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

IN RE: APRIL 6, 2022 ELECTRIC SERVICE INTERRUPTION

CASE NO.: NEPR-IN-2022-0002

SUBJECT: Adoption of supplemented LUMA's Root Cause Analysis ("RCA") of the April 6th Full Blackout – Final Report

FINAL REPORT

I. Introduction

On October 4, 2022, LUMA Energy, LLC and LUMA Energy ServCo, LLC (collectively, "LUMA") filed with the Energy Bureau of the Puerto Rico Public Service Regulatory Board ("Energy Bureau"), a document titled *Motion Submitting Root Cause Evaluation of April 6th Incident and Request for Confidential Treatment* ("October 4 Motion"). As Exhibit 2 of the October 4 Motion, LUMA included a document titled *Costa Sur Outage Event April 6, 2022 Root Cause Evaluation* ("Root Cause Evaluation")¹ in compliance with the April 8, 2022 Resolution ("April 8 Resolution")² ordering LUMA to identify and report the root and contributing causes of the April 6, 2022 Full Blackout ("Outage Event") and further recommend future action to prevent an outage reoccurrence.

On the October 4 Motion, LUMA informed that they have retained the technical services of Exponent, Inc. ("Exponent") to perform the Root Cause Analysis ("RCA") of the Outage Event. Exponent has experience assisting many utilities in the mainland United States with similar accident and failure analysis.³

The Energy Bureau, as stated in its October 19, 2022, Resolution and Order ("October 19 Resolution"), ⁴ retained the services of the Electric Power Research Institute ("EPRI") to act as an independent investigator with the purpose of validating the LUMA's RCA of the Outage Event. EPRI has principal offices and laboratories in Palo Alto, California; Charlotte, North Carolina; Knoxville, Tennessee; and Lenox, Massachusetts. EPRI conducts research and development relating to the generation, delivery, and use of electricity to benefit the public. As an independent nonprofit organization, EPRI brings together its scientists, engineers, and other experts from academia and industry to help address challenges in electricity relating to reliability, efficiency, health, safety, and the environment.

II. Discussion

In its April 8 Resolution and October 19 Resolution, the Energy Bureau directed LUMA to perform and submit a report on the RCA and provide supporting material respectively to determine the causes of the Outage Event and identify mitigating mechanisms to prevent recurrence.

As part of the Outage Event investigation opened under the April 8 Resolution, personnel from the Energy Bureau conducted field visits on June 28 and 29, 2022 to inspect the

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 $^{^1}$ See, In re: April 6, 2022 Electric Service Interruption, Case No.: NEPR-IN-2022-0002, Motion Submitting Root Cause Evaluation of April 6^{th} Incident and Request for Confidential Treatment, October 4, 2022, Exhibit 2 ("Root Cause Evaluation").

² See, Resolution and Order, In re: April 6, 2022 Electric Service Interruption, Case No.: NEPR-IN-2022-0002, April 8, 2022 ("April 8 Resolution").

³ See, October 4 Motion, Exhibit 1, p. 2.

⁴ See, Resolution and Order, In re: April 6, 2022 Electric Service Interruption, Case No.: NEPR-IN-2022-0002, October 19, 2022 ("October 19 Resolution").

damaged switchgear equipment transported from the Costa Sur Steam Plant 230kV Switchyard in Guayanilla, Puerto Rico to LUMA's managed facilities at Central Palo Seco in Toa Baja, Puerto Rico. Personnel representing the switchgear manufacturer⁵ were also on hand during these field visits.

As an independent investigator for the Energy Bureau, technical resource personnel from EPRI met several times with personnel from LUMA to obtain information not in the Root Cause Evaluation or the material requested from the Energy Bureau through the Requirement of Information in the October 19 Resolution that consisted of:

- 1. Hitachi Energy, LUMA OCB Circuit Breaker Failure: Field Service Inspection Report, dated June 27, 2022;
- 2. Independent Engineering Report PREPA Transmission and Distribution System prepared by Sargent & Lundy, Report No. SL-O 14468.TD, dated June 2019;
- LUMA Transmission Reliability Standards and Critical Infrastructure, dated July 12,
- 4. Puerto Rico Electric Power Authority (PREPA) Letter Análisis Estadístico y Proyectado de la Conservación de Equipos Eléctricos de la Subdivisión de Conservación Eléctrica, dated October 19, 2016;
- 5. LUMA Substation Assessment Costa Sur, dated July 26, 2021; and
- 6. Operating Procedure Number 401 -C.S. 5&6, dated September 1, 1977.

