

**GOVERNMENT OF PUERTO RICO
PUERTO RICO PUBLIC SERVICE REGULATORY BOARD
PUERTO RICO ENERGY BUREAU**

NEPR

Received:

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IN RE: INTERRUPCIÓN DE SERVICIO
ELÉCTRICO DE 17 DE AGOSTO DE 2022

CASE NO. NEPR-IN-2022-0004

SUBJECT:

**Motion Submitting Final Report on August
17th Incident and Request for Confidential
Treatment**

**MOTION SUBMITTING FINAL REPORT ON AUGUST 17TH INCIDENT AND
REQUEST FOR CONFIDENTIAL TREATMENT**

TO THE HONORABLE PUERTO RICO ENERGY BUREAU:

COME now **LUMA Energy, LLC** (“ManagementCo”), and **LUMA Energy ServCo, LLC** (“ServCo”), (jointly referred to as the “Operator” or “LUMA”), and respectfully state and request the following:

1. On August 17th 2022, a failure in the electric system led to a power outage event, which affected customers on the southeast area of the Island (hereinafter, the “August 17th Incident”).
2. On the same day, this Honorable Puerto Rico Energy Bureau (“Energy Bureau”) issued a Resolution and Order whereby it initiated a confidential investigation of the August 17th Incident (“August 17th Order”).
3. Among other things, the August 17th Order instructed LUMA to submit on or before August 18th, 2022, at noon, a preliminary report on the causes of the August 17th Incident and the corrective actions taken by LUMA (the “Preliminary Report”).

4. Further, the August 17th Order instructed LUMA to submit on or before August 31st 2022, a final and more detailed report on the August 17th Incident with the following information (the “Final Report”):

- (i) A summary of the incident including, but not limited to, a chronological description of the events and their effect, if any, on the Puerto Rico Electric Power Authority’s (“PREPA”) generation fleet, other energy producers, and the transmission and distribution system, as well as investigative, corrective, or other actions taken by LUMA;
- (ii) Any information received, obtained, or gathered in the course of investigative, corrective, or other efforts undertaken by LUMA and/or PREPA, its agents, attorneys, or consultants to determine the cause of the incident and its effect, if any, on PREPA’s generation fleet and the transmission and distribution system;
- (iii) Any document produced, prepared, or received by LUMA and/or PREPA, its agents, attorneys, or consultants in the course of investigative, corrective, or any other efforts were undertaken to determine the cause of the incident, including, but not limited to, the root cause report of the incident and its effect, if any, on PREPA’s generation fleet and the transmission and distribution system;
- (iv) Repercussions, consequences, or effects that clients and the electricity system will face in the short or long term because of the incident; and
- (v) Any information, in digital or tangible format regarding the incident in possession of LUMA and/or PREPA, which includes, but is not limited to, data, graphs, maps, videos, audios, photos, reports, or documents related to the incident and its effect on the electric service, the generation fleet, and the electricity transmission and distribution system of Puerto Rico.

5. On August 18, 2022, LUMA filed with the Energy Bureau a *Request for a Brief Extension of Time to Comply with the August 17th Resolution and Order on the August 17th Incident Investigation* (“August 18th Motion”). Therein, LUMA requested the Energy Bureau a brief extension until the end of Monday, August 22, 2022, to submit the Preliminary Report in compliance with the August 17th Order.

6. On August 22, 2022, LUMA filed a *Motion Submitting Preliminary Report on August 17th Incident and Request for Confidential Treatment*. The Preliminary Report submitted therein included the information LUMA has gathered thus far and preliminary findings and assessments of the August 17th Incident. It specifically encompassed:

- (i) Executive Summary of the August 17th Incident
- (ii) Incident Chronology
- (iii) LUMA's Response to the Outage
- (iv) Action Plan and Next Steps

7. On August 30, 2022, LUMA filed a *Request for a Brief Extension of Time to Comply with the August 17th Resolution and Order on the August 17th Incident Investigation*, where it sought a brief extension until September 2, 2022, to submit the Final Report in compliance with the August 17th Order.

8. In compliance with the August 17th Order, LUMA hereby submits the Final Report of the August 17th Incident. *See* Exhibit 1. The Final Report includes 6 confidential figures. *See* Figure 3-1, Figure 5-1, Figure 5-2, Figure 5-5, Figure 5-7 and Figure 5-8. The figures are being submitted under seal of confidentiality as they constitute Critical Energy Infrastructure Information ("CEII") that garners protection from public disclosures pursuant to federal statutes and regulations, see e.g., 6 U.S.C. §§ 671-674; 18 C.F.R. §388.113 (2020), and the Bureau's Policy on Management of Confidential Information. *See* Energy Bureau's Policy on Management of Confidential Information, CEPR-MI-2016-0009 ("Policy on Management of Confidential Information"), issued on August 31, 2016, as amended by the Resolution dated September 20, 2016.

9. Under separate cover and expediently, within the next ten days, as allowed by Section A.2 of the Energy Bureau's Policy on Management of Confidential Information, LUMA will submit a memorandum of law in support of this request to file the aforementioned portions of the Final Report of the August 17th Incident under seal of confidentiality.

WHEREFORE, LUMA respectfully requests that the Energy Bureau **take notice** of the aforementioned and **accept** the Final Report of the August 17th Incident that is being filed as Exhibit 1 to this Motion and **treat confidentially** the portions identified as such herein.

RESPECTFULLY SUBMITTED.

We hereby certify that we filed this Motion using the electronic filing system of this Energy Bureau and that we will send an electronic copy of this Motion to the attorney for the Puerto Rico Electric Power Authority, Katiuska Bolaños-Lugo, kbolanos@diazvaz.law.

In San Juan, Puerto Rico, this 2nd day of September 2022.



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Exhibit 1



17 AUG 2022 – 230kV Lines to AES Outage, Load Shed Event Analysis

NEPR-IN-2022-0004

September 2, 2022

CONFIDENTIAL/PROPRIETARY: In the interests of protecting the electric infrastructure of Puerto Rico, portions of this document are protected from disclosure as Critical Energy Infrastructure Information (“CEII”), in accordance with 6 U.S.C. §§671-674; 18 C.F.R. §388.113 (2020), and pursuant to the Puerto Rico Energy Bureau’s Policy on Management of Confidential Information, CEPR-MI-2016-0009, issued on August 31, 2016, as amended by the Resolution dated September 16, 2016.

