Office of Utilities Regulation

JAMAICA PUBLIC SERVICE COMPANY LIMITED

SYSTEM SHUTDOWN – 24 OCTOBER 2001

REPORT OF INQUIRY

OUR

OFFICE OF UTILITIES REGULATION

December 2001

INVESTIGATION INTO JPS SYSTEM SHUTDOWN - 24 OCTOBER 2001

1. Authority

The Office has conducted this enquiry under the authority granted to it by virtue of Section 8 of the Office of Utulities Regulation Act.

2. Summary

On Wednesday October 24, 2001 at approximately 5:37 p.m. a series of events led to the total shutdown of the JPS power system.

The shutdown was initiated by the failure of the protection scheme to clear a two-phase to ground fault on the 13.8 kV underground cable supplying the Esso complex/Petrojam refinery from the Hunts Bay 'A' station. Almost simultaneously the Greenwich Road /Rockfort 69 kV line failed because of damage to a conductor caused by a 7.62 mm bullet.

Full restoration of the system was completed at 11:23 p.m., approximately five hours and forty-six minutes after the shutdown. The restoration, however, did not commence until 7:28 p.m., implying that the restoration process, once started took approximately three hours and fifty-six minutes.

After reviewing the information provided by the Company, the Office is of the view that the initiating event was precipitated by a decision to close a circuit breaker whose trip circuits were inoperable due to discharged batteries. The circuit breakers that would have provided the second contingency protection were probably also inoperable for the same reasons.

The Office is of the view that the shutdown would most probably not have occurred if the battery power had been first restored before closing the circuit breaker to energize the cable. This speaks to either (a) inexperience on the part of the staff involved or (b) the absence of appropriate procedures governing the operation of circuit breakers/restoration of circuits to service, or (c) if procedures exist, ignorance by the staff of the procedures.

With regard to the time taken to commence the restoration process, the Office believes that the almost two hours' delay in commencing the process could have been improved. Although there is no specific information available to explain the delay, that which is available suggest that there may have been some procedural limitations that impacted on the efficiency of the operational decisions or actions.

As the issue of "compensation" to customers has been raised, the Office is mindful of the company's obligations under its Licence to provide quality service to its customers. There are two mechanisms that address this issue –

a) Guaranteed Standards
b) Overall Standards

Under the Guaranteed Standards scheme the Company is obliged to make compensatory payments to customers when a standard is breached. In this case, no specified standard has been breached. The Overall Standards provide performance measures for the system as a whole affecting large groups of customers. In this case, two overall standards will have been affected:

i) Average number of customer minutes lost per customer;

ii) Total number of customer minutes lost through faults on the Transmission/Distribution system.

The impact of this outage on these standards can only be objectively assessed at the annual review of the Company's performance.

3. Introduction

On Wednesday October 24, 2001 at approximately 5:37 p.m. a series of events led to a total shutdown of the JPS power system. The events were initiated by the closing of a circuit breaker, designated 8-330, at Hunts Bay 'A' switchyard in an attempt to energize the 13.8 kV feeder that supplies the Esso complex and the Petrojam refinery and on which it was reported that repair work was just completed. For clarity, it was reported that the cables between the 69/13.8 kV transformer and the related 13.8 kV switch, designated 5-330, were replaced.

On closing, a two-phase to ground fault occurred on the cable on the supply side of the switch referred to above, but as the protection schemes did not operate as intended and with an almost simultaneous fault on the Greenwich Road 69 kV line, the collapse of the entire system was precipitated.

JPS' representatives met with the Office on October 29 and offered a preliminary report of their investigation into the circumstances leading to the system collapse. On November 16, 2001 the Office received a detailed written report from JPS. The Office had a number of questions arising out of its review of the report and also required certain other information, all of which was provided expeditiously by the Company.

This report sets out the conclusions of the Office after reviewing the information that has been provided and prescribes certain measures that the company must take to provide a basis for preventing the recurrence under similar circumstances.

4. JPS Reports on the Incident

A. System Shutdown

The JPS report is provided as Appendix 1. The report quite logically deals with the shutdown as two events – (1) the circumstances leading to the shutdown and (2) the system restoration activities.

The system conditions immediately prior to the Shutdown at approximately 5:30 p.m. were reported as follows:

- Generation - 438 MW gross
- Net Demand - 425 MW
- Spinning Reserve - 70 MW
- Frequency - 50 Hz
- Transmission System - Intact
- Distribution System - Intact

- The 69 kV/13.8 kV interbus transformer at Hunts Bay that serves the Esso complex /Petrojam refinery was de-energized.

- Circuit breaker (36) 8-330 at Hunts Bay 'A' was in the 'open' position to facilitate repair work on the 13.8 kV cables, which serve Esso/Petrojam.

JPS reports that upon energizing the circuit breaker (36) 8-330 referred to above, a series of events took place all of which are detailed in the report as records from the System Control Sequence of Events Record. The company summarizes the incident as –

> "In essence, the primary protection failed to operate and the secondary protection operated improperly allowing faults to remain on the system for an extended period, causing generators to become unstable and trip."

Approximately 3.184 seconds after the initiating event, a second fault developed on the Greenwich Road /Rockfort 69 kV line as a result of damage to one of the conductors from a gunshot that had pierced the conductor. A Report provided by the Government's ballistic expert confirms that the "hole through and across the conductor was consistent with a hole made by high velocity firearm bullet discharged from a firearm of caliber of a 7.62 mm/.30, most likely a 7.62 rifle."

It should be noted that the damage to the conductor did not necessarily occur simultaneously with the fault at Hunts Bay. The resulting reduced cross sectional area of the conductor would have limited its current carrying capacity and the increased current flows through the conductor as a result of the fault at Hunts Bay would have caused the conductor to fail in much the same way that a fuse would blow.

As a consequence of the failure of primary and secondary protection to trip (the Office's words) the JPPC Units 1 & 2 first came off line evidently due to the tripping of their negative phase sequence protection (46).

The next significant block of generators to trip were the JPS Old Harbour Units Nos. 1 and 2 (just over 3 seconds after the JPPC units) due to auxiliaries tripping as a result of voltage on the 2.4 kV bus bars.

Consequent on the loss of these generating units the System would have experienced an overload condition (as demand exceeds supply) and other units tripped as the system became unstable thus leading to the collapse of the entire system.

In its report on the incident, JPS concludes the following:

1. "Faults on the Esso/Petrojam 13.8 kV underground cable should not have impacted the stability of the System, if cleared in a timely basis.

2. Because the cable fault was not cleared in a timely fashion, the interbus transformer faulted and the fault transferred to the 69 kV grid.

3. The lack of AC supply, due to the 69/13.8 kV interbus transformer being out of service, prevented circuit breaker (36) 8-330 from isolating the fault, which was seen by the over-current relay. Hence, interbus transformer was damaged.

4. The fault remained on the bus for too long because:

    - Although Zone 2 distance relay on the Hunts Bay to Greenwich Road 69 kV line sees the fault, it did not initiate the tripping of the circuit breaker at the Greenwich Road Substation in Zone 2 time. The fault was therefore cleared in Zone 3 from Rockfort.

- The Hunts Bay to D&G to Duhaney 69 kV line did not isolate the circuit.

- Circuit breakers 8-350 and 8-530 (Hunts Bay B) isolated the fault after being initiated by backup over-current protection.

5. Although the occurrence of the second fault on the Greenwich Road to Rockfort 69 kV line would affect the ability of the System to settle down to a new operating state, it would not ordinarily cause the collapse of the System. The CFCT at the Hunts Bay 69 kV bus is 0.54 seconds. Therefore any fault remaining on the bus beyond this time would result in the generating units at Hunts Bay and the Corporate Area, to a greater extent, starting to swing out of step with respect to the other machines on the System.

6. In addition to the loss of synchronization of the Corporate Area units, the simulations done show that the duration of the fault would suppress generator terminal voltages at Hunts Bay, Rockfort and Old Harbour Power Stations. These units would therefore trip off line, adding to the collapse of the System."

