**WANO EVENT REPORT**

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| **\*\* Note:** |  |  |
| **\*\* Station:** | Bushehr Unit 1 |  |
| **\*\* Event Date:** | 9 January 2022 |  |
| **\*\*Title:** | Disconnection of the Plant from the 400 KV power grid due to actuation of first differential protection complex of the Unit transformers (AT01, AT02), due to the third arm of this protection being incomplete |  |
| **\*\*Reference Unit:** | Unit, Year Commercial: Bushehr 1(2012)Reactor Type (size): VVER 1000 / V-446 (PWR)Plant Designer: AEPPower: 1000 MW |  |
| **\*\*Station Event:** | Unit event |  |
| **Summary:** | On 09.01.2022, the Plant at 442 MW power was disconnected from the 400 KV power grid due to actuation of the first differential protection complex of the Unit transformers (AT01, AT02), due to the third arm of this protection being incomplete and after that the loss of power of internal power consumption busbars 10BC and 10BB and stepwise start-up of Diesel Generators (DGs) of Safety Channels 2 and 3 occurred. | **Station Status -** 110- Steady power operation |
| **Event units:** | No others |  |
| **References:** | None |  |
| **Report Description:** | On 09.01.2022 at 11:10:14, the Plant was in the “Operation at Power” state with neutron power equal to 50% of the nominal power and electrical power equal to 442 MW. Electrical tests (no load, short circuit) of the Turbogenerator were completed and synchronization of the Unit with the national power grid was done through the Turbogenerator circuit breaker switch No.1 10AQ01Q01 from the Main Control Room (MCR) by the Electrical Power Department Shift Supervisor.The circuit breaker switch No.2 of the Turbogenerator 10AQ02Q01 was connected from the MCR by the Electrical Power Department Shift Supervisor and connection to the grid was completed through the Unit transformer 10AT02. At this moment, momentary electrical power was 434.7 MW and reactive power was 83.304 MVAR when sudden actuation of differential protection and relay device of the Unit transformer occurred. Due to simultaneous disconnection of circuit breakers 10AC10-11Q00 in the 400 KV gas insulated substation resulting from actuation of first differential protection complex of the Unit transformers, the Plant was disconnected from the national power grid.Disconnection of the Turbogenerator circuit breaker No.2 10AQ02Q01 followed by the Turbogenerator circuit breaker No.1 10AQ01Q01 due to actuation of the first differential protection complex of the Unit transformers (10AT01, 02) led to isolation of the Unit transformer (10AT02). After these occurrences, the following happened:* Loss of power of internal power consumption transformer (10BT01) and drop of momentary voltage of normal operation busbar 10BA to 8.714 KV;
* Loss of power of internal power consumption transformer (10BT02) and drop of momentary voltage of normal operation busbar 10BB to 0.08 KV;
* Loss of power of internal power consumption transformer (10BT01) and drop of momentary voltage of normal operation busbar 10BC to 0.058 KV;
* Loss of power of internal power consumption transformer (10BT02) and drop of momentary voltage of normal operation busbar 10BD to 8.571 KV;
* Loss of power of internal power consumption transformer (10BT03) and drop of instantaneous voltage of normal operation busbar of the Plant common/general power consumers 10BE to 8.97 KV;
* Loss of power of internal power consumption transformer (10BT03) and drop of instantaneous voltage of normal operation busbar of the Plant common power consumers 10BF to 9.127 KV;
* Disconnection of the main input circuit breaker of the normal operation busbar due to actuation of the first differential protection complex of the Unit transformers;
* Actuation of priority selection switch (ABP) of normal operation busbar of 10BA, 10BB, 10BC and 10BD;
* Actuation of priority selection switch (ABP) of normal operation busbar of the Plant common power consumers 10BF and 10BE;
* Decrease of momentary voltage of normal operation busbar 10BB to less than 0.25 Un of the nominal voltage; disconnection of circuit breaker connected to the normal operation busbar and, as a consequence, disconnection of circuit breaker connected to the Safety Channel busbar.