DISCLAIMER: The information provided in this document in the following sections is based on the facts known to LUMA as of September 2, 2022. LUMA reserves its right to supplement or modify this document if additional facts become available as part of the investigation.

Incident Summary

Name: 17AUG2022 Major Outage Event – AES 230kV Line 50700 Outage, Loss of Generation and Load Shedding Event

Date: August 17, 2022

Time: 11:07

Location: AES Generation and 230kV Switchyard and 230kV lines

Description: The 50700 230kV line from AES to Yabucoa tripped due to high impedance fault and the AES to Aguirre line tripped due to an open jumper. This isolated the AES generation from the grid causing the frequency of the system to drop and initiating a load shedding event. Delays in the return of the Aguirre generation plant from a previously planned outage by the generation plant posed increased stress on the transmission system, and this led to additional load shedding needed to stabilize the system and a longer restoration process. LUMA immediately took action to stabilize the system, identify the cause, repair, and restore the damage lines and jumpers. All facilities and customers were back in service by 18:31 hours.

Resumen Del Evento

Nombre: 17AGO2022 Evento de Interrupción de Servicio –Líneas 50700 -230kV, Desconexión, Pérdida de Generación y Relevo de Carga.

Fecha: 17 de agosto de 2022

Hora: 11:07

Localización: Generación AES, patio de interruptores de 230kV y líneas de 230kV

Descripción: La línea 50700 que discurre de 230kV de AES a Yabucoa se disparó debido a una falla de alta impedancia y la línea que discurre AES a Aguirre se disparó debido a un puente abierto. Esto aisló la generación de AES de la red eléctrica haciendo que la frecuencia del sistema cayera e iniciando un evento de relevo de carga. Los retrasos en la disponibilidad de la planta de generación de Aguirre de una interrupción previamente planificada por dicha central generatriz causaron un estrés mayor en el sistema de transmisión, lo cual condujo a un relevo de carga adicional necesario para estabilizar el sistema y a un proceso de restauración de mayor duración. LUMA tomó acción inmediata logrando estabilizar el sistema, identificar la causa, reparar y restaurar las líneas y los puentes afectados. Todas las instalaciones y los clientes recuperaron el servicio a las 18:31 horas.

Executive Summary

Any significant outage, no matter the cause, is a deeply frustrating event for all customers impacted. The August 17th, 2022 event represents a clear reminder that the electric system remains incredibly fragile and that much more work remains to be done to reduce the risk of such events. While there are many factors that may contribute to such large-scale outage events, the one consistency remains that the electric grid, after decades of operational neglect, remains vulnerable to any fault or issue. The ultimate preventative solution to such systemic events will require a focus on both rebuilding the T&D electric grid and addressing persistent challenges in the generation system. LUMA, as well as PREPA and other generators, must address these challenges together if we are to build the reliable, sustainable, and resilient energy system that the people of Puerto Rico expect and deserve.

In this case, there were challenges that occurred on both the generation system as well as the transmission grid, which ultimately resulted in the load shed affecting our customers. Specifically, delays in the return of the Aguirre generation plant from a previously planned outage by the generation plant posed increased stress on the transmission system, and this led to additional load shedding needed to stabilize the system and a longer restoration process. To reduce future outage events, it is essential that a clear-eyed evaluation is conducted of what precisely causes these outages, and how they can best be avoided. As part of our commitment to transparency, LUMA has made it clear that it is providing updates during its investigations, and working with PREPA, other generators, and relevant stakeholders to gather the necessary evidence for root cause analyses.

This report is based on the forensic analysis of the system and protection performance during the fault events at both segments of 230 kV line 50700 from AES Plant to Yabucoa Transmission Center (Yabucoa) and Aguirre Steam Plant (Aguirre) that isolated all AES generation from the system causing automatic underfrequency load shedding on August 17th, 2022.

Sequence of Events

The following conditions were present before the initial fault:

- AES generators were serving 447 MW (net) to the grid.
- 230 kV line 50100 from Manatí Transmission Center to Cambalache Gas Plant was out of service for repairs.
- 115 kV line 40300 from Ponce Transmission Center to Pattern Wind Farm was out of service due to a planned outage.

Aguirre generator #1 was out of service for repairs. As a result, generation reserves were lower than desirable.

At 11:07:24, line 50700 from Yabucoa to AES tripped due to a high impedance fault caused by vegetation. The protection system cleared this fault correctly. The loss of line 50700 resulted in all the generation from AES flowing through the remaining 50700 line from AES to Aguirre. At 11:08:27, 230 kV circuit breaker 50780 from Yabucoa was reclosed by the Control Center to restore service but the line tripped again indicating a permanent fault at the line. The protection cleared both faults instantly from the system.

At 11:10:47, an open jumper contacted the 230 kV structure at line 50700 near Aguirre to AES. An instantaneous protection trip in Aguirre isolated this line segment. As a result, there was no transmission line available to connect the AES plant to the system.

At 11:10:51, with the AES generation loss, the system frequency dropped. Due to prior system conditions, including the lack of generation on the system, and the failure of line 50200, a contingency load shed operation was required to maintain system stability. The total load shed operation affecting approximately 299,970 customers was necessary to stabilize and then restore the electric system. LUMA completed service restoration to all customers impacted by both the automatic and the contingency manual load sheds at 18:31 hours.

LUMA Immediate Actions Taken

In response to the outage event on August 17th, LUMA took a series of actions including:

- Responded to this event immediately at 11:07, and within minutes began mobilizing crews to address loss of lines and generation at AES.
- Mobilized helicopter crews for line patrols, sent crews to various substations and dispatched vegetation management crews to the AES to Yabucoa line.
- LUMA activated the Emergency Operations Center (LEOC) which coordinated restoration activities and external communications to partners across the island.
- Repairs of the lines, jumpers, and other substation equipment.

