NEPR

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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:** **Motion Submitting Root Cause Evaluation of April 6th Incident and Request for Confidential Treatment**

MOTION SUBMITTING ROOT CAUSE EVALUATION OF APRIL 6TH 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]:

1. On April 6th, 2022, a failure in the electric system led to a fire at the Costa Sur transmission substation and 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. LUMA, in its role as the operator of the Puerto Rico Transmission and Distribution system, believes it is critical that a transparent and scientific investigatory process is followed to

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[1] Capitalized terms not defined herein shall have the meaning ascribed to them in LUMA's *Motion Submitting Updated Report and Request for Confidential Treatment,* filed in this Energy Bureau on April 18th, 2022.

protect the integrity of the analysis and credibility of any conclusions in response to the Energy Bureau's April 8th Order. Multiple steps occurred as part of this investigatory process in order to fully comply with the investigation ordered by this Energy Bureau, understand the April 6th Incident in its entirety, and reduce the probability of similar events occurring in the future. To that end, a scientific and rigorous investigation and a forensic analysis was led by a third-party investigation firm, Exponent, led by Dr. Richard Brown. Dr. Richard Brown is an internationally recognized industry expert in power system reliability including major event investigations and root-cause analysis. Throughout the investigation, Exponent led the outage investigation analysisand provided associated recommendations for corrective actions that led to the final report that is filed as **Exhibit 2** to this Motion.

4. In connection with the April 8th Order, on April 12th, 2022, 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, preliminary findings and assessments of the April 6th Incident, and a summary of the corrective actions taken by LUMA.

5. On April 14th, 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 recording from the Costa Sur transmission substation that shows a few minutes before and after the failure at the Costa Sur Substation's 230kV switchyard on April 6th, and an aerial view video of the Costa Sur Substation taken the morning after the April 6th Incident.

6. On April 18th, 2022, in compliance with the April 8th Order, LUMA filed a *Motion Submitting Updated Report and Request for Confidential Treatment.* Therein, LUMA submitted the Updated Report of the April 6th Incident, which provided 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.

7. On April 22nd, 2022, the Energy Bureau issued a Resolution and Order instructing LUMA and PREPA to submit, on or before May 6th, 2022, at noon, certain documents, and information in connection with the April 6th Incident ("April 22nd Order").

8. On May 9th, 2022, LUMA submitted all documents and information in its possession, custody, and control, which were responsive to the Energy Bureau's requests for documents and information. They included a sworn statement signed by Darrell Wilvers, LUMA's Director of Asset Management, stating that the documents produced were exact copies of the original documents and that the information provided was true and correct. Further, LUMA also submitted a Second Updated Report of the April 6th Incident, which provided an update on the schedule and status of the investigation.

9. In the Second Updated Report of the April 6th Incident, LUMA informed the Energy Bureau that the remaining elements of the investigation schedule included a Root Cause Evaluation Report of the April 6th Incident (the "Root Cause Evaluation Report) that would be submitted on or before September 23, 2022.

10. On September 23, 2022, LUMA filed an informative motion to inform the Energy Bureau that due to the unforeseen event beyond LUMA's control of the passage through Puerto Rico of Hurricane Fiona (a Category 1 Hurricane), LUMA would not be able to file the Root Cause Evaluation Report on or before September 23, 2022 as indicated in Second Updated Report. Due

to the island-wide emergency, LUMA respectfully informed the Energy Bureau that it was going submit the Root Cause Evaluation Report on or before October 7, 2022.

11. As advanced in the Second Updated Report of the April 6th Incident, LUMA hereby submits Exponent's Root Cause Evaluation Report of the April 6th Incident. Specifically, (1) attached hereto as **Exhibit 1** is a Summary of the Investigation and Corrective Actions, and (2) attached hereto as **Exhibit 2** is the Root Cause Evaluation Report. Exponent, the third-party expert contracted by LUMA to carry out the investigation, has prepared the Root Cause Evaluation Report.