At 12:27:38, momentary voltage of normal operation busbar 10BB dropped to less than 0.25 Un of the nominal voltage; disconnection of circuit breaker connected to the normal operation busbar and, as a consequence, disconnection of the circuit breaker connected to the Safety Channel busbar and actuation of algorithm for stepwise start-up of mechanisms of Safety Channel No.2 occurred. Signal indicating the start of actuation of stepwise start-up algorithm of mechanisms of the Safety Channel No.2 was formed.To start up again, following steps were carried out:1) Decrease of momentary voltage of normal operation busbar 10BC to less than 0.25 Un of the nominal voltage; disconnection of the circuit breaker connected to the normal operation busbar and as a consequence disconnection of the circuit breaker connected to the Safety Channel busbar.2) Performance of Stage.0 of connection of mechanisms of Safety Channel No.2 simultaneously with powering up the busbar 12BV;3) The pump of complementary boric acid injection system 12TW20D001 shutting down 11 seconds after being turned on in the Stage.0 of connection of mechanisms of the Safety Channel No.2;4) Performance of the Stage.1 of connection of mechanisms of the Safety Channel No.2 – 10 seconds after the busbar 12BV powering up;5) Performance of the Stage.2 of connection of mechanisms of the Safety Channel No.2 – 20 seconds after the busbar 12BV powering up;6) Performance of the Stage.3 of connection of mechanisms of the Safety Channel No.2 – 30 seconds after the busbar 12BV powering up;7) Connection of the Diesel Generator circuit breaker 13BW09G001 and the busbar 13 BW powering up;8) Performance of the Stage.0 of connection of mechanisms of the Safety Channel No.3 – simultaneously with the busbar 13BV powering up9) Performance of the Stage.1 of connection of mechanisms of the Safety Channel No.3 – 10 seconds after the busbar 13BV powering up10) Performance of the Stage.2 of connection of mechanisms of the Safety Channel No.3 – 20 seconds after the busbar 13BV powering up11) Performance of the Stage.3 of connection of mechanisms of the Safety Channel No.3 – 30 seconds after the busbar 13BV powering up12) Disconnection of the DG circuit breaker 12BV09G001, transfer of power supply of electrical power consumers of the Safety Channel No.2 to the normal operation busbar 10BB; 13) Disconnection of the DG circuit breaker 13BW09G001, transfer of power supply of electrical power consumers of the Safety Channel No.3 to the normal operation busbar 10BC;14) Connection of backup input circuit breaker and supply of power through the backup normal operation busbar 10BN, 10BM of the Unit backup transformer;15) Connection of electrical power supply of the Unit to the energy exchange grid 10AL01;16) Simultaneous connection of circuit breakers 10AC20-22Q00 in the 400 KV gas insulated substation and internal consumption (10BT01) and the Unit transformers (10AT01) going under tension17) Connection of electrical power supply of the Unit to the energy exchange grid 10AL02 through 10AC0118) Simultaneous connection of circuit breakers 10AC10-11Q00 in the 400 KV gas insulated substation and internal consumption (10BT02, 03) and the Unit transformers (10AT02) going under tension19) Synchronization of the Unit Turbogenerator with the national power grid by connecting the Turbogenerator circuit breaker No.1 10AQ01Q01;20) Synchronization of the Unit Turbogenerator with the national power grid by connecting the Turbogenerator circuit breaker No.2 10AQ02Q01;At 18:07:18, the Plant was connected to the national power grid. | **Station Activity –** 05-Normal equipment operations**System(s)-** 430- Low voltage AC 440 -AC & DC supplies to vital instrumentation, control and computers450-Emergency power generation and auxiliaries  |
| **\*\*Consequences:** | Duration of Plant Downtime due to Occurrence of Event: 05.5 hoursLoss of Energy Production: 1826 MW/h |  |
| **Report Analysis and Comments:** | In order to conduct review and investigation of the perturbation, the following documents and information were collected:* Explanatory notes of personnel
* Copy of logbooks
* Technical conclusions and reports related to protections, interlocks, equipment and personnel
* Prints and diagrams of working parameters of equipment
* Analysis of information and performance of personnel at the time of occurrence of perturbation specified the followings:

As mentioned in the sequence of occurrence of the event, the direct cause of occurrence of the event is creation of Unbalance phenomena error in Unit transformers (10AT01, 02) and then actuation of Unit transformers differential protection and relay device (10AT01, 02).Generally, the differential relay as the main protection of Unit power transformers, with differential function, is responsible for comparing the currents entering and leaving the transformer by calculating the conversion ratio and its actuation can be due to the 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 factors within the relay protection zone i.e. between the Current Transformers (CTs) at the sides;
* Spurious states resulting from problem in CT or connected circuits.