Identified Causes

This event was initiated by several line trips and the lack of generation available on the system. The loss of 50700 line from AES to Yabucoa was caused by vegetation in the line. The loss of the 50700 line from AES to Aguirre was caused by an open jumper. This caused the loss of the 447 MW of generation at AES and the frequency of the system to drop. The lack of generation from Aguirre Unit 1 on extended outage also caused additional load shedding that would not have been needed. For these reasons, subsequent manual load shed that lasted several hours was necessary to restore the system and avoid a black-out.

Next Steps

The actions identified to help mitigate the impact of these issues on reliability and improve the grid's resiliency are noted below:

- Troubleshooting 230kV circuit breaker 0074 at Aguirre. This had no impact to this event but could be problematic for future events.
- Maintain and update the line relaying systems on both lines.
- As part of LUMA's Area Planning and Substation improvement and expansion plans, the team will continue to analyze capacity, redundancy, and reliability factors affecting the transmission system, electrical substation, or switchyard facility. For example, open jumper failures.
- Work with generation facilities to maintain a good generation reserve.

As part of its commitment to improving future outage response, LUMA is currently verifying the specificity of the timeline and system performance during the transmission lines and the subsequent generation outages. Generators must be able to "ride through" system disturbances such as line outages. Confirmation of these details will help support further actions about what can and must be done going forward to avoid such events in the future.

Lastly, we want to express our deep appreciation to our 1.5 million customers for their patience. We share their frustration when any outage occurs and cannot stress enough how committed the 3000 men and women of LUMA are to making the necessary infrastructure improvements that will build a better and more reliable energy future for Puerto Rico.

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1.0 Overview of the Event

1.1 Event Details

This report covers the forensic analysis of the system's behavior and protection performance with the known details of the of the two faults at line segments of 50700 and the automatic underfrequency load shed event from AES isolation, as described in further detail in Sections 2 and 3. The fault events on both lines 50700 caused the loss of 447 MW of generation from AES on Wednesday, August 17, 2022.

- Event name: OE2208-29
- Outage date: August 17th, 2022
- Outage time: 11:07:24

1.2 Overview of Event

Before the event, AES generators were serving 447 MW (net) to the grid. The 230 kV line 50100 from Manatí to Cambalache was out of service for repairs. The 115 kV line 40300 from Ponce Transmission Center to Pattern Wind Farm was under a planned outage. Aguirre generator #1 was out of service for repairs meaning a low generation reserve was available.

At 11:07:24, 230 kV line 50700 from Yabucoa to AES tripped due to a high impedance type fault caused by vegetation. With line 50700 from AES to Yabucoa open, all the generation from AES was served to the system via the remaining 50700 line from AES to Aguirre. At 11:08:27, 230 kV OCB # 50780 from Yabucoa was reclosed by the Control Center and tripped again instantly. This indicated a permanent fault was present at line 50700 from Yabucoa to AES.

At 11:10:47, an open jumper contacted the 230 kV structure at line 50700 near Aguirre to AES. The instantaneous back-up Zone 1 protection tripped OCBs 50730-0052 at Aguirre to clear the fault from the system. OCB# 0074 from Aguirre CC#1 tripped during this event for unknown reasons and did not impact this event. This was not a protection issue as the CC#1 unit remained in service.

With both lines from AES out of service, 447 MW (net) were disconnected from the system creating a generation/load unbalance. At 11:10:51, the frequency continued the descend and the system enters the In Extremis state. At this state, automatic underfrequency load shed was activated. The number of customers affected by this automatic underfrequency load shed were 299,970 or 20.43% of the client base. LUMA restored the transmission lines affected at 12:16 hours, 1 hour and 05 minutes after the load shed occurred.

During the restoration of AES disturbance, another unrelated trip of 230 kV line 50200 from Costa Sur to Manatí occurred at 11:37. A contingency manual load shed was necessary to avoid overload of line 50300 from Costa Sur to Aguirre, affecting 152,290 customers. This event is not discussed in this report as this happened after the AES events. LUMA completed service restoration to all customers impacted by both the automatic and the contingency manual load sheds at 18:31 hours.

The following Table 1 (below) provides a summary of the various events that occurred leading to the load shed.

Table 1 - Timeline of Events

Time	Event
11:07:24.992	Phase A to ground fault due to vegetation was sensed by the system at line 50700 from AES to Yabucoa.
11:07:25.092	230kV circuit breakers 50720-0062 (SEL-321 Zone 1, A-G, RFL-9300) at AES trip in 0.1 seconds.
11:07:25.099	230kV circuit breakers 50780-0070 (SEL-321 Zone 1, A-G, RFL-9300) at Yabucoa opened in 0.107 seconds to clear the fault at line 50700 from the system.
11:08:27.625	230kV circuit breaker 50780 at Yabucoa was remotely closed by the Control Center, the fault at line 50700 was present.
11:08:27.710	230kV circuit breaker 50780 at Yabucoa tripped in 0.085 seconds and stayed open as a permanent fault was detected at line 50700. AES generation to the loads remained via line 50700 to Aguirre.
	System recovered to normal state
11:10:47.375	An open jumper at line 50700 near Aguirre contacted the 230 kV structure creating a Phase B to ground fault of maximum short circuit current magnitude of 37,000 amperes.
11:10:47.451	230 kV circuit breakers from line 50700 at AES and Aguirre open to clear the fault at line 50700. Generation from AES was isolated from the system and the system frequency stated to decrease. The system entered the emergency state.
11:10:51.260	The frequency continued to decrease, and the electrical system entered the <i>In extremis</i> state as the automatic load shed was necessary to recover stability. The frequency was below 58.6 Hz.
11:10:51.630	The system frequency decreased below 58.5 Hz as the load shed continued.
11:10:53.480	The system frequency decreased below 58.4 Hz as the load shed continued.
11:10:55.710	The system frequency decreased below 58.3 Hz as the load shed continued.
11:10:56.440	The system frequency reached the lowest frequency at 58.286 Hz and started to recover.
	System in restoration state

2.0 LUMA's Response to the Outage

LUMA responded to this event immediately by mobilizing crews to address loss of lines and generation at AES. Mobilized helicopter crews for line patrols, sent crews to various substations and dispatch vegetation management crews to the AES to Yabucoa line.