B. System Restoration

The JPS reports suggest that the System was completely shutdown by 17:38 p.m. The last time provided on the Sequence of Events Recorder was Old Harbour Unit No. 2 tripping at 17:37: 43.303 after which the gas turbines all tripped.

The reports indicate that after failed attempts to synchronize GT10 at Hunts Bay and GT4 at Bogue at 17:52 and 18:28 respectively, the restoration process commenced at 19:28 p.m. (approximately 1 hour and 50 minutes after the shutdown) with the closing of the GT4 breaker at Hunts Bay. The System was completely restored at 23:23 (some 5 hours and 46 minutes after the shutdown).

5. OUR Findings

A. System Shutdown

The JPS report prompted requests for additional information and clarification by the Office. These requests dated November 20, 2001 and November 27, 2001 are attached as Appendices 2 and 4 while the respective JPS responses are at Appendices 3 and 5.

The main issues of concern to the Office are:

1) It is clear that the initiating event was the failure of the 69 kV circuit breaker at Hunts Bay A (8-330) to clear the fault on the 13.8 kV cable supplying the Petrojam Refinery/Esso Complex. [The fact that the associated 13.8 kV breaker was rendered inoperable as a circuit breaker with automatic tripping features but was operating as a manually operated switch is an operating practice which is known to occur from time to time but is not desirable]. What were the circumstances which impacted on the operations of this circuit breaker (8-330). Could these have been avoided?

   The Company's reports on the initial status and operation of this breaker indicate the following:

   As a consequence of the outage on the 13.8 kV feeder, there was no AC supply to the battery chargers associated with the batteries that energize the DC control circuits for the circuit breaker in question.

   The batteries were therefore dead and the control circuits inoperable. The circuit breaker would therefore be unable to trip automatically. A decision to close the breaker manually was taken, knowing that the trip circuits were inoperable.

   The Office has not received a response explaining or justifying this decision. Clearly this decision precipitated the events that led to the eventual shutdown of the System. The company appears to be deficient in its procedures and operating practices relating to the return of circuits to service.

2) Not only did the first contingency protection fail to operate, but the 2nd contingency failed as well. These would be the related protection schemes associated with circuit breakers 8-160 and 8-130 at Hunts Bay 'A' Station. (These being the bus tie breakers between the Hunts Bay 'A' and 'B' stations). Why did these not operate?

   They probably did not operate because the AC power to charge the batteries for the control circuits was likely to have been derived from the same source as circuit breaker 8-330.

3) The third contingency protection – to isolate the faulted circuit from the Hunts Bay 'B' switchyard circuit breakers 8-350/8-530 and 8-450/8-430 at Hunts Bay 'B' switchyard did not operate in time. Why not?

The company has admitted that, but offered no comment on the reason why, the protective relaying coordination was not revisited after the shutdown of the Hunts Bay 'A' Station. It is possible that the initial fault would have cleared earlier on the backup protection at the Hunts Bay 'B' switchyard (circuit breakers (265) 8-330 and 8-530, 8-540 and 8-630), had this been done. Whether this would have been fast enough to prevent the shutdown is questionable as the almost simultaneous loss (0.03 second interval) of the Greenwich Road/Rockfort 69 kV line would have influenced the dynamics of the system and the power flows causing other protection to operate faster than the backup protection in question. Nevertheless, the fact that this activity has been outstanding since 1996 (5 years) is cause for concern.

Although there are a number of other issues that may be relevant, the Office is of the view that, had the protective relaying schemes, related to the three contingencies outlined above, operated as they ought to have by design, the system collapse would most likely not have occurred.

B. System Restoration

The procedure for System restoration after a complete shutdown is necessarily tedious and must be carried out systematically, constantly balancing increasing load with capacity. While the Office will not comment on the actual time taken to complete the restoration (some 4 hours after the first unit was synchronized) it will comment on the time taken to bring the first unit back on line (approximately 1 hour and 50 minutes). The time lapse between shutdown and commencement of the restoration should not be significant given the modern SCADA system and the many gas turbines on the JPS System. These would allow for remote tripping of circuit breakers, from System Control, to strip the load and speedy run-up and synchronization of generating capacity. Not surprisingly therefore, that the System was in a state to commence restoration by 17:52 (some 7 minutes after the shutdown), which is commendable.

The Company has indicated that some difficulties were experienced initially and while these have been reported, no information has been offered as to the reasons why they occurred. The Office would opine that analysis of the events will result in the conclusion that, initially, the restoration process was flawed. The basis for this opinion is that each of the difficulties suggests that System conditions were not stable enough for successful synchronization and it may very well be that the controllers had not fully taken into account the conditions across the entire System.

6. Conclusion

While the Office notes the conclusions of the Company, it is also of the view that:

1) The decision to close circuit breaker 8-330 at Hunts Bay was at best poor operating procedure (or reflects an absence of same) or at worst an error of judgement given that it must have been known that the breaker control circuits were inoperable due to dead battery supplies.

2) The shutdown was precipitated not so much as a result of the fault on the cable but more so as a result of closing a breaker that was unable to trip, one the fault occurred.

3) The bus tie breakers at Hunts Bay 'A' 8-160 and 8-130 probably failed to operate because their control circuits were powered by the same batteries as 8-330. Had these operated, the impact of fault would most probably have been contained.

4) The protective relaying schemes at the Hunts Bay stations including the tripping logic appear to be flawed.

5) The System restoration procedures appear to be in need of review.

The Licence does not provide a specific remedy for breaches of Overall Standards, suffice it to say that the overall performance of the company in relation to "quality of service" is taken into account at tariff reviews. After 2004, the ratemaking mechanism provides for the impact of "quality of service" to be explicitly factored into the tariff determination.

Finally, the Office must comment on the issue of the company's liability to its customers under the various Standards and provisions of the Licence. The Office is of the view that there has been no breach of any Guaranteed Standards for which compensatory payments may be made. The company's performance in respect of the Overall Standards is, however, affected. The precise implications can only be objectively evaluated at the time that the annual review of the Company's performance takes place.

7. Office Memorandum

Under the provisions of Section 9 of the OUR Act the Office issues the following memorandum to the company:

1. JPS is to complete the actions 1 – 7 as set out in its own report and to provide the Office with statements of completion in respect of each activity by February 15, 2002.

2. The company is to review its operational and commissioning procedures and ensure that these are consistent with prudent utility practice. Where non-existent, appropriate procedures are to be written and instituted over the next 12 months (ending December 2002). The Company will provide the Office with a detailed time-bound plan by February 28, 2002, indicating how it intends to complete the preparation of the procedures within the time stipulated and shall subsequently provide the Office with quarterly status reports.

3. The company must, as a priority, complete an assessment of all staff who have responsibility for operating circuit breakers (at power stations as well as T&D) to determine experience gaps. Within 12 months specific training and exposure of the staff must be completed.

   The company will provide the Office with regular reports on this activity.

4. The procedures for System restoration are to be reviewed and where feasible, simulations of shutdown events instituted on a regular basis for the purpose of training the System Controllers to respond to such events.

5. By July 2002, the company is to complete an extensive review of its protective relaying systems and will have applied new relay coordination for optimal performance of the System. The Company is to file a report on the status of this activity with the Office on May 17 and August 16, 2002.

6. A detailed review of the system operations is to be carried out and simulations done to determine the reasons for the sensitivity of the Old Harbour 2.4 kV system to fault conditions distantly remote from Old Harbour. If feasible remedial action is to be taken to limit the sensitivity of the 2.4 kV system to external faults.