EPRI personnel reviewed the root cause analyses developed by LUMA and its contractors, in addition to assessing information it received through in-person meetings with LUMA and its representatives. The EPRI personnel also reviewed the information items listed above in completing its independent investigation into the root and contributing causes to the April 6, 2022, Outage Event. Based on its review, EPRI submitted a Technical Memorandum to the Energy Bureau ("Technical Memorandum").

In its Technical Memorandum to the Energy Bureau, EPRI concludes that:

(1) "LUMA's reports and supporting technical information provide a comprehensive forensic investigation into the contributing events and ultimate catastrophic failure of the bulk-oil circuit breaker at Costa Sur substation on April 6, 2022;" and

(2) "[t]he complete set of technical reports and supporting information provided by LUMA present a fair and credible overview of the event based on available information."

A. Adoption of LUMA's Root Cause Analysis.

The Energy Bureau FINDS that the Root Cause Evaluation filed by LUMA ("LUMA's FINAL REPORT"), with the supplemental information gathered and evaluated by EPRI, produces a technically sound representation of the Outage Event. The Energy Bureau **ADOPTS** LUMA's supplemented Root Cause Analysis.

B. Bulk Electric System (BES) Stability.

Failures of electric system protection parts, e.g., the Costa Sur 230 kV circuit breaker "0082", are not unusual, what is unusual is this failure will cascade to a full blackout. EPRI's analysis found that "[a] small amount of frequency response was delivered by some generators during the event, but this was not sufficient to compensate for the power lost due to disconnection of the generators at Costa Sur and EcoEléctrica".6 This lack of frequency response, worsened by the impact of Hurricane Fiona,

6 *Id*





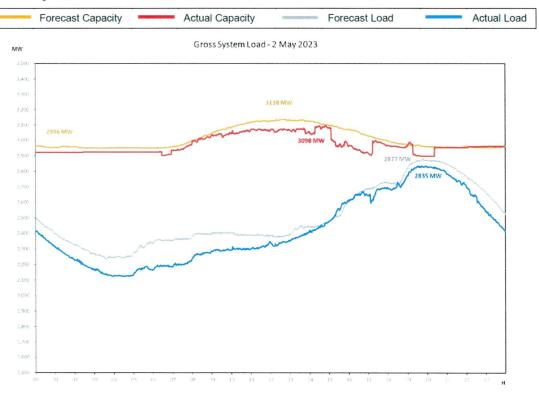




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detrimentally impacts the rate at which the frequency changes because of a system imbalance, i.e., system inertia. Without adequate system inertia, the Bulk Energy System ("BES") remains unstable and exposed to periodic frequency excursions.

In addition to the lack of inertia, the generation fleet also suffers from a lack of adequate reserves. This condition was also exacerbated by the impact of Hurricane Fiona during September 2022. Required generation reserves vary as a function of projected generation availability. Due to the current condition of the generation fleet, required reserve margins will be larger than those securing generators that exhibit adequate availability. These larger reserve margins are required to ensure that the system is run in a secure fashion. The system is often operated with inadequate reserves, sometimes requiring the operator to resort to manual load shedding during a contingency event when reserve margins are in double digits – see below, System Status Daily Update – LUMA May 3, 2023.



To stabilize the system to conform to current reliability industry standards, adequate reserves and frequency response capabilities are required. The present state of the BES does not properly averts the need for load shedding. Operating without adequate reserves is not a sound planning strategy and categorically goes against reliability standards adopted by the electric industry for the Bulk Electric System.