In addition, LUMA activated the Emergency Operations Center (LEOC) which coordinates the external communications to partners across the island and directed stabilization and restoration activities.

Throughout the day the LEOC coordinated with agency partners including FEMA, Department of Public Safety and PREMB, ES12, and Department of Homeland Security as well as other government agencies to ensure they had the latest information and were aware of ongoing restoration efforts.

3.0 Faults at lines 50700 and AES Isolation

1.3 System Status Prior to the 50700 Lines from AES Fault Events

The electrical system was in the normal state with certain conditions after the 2017 hurricanes, 2020 earthquakes and system deterioration. The major contingencies before the faults at line 50700 were:

- The 230 kV line 50100 from Cambalache to Manatí out of service due to insulation repairs from a previous fault.
- 115 kV line 40300 from Ponce Transmission Center to Pattern Wind Farm was under a planned outage.
- System generation was limited with major generation from Aguirre Unit #1 (450 MW) out of service. With this unit out of service, less generation was available for system contingencies. It had been expected to return to service on June 8th but remains out of service.

AES generators #1 and #2 were serving a combined 447 MW to the system. Lines 50700 from AES to Yabucoa and AES to Aguirre were in service. The rest of the load current from AES, more than half of its generation, was flowing thru the line 50700 AES to Yabucoa side to the north loads of the island.

AES Plant single line with both line segments of 50700 is presented in figure 3-1 below.

Figure 3-1 - AES Single Line Diagram



1.4 Initial Vegetation Fault at 230 kV Line 50700 from AES to Yabucoa

At 11:07:24, line 50700 from Yabucoa to AES tripped due to a high impedance type fault caused by vegetation (figure 3-2 below). With line 50700 from AES to Yabucoa open, all the generation from AES was served via the remaining 50700 line to Aguirre.

At 11:08:27, 230 kV circuit breaker 50780 from Yabucoa was reclosed by the Control Center to restore service but the line tripped again indicating a permanent fault at the line. The protection cleared both faults instantly from the system. With this line trip, the system enters in the Alert state.

The 230 kV line 50700 was restored to the system at 19:14.

Figure 3-2 Burned Vegetation at the point of the fault in Line 50700 from Yabucoa to AES



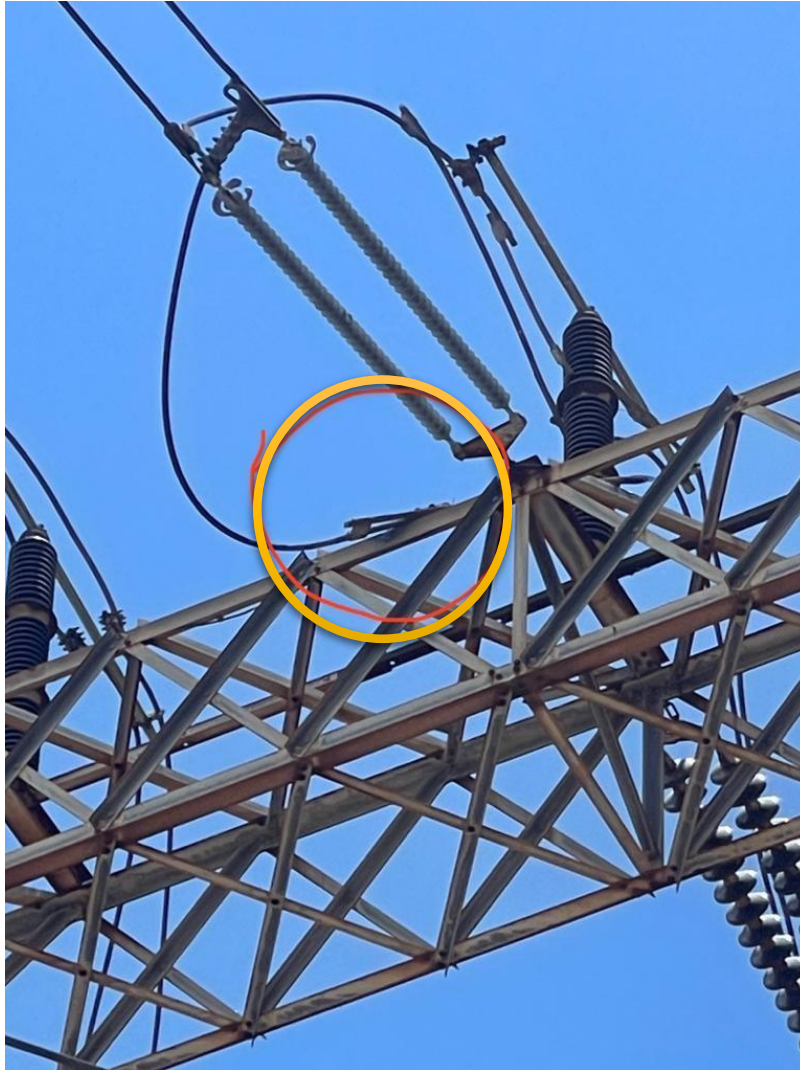
1.5 Second Event at Line 50700 AES-Aguirre and AES generation isolation

At 11:10:47, an open jumper occurred at line 50700 near Aguirre to AES (figure 3-3 below). The open jumper contacted the 230 kV structure. The line differential protection tripped instantly the 230 kV circuit breakers 50730-0052 at Aguirre and 50710-0052 at AES. Generation from AES was isolated from the system and automatic underfrequency load shed was necessary to avoid a black-out.

During this event, 230 kV circuit breaker 0074 at Aguirre opened for unknown reasons and did not impact this event. The Aguirre Combined Cycle #1 generation remained in service as this was not a protection related trip.

The open jumper was repaired by LUMA crews, and 230 kV line 50700 was restored to the system at 17:37.

3-3 Figure Open Jumper contacting 230 kV structure at 50700 from AES to Aguirre



4.0 List of Affected Equipment

The table below reflects the affected transmission equipment after the faults at lines 50700 and the activation of the automatic underfrequency load shed protection scheme after the 447 MWs of generation from AES were isolated from the system.

