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

IN RE: INTERRUPCIÓN DE SERVICIO ELÉCTRICO DE 6 DE ABRIL DE 2022

**CASE NO. NEPR-IN-2022-0002**

**SUBJECT:**

**Submission in Compliance with Request for Information on April 6th Incident and Request for Confidential Treatment**

**MOTION SUBMITTING UPDATED REPORT 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 April 6th 2022, a failure in the electric system led to a fire at the Costa Sur transmission substation, which resulted in a power outage of the entire electrical system (hereinafter, the "April 6th Incident").

2. On April 8th 2022, this Honorable Puerto Rico Energy Bureau ("Energy Bureau") issued a Resolution and Order whereby it initiated an investigation of the April 6th Incident ("April 8th Order").

3. The April 8th Order instructed LUMA to submit on or before April 12th, 2022, at noon, a preliminary report on the causes of the April 6th Incident and the corrective actions taken by LUMA (the "Preliminary Report").

4. Further, the April 8th Order instructs LUMA to submit on or before April 18th 2022, at noon, a final report on the April 6th 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 and PREPA;

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 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 April 12, 2022, LUMA filed a *Request for a Brief Extension of Time to Comply with April 8th Resolution and Order on April 6th Incident Investigation*. Therein, LUMA requested a brief extension until the end of the day to submit the Preliminary Report in compliance with the April 8th Order, which the Energy Bureau granted hours later.

6. On that same day, in compliance with the April 8th Order, LUMA submitted the Preliminary Report of the April 6th Incident. The Preliminary Report included the information that LUMA had gathered thus far and preliminary findings and assessments of the April 6th Incident.

7. On April 14, 2022, to aid the Energy Bureau in its investigation and supplement the Preliminary Report, LUMA filed a *Motion to Supplement Preliminary Report on April 6th Incident.* Therein, LUMA submitted two (2) video recordings, including a screen camera from the Costa Sur transmission substation, which shows the moment of the explosion, and an aerial view video recorded the morning after the April 6th Incident.

8. On that same day, LUMA filed a *Motion to Request a Brief Extension to Submit Updated Report.* Therein, LUMA requested a brief extension until the end of the day today to submit an updated report ("Updated Report") in compliance with the April 8th Order.

9. In compliance with the April 8th Order, and to be transparent with its customers and regulators about its operations, LUMA hereby submits the Updated Report of the April 6th Incident. See Exhibit 1.

10. The Updated Report filed as Exhibit 1 to this Motion, provides an update on the following topics:

i. Overview of third-party industry expert hired to assist with analysis;

ii. Outage investigation update and proactive maintenance plan/strategy;

iii. System analysis update including adding dynamic stability analysis into model; and

iv. Ongoing restoration activities at Costa Sur.

11. As detailed in the Updated Report, LUMA is conducting a thorough investigation of the April 6th Incident, including an independent forensic assessment of the failed equipment. To this end, LUMA hereby informs that, a third-party investigation firm, Exponent, has been retained to assist with the investigation and analysis of the April 6th Incident. The investigation is being led by Richard E. Brown, PH.D., P.E. ("Dr. Bown").

12. Dr. Brown is an internationally recognized expert in infrastructure asset management, power system reliability, major event performance, system hardening, reliability improvement, power delivery system planning, smart grid, system automation, distributed energy resources, and risk assessment. Further, Dr. Brown has extensive experience in electric system outage investigations and root cause analysis. Most notably, he has previously conducted outage investigation work in Puerto Rico.

13. As is noted in the Updated Report, Puerto Rico has endured large-scale outages similar in scale to the April 6th Incident several times in the past five years. Conducting a proper investigation that follows a rigorous process and conducting a thorough dynamic system analysis are critical to finding out the root causes of the April 6th Incident and what must be done to prevent these types of large-scale outages in the future.

14. Given the highly technical and extensive nature of the investigation and desire to conduct an exhaustive, comprehensive, and scientific review, it is not possible at this juncture to

establish a fixed date for completion of the root cause investigation and analysis. By way of comparison, the final report from LUMA on the June 10, 2021, incident at the Monacillos substation was submitted to the Energy Bureau on September 15, 2021. The June 10, 2021 incident was of more limited scope and did not have as large an impact as the April 6th Incident.