The investigations conducted from the moment of disconnection of the Unit from the national power grid with disconnection of circuit breakers of the 400 KV gas insulated substation followed by disconnection of circuit breakers of the 27 KV generator, the main input switches of normal operation busbars and the 10 KV common power consumers of the Plant and transition of the Unit to the backup power supply indicate the accurate performance of differential protection and relay device of the Unit transformers at 40% of nominal electrical power of the Unit.* Based on the reports of the Protection And Relay Group and field visit to the location of main relays of the Unit, the direct cause of occurrence of the event is failure in completing the connections related to 4 test block circuits related to protection zones (10AE01, 10AP10, 10AP02) that caused the creation of spurious states resulting from defect in the connected circuits
* After the occurrence of the event, by reviewing the reports of the Electrical Power Department Shift Supervisors, operator’s logbook, switching form, and other technical documents and by conducting few in-person interview meetings with personnel related to the event, it was specified that the Turbogenerator initial preparation stages for connection to the national power grid were carried out by using switching form in two shifts before the event (evening shift dated 08.01.2022) up to row No.65 and the rest were make dependent on rotating the turbine and conducting short circuit and no load tests of the generator, which due to occurrence of technical problems (not power-related) in the process of preparing the Unit for rotating the turbine, the 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 and they put these test blocks in their own place by going to this panel.
* It should be mentioned that the workgroup comprising of shift personnel of the Electrical Power Department (Shift Supervisor and Shift Operator) and day-work personnel of the Protection And Relay Group was made responsible for preparing and organizing the conditions for conducting the short circuit test and returning them to the state before the test, and the personnel of the Protection and Relay Group were just responsible for conducting the short circuit test itself.

Conclusion:Using the approved checklists and program to accurately plan the Unit start-up works and activities (getting parallel with the grid, short circuit, and no load tests) and making sure that no detail of any activity will not be forgotten and will be performed in a standard manner and a logical order, making use of experiences of similar occurrences, not relying on individuals’ memory and knowledge, and using the methods to prevent the forgetfulness and human error during work such as effective interpersonal communication would have prevented the occurrence of the event. Direct causes:

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| * Incompletion of third arm of differential protection of the Unit transformers in the first differential protection complex of the Unit transformers (AT01, AT02) due to operating personnel error