The distribution loads affected by the automatic underfrequency load shed event after the AES generation isolation from the system and the subsequent manual load shed events of August 17, 2022, are not shown in Table 2 (below).

Table 2 - Major Equipment Operations at Load Shed

Breaker	Location	Relay Targets	Description
50720-0062	L50700 - AES - YABUCOA	SEL 321	VEGETATION
50780-0070	L50700 - YABUCOA - AES	SEL 321	VEGETATION
50710-0052	L50700 - AES – AGUIRRE	SEL 321	OPEN JUMPER – TOWER CONTACT
50730-0052	L50700 - AGUIRRE – AES	SEL 321	OPEN JUMPER - TOWER CONTACT
0074	AGUIRRE CICLO COMBINADO #1		UNKNOWN CAUSE. CC#1 REMAINED IN SERVICE
3054	CAGUAX SECT.	ITE-81	UNDERFREQUENCY. 58.6 HZ.
9340	GAUTIER BENITEZ SECT.	MiCOM-P942	UNDERFREQUENCY. 58.6 HZ.
3050	JUNCOS T.C.	MiCOM-P942	UNDERFREQUENCY. 58.6 HZ.
3070	JUNCOS T.C.	MiCOM-P942	UNDERFREQUENCY. 58.6 HZ.
9320	JUNCOS T.C.	MiCOM-P942	UNDERFREQUENCY. 58.6 HZ.
0060	JUNTOS T.C.	MiCOM-P942	UNDERFREQUENCY. 58.6 HZ.
5336	LAS PIEDRAS	MICOM-942	UNDERFREQUENCY. 58.6 HZ.

5280	CAGUAS T.C.	MICOM-942	UNDERFREQUENCY . 58.6 HZ.
5460	RIO BLANCO	MiCOM-P942	UNDERFREQUENCY . 58.6 HZ.
3060	RIO BLANCO	MiCOM-P942	UNDERFREQUENCY . 58.6 HZ.
5350	HUMACAO T.C.	ITE-81	UNDERFREQUENCY . 58.5 Hz
10450	HUMACAO T.C.	ITE-81	UNDERFREQUENCY . 58.5 Hz
12550	HUMACAO T.C.	ITE-81	UNDERFREQUENCY . 58.5 Hz
0250	JOBOS T.C.	ITE-81	UNDERFREQUENCY . 58.5 Hz
3750	JOBOS T.C.	ITE-81	UNDERFREQUENCY . 58.5 HZ.
0210	PONCE T.C.	ITE-81	UNDERFREQUENCY . 58.5 HZ.
0160	SANTA ISABEL SECT.	ITE-81	UNDERFREQUENCY . 58.5 HZ.
0330	TORO NEGRO # 1	ITE-81	UNDERFREQUENCY . 58.5 HZ.
6530	TORO NEGRO # 1	ITE-81	UNDERFREQUENCY . 58.5 HZ.
6520	COMERIO T.C.	ITE-81	UNDERFREQUENCY . 58.5 HZ.
6510	COMERIO T.C.	ITE-81	UNDERFREQUENCY . 58.5 HZ.
4110	COMERIO T.C.	ITE-81	UNDERFREQUENCY . 58.5 HZ.
7930	TORO NEGRO # 1	ITE-81	UNDERFREQUENCY . 58.5 HZ.
6560	BARRANQUITAS SECT.	MICOM-942	UNDERFREQUENCY . 58.5 HZ.
18410	BARRANQUITAS T.C.	TNR	UNDERFREQUENCY . 58.5 HZ.
6550	BARRANQUITAS SECT.	TNR	UNDERFREQUENCY . 58.5 HZ.
3740	HUMACAO T.C.	TNR	UNDERFREQUENCY . 58.5 HZ.
3410	MONACILLOS T.C.	ITE-81	UNDERFREQUENCY . 58.4 HZ.

3510	MONACILLOS T.C.	ITE-81	UNDERFREQUENCY. 58.4 HZ.
3520	CAPARRA SECT.	ITE-81	UNDERFREQUENCY. 58.4 HZ.
4310	CAPARRA SECT.	ITE-81	UNDERFREQUENCY. 58.4 HZ.

5.0 Protection Performance Analysis

Protection systems are an integral part of maintaining reliability and this section provides the performance of the protection systems during this event.

1.6 Vegetation Fault at 230 kV Line 50700 segment from Yabucoa to AES

The correct fast operation for the initial high impedance vegetation fault at line 50700 was documented by the power line carrier protection (85L) records of SEL-321 of both Yabucoa and AES line terminals and the digital faults recorders. The transient line fault was cleared from the system in 0.105 seconds.

1.6.1 50720-0062 from AES to Yabucoa

At 11:07:24.992, the SEL-321 protection from AES to Yabucoa recorded the correct operation due to the vegetation fault on line 50700. The record documented the phase A to ground fault clearing instantaneously by the directional comparison blocking power line carrier protection scheme (85L), 50G element. 230 kV OCBs 50720-0062 at AES open to clear the fault after 0.105 seconds from fault initiation.

Significant short circuit current was sensed by the protection. Peak amps short-circuit currents observed in the SEL-321 relay from AES were $I_a = 2,328$ A, $I_b = 659$ A, $I_c = 680$ A, see figure 5-1 (below).

Figure 5-1 AES 50720-0062 SEL-321 - 85L Protection Event



1.6.2 50780-0020 from Yabucoa to AES

At 11:07:24.992, the SEL-321 protection from Yabucoa to AES recorded the correct operation due to the vegetation fault on line 50700, see figure 5-2 (below). The record documented a high impedance phase A to ground fault clearing instantaneously by the directional comparison blocking power line carrier protection scheme (85L), 50G element. 230 kV OCBs 50780-0070 at Yabucoa open to clear the fault from the system after 0.105 seconds from fault initiation.