15. LUMA is committed to, in due course, providing the Energy Bureau with timely updates on the investigation of the April 6th Incident. LUMA expects that the third-party lead investigator will review and provide feedback on the timeline and scope after a preliminary assessment of the collected data. LUMA anticipates being able to provide an update to the Energy Bureau on schedule, scope, and status based on the investigator's review by May 9th, 2022.

16. Exhibit 1 includes a confidential figure. *See* Exhibit 1 on page 9 (Figure 4-1). It is being submitted under seal of confidentiality as it constitutes 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 16, 2016.

17. 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 portion of the Updated Report of the April 6th Incident under seal of confidentiality.

**WHEREFORE,** LUMA respectfully requests that the Energy Bureau **take notice** of the aforementioned and **accept** the Updated Report of the April 6th Incident that is being filed as

Exhibit 1 to this Motion in compliance with the April 8th Order, and **accept and treat confidentially** the figure included at page 9 (Figure 4-1) of Exhibit 1.

**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 attorneys for PREPA, Katiuska Bolaños-Lugo, kbolanos@diazvaz.law, and Joannely Marrero-Cruz, jmarrero@diazvaz.law.

In San Juan, Puerto Rico, this 18th day of April 2022.

**DLA Piper (Puerto Rico) LLC**
500 Calle de la Tanca, Suite 401
San Juan, PR 00901-1969
Tel. 787-945-9107/ 9132
Fax 939-697-6147/ 6102

*/s/ Yahaira De la Rosa Algarín*
Yahaira De la Rosa Algarín
RUA NÚM. 18,061
yahaira.delarosa@us.dlapiper.com

*/s/ Iván Garau-González*
Iván Garau-González
RUA NÚM. 20,229
ivan.garau@us.dlapiper.com

*Exhibit I*

*Update to Costa Sur Substation Incident on April 6, 2022 Incident*

LUMAPR.COM

# NEPR-IN-2022-0002

*Updates to Costa Sur Substation Incident on April 6, 2022*

April 18, 2022

In the interest 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.

## Incident Summary

**Name:** 06APR2022 Major Outage Event –
Costa Sur Substation's 230 kV Circuit Breaker Failure

**Date:** April 06, 2022

**Time:** 20:42

**Location:** Costa Sur Substation – 230 kV Switchyard

**Description:** Oil-circuit breaker number 0082 failed during an attempt to connect Costa Sur Steam Plant's Unit #5 to the grid. The fault was cleared by the protective relaying system. A series of faults, caused by the subsequent ball of burning oil and flying debris, were cleared in the initial eight (8) seconds of the event. The disconnection of the generation at Costa Sur SP and EcoEléctrica triggered a complete system collapse. The island lost power 19 seconds after the initial fault was recorded.

## Resumen Del Evento

**Nombre:** Evento Mayor del 06ABR2022 –
Fallo de interruptor en el patio de 230 kV en Costa Sur

**Fecha:** 06 de abril de 2022

**Hora:** 20:42

**Localización:** Subestación de Costa Sur - Patio Interruptores 230 kV

**Descripción:** Durante la conexión a la red eléctrica de la unidad de generación número 5 en la planta de generación de Costa Sur, el interruptor de aceite numero 0082 sufrió un fallo. La falta original fue despejada por el sistema de relés de protección. La consecuente nube de aceite en llamas y los pedazos de material despedidos por el fallo ocasionaron una serie de faltas durante los ocho segundos iniciales del evento. La desconexión de las plantas de Costa Sur y EcoEléctrica fue seguida por un colapso del sistema eléctrico de Puerto Rico. La isla sufrió un apagón general 19 segundos después de la falta inicial.

# Executive Summary

In compliance with Puerto Rico Energy Bureau's Resolution and Order issued April 8 in case number NEPR-IN-2022-0002 and as part of our commitment to keep the Puerto Rico Energy Bureau (PREB) aware of the status of the investigation, we wanted to provide a briefing of where the investigation currently stands, next phases, and how LUMA is working with PREPA and other parties to obtain the various data points. LUMA's goal is to provide additional updates during each phase of the investigation. While the forensic analysis is expected to take some time to gather and analyze evidence from various internal and external parties, the findings and conclusions of the root causes of this event will be made public and provided to all relevant parties once conclusive.