APPENDIX 1

APPENDIX 1

Appendix 1

Jamaica Public Service Company Limited

SYSTEM SHUTDOWN REPORT

Table of Contents

1.0 INTRODUCTION **1**

2.0 SYSTEM CONDITION PRIOR TO SHUTDOWN **1**

3.0 DESCRIPTION OF INCIDENCE **1**

Rockfort 3
Old Harbour 3
Bogue 4
Hunts Bay 4

4.0 SYSTEM RESTORATION **5**

Analysis 6

5.0 CONCLUSIONS **7**

6.0 RECOMMENDATIONS **7**

1.0 INTRODUCTION

On Wednesday October 24, 2001 at approximately 5:37 p.m., a series of events led to the total shutdown of the JPS Power System. The events were initiated by the closing of circuit breaker 8-330 at the Hunts Bay 'A' switchyard. This circuit breaker is connected to the 13.8kV underground cable, which provides distribution supply to the Esso and Petrojam refineries, and on which repair work had just been completed. The circuit breaker which was isolated for two weeks, was closed in order to re-energize the cable. Upon closing a two phase to ground fault occurred. A few seconds afterwards, another fault was experienced on the Greenwich Road to Rockfort 69 kV line, close to the Rockfort end. These and other events led to the collapse of the entire system.

2.0 SYSTEM CONDITION PRIOR TO SHUTDOWN

The conditions prior to the system shutdown at approximately 5:30 p.m. are as follows:

- Generation, 438 MW, gross
- Net demand, 425 MW
- Spinning Reserve, 70 MW
- System frequency – 50 Hz.
- Transmission system intact
- Distribution system intact
- The 69/13.8 kV interbus transformer at Hunts Bay which serves the Esso complex and Petrojam refinery was de-energized
- Circuit breaker 8-330 at Hunts Bay was in the open position to facilitate repair work on the 13.8 kV cables, which serves Esso and Petrojam.

3.0 DESCRIPTION OF INCIDENT

Upon energizing the cable (via breaker 36/8-330, see Figure 1), a series of events took place which resulted in the collapse of the JPS electricity supply system, as outlined in Tables 1 and 2 below, which are the recordings from the System Control Sequence of Events (SOE) logger.

In essence, the primary protection failed to operate and the secondary protection operated improperly allowing faults to remain on the system for an extended period, causing generators to become unstable and trip.

Figure 2 shows the System Frequencies at the various locations, as reported by the System Control SOE.

Table 1: System Control SOE Report – Circuit Breaker/Line Tripping

Event	Substation	Line/CB Operation	SOE Time	Time (sec.) from initiating Event	Comment
Initiating Event – Fault at Hunts Bay 'A' Station					
1	Hunts Bay 'A' (Power Station)	Esso/Petrojam - underground cable		0.0	Two phase to ground fault on the A and B phases. Duration not known. But several locations on the cable were damaged. This is the initiating event.
2	Hunts Bay 'A' (Power Station)	Circuit Breaker (CB) 5-330			Did not operate. CB operating like a switch. No trip circuit available.
3	Hunts Bay 'A'	CB 8-330			Did not operate. CB was mechanically closed, hence trip mechanism was totally discharged.
4	Hunts Bay 'A'	CB, 8-160			Protection failed to operate.
5	Rockfort	Hunts Bay 'B' 8-250, 8-330	17:37:34.665, 17:37:35.088	0.423	Zone two distance protection operated to trip line.
6	PAJ	Hunts Bay 'B' 8-130, 8-430	17:37:35.092 17:37:35:098	0.433	Zone two distance protection operated.
7	Three Miles	Hunts Bay, CB 8-230	17:37:35.434	0.769	Fault detected intermittently on the threshold of zone 2 distance protection, but line tripped by directional overcurrent protection.
8	Greenwich Rd.	Hunts Bay 'B' CB 8-130			Fault detected intermittently on the threshold of zone 2 distance protection, but no tripping resulted.
9	Hunts Bay 'B'	L9, CB 8-350 and CB 8-530	17:37:36.223 17:37:36.233	1.568	Fault cleared by backup overcurrent protection.
10	Rockfort	Greenwich Rd., 8-230A and 8-230	17:37:36.966, 17:37:36.968	2.3	Line tripped by zone 3 distance protection.
11	Hunts Bay 'A'	Line 12 CB 8-130			CB tripped, by overcurrent protection to trip line
Second Event – Fault on Greenwich Rd. – Rockfort 69 kV line					
12	Greenwich Rd.	Rockfort	17:37:37.849	3.184	Fault on line, as a result of damage due to gunshot and increased power flow due to fault at Hunts Bay.
13	Greenwich Rd,	Rockfort, 8-230	17:37:38.209	3.544	Zone two distance protection operated to trip line.
14	Hunts Bay	D&G, Duhaney, 8-150, 8-330	17:37:39.961 17:37:39.986	5.32	Zone four distance protection at Duhaney detected fault, but did not issue trip signal because the fault was already cleared from the system. At Hunts Bay distance protection trip line due to subsequent power swing.

Table 2: Generator Tripping (SCADA)

No	Location	Breaker(s)	Relay(s) Operating	SOE Time	Comments
1	JPPC, Rockfort	Unit # 1	46, 86G	17:37:35.411	Unit tripped negative phase sequence protection as a result asymmetrical fault condition at Hunts Bay.
2	JPPC, Rockfort	Unit # 2	46,86G	17:37:35.434	Unit tripped negative phase sequence protection as a result asymmetrical fault condition at Hunts Bay.
3	Old Harbour	Unit #3 138 kV (9-320, 320A)	86G, 94T	17:37:38.766, 17:37:38:788	Tripped on undervoltage
4	Old Harbour	Unit #1 69 kV (8-120)	86U, 86B	17:37:39.234	Tripped on undervoltage
5	JEP, Old Harbour	Unit #s 1, 3, 4 & 5		17:37:39.303	Low voltage condition suspected
6	JEP, Old Harbour	Unit #2		17:37:40.303	Low voltage condition suspected
7	Hunts Bay	Unit B6 69 kV (8-650, 120)	86G, 94T	17:37:40.773, 17:37:40.842	Tripped on undervoltage
8	Old Harbour	Unit #2 138 kV (9-220)		17:37:43.303	Low voltage condition suspected
9	Hunts Bay	GT # 5	51V-Y, 94	-	Tripped on overload.
10	Hunts Bay	GT # 10	81	-	Tripped on underfrequency
11	Hunts Bay	GT # 4		-	Cause of trip undetermined.
12	Rockfort	Unit #1	27E, 186G	-	Tripped on undervoltage
13	Rockfort	Unit #2	27E, 286G	-	Tripped on undervoltage
14	Bogue	GT #3		-	Breaker opened on overload.
15	Bogue	GT #6	86G	-	Loss of AC supply. Under freq
16	Bogue	GT #7	86G	-	Loss of AC supply. Under freq
17	Bogue	GT #8 (9)	86G	-	Loss of AC supply. Under freq
18	Bogue	GT #11	81	-	Tripped on underfrequency
19	Maggotty			-	
20	Rio Bueno 'A'	Hydro			
21	Roaring River	Hydro			
22	U. White River	Hydro			

Rockfort

The time of tripping of the JPS Rockfort units No. 1 and No. 2 are not known, but relays indicated that they tripped on low voltage, thus resulting in the operation of the undervoltage (27) and the lockout (86) relays. Similar voltage situation would be experienced for the JPPC units. However relay indications are that these units tripped on negative phase sequence protection. Indications are that the high voltage (HV) circuit breakers and the generator breakers, 50-120 and 5-220 tripped. However, no information is available to tell which relay initiated the HV breaker trips.

Old Harbour

The Old Harbour units tripped off line due to the low voltage condition experienced on their 2.4 kV bus, as reported in their respective SOE.

Bogue

The Bogue Power Plant is the most remote from the location of the incident, and therefore the fault condition would have the least impact on these units.

However, with the other units around the corporate area tripping off line, the entire system would start experiencing a system overload since demand becomes greater than supply, hence the tripping of GT11 on underfrequency condition. GTs 6, 7 and 8 are designed to trip off line whenever there is a loss of AC supply to the lube oil pump motors. Hence with the collapse of the system these units would be lost

Hunts Bay

The Hunts Bay B6 unit tripped off line due to low voltage condition experienced on the 4.16 kV bus which supplies the units auxiliaries. GTs 4 and 10 are suspected to have tripped on overload, based on relay and annunciator indications. However the cause for the tripping of GT4 needs to be further investigated, but loss of auxiliaries was reported.