12. **Exhibit 2** includes two diagrams that are 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, 20216, as amended by the Resolution dated September 20, 2016. *See* Exhibit 2, on pages 6 and 7 (Figures 3 and 4).

13. 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 Root Cause Evaluation Report of the April 6th Incident under seal of confidentiality.

WHEREFORE, LUMA respectfully requests that the Energy Bureau **take notice** of the aforementioned; **accept** the Summary of the Investigation and Corrective Actions, submitted publicly as **Exhibit 1**, and the Root Cause Evaluation Report that is being filed publicly as **Exhibit**

2; and **treat confidentially** portions of the Root Cause Evaluation Report that is being filed with this Motion as identified in this Motion.

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 PREPA, Bolaños-Lugo, kbolanos@diazvaz.law.

In San Juan, Puerto Rico, this 4th day of October 2022.

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Exhibit 1

(Summary of the Investigation and Corrective Actions)

April 6th Incident: Summary of Event Investigation and Corrective Actions

NEPR-IN-2022-0002

October 4, 2022

Summary of Event Investigation and Corrective Actions

Event Summary

On the evening of Wednesday, April 6th, 2022, Puerto Rico's electric system suffered an island-wide blackout that left customers without power for several days. The catastrophic failure of a circuit breaker and fault in the 230 kV switchyard at the Costa Sur Steam Plant (SP) led to a subsequent cascading series of outage events which impacted the entire island, and which speaks to the fragility of the electric grid that has suffered from years – if not decades – of operational neglect and lack of maintenance.

We understand that any electrical outage, no matter its magnitude or reason is very frustrating for our customers. A major outage affecting most or all customers and lasting several days is obviously a deeply concerning event. Puerto Rico has a history of these types of large-scale outages in the past – most recently on September 21, 2016, April 18th, 2018, and January 7th, 2020. Each of these large outages, which lasted longer than three days for restoration to be completed, affected more than 500,000 customers. As part of the current investigation, LUMA was determined to understand the root causes of the April 6th, 2022, outage in order to better understand why such outages of the Puerto Rico electrical system happen in order to reduce the risks of similar outages in the future. To the best of our knowledge, this independent investigative process is a fundamental action taken by most utilities following large scale events.

Investigation Process

LUMA, in its role as the operator of the transmission and distribution system, believes it is critical that a transparent and scientific investigatory process is followed to protect the integrity of the analysis and credibility of any conclusions. Multiple steps occurred as part of this investigatory process in order to fully comply with the investigation ordered by the Puerto Rico Energy Bureau in case number NEPR-IN-2022-0002, understand the event in its entirety, and reduce the probability of such events occurring in the future. Given the need to conduct a scientific and rigorous investigation, the forensic analysis and investigation was led by a third-party investigation firm, Exponent, led by Dr. Richard Brown. Dr. Richard Brown is an internationally recognized industry expert in power system reliability including major event investigations and root-cause analysis. Throughout the investigation, Exponent led the outage investigation analysis and provided associated recommendations for corrective actions.

Following the April 6th event, LUMA made clear that it remained committed to providing updates throughout each phase of the investigation and worked with Exponent, PREPA and other generators to gather the necessary evidence. Throughout the investigation, LUMA prepared and filed the following reports with the Energy Bureau:

- April 12, 2022 – Preliminary report
- April 14, 2022 – Video recordings of the incident
- April 18, 2022 – First update report
- May 9, 2022 – Second update report, response to requests for information (RFIs) from the PREB
- July 1, 2022 – Response to remaining RFIs from the PREB

The complete and thorough investigation included several additional technical analysis reports carried out by Exponent and filed with the Energy Bureau by LUMA including:

- July 18, 2022 – Transmission Reliability and Critical Infrastructure Dynamic Analysis
- August 26, 2022 – Breaker Failure Forensics Analysis
- September 9, 2022 – Power Plant Report

In the final Root Cause Evaluation, Exponent analyzed all of the evidence to the fullest extent possible to explain the root and contributing causes of two key events on April 6:

1. the failure of circuit breaker CB-0082 in the Costa Sur 230 kV substation, and

2. the inability of the system response to prevent a cascading failure and a blackout of the entire electrical system.