We understand that any electrical outage, no matter its magnitude or reason is very frustrating for our customers. It is worth noting that Puerto Rico has a history of these types of outages in the past – most recently on September 21, 2016, April 18th, 2018, and January 7th, 2020. In the case of these large outages, which lasted longer than three days for restoration to be completed and affected more than 500,000 customers each time, answers on how to best prevent large scale outages remained elusive. As part of the investigation of the April 6th, 2022 outage, LUMA is determined to better understand why such outages happen in order to reduce the risks of similar outages in the future.

LUMA has also made clear that it is committed to providing additional updates during each phase of the investigation, and to working with PREPA and other generators to gather the necessary evidence. Given the need to conduct a scientific and rigorous investigation, the forensic analysis and investigation led by a third-party expert will require the gathering, collection, and analysis of data from various internal and external parties. While the investigative process may take time, which will be determined in large part by the timetable established by the third-party expert investigator, the findings and conclusions of the root causes of this event will be made public and provided to all relevant parties once conclusive.

To be clear, LUMA does not want the people of Puerto Rico to go without power, and we are committed to working together with PREPA and other generators to investigate this event, and to mitigate this from happening again. Most importantly, LUMA is determined to identify the root cause(s) and the improvement(s) needed to mitigate similar incidents from occurring in the future including any identified corrective short- and long-term actions.

The findings presented in this update are preliminary and may be revised as additional information and analysis warrants. This update reflects the information through Sunday, April 17th.

Topics addressed in this update include:

- Background of third-party industry expert hired to lead the analysis,
- Outage investigation update and proactive maintenance plan/strategy,
- System analysis update including adding stability analysis into model, and
- Ongoing restoration activities including 3D scanning for circuit breaker replacement.

All of us at LUMA remain committed to not only being transparent about the causes of such events, but to building an energy system that our 1.5 million customers can rely on. LUMA is committed to making infrastructure improvements every day and building the next generation electric grid that Puerto Ricans expect and deserve.

# Table of Contents

**Executive Summary** ..... iv

**1. Third-Party Expert Investigator, Dr. Richard Brown** ..... 1

**2. Outage Investigation Update and Maintenance Plan/Strategy** ..... 2

2.1 Outage Investigation ..... 2

2.1.1 Background ..... 2

2.1.2 Third-Party Investigation Experts ..... 2

2.1.2.1 Data Collection ..... 2

2.1.2.2 LUMA's Findings/Observations to Date ..... 3

2.1.2.3 Generation Requested Data ..... 3

2.1.2.4 Breaker Failure Analysis Update ..... 3

2.1.2.5 P&C Event Analysis Update ..... 3

2.2 Maintenance Plan/Strategy – Costa Sur SP's OCBs ..... 4

2.2.1 Pre-Maintenance Activities ..... 4

2.2.2 Circuit Breaker Maintenance and Inspection Cycles ..... 4

2.2.3 High-voltage Switch Maintenance ..... 5

**3. Dynamic System Analysis** ..... 6

**4. Restoration Activities at Costa Sur Substation** ..... 8

4.1 Circuit Breaker Replacement Project ..... 8

4.1.1 Completed and In-Progress Activities (April 10th-17th) ..... 9

1.1.2 Engineering Design Activities ..... 10

4.2 Maintenance Activities and Onsite Efforts ..... 10

4.2.1 Completed and In-Progress Activities (April 10th-17th) ..... 10

4.2.2 Upcoming Activities: ..... 16

4.2.2.1 Additional Tests ..... 17

# List of Figures

Figure 4-1 Single-line Diagram for 230 kV Switchyard at Costa Sur SP ..... 9
Figure 4-2 Sample of Lattice Steel Structures Tested for Integrity ..... 11
Figure 4-3 Ground Areas to be Evaluated ..... 12
Figure 4-4 Field Crews Testing Circuit Breaker Bushings Along with Performing a Full Circuit Breaker Maintenance Check ..... 13
Figure 4-5 LUMA Crews Inspecting and Cleaning an OCB ..... 14
Figure 4-6 LUMA Transmission Line Crews Replacing and Cleaning High-voltage Insulators ..... 15
Figure 4-7 Foundation to be Tested ..... 16
Figure 4-8 Close-up of Foundation to be Tested ..... 17