4.0 SYSTEM RESTORATION

The objective of the system restoration procedure was aimed at:

- Providing supply to the major power stations - Old Harbour, Hunts Bay, Rockfort and Bogue - to allow for the start-up of the auxiliary equipment and the subsequent restoration of the generators to the electric grid.
- To restore customer supply as quickly as possible.

To achieve this, units with black-start capability had to be started and a specific route created that allowed for good quality power to the targeted station(s).

The restoration procedure commenced within minutes after the shutdown, by stripping the system of all connected load and MVAR sources. Table 3 outlines the generation activities and the time at which the respective units were brought on bars.

The restoration process actually started with the closing of the GT4 breaker at the Hunts Bay Power Station at approximately 7:28pm.

19:24
17:38

Table 3: Generators Synchronization Process

Location	Gen on Bars	Time		Gen (MW) Online	Comment
		On Bars	Tripped		
Bogue	GT3	5:52 pm			Unit running off-bars at no-load and rated speed, brought back on bars, but tripped due to high vibration.
Hunts Bay	GT10	6:28 pm	6:40 pm	32	Tripped due to sudden load increase from 20 MW to 32 MW.
Hunts Bay	GT4	About 6:28 pm			No synchronization initially
Hunts Bay	GT4	7:28 pm			Generator Breaker Closed
Hunts Bay	GT10			53	Synchronized
Old Harbour	JEP	7:33 pm		62	Synchronized
Old Harbour	JEP	7:56 pm			Synchronized
Rockfort	RF2	8:01 pm		89	Synchronized
Bogue	GT6	8:17 pm			Synchronized
Bogue	GT11	8:26 pm			Synchronized
Old Harbour	JEP	8:31pm		132	Synchronized, demand 95 MW
Bogue	GT7	8:42 pm			Synchronized
Old Harbour	JEP	9:02 pm		164	Synchronized, demand 128 MW
Old Harbour	No. 2	9:08 pm			Synchronized
Hunts Bay	B6	9:10 pm		292.5	Synchronized. Load on unit reduced from 30 MW to 13 MW for reasons unknown.
Bogue	GT3	9:15 pm	9:24 pm		Synchronized
Jamaica Broilers	JAB	9:21 pm			Synchronized
Rockfort	No. 1	9:51 pm			
Rockfort, JPPC	No. 1	9:59 pm		313	Synchronized, demand 286 MW
Old Harbour	No. 1	11:05 pm			Synchronized
	All units	11:23 pm		378.2	Synchronized, demand 358.6 MW

The overall system restoration took five hours and forty-six minutes. It took one hour and thirty-six minutes, between the initiation of the restoration process to the steady synchronization of the first generating unit. This was the result of problems encountered during synchronization, including the high voltage situation being experienced.

Analysis

Data Collection

Data collected includes:

- Relay oscillographs
- System Control, SCADA data – SOE and Historian
- Hunts Bay Power Station – SOE for B6
- Old Harbour Power Station – SOE data, for Old Harbour units 1, 2, 3 and the JEP complex

No data was available for the tripping of the JPS Rockfort units 1 and 2, since the points were not being monitored by SCADA. Also, no SOE data is available for the JPPC complex.

5.0 CONCLUSIONS

1. Faults on the Esso/Petrojam 13.8 kV underground cable should not have impacted the stability of the system, if cleared in a timely basis.

2. Because the cable fault was not cleared in a timely fashion, the interbus transformer faulted and the fault transferred to the 69 kV grid.

3. The lack of AC supply, due to the 69/13.8 kV interbus transformer at Hunts Bay being out of service, prevented circuit breaker 8-330 from isolating the fault, which was seen by the overcurrent relay. Hence, interbus transformer was damaged.

4. The fault remained on the bus for too long because:

   - Although Zone 2 distance relay on the Hunts Bay to Greenwich Road 69 kV line sees the fault, it did not initiate the tripping of the circuit breaker at the Greenwich Road substation in Zone 2 time. The fault was therefore cleared in Zone 3 time from Rockfort.

   - The Hunts Bay to D&G to Duhaney 69 kV line did not isolate the circuit.

   - Circuit breakers 8-350 and 8-530 isolated the fault, after being initiated by backup overcurrent protection.

5. Although the occurrence of the second fault on the Greenwich Road to Rockfort 69 kV line would affect the ability of the system to settle down to a new operating state, it would not ordinarily cause the collapse of the system. The CFCT at the Hunts Bay 69 kV bus is 0.54 seconds. Therefore, any fault remaining on the bus beyond this time would result in the generating units at Hunts Bay and the Corporate Area, to a greater extent, starting to swing out of step with respect to the other machines on the system.

6. In addition to the loss of synchronism of the Corporate Area units, the simulations done show that the duration of the fault would suppress generator terminal voltages at Hunts Bay, Rockfort, and Old Harbour Power stations. These units would therefore trip off line, adding to the collapse of the system.

6.0 RECOMMENDATIONS

1. Alternative AC supply to be provided for battery charging in cases where the interbus transformer is taken out of service

2. Relay settings to be coordinated with the CFCT

3. Accelerate the implementation of backup distance protection scheme

4. Investigate the reason why the Hunts Bay to Duhaney L1 did not clear the fault in zone 2 or 3 distance protection time.

5. Review system restoration procedure in order to minimize system restoration time

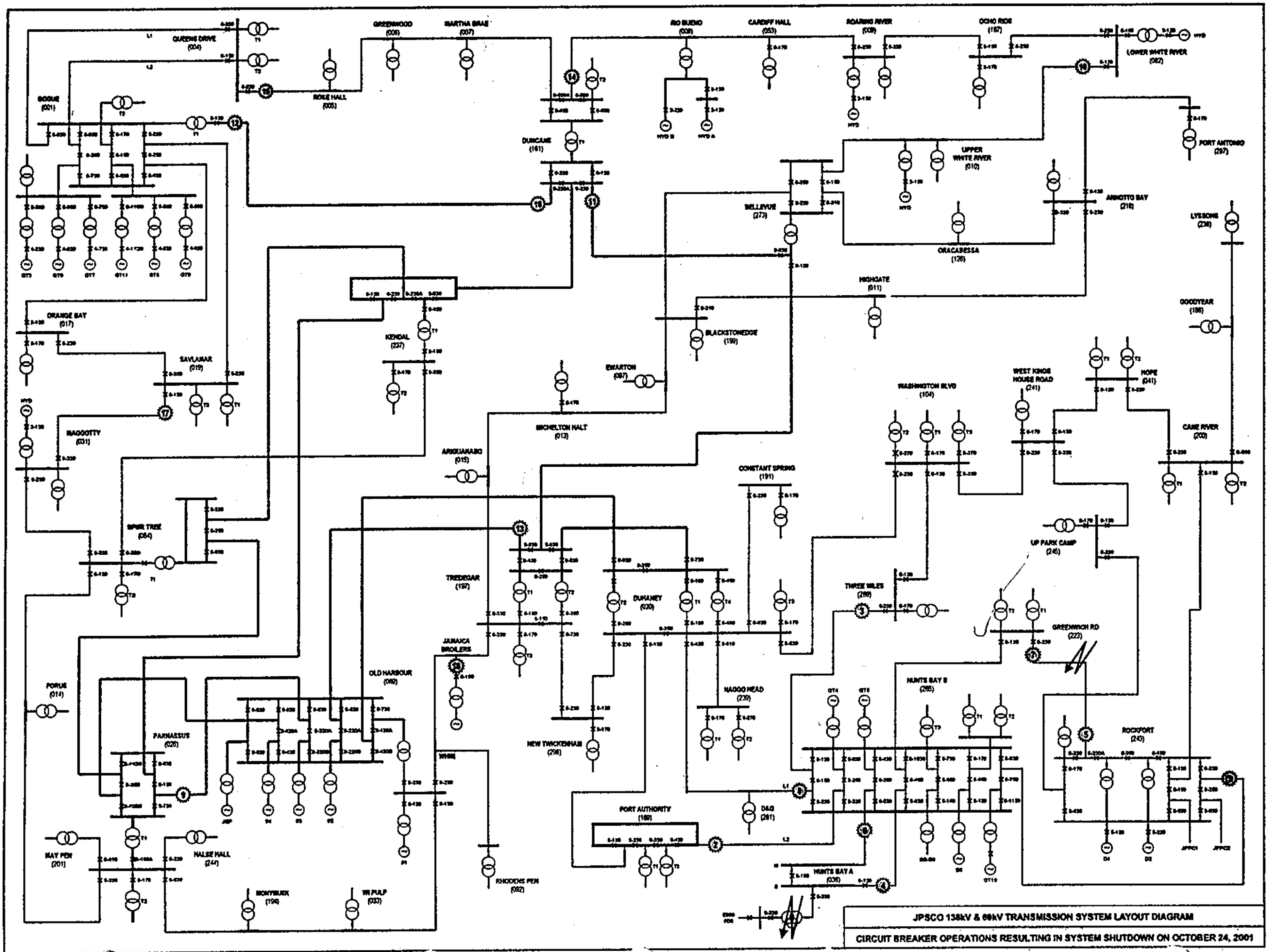
6. Evaluate the reason for the high voltage situation during the restoration process