As part of its investigation, the Energy Bureau, assisted by EPRI, identified that:

- 1. Current system topology flows two of the largest baseload generators, the Costa Sur and EcoEléctrica steam plants, exclusively through one point, the Costa Sur Switchyard. System topology needs to be analyzed further to ensure adequate performance under contingency scenarios.
- 2. Frequency response capabilities are inadequate. The lack of this capability places the BES at grave risk of having to resort to Under-Frequency Load-Shedding ("UFLS") to maintain system stability.
- 3. The UFLS as configured/designed could not prevent system collapse.
- 4. Ride-through capabilities of Independent Power Producers (IPP) and PREPA thermal generation facilities need to be investigated further to ensure coordination with Bulk Electric System needs.
- 5. System protection coordination studies are outdated.

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⁷ See System Status Daily Updates, LUMA. Available at: https://lumapr.com/system-overview/ flast visit May 5, 2023).

C. Energy Bureau approved activities that support corrective/mitigation actions identified in this investigation.

Among other initiatives, the Energy Bureau has approved specific activities under federal funding disaster recovery obligations that address system deficiencies highlighted by this investigation, these activities include:

Project Title	Scope	Category	PREB's Approval dates
Costa Sur SP TC Equipment Repair- Replacement	Costa Sur Repair/Replacement 230kV/115kV BKRS, Control House.	Substations	6/8/21
Aguirre TC BKRS 230kV	Aguirre TC Repair/Replacement 230kV/115kV BKRS.	Substations	6/8/21
Bayamon TC – MC- BKRS-Y1	Bayamón TC Repair/Replacement 230kV, Control House.	Substations	6/8/21
SCADA Remote Access and RTU Replacements	SCADA platform, RTU/Communications Gateway, Remote Device Access Management System.	IT OT Telecom Systems and Network	9/22/21
Energy Management System (EMS)	Planning, design, procurement, and implementation of a new modern EMS with the additional capabilities required to provide monitoring and control of the reconstructed substations as well as to meet the operational requirements for 100% renewable energy.	Critical Energy Management System Upgrades	9/22/21
Field Area Network (FAN)	AMI integrated deployment, support distribution automation, volt/var control	IT OT Telecom Systems and Network	3/15/22
Advance Metering Infrastructure (AMI)	Islandwide implementation of AMI, 2-way communication system to Island wide implementation of AMI, 2-way communication System to collect detailed metering information, smart meters, digital communications network (DCN), head-end system, meter data management system (MDMS) to speed outage restoration by proactively manage and control key aspects of the grid, supports increased integration of distributed generation	AMI Implementation Program	4/6/23
Aguirre TC – Phase II	Replace all protection, control, and telecommunications	Substations	8/25/22

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Project Title	Scope	Category	PREB's Approval dates
	equipment in a new control center enclosure for the 230kV and 115kV switchyards		
Costa Sur TC – Phase II	Replace 115kV and 38kV AIS substation with GIS in a breaker-and-half configuration	Substations	8/25/22
Bayamón TC – Phase II	Replace 38kV AIS substation with GIS and Build new 115/13.2kV GIS substation	Substations	8/25/22
Aguirre Power Plant	 Unit 1 - Major Inspection (Replacement Turbo-Generator) Unit 2 Excitation System Procurement of Stages 1-1 & 1-2 Turbine Rotor Bucket Set New Water Condensate Tank Major inspection Unit 1-3 Hot Gas Path Repairs Work Units 2-4 and stand by transformer Hot Gas Path Inspection Work Units 1·1 and 1-2 Rehabilitation Fuel Tank Farm Liners Two New Condenser Discharge Water Pumps Motors Two New BCWP Motors Purchase and Installation Breakers 480 V Unit 1 South Wall Boiler Tubing Replacement and Boilers Repairs /Air and Gas Replacement of Load Center 1-4 Condenser Circulating Water Pump Inner Barrel Bundle 	Generation	2/10/22 2/18/22 3/9/22
Costa Sur Steam Plant	 AGC - Replacement Project Traveling Screens Replacement Replacement of Regulator Valves for Boiler Feed Water Units 5 & 6 Low Pressure Water Heater 3 Repair Work Procurement of Water Heater 5 (Deaerator) Spare Pump Replacement of Air- Preheaters Baskets, Unit 5 	Generation	2/28/22 3/9/22 4/13/22