# 1. Third-Party Expert Investigator, Dr. Richard Brown

Avoiding events of this magnitude is of utmost importance to LUMA and our customers. To accomplish this goal, a third-party investigation firm, Exponent, has been engaged to assist with the investigation and analysis of this event.

Dr. Richard Brown is a Principal Engineer with Exponent and is an internationally recognized industry expert in power system reliability including major event investigations and root-cause analysis. He is the author of the books Electric Power Distribution Reliability and Business Essentials for Utility Engineers and is a Fellow of the IEEE. He received his PhD from the University of Washington in Seattle, his MBA from the University of North Carolina in Chapel Hill and is a registered professional engineer in North Carolina.

Dr. Brown has extensive experience with studying the root causes of major outage events, including those that were the result of extreme weather including hurricanes. Dr. Brown has extensive experience in electric system outage investigations including major urban interruption events in cities including Chicago, San Francisco, New York City, Calgary, B.C., Vancouver B.C., and Denver. Of note, he has previously undertaken outage investigation work for PREB, including the Root Cause Assessment of the PREPA Outage Event on July 28th, 2020.

A core focus of his past research and analysis has been to examine utility infrastructure performance, restoration performance, and storm cost-recovery support. Dr. Brown is also one of the early pioneers in transmission and distribution system hardening against major weather events and has helped several major utilities develop and implement infrastructure hardening programs. He led a consortium of Florida utilities under the direction of the Florida Public Utilities Commission develop a probabilistic storm and restoration simulation to quantify the costs and benefits of hardening options. Dr. Brown was also retained by the Public Utilities Commission of Texas to quantify the costs and benefits of proposed system hardening legislation, and to recommend best practices.

The investigation by Exponent of the April 6, 2022 outage has already commenced and Exponent will lead the outage investigation effort regarding analysis and associated recommended corrective actions. The investigation timeline and scope may be refined to reflect the feedback provided by the lead investigator after a preliminary assessment of the collected data.

# 2. Outage Investigation Update and Maintenance Plan/Strategy

This section is intended to provide an update on the outage investigation, including background, independent review of the outage by a contracted expert investigator, data collection, observations, and findings to date, further steps needed for data collection, followed by maintenance strategy for similar type of OCBs as the one that failed catastrophically at Costa Sur Substation on April 6th, 2022.

## 2.1 Outage Investigation

### 2.1.1 Background

On April 6th, 2022, with the system in normal state, the generation unit #5 at Costa Sur SP was in the starting process to connect to the system. While synchronizing unit #5 to the grid and during the circuit breaker's closing operation, the circuit breaker experienced a catastrophic failure followed by fire and flying debris that damaged bus #6, the three adjacent circuit breakers, and several portions of the substation's lattice structures.

### 2.1.2 Third-Party Investigation Experts

A leading, world-wide energy expert Exponent and Dr. Richard Brown have been contracted to carry out an expert, third party review and analysis of the Costa Sur Outage. Dr. Brown has extensive experience in major outage investigations and is very well respected in the industry. He has also previously undertaken outage investigation work for the Puerto Rican Energy Bureau (PREB), including the Root Cause Assessment of PREPA Outage Event on July 28th, 2020 where a vegetation issue on the 230KV line resulted in load shed event with 800,000 customers out of service. A brief overview of Dr. Brown is provided in section 1.

LUMA has continued to make progress in the outage investigation by carrying out the following activities:

#### *2.1.2.1 Data Collection*

The data collection and analysis for the Costa Sur Substation power outage on Wednesday, April 6th, 2022 initiated immediately after the event occurred.

LUMA's Energy Control Center provided the SCADA data recorded prior and during the event with the sequence of events and metering data of the system.

