours of the shift due to the increased likelihood of human error (especially in the last hours of the night shift) to the extent practicable.  4. A training course will be held for all shift personnel of the Electrical Equipment Department, as well as for all personnel of Relay and Protection Group and management of the Electrical Power Department on human error prevention tools.  5. An unscheduled briefings will be held for Shift Supervisors of the Electrical Equipment Department on the actuation mechanism of unit transformers differential protection and on the test blocks function of this protection.  6. An unscheduled briefings will be held for Shift Supervisors and shift personnel of the Electrical Equipment Department on how to perform switching based on switching form, emphasizing the importance of the duties of the executor and the controller based on their working relationship.  7. A necessary actions will be arranged to ensure the doors of electrical panels are sealed that, based on documents, shall be done immediately after the generator synchronized. Such as:  - use a checklist during the sealing to be sure of the accuracy of performed switching,  - recording all performed sealings in related logbooks, etc.  8. A checklist will be developed for the final inspection of the protective panels to ensure proper conditions are provided before connecting the generator to the national grid. They should include an assignment of a responsible person, as well as the manner and time of execution.  9. The switching form will be designed to be used at the completion of the generator short circuit testing to restore the proper conditions as they were before that test started. |
| **Note:** | It is requested that all code fields below be completed. |
| **\*Note:** | **\***These code fields may contain more than one code. |
| **INES Level:** | 0. |
| **Station Status:** | 110 – Steady power operation |
| **Station Activity:** | 25 – Routine testing (of existing equipment) with existing procedures/documents |
| **Direct Cause:** | 0206 – Bad contact, disconnection |
| **Category:** | 1 – Unusual station transient or events |
| **\*Consequences:** | 02 – Station transient |
| **\*Systems:** | 410 – High voltage AC (greater than 15kV including offsite power)  430 – Low voltage AC (less than 600V, mainly 480V)  440 – AC & DC supplies to vital instrumentation, control and computers  450 – Emergency power generation and auxiliaries |
| **\*Components:** | 190 – Electrical (current, voltage, power etc.)  410 – Switchyard equipment (switchgear, transformers, buses, reactors, arresters, line isolators)  420 – Circuit breakers, power breakers, fuses  440 – Generators of emergency and standby power  470 – Wiring, logic circuitry, controllers, starters, cables, transmitters, switches |
| **\*Groups:** | 120 – Electrical  210 – Shift – control room operators  220 – Shift – field operators  360 – Electrical  440 – Training  450 – Document production |
| **\*Root Causes:** | 0202 – System alignment/isolation not verified  0212 – Unsafe working practices applied  0218 – Violation of policies/rules/procedures  0704 – Cautionary information not included  0903 – Co-ordination of all relevant on-site departments not achieved  1230 – Inadequate coordination/communication between departments |
| **\*Causal Factors:** | 0408 – Distractions |
| **List Attachments:** | None. |
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