Root causes: * Performing operating switching (taking out the test block) not predicted in the generator short circuit test program due to having a wrong technical understanding of role and duty of test blocks
* Electrical Power Department Shift Supervisor failure in notifying the other members of the workgroup about the switching not included in the test program because he thought he himself will return these switches to their initial position after completion of the test.
* Failure in performing duties specified in the short circuit test program for the Electrical Power department Shift Supervisor after the completion of the generator short circuit test and performance of this activity by the Protection and Relay Group personnel due to concurrency of test completion with the new shift handover
* The Electrical Power Department Shift Supervisor not controlling the accuracy of the performed switching after returning everything to conditions before the short circuit test in the night shift due to concurrency of test completion with the new shift handover
* Incompletely controlling the accuracy of switching performed in the night shift by the Electrical Power Department Shift Supervisor of the morning shift due to not using the checklist.
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 | **Component(s(-**410-High voltage AC420-Circuit breakers, power breakers440- Generators of emergency and standby power460- Relays, connectors, hand switches, push buttons, contacts**Consequence(s)-** 02- Station transient**Category-** 1- Unusual station transient or events**Group(s)-**  210 -Shift – control room operators 120 -Electrical  |
| **Corrective Actions:** | * Reviewing the subject of impact of switchings considered in the short circuit test program and the generator open circuit on the switchings performed based on the switching form No.2130
* Reviewing the cause of incomplete performance of function of the switch for determining the priority of three-phase selectors S04 in the panel 10BA14 and adopting the proper solution for resolving the issue for the purpose of complete performance of the switch function
* Providing briefings for all managements and shift supervisors to remind them of increase in probability of occurrence of human error in the last hours of the shifts (particularly the last hours of the night shift) and emphasizing on not organizing the conduct of important tests and switchings in the last hours of the shift to the extent practicable.
* Holding training course on human error prevention methods for all shift personnel of the Electrical Power Management.
* Holding training course on human error prevention for the personnel of Relay and Protection Group of the Electrical Power Management.
* Holding unscheduled briefings for the Electrical Power Departments Shift Supervisors regarding on mechanism of actuation of differential protection the Unit transformers and the working function of test block of this protection.
* Holding unscheduled briefings for shift supervisors and personnel of the Electrical Power Shift on how to perform switching based on switching form emphasizing the importance of duties of performer and controller based on the form and their working relationship.
* Arranging the necessary organization (including: Making sure of accuracy of the performed switchings, using control checklist at the time of sealing and recording all performed sealings in related logbooks, etc.) for sealing the doors of electrical panels that, based on documents, shall be sealed immediately after synchronization of generator.
* Developing conditions control checklist for protective panels for their final control before connecting the generator to national grid by assigning a person incharge and the manner and time of performing it.
* Developing switching form for using at the time of completion of short circuit test of generator for creating the conditions of before the conduct of short circuit test of generator.
 | **Direct cause** * Incompletion of third arm of differential protection of the Unit transformers in the first differential protection complex of the Unit transformers (AT01, AT02) due to operating personnel error

0206- Bad contact, disconnection**Root cause(s)-** * 1) Performing operating switching (taking out the test block) not predicted in the generator short circuit test program due to having a wrong technical image of role and duty of test blocks

0212- Unsafe working practices applied* 2) Electrical Power Department Shift Supervisor failure in notifying the other members of the workgroup about the switching not included in the test program because he thought he himself will return these switches to their initial position after completion of the test.

0903- Co-ordination of all relevant on-site departments not achieved* 3) Failure in performing duties specified in the short circuit test program for the Electrical Power department Shift Supervisor after the completion of the generator short circuit test and performance of this activity by the Protection and Relay Group personnel due to concurrency of test completion with the new shift handover

0218- Violation of policies/rules/procedures* 4) The Electrical Power Department Shift Supervisor not controlling the accuracy of the performed switching after returning everything to conditions before the short circuit test in the night shift due to concurrency of test completion with the new shift handover

0202-System alignment/not verified5) Incompletely controlling the accuracy of switching performed in the night shift by the Electrical Power Department Shift Supervisor of the morning shift due to not using the checklist0202-System alignment/not verified1230- Inadequate coordination/communication between departments |
| **Note:**  |  |  |
| **INES Level:** | 0 |  |
| **Station Status:** | 05-Normal equipment operations |  |
| **Station Activity:** | 05-Normal equipment operations |  |
| **Direct cause:+-** | 0206- Bad contact, disconnection |  |
| **Category:** | 1- Unusual station transient or events |  |
| **Consequence(s)\*:** | 02- Station transient |  |
| **System(s)\*:** | 430- Low voltage AC 440 -AC & DC supplies to vital instrumentation, control and computers450- Emergency power generation and auxiliaries  |  |
| **Component(s)\*:** | 410-High voltage AC420-Circuit breakers, power breakers440- Generators of emergency and standby power460- Relays, connectors, hand switches, push buttons, contacts |  |
| **Group(s)\*:** | 210 -Shift – control room operators 120 -Electrical  |  |
| **Root cause(s)\*:** | 0212- Unsafe working practices applied0903- Co-ordination of all relevant on-site departments not achieved0218- Violation of policies/rules/procedures0202-System alignment/not verified1230- Inadequate coordination/communication between departments |  |
| **Causal factor(s)\*:** |  |  |
| **List Attachments:** |  |  |