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Project Title	Scope	Category	PREB's Approval dates
	CCWP and BCWP Spare		
	Motors for Units 5 and 6		
	Procurement of Induced		
	Draft Fan (IDF) and Forced		
	Draft Fan (FDF) Spare		
	Motors for Units 5 and 6		
	• Procurement of Condensate Pump (GP) Motor for Units		
	5 and 6		
	• Replacement of Unit 5		
	Electric Load Center		
	• Replacement of Excitation		
	System Units 5 and 6		
	• Replacement of 4160 V		
	Electric Cable Normal		
	Transformer 5A, 5B		
	• CS5 Major Inspection - HP/IP/LP Turbine Rotor		
	Replacement		
	• Unit 5 Boiler Replace and		
	Repairs & Auxiliary		
	Equipment Repairs		
	• Water Heater 6		
	Replacement Work		
	• Unit 6 - HP/IP/LP		
	inspection		
	BFWP Inner Barrel BundleUnit 6 LP-B Repair &		
	installation Work		
	• Fuel Igniters Replacement		
	Work		
	 Unit 5 Cooling Tower 		
	Replacement		
	• Unit 5 New High-Pressure		
	Pumps		
	Unit 5 Condenser Repair and Coating Application		
	• Unit 5 HP Bleed Valve, LP		
	Bleed Valve and Heat		
	Injection Steam Valve		
	 Unit 5 and 6 Black Start 	Generation	12/20/21 2/10/22
	Emergency Generator		
San Juan Power Plant	Upgrade		
	Unit 5 Replacement of Outlet Welson and Elbana		3/9/22
	Outlet Valves and Elbow Condenser		4/13/22
	Steam Rotor Replacement		3/20/23
	Unit 5 & CT Repairs		
	Control System Upgrade		
	units 5 & 6		
	 Purchases and Installation 		
	of Modules D&E HRSG Unit		and transmission of the Park
	5		CIADOD
	• Unit 6 - Major Overhaul		200
	(Steam Turbine Replacement and CT	/-	2/5
	Repairs)		NILL
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Project Title	Scope	Category	PREB's Approval dates
	 Replacement of the Online Condenser Cleaner Unit 5 Unit 6 - Major Overhaul Boiler Repairs Purchase and installation 20 TON for UPS Units 5 & 6 Unit 7 Air Preheater Maintenance and Replacement Replacement of Two Uninterruptible Power Supply Systems for Units 7 and 8 Unit 7 Rehabilitation (Turbine) Unit 7 Boiler Sections Replace, Repairs & Auxiliary Equipment Inspection Work Cyberex load sharing battery chargers rated 200 		
Palo Seco Steam Plant	 amps. ac input: 4 PS 3 Procurement and Delivery of Water Wall Boiler Tubes and Economizer PS 3 Low Pressure Turbine Rotor Refurbished, Unit Procurement Turning Gear System, Units 3 and 4 Upgrade to Mark VI e MOBILEPAC Environmental Commissioning Unit 4, Superheater Header Num. 5 Material, and Installation PS3 Boiler Repairs; MPT, Generator and turbine Repair & Aux. Equipment New (4) Cell FRP Counterflow Cooling Tower Upgrade OSI DCS Fuel Tanks Level Measurement System Water Retention Tank Num. 3 New Water Condensate 1-2 Tank 	Generation	2/10/22 2/18/22 2/28/22
Cambalache Power Plant	Automatic Voltage Regulator & SFC Upgrade for 2 Units	Generation	2/28/2
Central Hydro Gas Mayagüez Plant	Unit 1A, 1B and 4A Rehabilitation	Generation	2/10/22

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D. Activities sought to increase the stability of the Bulk Electric System