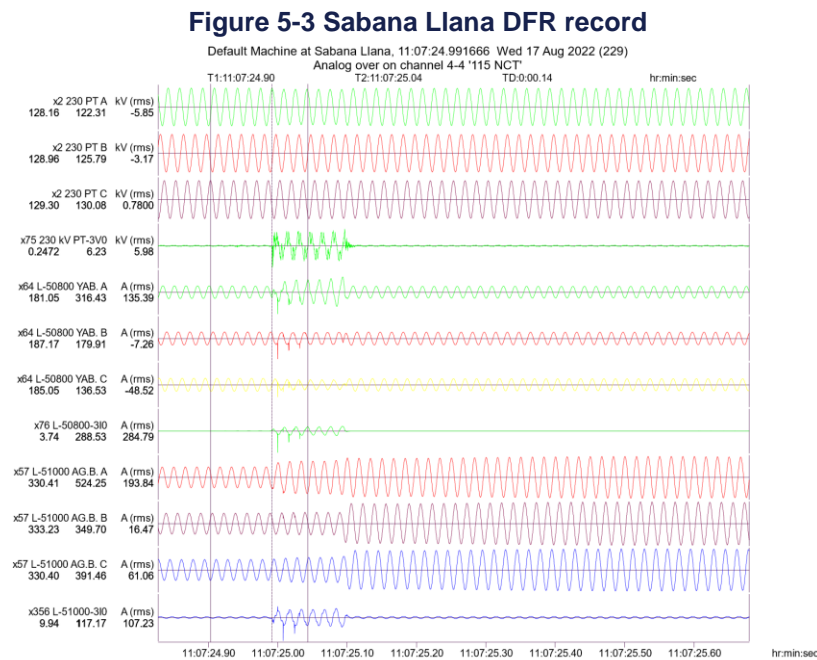
No significant short circuit current was sensed by the protection. Peak amps short-circuit currents observed in the SEL-321 relay from Yabucoa were $I_a = 885$ A, $I_b = 967$ A, $I_c = 978$ A.

Figure 5-2 Initial fault - 50780-0070 SEL-321 from Yabucoa Event



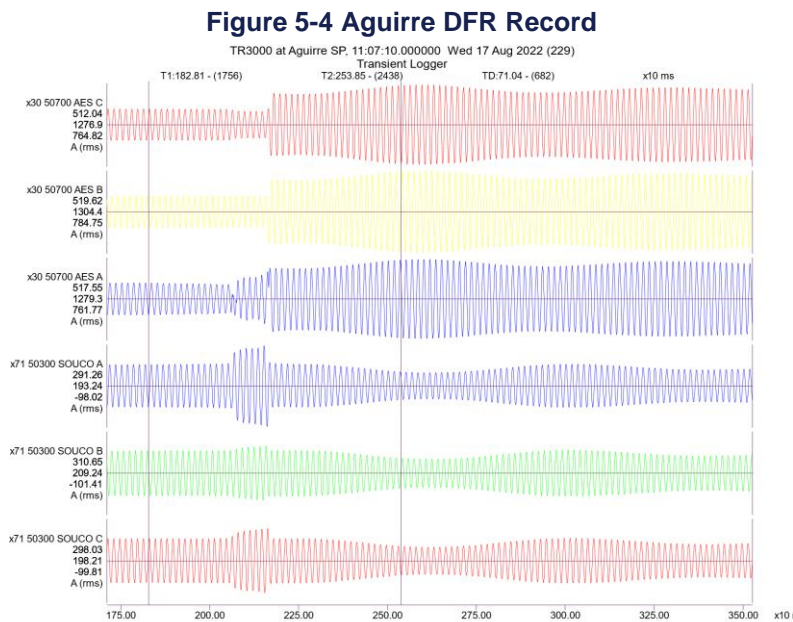
1.6.3 Digital Fault Recorder at Sabana Llana Transmission Center

The digital fault recorder from Sabana Llana Transmission Center recorded the transient vegetation fault at line 50700 from AES to Yabucoa was cleared from the system (refer to figure 5-3 below). With the loss of 50700 transmission line segment, some of the load current from the south generation to the north loads was then transmitted via 230 kV line 51000 from Aguas Buenas to Sabana Llana to balance the system after the fault.



1.6.4 Digital Fault Recorder at Aguirre Steam Plant

The digital fault recorder from Aguirre recorded the initial fault at line 50700 from AES to Yabucoa (refer to figure 5-4 below). With the loss of this 50700-transmission line segment, all the generation from AES to the system was served via line 50700 segment to Aguirre, the load current at line 50700 increased to an average of 1,283 amperes.



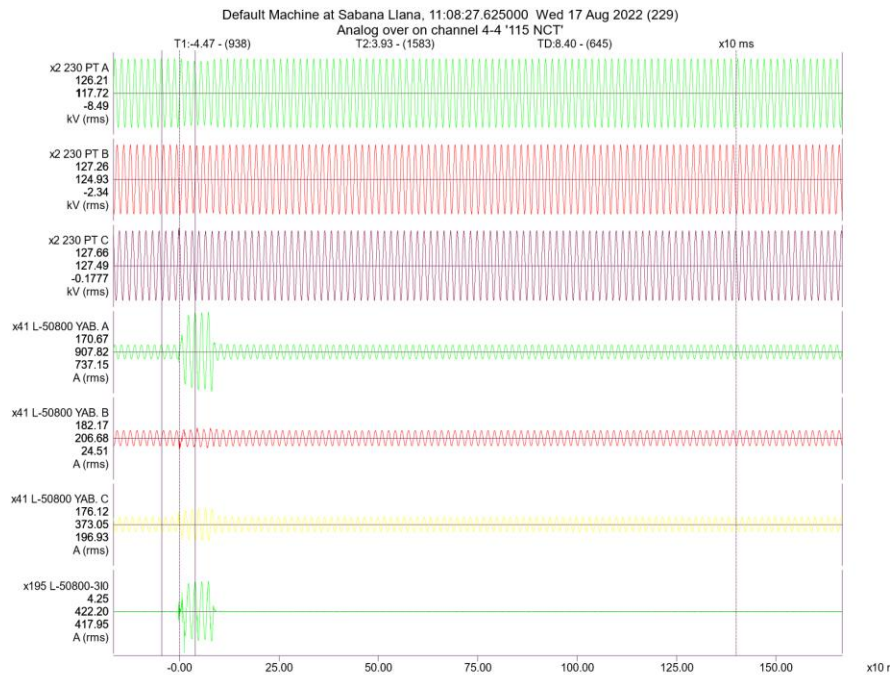
1.6.5 Remote Reclose of 230 KV GCB# 50780 from Yabucoa

At 11:08:27.625, 1:02 minutes after the fault at line 50700 from AES to Yabucoa was cleared from the system, the Control Center remotely closed breaker 50780 from Yabucoa to test the line. The SEL-321 record shows the initial high impedance fault evolved to a permanent fault with peak short-circuit currents of $I_a = 2,554$ A, $I_b = 50$ A, $I_c = 32$ A, and was cleared from the system in 0.081 seconds, see figures 5-5 and 5-6 (below).