7. Isolate L9 and L12 from Hunts Bay 'B' and provide alternate feed for Esso from Hunts Bay 'B', thus retiring Hunts Bay 'A' fully

8. Perform transient power system stability studies to determine critical lines for out-of-step protection implementation

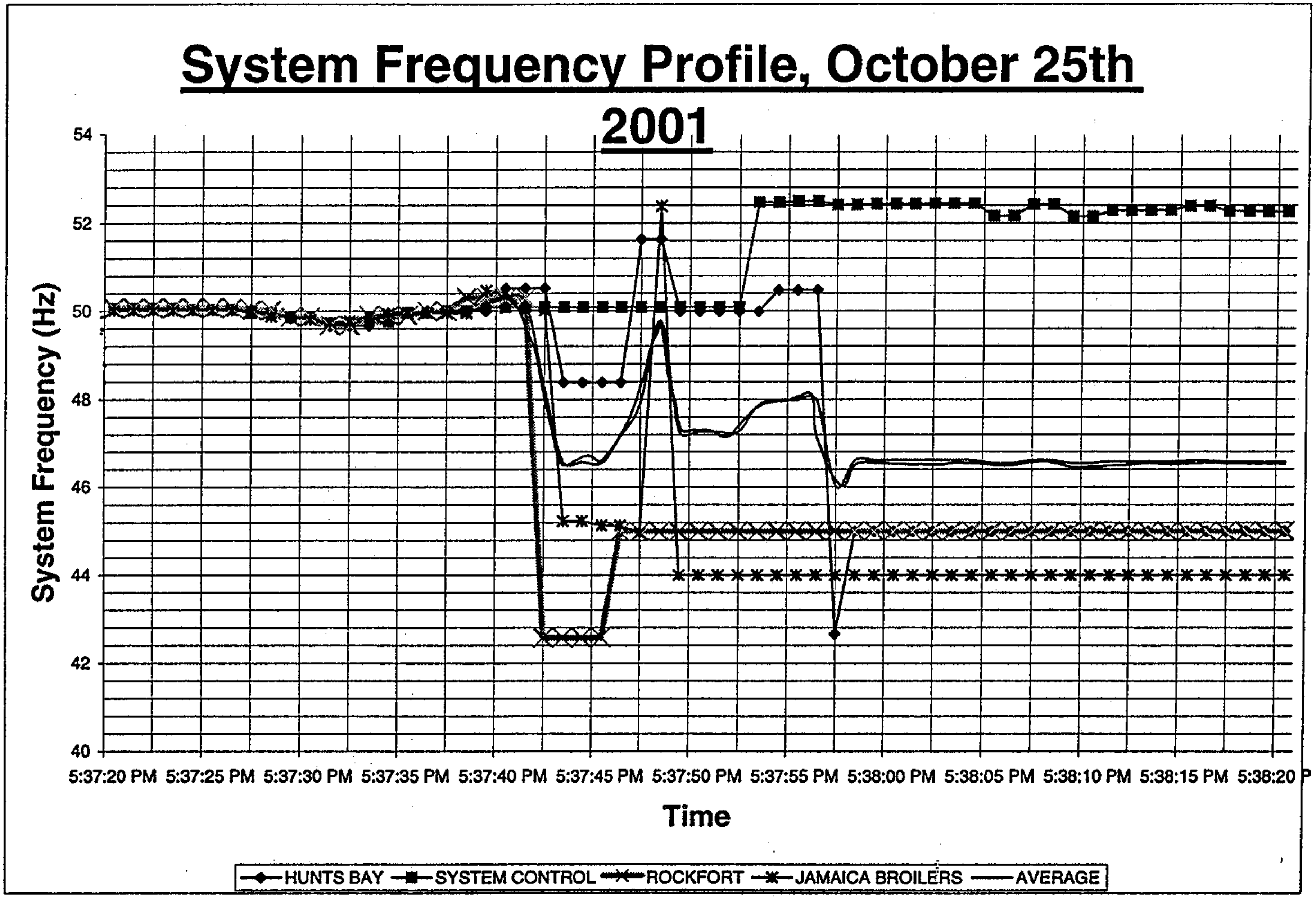
9. Review tripping logic for generators.

10. Implement distance zone 4 protection on the primary distance relay for all lines



JPSCO 138kV & 69kV TRANSMISSION SYSTEM LAYOUT DIAGRAM

CIRCUIT BREAKER OPERATIONS RESULTING IN SYSTEM SHUTDOWN ON OCTOBER 24, 2001


System Frequency Profile, October 25th 2001
System Frequency (Hz)
54
52
50
48
46
44
42
40
5:37:20 PM
5:37:25 PM
5:37:30 PM
5:37:35 PM
5:37:40 PM
5:37:45 PM
5:37:50 PM
5:37:55 PM
5:38:00 PM
5:38:05 PM
5:38:10 PM
5:38:15 PM
5:38:20 P
Time
HUNTS BAY
SYSTEM CONTROL
ROCKFORT
JAMAICA BROILERS
AVERAGE

APPENDIX 2

Appendix 2

OFFICE OF UTILITIES REGULATION

3rd Floor, P.C.J. Resource Centre, 36 Trafalgar Road, Kingston 10, Jamaica, W.I.
Tel: (876) 968-6053, 968-6057, Fax: (876) 929-3635, Toll Free: 1 - 888-991-2209

20 November 2001

Mr. Charles Matthews
President & Chief Executive Officer
Jamaica Public Service Co. Ltd.
6 Knutsford Boulevard
Kingston 5

Dear Mr. Matthews:

Re: <u>System Shut Down - October 24, 2001</u>

We acknowledge receipt of and thank you for your report on the system shut down that occurred on October 24, 2001. We are aware that the report has been submitted to the Minister of Mining and Energy.

We have a number of comments arising out of the report which we should like to bring to your attention and to which we expect your responses.

A. <u>Description of Incident</u>

I. Initiating event – fault at Hunts Bay A Power Station

We note your summary statement "In essence, the primary protection failed to operate and the secondary protection operated improperly allowing faults to remain on the system for an extended period, causing generators to become unstable and trip". While we would agree that ~~that~~ this reflects the events as reported, the following has to be clarified:

i. <u>Energization of (036) 8-330</u>

We are aware that the cable feeding the Petrojam is an old paper insulated cable operating in a (presumably) moist or damp environment. It appears that the cable had been deenergised for about two weeks. Normally,

.../2

---

given the operating conditions, for cable of this type and age it could be anticipated that there would have been some ingress of moisture. Were the appropriate commissioning tests done to establish the integrity of the cable? If not, why not?

ii. Operation of circuit breaker (036) 8-330

We do not understand the statement – "CB was mechanically closed, hence trip mechanism was totally discharged". It is our understanding that, once closed, a circuit breaker's mechanism is fully charged ready to trip. The effect of a discharged mechanism should impact on the ability of the breaker to be closed, not tripped. Would you explain, please?

iii. Operation of circuit breaker (036) 8-160

In the scheme of things, one would have expected this breaker to open. You indicate that the protection failed to operate. As in the case of the corresponding 8 – 330, the failure of this breaker to operate led to the eventual cascading of the system as breakers further removed from the fault cleared. What is the explanation as to the failure of the protection to operate?

iv. Operation of circuit breakers (265) 8-350 and 8-530, 8-450 and 8-330

It would appear that the operation of these breakers would be the next contingency for clearing the fault. What is the explanation as to why the primary protection did not operate? (Is the description of the circuit breaker operation at event no. 9 correct?)