Data was downloaded from five digital protective relays that operated at Costa Sur complex. Note than most of the relays in this substation are electromechanical and only the targets of the six electromechanical relays that operated were reported, with no additional data available from these devices.

Relay data was also collected from the six substations with remote ends for the power lines in Costa Sur, including Aguirre, Cambalache, EcoEléctrica, Manatí, Mayagüez, and Ponce, and potentially more depending on what the analysis presents. **Approximately up to 30 protective relays, transient recorders, and event loggers have been interrogated and data retrieved thus far.**

Transient recorder data was downloaded from the devices in Aguas Buenas, Aguirre, Bayamón TC, Manatí, Mayagüez, Monacillo, and Ponce. The transient recorder at Costa Sur Substation was locked out, therefore, no data was able to be retrieved. The last records available are from three hours prior to the event. LUMA is investigating the cause of the locked-up condition.

The videos from the security cameras at the 230 kV switchyard provide useful information to determine the timeline of the circuit breaker's failure.

#### *2.1.2.2 LUMA's Findings/Observations to Date*

OCB #0082 failed during an attempt to connect Costa Sur SP's unit #5 to the grid. The fault was cleared by the protective relaying system. A ground potential rise was observed during the event.

With the isolation of Costa Sur's bus #6, the frequency started to decline due to the loss of generation from Costa Sur and EcoEléctrica. Several load-shedding events are recorded in the next 15 s. The system frequency reached 56.5 Hz and the Palo Seco units #3 and #4 tripped and the frequency decline accelerated. Further frequency drop required additional load shedding, but no additional load was available for shedding. After no further load-shedding activities could be utilized, the system collapsed.

LUMA is obtaining the services of third-party consultants to assist in the protection and control study of the event's analysis.

#### *2.1.2.3 Generation Requested Data*

LUMA sent the standard Request for Information form to the generation companies affected (PREPA, AES, and EcoEléctrica). The form includes information requests related to the Generation Unit (generator and transformer) and documentation and reports of the disturbance as seen from the generation plant.

As of today, the sequence of events from the plant SCADA systems have been received from Costa Sur, AES, and EcoEléctrica.

The following information from PREPA remains outstanding: turbine control and synchronizing systems, including the operational parameter settings for alarms and trips, and the turbine protection that operated. The outstanding information also includes the following:

- Generator and GSU step-up transformer protection trip and alarm settings for the Beckwith generator protection relay and Mark VI controller for all protective functions including frequency, voltage, overspeed, overexcitation, and overcurrent.
- Relay setting native files for above protection and control equipment.
- Automatic Generator Synchronizer settings (XASV).
- Mark VI turbine control settings, internal logic diagrams, and native files.
- Electrical drawings (Costa Sur's plant and substation).
- Event logging and DATA information including SCADA logs, and operator logs before and after the event and other information.

#### *2.1.2.4 Breaker Failure Analysis Update*

LUMA is engaging the National Electric Energy Testing, Research & Applications Center (NEETRAC) for a forensic assessment of the circuit breaker and engaging the equipment manufacturer to support the investigation.

#### *2.1.2.5 P&C Event Analysis Update*

LUMA is obtaining the services from third-party consultants to assist in the protection and control study of the event's analysis.

## 2.2 Maintenance Plan/Strategy – Costa Sur SP's OCBs

The maintenance plan and strategy for the 230 kV OCBs at Costa Sur SP is the highest priority, followed up with maintenance inspections and tests on the gas circuit breakers. The schedule of work at Costa Sur Substation is defined in Section 4.2. The strategy consists of three main sections as presented below:

### 2.2.1 Pre-Maintenance Activities

Perform thorough review of the available inspection records for the Costa Sur 230 kV circuit breakers, with priority on the OCBs followed by the $SF_6$ circuit breakers.

- Compare test results with manufacturer's manuals and recommended values, if available.
- Compare test results with industry experts on late 1960s – early 1970s OCBs especially where manufacturers' recommendations are unclear or missing.
- If previous test standards are not aligned with manufacturers' or industry experts' recommendations, then update test standards to align with the existing best practices.