Figure 5-5 SEL-321 - 50780 Reclose from Yabucoa



Figure 5-6 Sabana LLana DFR - Reclose of Line 50700



1.7 Open Jumper Fault at 230 kV Line 50700 segment from Aguirre to AES

The correct fast operation for open jumper that contacted the 230 kV structure near Aguirre at line 50700 was documented by the back-up protection records of SEL-321 of both Aguirre and AES line terminals and the digital faults recorders. The line fault was cleared instantly from the system by the Aguirre terminal in 0.076 seconds.

The power line carrier protection for line 50700 from Aguirre to AES was out of service. As line 50700 segment from Yabucoa to AES was open, the delayed back-up protection operation of AES to Aguirre terminal had no effect on system stability.

1.7.1 50730-0052 from Aguirre to AES

At 11:10:47.375, some 2:19 minutes after the fault at line 50700 from Yabucoa to AES was cleared from the system, the SEL-321 protection from OCBs 50730-0052 at Aguirre to AES recorded the correct operation of an open jumper that contacted the 230 kV structure of line 50700 near Aguirre fault. The record documented the phase B to ground fault clearing instantaneously by the back-up ground Zone 1 protection element. 230 kV OCBs 50730-0052 at Aguirre open to clear the fault the fault from the system in after 0.076 seconds.

High short circuit current was sensed by the protection. Peak short-circuit currents observed in the SEL-321 relay from Aguirre were $I_a = 2,005$ A, $I_b = 28,973$ A, $I_c = 1,145$ A, see figure 5-7 (below).

Figure 5-7 SEL-321 50730-0052 at Aguirre Event



1.7.2 50710-0052 from AES to Aguirre

At 11:10:47.375, some 2:19 minutes after the fault at line 50700 from Yabucoa to AES was cleared from the system, the SEL-321 protection from OCBs 50710-0052 at AES to Aguirre recorded the correct operation of an open jumper that contacted the 230 kV structure of line 50700 near Aguirre fault. The record documented the phase B to ground fault was cleared by the back-up inverse time overcurrent protection element. The delayed opening of the AES terminal had no effect on the system.

High short circuit current was sensed by the protection. Peak short-circuit currents observed in the SEL-321 relay from Aguirre were $I_a = 2,005$ A, $I_b = 28,973$ A, $I_c = 1,145$ A, see figure 5-8 (below).

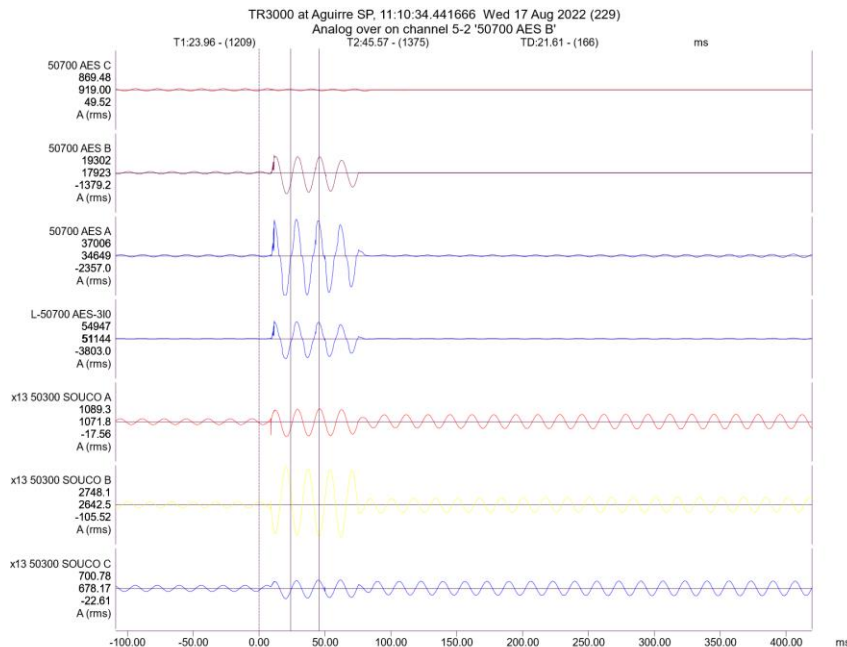
Figure 5-8 50710-0052 SEL-321 from AES Event



1.7.3 Digital Fault Recorder at Aguirre Steam Plant

The digital fault recorder from Aguirre recorded the fault at line 50700 from AES to Yabucoa (refer to figure 5-9 below). With the trip of this 50700-transmission line segment, all the generation from AES to the system was isolated from the system.