- 1. Genera PR LLC ("GENERA") aggressive generation maintenance schedule that takes advantage of the temporary emergency generation provided by FEMA.
- 2. Identification and prioritization of measures to reduce system risks.
 - a. System Studies
 - Review and re-configure the system defense scheme to respond to declining frequency conditions, including the under-frequency load shedding scheme designed to ensure that load is disconnected quickly and in proportion to the fall in system frequency.
 - ii. Develop power system analysis capability with a network model with an adequate and validated representation of the dynamic response and behavior of main generating units, loads, and relevant protection systems such as voltage protection, frequency protection, and volts/hertz.
 - iii. A wide-area protection coordination study of the transmission grid in line with methodologies such as those documented in NERC PRC-027 on Coordination of Protection Systems for Performance During Faults
 - iv. Review generator-grid protection coordination using methodologies such as those documented in NERC PRC-019 on Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls, and Protection and NERC PRC-025 on Generator Relay Loadability.
 - v. Creation of high-risk equipment and plant catalog to help develop and implement a risk management plan and asset replacement strategy.
 - b. System performance standards and criteria
 - i. Define clear policies and procedures to ensure equipment and plant are fit for service before re-energization after maintenance and repair activities.
 - ii. Introduce a standard system event analysis template and process for future investigations, like the NERC Event Analysis Process ("EAP") and associated template report.
 - iii. Develop codes, standards, and auditing practices to define and ensure generator and grid performance requirements are established and met, including abnormal voltage and frequency ride-through requirements.
 - c. Deployment of monitoring devices and other control solutions
 - i. High-resolution monitoring devices (such as Phasor Measurement Units or PMU, Power Quality sensors, and Digital Fault Recorders) at key transmission nodes and generation sites to assist with performance monitoring and event analysis.
 - ii. Supply and/or demand-side frequency control to regulate frequency. If the existing generator fleet is unable to provide frequency control solutions, explore alternative solutions such as energy storage systems.
 - d. Deployment of utility scale energy storage (as transmission assets) with primary frequency response capabilities and be able to support system stability in order to satisfy industry reliability standards.

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III. Conclusion

Based on the Final Report presented by LUMA and EPPRI's independent investigation, the Energy Bureau **ADOPTS** LUMA Final Report as the RCA and **ACCEPTS** EPRI's recommendations to improve the electric system in order to avoid future similar events. The Energy Bureau notes that while the failure of system protection equipment is to be expected during the day-to-day operations of an electric utility, the inability to contain this failure needs to be addressed. To reduce the risk of an equipment failure propagating and affecting the electric system the Energy Bureau **SHALL**, in a separate procedure, implement EPRI's recommendation as per its Technical Memorandum.

As per Sections 15.07 and 15.08 of Regulation 8543, LUMA has the right to file a Motion in regard to this FINAL REPORT on or before twenty (20) days from the notification of this FINAL REPORT.

The Energy Bureau **WARNS** LUMA that as per Section 15.10 of Regulation 8543, the file of this procedure will be available to the public at the date this FINAL REPORT has been duly notified, except for those documents for which the Energy Bureau granted confidentiality treatment.

The Energy Bureau **WARNS** LUMA, GENERA and PREPA that (i) noncompliance with this Resolution and Order, regulations and/or applicable laws may carry the imposition of fines and administrative sanctions of up to \$25,000 per day; (ii) any person who intentionally violates Act 57-2014, as amended, by omitting, disregarding, or refusing to obey, observe, and comply with any rule or decision of the Energy Bureau shall be punished by a fine of not less than five hundred dollars (\$500) nor over five thousand dollars (\$5,000) at the discretion of the Energy Bureau; and (iii) for any recurrence of non-compliance or violation, the established penalty shall increase to a fine of not less than ten thousand dollars (\$10,000) nor greater than twenty thousand dollars (\$20,000), at the discretion of the Energy Bureau.

Chairman

Be it notified and published.

Lillian Mateo Santos

Associate Commissioner

Ferdinand A. Ramos Soegaard

Associate Commissioner

Sylvia B. Ugarte Araujo

Associate Commissioner

Antonio Torres Miranda

Associate Commissioner



CERTIFICATION

I hereby certify that the majority of the members of the Puerto Rico Energy Bureau has so agreed on May 3, 2023. I also certify that in May 8, 2023 a copy of this Resolution and Order was notified by electronic mail to the following: Yahaira.delarosa@us.dlapiper.com; ivan.garau@us.dlapiper.com; margarita.mercado@us.dlapiper.com; jmarrero@diazvaz.law; brannen@genera-services.com; kbolanos@genera-services.com; regulatory@genera-pr.com. I also certify that today, May 8, 2023, I have proceeded with the filing of the Resolution and Order issued by the Puerto Rico Energy Bureau.

For the record, I sign this in San Juan, Puerto Rico, today May $\underline{\mathcal{S}}$, 2023.

Sonia Seda Gaztambide

Clerk