II. Operations at Old Harbour

We are concerned that a fault on the Greenwich Road/Rockfort 69 line would result in the auxiliaries at Old Harbour tripping on low voltage. This seems to be a recurring problem and one which needs thorough analysis and corrective action as the system will always be susceptible to disruption for what should be accepted as unacceptable reasons.

III. Operations at Hunts Bay

See comments as for Old Harbour.

B. Restoration

What problems were encountered during synchronization and what was the genesis of the high voltage problem that was experienced?

C. Conclusions

We do not understand the conclusion that the lack of ac supply prevented circuit breaker (036) 3-330 from clearing the fault. Aren't the control circuits d.c.?

D. Recommendations

If, in fact, recommendation no. 7 is implemented, is it necessary to implement no.1?

Further action and responses to OUR.

1) Please provide us with specific responses to the questions and issues raised above.

2) In addition we should like you to provide us with your proposed timetable for implementing the action that has been recommended.

3) Included in your action plan is to be the analysis alluded to under our comments on Old Harbour.

We anticipate your response by November 30, 2001.

Yours sincerely,

....
J. Paul Morgan
Deputy Director General

c. Hon. Anthony Hylton, M.P., Minister of Mining and Energy
Mr. Sam Davis, Manager, Government and Regulatory Affairs JPS

APPENDIX 3

JPS

Jamaica Public Service Company, Ltd.

6 KNUTSFORD BOULEVARD, P.O. BOX 54, KINGSTON, JAMAICA, W.I.
TELEPHONE: (876) 926-3190-9, TELEX: 2180, FAX: (876) 968-3337, CABLE: JAMSERV, WEBSITE: www.jpsco.com

November 21, 2001

Mr. J. Paul Morgan
Deputy Director
Office of Utilities Regulation
36 Trafalgar Road
Kingston 10

Dear Mr. Morgan

Re: System Shut-down – October 24, 2001

Your letter of November 20, 2001 is acknowledged and the following comments offered in response:

AI (i) We megger cables which have not been worked on but megger and hi-pot cables which have been worked on. No repairs were done to the feeder. Megger tests performed several days prior to the cable being returned to service were satisfactory. However, there were several heavy rain showers in the intervening days. A 1983 FPL Standard, discouraging hi-pot testing of XLPE cables over 10 years is enclosed. The cable which failed is an almost 40 year old PILC-SWA cable. We are reassessing the current procedure.

AI (ii) The breaker was closed using the push button switch which releases the latch on the solenoid. This would leave the trip coil fully discharged hence unable to trip. Had an a.c. supply been immediately available the coil would have re-charged.

AI (iii) Isolating the Petrojam feeder also isolated supply to the charger for the batteries which provide d.c. tripping for breaker 8-330. Consequently, the breaker did not trip.

AI (iv) Logically, one would expect breakers 8-350, 8-530, 8-450 and 8-630 to be next in line to operate in response to the fault. Given the different types of relaying involved, this need not necessarily be so. Also, relay settings had not been adjusted following decommissioning of the 'A' Station.

AII We share the view that the 2.4 kV Old Harbour bus undervoltage trip may be too sensitive, particularly for Units 1 and 3. This is being investigated.

AIII The Hunts Bay 2.4 kV bus undervoltage trip operated approximately 6.5 seconds after the first fault and more than 3 seconds after initiation of the second fault. Given the proximity of both faults to the plant and their persistence, undervoltage tripping of auxiliaries may not be unreasonable. The relay setting is nevertheless being reviewed.

B. We have not yet specifically identified the cause of the high voltage problem. It is likely due to the significant number of fixed (and switched) capacitors which have been added to the system.

C. See explanation at A I (iii).

D. Our recommendation 1 is generic as it might impact battery charging at various locations. Our recommendation 7 is specific and has already been implemented.

We expect to have fully researched, distilled and implemented necessary changes to our procedures to address the issues you have noted, as well as others which we have identified by not later than January 31, 2001.

Yours sincerely

Michael R. Moss
Chief Technical Officer

cc. Hon. Anthony Hylton
Mr. Sam Davis

CABLE TESTING AND CABLE TEST VOLTAGES

DISTRIBUTION CABLES

THE PURPOSE OF TESTING PRIMARY CABLES IS TO INCREASE SERVICE RELIABILITY TO OUR CUSTOMERS CONSISTENT WITH GOOD ECONOMICS.

CABLES ARE PERIODICALLY TESTED ONLY WHERE THERE ARE UNUSUAL CIRCUMSTANCES SUCH AS WHERE SERVICE CONTINUITY WILL BE OF CRITICAL IMPORTANCE OR SERVICE EXPERIENCE INDICATES THAT SUCH TESTING WOULD BE BENEFICIAL.

A HIGH VOLTAGE D-C TEST IS THE PREFERRED METHOD OF TESTING CABLE AND SHALL BE PERFORMED AFTER INSTALLATION, SPLICING AND TERMINATING WORK ON ALL PRIMARY CABLES EXCEPT CROSS-LINKED POLYETHYLENE OR POLYETHYLENE INSULATED CABLES THAT HAVE BEEN IN SERVICE MORE THAN 10 YEARS OR ARE SMALLER THAN 500 KCMIL. THE TEST VOLTAGE SHOULD NOT EXCEED THAT SHOWN IN THE TABLE. THE PHASES NOT UNDER TEST SHOULD BE GROUNDED DURING THE TESTING OPERATION AND ALL CONDUCTORS MUST BE GROUNDED AFTER D-C TESTING. FOR PROPER GROUNDING REFER TO FPL SAFE WORK PRACTICES BOOK FOR "CAPACITORS AND CAPACITANCE OF HIGH VOLTAGE CABLES"

TABULATED VOLTAGES ARE TO BE THE MAXIMUM D-C VOLTAGE APPLIED FOR FIVE MINUTES FROM CONDUCTOR TO SHEATH. THE VOLTAGE SHOULD BE RAISED AS RAPIDLY AS POSSIBLE TO THE TEST VOLTAGE WITHOUT TRIPPING OUT THE TEST SET DUE TO OVERLOAD FROM CHARGING CURRENT. THE TIME SHOULD START IMMEDIATELY UPON REACHING TEST VOLTAGE AND SHOULD NOT BE EXTENDED BEYOND 5 MINUTES UNLESS THE LEAKAGE CURRENT BEGINS TO INCREASE. RISE IN CURRENT MAY INDICATE THAT A FAILURE IS IMMINENT, AND CONSIDERATION SHOULD BE GIVEN TO EXTENDING THE TEST TIME TO AVOID A SUBSEQUENT SERVICE FAILURE.

CABLE OPERATING VOLTAGE CLASS (VOLTS)	MAXIMUM TEST VOLTAGE IN KV D-C
5,000	20
15,000	40
25,000	55

THE HIGH VOLTAGE D-C TEST SHALL NOT BE USED FOR CROSS-LINKED POLYETHYLENE OR POLYETHYLENE INSULATED CABLES, 500 KCMIL OR LARGER THAT HAVE BEEN IN SERVICE MORE THAN 10 YEARS. THE FOLLOWING ALTERNATE METHODS OF TESTING SHOULD BE USED FOR THE ABOVE MENTIONED CABLES AND FOR OTHER CABLES WHEN A HIGH VOLTAGE D-C TEST IS NOT POSSIBLE.