Figure 5-9 Aguirre DFR Record



1.8 System Underfrequency and Automatic Load Shed Disturbance

At 11:10:47.375, all the 447 MWs of generation from AES Plant were isolated from the system due to faults at both 230 kV line 50700 segments from AES to Yabucoa and Aguirre respectively that occurred

less than 3 minutes apart. With the isolation of AES generation, the system frequency descended below the normal level 60 Hz to critical levels down to 58.29 Hz. This severe frequency drop was due to Aguirre #1 generation (450 MW) out of service before the event. With this unit out of service, less generation was available for system contingencies. It had been expected to return to service on June 8th but remains out

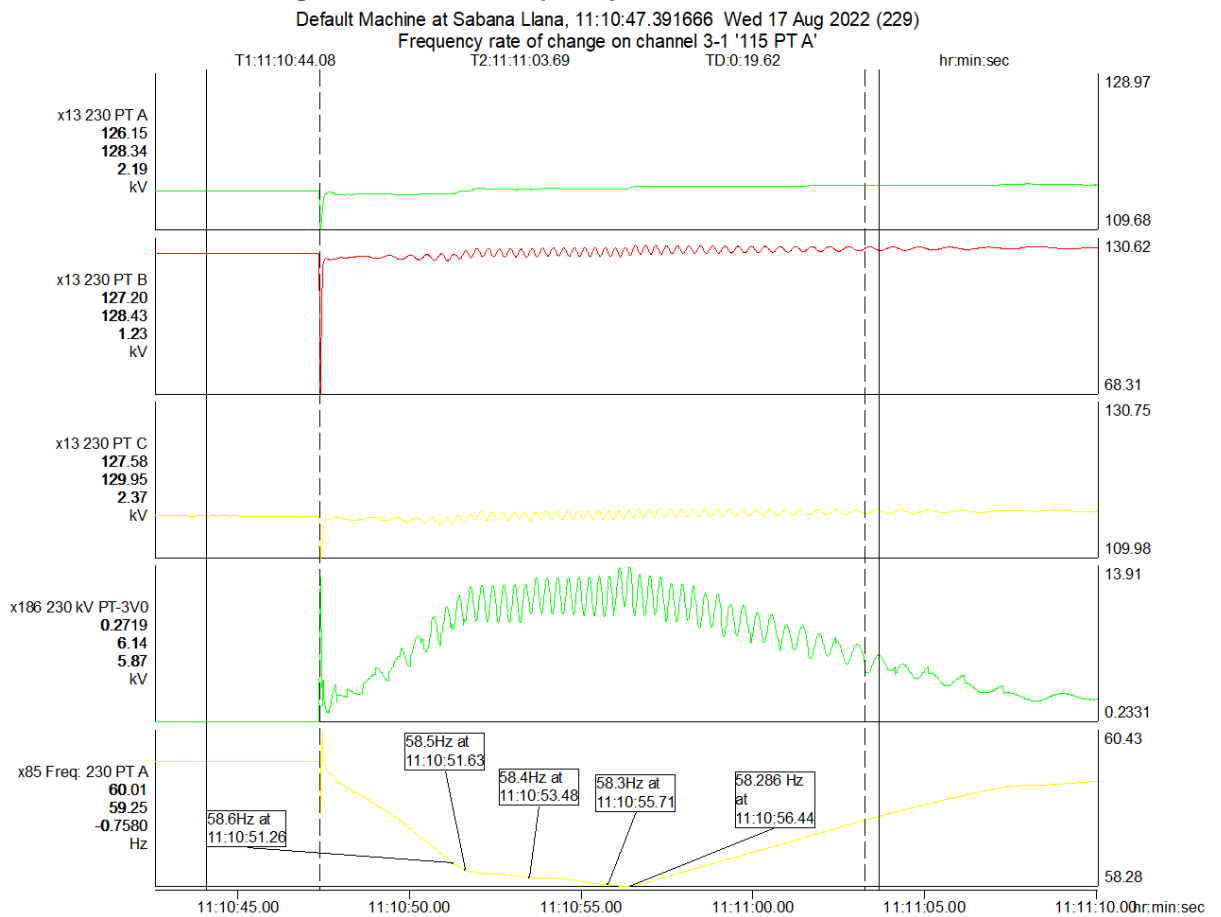
At 11:10:51.26, the system did not recover, and the frequency continued to decrease below 58.6 Hz. The electrical system entered the In-extremis state as the automatic load shed was necessary to recover stability.

At 11:10:51.63, the frequency continued to decrease below 58.5 Hz.

At 11:10:53.48, 6.02 seconds after the AES generation was isolated from the system, the load shed from 58.6 Hz and 58.5 Hz load blocks could not stabilize the system and the frequency continued to decrease below 58.4 Hz.

At 11:10:56.44, 9 seconds after the AES generation was isolated, the automatic underfrequency load shed scheme manage to stabilize the system. The frequency reached the lowest point of 58.29 Hz and started restoration, see figure 5-10 (below).

Figure 5-10 Underfrequency Disturbance - Load Shed



6.0 Root Cause Analysis

This event was initiated by several line trips and the lack of generation available on the system. The collective items listed below are what caused this load shed event.

- The initial fault at line 50700 from AES to Yabucoa was caused by vegetation. Instantaneous power line carrier protection (85L) acted as expected.
- The fault at line 50700 segment, from AES to Aguirre, was caused by an open jumper that contacted the 230 kV structure near Aguirre. The line differential protection (87L) acted as expected. With this second fault, the generation from AES was isolated from the system.
- The loss of 447 MW from AES under the existing generation limitations with Aguirre #1 out of service created a severe system unbalance and minimum frequency of 58.29 Hz. Automatic underfrequency load shed was necessary to restore the system from the In-extremis state.

The lack of generation at Aguirre Unit 1 of 450 MW created a situation where generation reserves were not ideal and under this event would require load shedding to balance the system.

7.0 Next Steps and Action Plan

The actions identified to help mitigate the impact of the event and potential similar future events include:

1. Repair line 50700 from Aguirre situation.
2. Control vegetation at line 50700 from AES to Yabucoa.
3. Verify the cause 230kV circuit breaker 0074 open at Aguirre. This had no impact to this event but could be problematic for future events.
4. Restore primary and secondary power line carrier protection to line 50700 from AES to Aguirre. This had no impact to this event but could be problematic for future events.

The Action Item table (table 3) is shown below.

Table 3 Action Items

Item	Action	Responsible Team	Target Date	Completion Date
1	Repair line 50700 from Aguirre situation.	Substation	08/17/2022	08/17/2022
2	Control vegetation at line 50700 from AES to Yabucoa.	Vegetation	08/17/2022	08/17/2022
3	Verify 230kV circuit breaker 0074 open at Aguirre.	Substation	09/30/2022	
4	Restore power line carrier protection to line 50700 from AES to Aguirre	Substation	09/15/2022	