
Office of Utilities Regulation

Enquiry into JPS Power System Shutdown of July 15, 2006

Preliminary Findings



OFFICE OF UTILITIES REGULATION

August 11, 2006

Office of Utilities Regulation

ENQUIRY INTO JPS POWER SYSTEM SHUTDOWN OF JULY 15, 2006

Preliminary Findings

BACKGROUND

The Jamaica Public Service Company Ltd. (JPS) power system suffered an island-wide shutdown on Saturday, July 15, 2006 commencing at 4:16 p.m. The Office of Utilities Regulation (OUR) is in receipt of a “*preliminary technical report*” on the power system shutdown which was provided to the OUR by JPS on July 27, 2006. An initial Report on the outage was earlier submitted to the OUR on July 17, 2006.

The *preliminary technical report* sets out the status of the operating conditions prior to the shutdown and outlines the company’s reconstruction of the events during the system failure. In addition, the Company’s analysis of the probable cause which initiated the shutdown together with voltages, frequency, loadings and functioning of communications, sequence of events recording and protective relaying systems, are indicated.

Prior to the shutdown, the generation and transmission systems were stable with 497.7 MW of generating capacity on-line supplying a system demand of 465.7 MW and a spinning reserve of approximately 32.0 MW. The total generating capacity available was 613.5 MW. Bad weather accompanied by lightning was reported on the northern side of the island.

The Company’s conclusions arising from the preliminary report are summarized as follows:

1. The Duncans/Bogue 138 kV transmission line was struck by lightning at about 4:16 p.m. on July 15, 2006. The incident resulted in a three-phase fault as evidenced by tracking/damage to insulator strings on steel towers (either tower No.75 or No. 90).
2. The fault caused the 138 kV line breaker at Bogue to trip on distance protection. However, the Duncan’s end did not clear as designed due to non-functioning of the DC trip circuit which was out of service.
3. The backup relays on the 138 kV system located at Bellevue and Kendal substations consisting of remote zone distance and over-current relays did not operate to clear the fault as designed.

4. JPS assumes that despite the non-isolation of the fault, the fault nevertheless cleared as it was only transient in nature and disappeared in a short time.
5. The disturbance caused immediate tripping of JEP generators on barges #1 and #2, as well as Bogue combined cycle steam unit ST14.
6. JPPC generators at Rockfort also came off-line.
7. This is followed in sequence by the operation of stage 1 under-frequency relays which would have shed a block of system load.
8. Also, other generators in the system and 69 kV breakers at Queens Drive, Halse Hall and Spur Tree substations eventually tripped.
9. Severe voltage fluctuations on the 138 kV bus bars at Old Harbour and Duhaney were recorded.
10. System frequency decay was also recorded, however, only stage 1 under-frequency relays operated due to the voltage restraint settings of the relays which would have prevented other stages from functioning.
11. The sequence of generator and circuit breaker operations caused the system to collapse island-wide.
12. The timing of Old Harbour Unit 4 generator which was on-line is not stated.
13. Also, it is noted that due to the failure or non-functioning of the communications/SCADA system across the island, remote control activities and status and telemetry data were impaired.

QUESTIONS

The OUR Investigating Team has examined the JPS preliminary technical report in detail. In addition, it is in receipt of some records and data provided by both Jamaica Energy Partners Limited (JEP) and Jamaica Private Power Company Limited (JPPC) as to system operations prior to and during the outage, in respect of their generators. The OUR conducted interviews with JPS and JEP operating personnel. In addition, other relevant items of materials and documents, such as, the under-frequency relaying scheme, reports on prior system failures, etc were reviewed by the OUR. Photographs of the insulator strings and maintenance report for the Duncans/Bogue 138 kV transmission circuit, assumed by JPS to be the initiating cause of the problem, were also examined and the extent of damage noted.

As a consequence of the preliminary reviews and examination of the information specified above, a number of technical observations and other questions arise, to which a response is required. These are as follows:

- a. JPS has aligned the timings of JEP and JPS operations during the outage through the linkage of identified similar events. However, the result suggest that JEP barge #1 came off-line instantaneously with the occurrence of the line fault and tripping of the Bogue 138 kV breaker. This instantaneous trip is questionable given that there should be a discernable time lag designed into the system to avert spurious tripping of generators for system faults.
- b. JEP barge #2 over-current earth fault relay operated. This is a backup relay in the event that there is failure of the grid protection system. This operation appears incorrect unless the settings are wrong or the line fault was in fact sustained for some time before clearance. Please confirm whether the relay type is instantaneous over-current (50N) or a time delayed over-current (51N). Also, please indicate the CT connections on the step-up transformer for this relay.
- c. What is the operating state of the sequence of events (SOE) recorder for the Old Harbour power station? Is it functioning and if not why not?
- d. What time did Old Harbour Unit 4 trip and what was the reason for the generator disconnecting itself from the system? Report from an independent witness would suggest, based on the noise made by the blowing of the steam valve that JEP barge #1 and this unit tripped almost simultaneously.
- e. Did the Old Harbour 2.3 kV auxiliary bus bars disengage on the occurrence of the low voltage recorded on the 138 kV bus bars?
- f. Does the Old Harbour station have the capability to monitor and record voltages on the 138 kV bus bars and if so, is this information available for the incident?
- g. JEP barge #1 tripped on the governor control limits being exceeded. However, the initiating cause is not clear. Please indicate whether a bus bar low voltage condition affecting the control system for the generators could have been a factor and therefore a weakness which require remedy to avert future incidents of tripping.
- h. The JPPC generators appear to have come off-line due to problems with the auxiliary controls. Please indicate exactly what caused the JPPC units to trip and whether there has been a history of sensitivity to system and line faults.

- i. What is the JPS spinning reserve policy for generation dispatch? What is the expected system response when loss of the largest unit on the system is experienced, particularly in respect of the under frequency load shedding?
- j. Please confirm the operational setting of the governor controls for Hunts Bay Unit B6 and Old Harbour Unit 4, during the shutdown. Were they on “manual only” operation during the shutdown?
- k. What exactly caused GT12 and GT13 to trip, given that loads were being served independently after separation from the grid?
- l. Key SCADA and communication systems links were not in operation during the shutdown. Please indicate why and when this was known. Are the systems being adequately inspected and maintained given their importance? Please provide appropriate documentation in support of inspection and maintenance activities.
- m. Please indicate why the DC circuit for the tripping relay at Duncans substation was out of service, when was this known and why did the “trip circuit supervision” remote alarm at the System Control Centre not operate to alert the system Controllers to the situation, given that a primary relay system was non-functional. As well, advise what other circuits and relays supplied from this particular DC circuit were also affected by it being out of service?
- n. Why did the backup protection relays at Duncans substation not operate following failure of the primary protection?
- o. Please provide micro processor oscillograph recordings for 1) Duncans/Bogue 138 kV line at Bogue 2) Duncans/Queens Drive 69 kV line at Queens Drive 3) Magotty/Spur Tree 69kV line at Spur Tree. Also, explain reason for distance relay on the Magotty/Spur Tree line, operation on zone 3 at Spur Tree substation.
- p. What is the history in respect of reliable operation and clearance of the Duncans/Bogue 138 kV line, for the SEL distance relaying scheme?
- q. What is the critical fault clearing time for a three-phase fault on the Bogue/Duncans 138kV line section? Is this time within the clearance time of back-up relays at Bellevue and Kendal?
- r. Would the earlier than expected trip of major generators have worsened or precipitated a relay coordination problem?

OBSERVATIONS AND COMMENTS

It is recognized that the investigation is still at a preliminary stage and that further work will likely unearth other items which will contribute to the diagnosis of the shutdown. Nevertheless, the OUR feels constrained to make a number of observations and comments. These are as detailed below.

The insulator strings on the Duncans/Bogue 138 kV transmission line reflect relatively minor damage and would be indicative of a flash-over which is not sustained or if sustained, the fault current would have to be of comparatively low level. A high current sustained fault would probably have melted or shattered some of the insulators, assuming that this is indeed the initiating cause of the incident. However, the severe voltage depression noted throughout the transmission system does suggest that the fault was indeed maintained for several seconds.

Indeed, preliminary calculations carried out by the OUR Investigating Team indicates that the level of fault current on the Duncans/Bogue 138 kV line would be significantly low when the JEP and Old Harbour #4 generators are disconnected from the grid, together with no power being available from the Bogue end of the line. This situation could prevent the proper operation of key backup protection, which depends on optimum levels of fault current to ensure correct relay coordination and reliable clearance of faults.

The alignment of timings between JPS and JEP operations is in question and should be carefully reviewed. The absence of common time synchronism between JPS System Control and the various generating plants is a major handicap to effective operation of the system and to subsequent diagnosis of system failures.

It appears that some of the generators did not meet the full-load rejection capability standards during the shutdown. This requires further examination.

The control circuits for the Old Harbour generators should preferably be supplied from a reliable DC battery source. The feasibility of converting the controls from AC to DC should be investigated.