1) AN INSULATION TEST USING AN APPROVED INSULATION TESTER (MEGGER)

2) A SMALL PRIMARY FUSE (APPROXIMATELY 1 AMPERE PER 1000 FEET OF CABLE)

3) A CIRCUIT BREAKER ON "ONE SHOT" OPERATION

SEE PROCEDURE NUMBER 2510 FOR FURTHER INSTRUCTIONS

Supersedes UV-4 last revised 03-10-83

STANDARDS
UNDERGROUND DISTRIBUTION SYSTEM
FLORIDA POWER & LIGHT COMPANY

NO.	DATE	REVISION
1	3-1-89	REVISED PER T&D PROC. 2510

DATE 3-10-83 APPROVED R K Cielo
DIRECTOR, DISTRIBUTION ENGINEERING

APPENDIX 4

Appendix 4

OFFICE OF UTILITIES REGULATION
3rd Floor, P.C.J. Resource Centre, 36 Trafalgar Road, Kingston 10, Jamaica, W.I.
Tel: (876) 968-6053, 968-6057, Fax: (876) 929-3635, Toll Free: 1 - 888-991-2209

November 27, 2001

Mr. Michael Moss
Chief Technical Officer
Jamaica Public Service Co., Ltd.
6 Knutsford Boulevard
Kingston 5

Dear Mr. Moss:

Re: **System Shutdown – October 24, 2001**

We acknowledge receipt of and thank you for letter dated November 21, 2001, which was a prompt reply to ours of November 20, 2001.

We are not satisfied that your responses have adequately clarified the various issues raised in our letter of November 20th and we would appreciate some further clarification by way of responses to the following:

A.1. (i) We presume that the first few words of this paragraph should read " we do not megger cables which ...... " This being the case we do not understand the basis on which a decision would have been taken to return the cable to service, a paper insulated cable that was sitting de-energized for a two-week period in moist conditions, without the appropriate recommissioning tests being conducted. We are of the view, that this would have been standard operating practice instituted within the company over many years. Are the results of the megger tests that were performed several days prior to the cable being returned to service available? If yes, please provide us with a copy.

Your letter states that no repairs were done to the feeder (the cable supplying Petrojam) yet the report of the system shutdown states (Section 2.0) that the 'circuit breaker 8-330 at Hunts Bay was in the open position to facilitate repair work on the 13.8 kV cables, which serve Esso and Petrojam. Please clarify.

We do not believe that the FPL Standard discouraging Hi-pot testing of XLPE cables that are over 10 years is relevant to PILCSWA cables. Please comment.

Please provide us with copies of the procedures relating to the commissioning of PILCSWA cables.

A.1. (ii) We continue to have a difficulty with the concept that a circuit breaker (anywhere on the system) could have been closed, knowing that it would have been unable to trip. Nevertheless, if your inference regarding the trip coil being fully discharged is correct, the circuit breaker should have some means to mechanically latch in the solenoid. In relation to the circuit breaker (36)8-330, would you please provide us with information on its make and type as well as copies of the manufacturer's catalog and technical specifications.

Are we to conclude from your reference to the absence of the a.c. supply that, had this been available, the battery charger would have been functioning and the batteries, therefore, would have been fully charged, thus rendering the circuit breaker's d.c. control circuits operational?

A.1. (iii) How could it be, that in recommissioning the feeder the appropriate checks were not made to ascertain the status of the battery supply? What are the standard operating practices? Is it reasonable to expect that, knowing that the a.c. supply to the battery charger was non-functional, the battery status should have been checked? Is it reasonable to return a breaker (anywhere on the system) to service knowing that its control circuit are not operational or, if this is known, without taking the necessary steps to restore the integrity of the control circuit?

A.1. (iv) We agree that "logically" one would have expected breaker (265) 8-330 and 8-530, 8-540 and 8-630 to have been the next contingency for clearing the fault. We do not understand your comment that "given the type of relaying involved, this need not necessarily be so". Please clarify. What type of relaying is involved and what are their functionalities. Please provide us with the A.C. schematics and logic diagrams for the circuits in question. Is it not more so the case, that had the relay settings been adjusted following decommissioning of the 'A' Station, the relays would have been coordinated to trip in the correct sequence? Why were the settings not adjusted? Is the description of the circuit breaker operation at event No. 9 in the System Shutdown Report correct? (The question was posed in our previous letter).

B. Although you have responded to our inquiry about the high voltage problems that were experienced, you have not responded to that aspect of our inquiry that relates to the problems that were encountered during synchronization. This is in direct reference to the statement immediately under table 3 in the System Shutdown Report.

../3

We look forward to receiving a report of your conclusions after having analysed the System conditions in relation to the high voltage problem that was experienced.

Please provide us with copies of the system control and station logs that relate to the original removal of the 13.8 kV feeder from service some two weeks previously and its return on October 24th.

We are also requesting that you provide us with the time bound plan and activity schedule that is being implemented to secure completion of the remedial work and follow up analyses by January 31, 2002.

We are hoping to complete our own report by December 5, which effort would be greatly facilitated if we were to receive your responses by the morning of December 3, 2001 at the latest.

Thanks for your cooperation.

Yours sincerely,

J. Paul Morgan
Deputy Director General

Copy: Mr. Sam Davis, Manager – Government & Regulatory Affairs JPS

JPM:ctj.

APPENDIX 5

5

Jamaica **Public Service Company, Ltd.**

6 KNUTSFORD BOULEVARD, P.O. BOX 54, KINGSTON, JAMAICA, W.I.
TELEPHONE: (876) 926-3190-9, TELEX: 2180, FAX: (876) 968-3337, CABLE: JAMSERV, WEBSITE: www.jpsco.com

December 4, 2001

Mr. J. Paul Morgan
Deputy Director General
Office of Utilities Regulation
36 Trafalgar Road
Kingston 10

Dear Mr. Morgan

Re: System Shutdown – October 24, 2001

Your November 27, 2001 letter is acknowledged. Our response to the queries raised follows:

A1(i) Our practice, for cables which have been out of service for extended periods but not worked on, is to megger only prior to return to service. Cables which have been worked on are meggered and subjected to a high voltage d.c. test.

The supply cable to ESSO/Petrojam was not worked on, it was meggered. The cables between the 69/13.8 kV transformer and 13.8 kV 'switch', found to be defective following a transformer differential trip, were replaced, meggered and subjected to a Hi-pot test.

We do not have a policy for testing aged PILCSWA cables. We do, however, believe the FPL standard for testing aged XLPE cables is relevant to PILCSWA cables. Insulation quality deteriorates with age. Stressing aged insulation will likely promote premature failure.

A copy of our policy for commissioning high voltage cables is enclosed. Please note that once cables have been in service subsequent testing is at 65% of the original test value. The policy is silent on the conditions which should prompt subsequent tests.

A1(ii) Your conclusion that the breaker would have operated had an a.c. supply been available to the battery charger allowing the batteries to remain charged, rendering the breaker's d.c. control circuits operational, is correct. Our earlier description of the operation is incorrect. A copy of the manufacturer's catalogue and technical specifications will be forwarded.

A1(iii)We do not appear to have a procedure for returning breakers to service. The manner in which the breaker was returned to service appears to represent a deficiency which will be addressed. An appropriate procedure will be developed.

A1(iv)Details of the relays involved will be forwarded under separate cover. Our earlier communication noted that relays influenced by operation of the 'A' station had not been adjusted when operations ceased. Appropriate adjustments to these relays would have improved relay coordination. We offer no comment on why the relays were not adjusted when the 'A' station was decommissioned in 1996. The description of the circuit breaker's operation at event #9 is a correct representation of our record.

B. The problems encountered during system restoration were as follows:

- GT3 tripped on vibration during initial restoration effort.
- GT10 was put on line at 18:48, high system voltage prevented synchronization of Unit 4. GT10 tripped at 19:16.
- Following the 19:16 trip of GT10, two failed attempts were made to put GT4 on line.
- GT4 was eventually synchronized at 19:48 following closing of GT10 on a dead bus for a second time at 19:26.