### 2.2.2 Circuit Breaker Maintenance and Inspection Cycles

- Perform full maintenance and inspection testing of 230 kV OCBs.
- Perform full maintenance and inspection testing of 230 kV $SF_6$ circuit breakers per manufacturer's recommendation, typically every eight to 10 years, in accordance with updated test standards.
- Perform dielectric test of oil in OCBs.
- Check pneumatic circuit breaker mechanism (OCBs only) for water accumulation.
- Perform functional tests of protection relaying system to circuit breakers.

Circuit breakers' full maintenance and inspection to include the following activities:

- Disconnect circuit breaker from service and isolate.
- Inspect and clean bushings.
- Drain accumulated water from compressor assembly (OCBs only).
- Inspect and lubricate circuit breaker's mechanism.
- Perform contact resistance test (Ductor test, pre-maintenance).
- Perform general insulation test (Megger test, pre-maintenance) on circuit breaker's assembly.
- Bushing insulation test and power factor test (Doble test).
- Perform circuit breaker timing test.
  - Interrupter speed for opening and closing sequence.
  - Interrupter trip and close time.
- Test oil (OCBs only, pre-maintenance).
  - Dielectric test.
  - Acidity check.
- Drain breakers of oil (OCBs only).
  - Recirculate and filter oil to remove any carbon residues.
- Inspect and clean interrupting chambers (replace if necessary).
- Inspect and clean stationary and moving contacts (replace if necessary).
- Close circuit breaker's contacts to check contact adjustments (adjust if necessary).
- Perform contact-resistance test (Ductor test, post-maintenance).

- Open circuit breaker's contacts.
- Inspect condition of circuit breaker tanks' gasket (replace if necessary).
- Close circuit breaker's tank and fill with cleaned oil.
- Verify oil level.
- Test oil (OCBs only, post-maintenance).
  - Dielectric test.
  - Acidity check.
- Perform general insulation test (Megger test, post-maintenance).
- Clean connection points.
- Connect circuit breaker for service.

### 2.2.3 High-voltage Switch Maintenance

In conjunction with circuit breaker maintenance and inspections, also perform inspection and test of adjacent disconnect switches:

- Perform maintenance and inspection testing in accordance with manufacturer's recommendation and industry standards and guidelines.
- Verify contact surfaces for pitting and corrosion due to coastal location.

# 3. Dynamic System Analysis

Dynamic system simulations are necessary analysis tools to assess the electric system's response to various conditions impacting the system which could lead to a massive power outage. For the outage event investigations, the dynamic simulations are necessary to understand how a failure to system components caused the broader issues across the system. They are also critical for recommending future actions to mitigate the impact on the overall system. A typical dynamic power system model includes dynamic models of the generation, transmission network and loads, along with the associated control systems for stable power system operation.

To the best of our knowledge, a dynamic system analysis has never been conducted with accurate generating units responses from power plants in Puerto Rico during large scale outages under the previous operator.

The existing LUMA Transmission system model for dynamic simulation is based on the legacy information over the past decades and on previous evaluations of system events. The performance of the dynamic model, when compared to the actual system measurements during two prior events, was found to be inaccurate and cannot be relied upon to determine future system behavior or to design appropriate mitigations. The model was not built with detailed information on the components, particularly the details of the generating units connected to it. In other words, the existing system model's dynamic performance does not represent the observed reality of how the transmission system behaves under disturbances.

The main issue of the existing model is that the dynamic performance of the generation units connected to the LUMA Transmission grid is not properly modeled. To improve system stability over the long-term, the quality of the analysis of the dynamic power system performance must be corrected to better understand threats to grid stability. Thus, a testing consulting company is being engaged to perform analysis of all major generating units connected to the LUMA transmission system.

To obtain this critical information, LUMA has developed a scope of work and shortlisted vendors to provide quotations for performing this work. The work will require the testing vendor to access the power generation sites connected to LUMA's system, 30 generating units owned and operated by PREPA as well as units owned and operated by AES and Ecoeléctrica and set up measurements for data collection for the generating units to determine/confirm each unit's dynamic model.