A study should be undertaken and consideration given to operating sections of the 69 kV grid in a radial configuration. This would entail opening existing loops not essential for systems stability, on the 69 kV grid and supplying loads radially away from 138/69 kV substations. The enactment of automatic reclosing feature on the radial lines should also be looked at.

The OUR has observed that JPS experienced problems in its efforts to restore the system following the shutdown. The concern arises as to whether JPS have a comprehensive System Restoration Plan inclusive of policies and procedures to respond to a major

outage crisis and the level of preparedness of the System Controllers to enact its implementation.

While the “shutdown” will require further study with one objective being to precisely establish the sequence of events and identify problems, based on the information submitted and currently available to the OUR, it is probable that the scenario of the system shutdown occurred in the following manner and for the causes indicated:

- Lightning struck either a tower or overhead shield wire(s) on the Duncans/Bogue 138 kV steel tower line causing critical voltage uplift on one tower which resulted in a three-phase flashover of insulators.
- The three-phase flashover may or may not have been transient. However, the probability is that it was in fact sustained for some time.
- The Bogue end of the line tripped but protective relays on the Duncans side did not operate due to a DC supply failure.
- Backup protection relays at Duncans, as well as at Kendal and Bellevue substations did not operate. The clearance for the backup relays at these locations may have exceeded the critical fault clearing time for a three-phase fault on the Duncans/Bogue 138 kV line, which would lead to instability of the generating power grid before the backup relays could operate.
- JEP barges and Old Harbour Unit 4 came off line almost simultaneously, JEP barge #2 from an improper earth fault relay operation and the Old Harbour Unit probably due to tripping of the auxiliaries from under-voltage.
- The loss of major units at Old Harbour carrying over 150 MW would have severely depressed the 138 kV grid feeding power into the Corporate Area.
- Stage 1 under-frequency relays operated to shed some of the load following a frequency decay, however, additional stages were inhibited by the voltage restraint setting on the relay devices.
- In the absence of additional under-frequency protection operation, overload on the remaining generators at Old Harbour, Hunts Bay and Rockfort resulted in a complete shutdown of power supplies.
- The 69 kV lines linking Bogue and the northwest transmission infrastructure to the rest of the island grid had earlier separated at various points.

- The resulting overload of gas turbines 12 and 13 which had remained on-line caused both units to trip eventually on overload.

INTERIM RECOMMENDATIONS

Arising from the OUR's preliminary investigation, the following recommendations, which are general in nature, are being submitted to JPS:

1. A system stability study which takes into account the various operating conditions of the system, as well as contingency failures, should be commissioned as soon as possible. This should include simulation of the shutdown event establishing current flows, fault levels and voltages for various scenarios of generation on-line.
2. The overall system relay coordination scheme should be reviewed by appropriate experts. Particular attention should be paid to the early clearance of JEP and JPPC generators and the probability of low fault currents occurring on the transmission infrastructure in specific contingency situations.
3. A review of the linkage of the 138 kV grid to the northwest transmission system should be undertaken. The question as to whether investment should be made in establishing a 138 kV line between Kendal/Spur Tree and Bogue substations should be determined.
4. The non-operation of under frequency relays during a system stability crisis requires remedy. Consideration should be given to relocating the relays to the 69 kV bus bars and/or providing supply from a DC source which will prevent spurious tripping caused from the distribution side.
5. The company's spinning reserve and under frequency load shedding policies should be critically reviewed to ensure dynamic stability of the generating system under normal operating conditions and probable contingency scenarios.
6. The non-functioning of highly important communication links and SCADA monitoring systems to facilitate vital remote control operations, is completely unacceptable. The maintenance of this system must be accorded immediate and first priority in order to effect full operating status at all times. Also, backup systems for the communication network is crucial and must be put in place where not now existing.
7. Comments under (6) above, also apply in general to the primary relaying system for the 138 kV and 69kV transmission grid.

8. All JPS generating stations, IPP plants and JPS System Control Centre must be time synchronized as a matter of urgency.
9. The sequence of events recorders for all power stations and generators should be made fully functional and kept in a state of serviceability at all times.
10. JPS should have in place complete and detailed procedures for the step by step restoration of the system in the event of a major shutdown of the grid, in whole or in part and System Controllers should be fully trained in the restoration process.

The OUR expects that as the investigation progresses and other facts emerge, it will be in a position to put forward additional recommendations in order to mitigate or avert the risk of the recurrence of an island-wide power system shutdown and to minimize the restoration periods if such system failures should in fact recur in the future.

August 11, 2006