We trust that the foregoing adequately addresses your queries.

Yours sincerely
JAMAICA PUBLIC SERVICE COMPANY LIMITED

Michael R. Moss
Chief Technical Officer

cc. Mr. Sam Davis

POLICY AND PROCEDURES

JAMAICA PUBLIC SERVICE COMPANY LTD.	Ref. No.________ Page____ of____
SUBJECT: VOLTAGE WITHSTAND TESTS ON HIGH VOLTAGE CABLE INSTALLATIONS	Effective Date________

PROCEDURES	RESPONSIBILITY	Reference
1. Inform Test Engineer (High Voltage Testing) that cable at a specific location has been installed (run and terminated), and ready for testing. Additionally, information on cable (type, class, approximate length, isolating points, etc.) shall be given.	[illegible]	
2. Ensure on site, that cable(s) to be tested are de-energized and isolated (i.e. disconnected from all connected loads, potential and current transformers, and surge arresters), then grounded before any contact is made with them.	[illegible]	
3. Place over the terminals of the remote end of the cable where possible, a "hood" (glass bottle or plastic bag), in very humid areas to stop ionization by containing the body of ionized air in the hood. Care should be taken to ensure that the hood does not touch the energized conductor.	" "	
4. Keep test personnel clear of all energized parts, by not less than one inch per 10kV of DC and all other personnel away from the test location or equipment, barricading with rope or other means. A guard person should be posted at the remote end of the cable, to keep others (and himself) away, if it cannot be enclosed, barricaded, or locked in its enclosure. This person should stay until advised that the test is completed. N.B. People within the barricades, must be kept to an absolute minimum when test voltages are applied, preferably only the tester himself. Any others permitted within the barricade should be knowledgeable about testing and the hazards involved.	[illegible]	
5. Arrange the remote end of the cable (which already would have been disconnected), such that conductors are not within one inch (1") per 10kV of test potential from one another or any other metal parts. A small rope is convenient for this, however, no part of the rope should be above the wide part of the stress cone or base of the terminations.	[illegible]	
6. Assemble and connect test equipment in accordance with manufacturers instructions. A connection made from the substation or similar solid earth shall always be the first operation.	" "	
7. Make a temporary connection from the cable sheath to the earth terminal of the test equipment, if the sheath of the cable under test is not earthed.	" "	
8. Attach the test lead to (one of) the terminal(s). Then remove the ground lead from this terminal. Thereafter arrange this terminal so that it is not within 1" per 10kV of test potential from the other grounded terminals and any other metal parts. This arrangement, as in step (5), can be achieved with use of a rope or other means, noting the precautions.	" "	
9. Turn on power in the test equipment after ensuring that the voltage adjustment is at zero.	" "	
10. Increase voltage from zero towards the maximum test voltage, very slowly, in steps of not more than ten kilovolts (10 kV). Observe a pause of fifteen (15) seconds after each step.	" "	Appendix A

APPROVED	STATUS	FIRST EFFECTIVE	SUPERSEDES	REVIEWED BY

POLICY AND PROCEDURES

JAMAICA PUBLIC SERVICE COMPANY LTD.
SUBJECT: VOLTAGE WITHSTAND TESTS ON HIGH VOLTAGE CABLE INSTALLATIONS

Ref. No.______ Page____ of ____

Effective Date______

PROCEDURES CONT'D	RESPONSIBILITY	Reference
11. Carefully observe current and volt meters during adjustment and also within the pause period to ensure that there is no spark-over in case of faulty cable. (N.B. The former will rise moderately, and the latter slowly)	[illegible]	Appendix I
12. Observe a pause of three (3) minutes when the test voltage reaches the maximum limit indicated by the output voltmeter on test equipment, then record readings of voltage and leakage current.	" "	
13. Gradually reduce test voltage to zero at the conclusion of the test period, then turn off the test equipment and apply a shorting stick to the high voltage terminal to fully discharge energy stored in the cable.	" "	
14. Attach a permanent ground to the cable just tested, and remove the test lead from it and attach same to the next conductor. Then continue with the procedure described from step 8 to step 12 above, until all conductors are tested.	" "	
15. Apply permanent earths immediately after discharge, through the direct grounding connection of the grounding stick, keeping ground on all cable conductors and drains which have been tested, until all activity at the test location is completed. (N.B. Rubber gloves shall be used to reduce the risk of shock.	" "	
16. Remove some charge from each conductor alternatively when the test is conducted between conductors, rather than to discharge any one completely	" "	
17. Disconnect the test equipment, power cable first, grounding conductor last.	" "	
18. Prepare test report and send copies for information to: (a) respective area distribution engineer, and (b) Director - Distribution Systems	" "	

APPROVED	STATUS	FIRST EFFECTIVE	SUPERSEDES	REVIEWED BY

APPENDIX A

Cable Test Voltages

Rated Voltage Class of Cable (kV)	D.C. Withstand Test Voltage (kV)	
	At Installation	In Service
25.0	60.0	40.0
69.0	150.0	100.0

At Installation

D.C. Withstand Voltage ≈ 2 × Rated Voltage Class of Cable (kV) + 10 kV (to the nearest ten)

In Service

D.C. Withstand Voltage ≈ 0.65 × D.C. Withstand Voltage @ Installation (to the nearest ten)

POLICY AND PROCEDURES

JAMAICA PUBLIC SERVICE COMPANY LTD.	Pol. No.______ Page____ of____
SUBJECT: VOLTAGE WITHSTAND TESTS ON HIGH VOLTAGE CABLE INSTALLATIONS	Effective Date______

APPENDIX B

RESPONSIBILITY | Reference

Notes on Leakage Current

(a) The leakage current noted from the meters will not generally exceed 0.1 mA for properly terminated cables under dry, clean conditions. Leakages in excess of this value may be obtained if the cable terminations are wet and dirty, but this leakage will generally reduce during the test period.

(b) Test failure is usually sudden and complete resulting normally in the tripping of the test equipment being used (i.e. overload protection)

N.B. This can either be a failure of cable or flashover at a termination. Greater clearance at terminations, better cleaning off of end semi-con material, or better cleaning of termination surface is necessary to correct the latter.

N.B. Instantaneous failure of a cable insulation (rather than failure with warning,occurring after a period of time of testing), is strongly associated with a complete perforation in its insulation, rather than progressive deterioration of remaining solid insulation.

(c) Occasional defects, however, due to moisture ingress will show high leakage currents at the test voltage. This leakage current will generally remain steady, or increase and such cases (the latter) should be investigated.

APPROVED	STATUS	FIRST EFFECTIVE	SUPERSEDES	REVIEWED BY

POLICY AND PROCEDURES

JAMAICA PUBLIC SERVICE COMPANY LTD.	Ref. No._____ Page___ of ___.
SUBJECT: VOLTAGE WITHSTAND TESTS ON HIGH VOLTAGE CABLE INSTALLATIONS	Effective Date_____

APPENDIX C	RESPONSIBILITY	Reference
Tests on Unterminated Cables Cables can be tested before being terminated, as outlined in the "Procedures." The shield drain and semi-con coating, however, should be ensured completely removed and cleaned, for a distance back from the cable ends for not less than 1" per 10kV of test potential.		

APPROVED	STATUS	FIRST EFFECTIVE	SUPERSEDES	REVIEWED BY

APPENDIX D

Equipment Test Voltages

It should be noted that allowable test voltages for cable are appreciably higher than for all types of equipment which it may be associated. The table below lists allowable field test DC voltages for the various types of equipment. Consequently, in order to test cable to its proper level, it must be disconnected from all such equipment.

Equipment Type	Rated Voltage Class (kV)			
	7.2	13.8	14.4	24.5
Switchgear Bus/Instrument Transformers	38	38	53	64
Transformers (Oil Immersed)	17	23	30	45
Motors/Generators	16	30		

These values should be adopted whenever disconnection is impractical.