After the work on site is performed, the information will be used by LUMA to build dynamic models of each of the generating units and those will be incorporated to the LUMA Transmission model in the PSS®E[1] software. This update to the system dynamic models is not just to support traditional post-event analysis and stability studies on the LUMA Transmission system, but it is also preparing LUMA for more accurate study of the impacts of large-scale renewable generation and energy storage systems to be connected to the LUMA Transmission and Distribution systems.

The following steps are necessary for performing the above-mentioned long-term process to update the existing generator models on the LUMA system and to further improve the capabilities to study the dynamics of the LUMA transmission system:

- **Step 1:** Select and commission a testing company to collect dynamic data from all generating units including the existing PREPA generating stations (30 generating units) as well as the

[1] PSS®E is the modeling software used for dynamic and steady state simulations of the LUMA transmission system.

existing AES and Ecoeléctrica units as needed to produce and verify complete dynamic models of each generating unit to enable dynamic grid modeling.

- **Step 2:** With the consultant working with LUMA and PREPA, develop a comprehensive testing plan for each of the 30 generating units for data collection based on known generator types and system components.
- **Step 3:** LUMA to work together with the consultant and PREPA to perform testing and data collection at each of the PREPA generating plants and for each unit.
- **Step 4:** Utilize the measured field data to derive tuned mathematical models for each component (generator, excitation system, turbine-generator Governor Speed Control (GOV) and Power System Stabilizer (PSS)) for each generating unit.
- **Step 5:** Update LUMA's transmission model in PSS®E with the new generation models to perform system dynamic and stability analysis.

# 4. Restoration Activities at Costa Sur Substation

This section outlines the activities undertaken by LUMA to return the system to its pre-outage configuration and to repair and replace the damaged equipment. This includes replacement of the damaged circuit breakers at Costa Sur 230kV switch yard, as well as maintenance activities and other on-site efforts at Costa Sur Substation.

## 4.1 Circuit Breaker Replacement Project

In parallel to re-energizing Costa Sur's 230 kV switchyard bus bar #5 and bus bar #6 as shown in Figure 4-1 Single-line Diagram for 230 kV Switchyard at Costa Sur SP, LUMA is working on the testing and engineering design for the affected circuit breaker replacements. LUMA is targeting to complete the rehabilitation work and installation of the circuit breakers within the next six to eight weeks. Two suitable spare 230 kV $SF_6$ gas circuit breakers have been identified in LUMA's warehouse.

CONFIDENTIAL
CRITICAL ENERGY INFRASTRUCTURE INFORMATION

Figure 4-1 REDACTED


### 4.1.1 Completed and In-Progress Activities (April 10th-17th)

Testing has been completed on structures directly impacted by the fire. The results are being evaluated to confirm the materials' integrity due to being exposed to high temperatures as well as to verify the physical capacity or molecular behavior of the materials was not compromised. This includes testing of the circuit breakers' concrete foundations, lattice steel structures, and grounds.

LUMA's Commissioning team is currently performing all electrical, control, and protection tests to determine elements that will require replacement. This team will also perform the acceptance tests for the new circuit breakers and components prior to energizing bus bar #6 at Costa Sur SP.

### *1.1.2 Engineering Design Activities*

Engineering design activities for the replacement of the two damaged circuit breakers are ongoing. The Engineering design package is to replace the damaged oil circuit breakers (OCBs) with new gas-insulated circuit breakers available in LUMA's warehouse. The design is expected to be completed by April 29th. The design will include wiring from the circuit breakers' terminal blocks to the existing junction boxes and any rehabilitation of the associated protection and control systems. The new circuit breakers' anchoring system and any other support structures will be designed as needed. The engineering firms were on-site April 13th to assess conditions and commence design engineering activities. A bill of materials identifying the necessary material to restore the affected areas is being developed for proper expediting from the LUMA warehouse or expedited purchase.

## 4.2 Maintenance Activities and Onsite Efforts

### 4.2.1 Completed and In-Progress Activities (April 10th-17th)

The below list presents the status of the various maintenance activities and onsite efforts being undertaken.

- **Continue environmental cleanup and removal of debris**, which is anticipated to finish by May 6th.
- **Replaced auxiliary disconnect #50220B and #0082B switches,** which enables the re-energization of 230 kV lines and connect Costa Sur SP's Unit #5.
- **Reenergized all 230 kV circuits,** which included all 230 kV circuits that feed through Costa Sur SP.
- **Ground-grid testing complete,** which included testing of 246 ground connections. Repairs are required.
- **The Engineering team performed a visual inspection of the damaged area and identified 20 steel lattice structures to be tested for their integrity condition prior to be returned to services.** Samplings of the steel structures as shown in Figure 4-2 Sample of Lattice Steel Structures Tested for Integrity were taken on April 13th and are being analyzed for their condition to ensure the structures integrity. The results will be available by the end of the week of April 18th. The results are being evaluated to confirm the materials' integrity due to their exposure to high temperatures as well as to verify the physical capacity or molecular behavior of the materials was not compromised.

**Figure 4-2 Sample of Lattice Steel Structures Tested for Integrity**

Testing of the circuit breakers around the affected area, concrete foundations, and grounds is also being performed.

The area around the affected breakers as shown in the Figure 4-3 Ground Areas to be Evaluated has been cleaned of debris and the soil in that area is being evaluated for ground integrity. Soil and gravel requirements are being identified to bring the area to their proper condition.

**Figure 4-3 Ground Areas to be Evaluated**

A 3D digital scanning of the affected area was completed on Thursday, April 14th. This information will be used to develop the Engineering package to replace the damaged OCBs with new gas-insulated circuit breakers available in LUMA's warehouse and any other affected areas.

Additional onsite activities include LUMA teams carrying out breaker testing including Ductor, Doble (bushing), and other maintenance activities as shown in Figure 4-4 Field Crews Testing Circuit Breaker Bushings Along with Performing a Full Circuit Breaker Maintenance Check. In Figure 4-6 LUMA Transmission Line Crews Replacing and Cleaning High-voltage Insulators, Transmission Line crews were working through the night to clean insulators where there was light contamination and replace insulators if there was significant contamination.

**Figure 4-4 Field Crews Testing Circuit Breaker Bushings Along with Performing a Full Circuit Breaker Maintenance Check**

**Figure 4-5 LUMA Crews Inspecting and Cleaning an OCB**

**Figure 4-6 LUMA Transmission Line Crews Replacing and Cleaning High-voltage Insulators**

### 4.2.2 Upcoming Activities:

- **Installation and commissioning of synchronizing potential transformers (PTs).**
- **Developing and then executing the protection testing plan,** which will be completed prior to synchronizing generator #5 to the grid.
- **Continue circuit breaker and high-voltage switch maintenance** on remaining equipment. Testing of OCBs #50320, #50220, and #0012 are complete. Full maintenance to be completed on OCBs #50320 and #50220 by April 23rd. OCB #0012 is ready to be placed into service.
- **Ground-grid repairs are anticipated to be complete by April 25th.**
- **Developed temporary design for partial re-energization of bus #6,** which will allow for additional redundancy on three 230 kV circuits. The partial re-energization of bus #6 is scheduled for April 26th.
- **Take core samples from the affected foundations** as shown in Figure 4-7 Foundation to be Tested and Figure 4-8 Close-up of Foundation to be Tested. These samples will be sent to a lab on the mainland for an integrity analysis that will determine if any modifications are required. This activity is scheduled to occur on Monday, April 18th.

**Figure 4-7 Foundation to be Tested**

**Figure 4-8 Close-up of Foundation to be Tested**

Engineering activities will be completed the week of April 18 to relocate potential transformers to the non-affected section of bus # 6 in order to restore this section to service.

#### *4.2.2.1 Additional Tests*

Before re-energizing any Costa Sur 230 kV circuit breakers as part of the restoration work, additional tests listed below will be completed:

- Perform bushing test of all circuit breakers, both oil and $SF_6$, using a Doble test set, following Doble's recommended test procedures.
- Perform dielectric test of oil in OCBs.
- Check pneumatic circuit breaker mechanism (OCBs only) for water accumulation.
- Perform functional tests of protection relaying system to circuit breakers.