As the Exponent Root Cause Evaluation (RCE) shows, the evaluation of the various event data, asset history, failure analysis, system protection analysis, system stability analysis, and power generation analysis led to the development of key findings and observations upon which a causal analysis was performed. From the causal analysis, two root causes and two contributing causes were identified. To be clear, root causes are those causes that, if removed, the event would have a high probability of not occurring.[1] Contributing causes are those causes that, if they were removed, had some chance of reducing the likelihood of the event.[2]

Root Cause and Contributing Causes Summary

As a result of its analysis, Exponent determined the following root causes and contributing causes:

Root Cause 1: Ineffective PREPA maintenance management and decision-making led to the Oil-Circuit Breaker (OCB) #0082 breaker being placed into service by PREPA after maintenance in 2020 with contact resistance significantly over the manufacturer's recommended limits. Exponent states that PREPA should not have placed the OCB #0082 back in service with this high level of contact resistance. This resulted in arcing across the contacts in the circuit breaker, heating the oil in the equipment which vaporized the oil, creating high pressure hydrogen that could not be released and resulted in the explosion.

Root Cause 2: Ineffective PREPA operational management and risk decision-making resulting from not having a system stability model to assist in development of load shedding schemes. The protection devices for the most part functioned as intended after the explosion of OCB#0082. When the Costa Sur and Ecoeléctrica plants disconnected, the under-frequency load shed was insufficient to stabilize the system and a blackout occurred. An accurate system stability model that includes generator performance characteristics, helps determine how much load shed is needed to maintain the balance between generation and load and prevent island wide blackouts of the electric system. Despite multiple requests from LUMA, PREPA has not provided access to the generator performance data needed to create the system model.

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[1] Exponent RCE, p. 38.

[2] Exponent RCE, p. 38.

Contributing Cause 1: The synchronization protocols (roles and responsibilities) do not match the current organizational structure. **Exponent could not identify PREPA's operating manual for the Costa Sur Steam Plant. PREPA relied on manual controls and individual knowledge to carry out synchronization of the Costa Sur 5 steam unit.**

Contributing Cause 2: The state of the electric system was not stable and is often not able to prevent cascading events after the loss of major facilities. Exponent states that "LUMA's takeover of operations included the inheritance of a T&D system that was aged, deteriorated, significantly undermaintained, and had very poor asset and maintenance documentation."[3] There is a design flaw in that the system is dependent on Costa Sur substation and the generation from Costa Sur and Ecoeléctrica that pass through the substation. There is an inability of the system to adequately prevent wider failures when there are faults to generation in the south that feeds into Costa Sur.

Corrective Actions Recommended by Exponent

Exponent recommended corrective actions for each cause and assigned LUMA and PREPA as action owners. The operational reality is that LUMA must now take actions to address the factors that contributed to the root cause failures related to PREPA's prior operations. Table 1 below includes the cause, corrective action and action owner as identified by Exponent and the current status of each action provided by LUMA.

[3] Exponent RCE, p. 25.

Cause	Corrective Action	Action Owner	Status (Provided by LUMA)
Root Cause 1: Ineffective PREPA maintenance management and decision-making. This circuit breaker should not have been returned to service by PREPA with this level of contact resistance.	1. Complete maintenance bases for circuit breakers and update maintenance procedures to include limits for pass/fail for inspection and maintenance. 2. Extend maintenance bases to other critical assets and update maintenance procedures accordingly. 3. Evaluate ITT oil circuit breakers for similar issues relative to OCB #0082 and perform maintenance and overhauls as needed. 4. Expedite Costa Sur capital program based on recent funding approvals.	LUMA	1. LUMA has completed maintenance of 25% of all the Oil Circuit Breakers (OCBs) in the system and 50% of the 230kV OCBs. The testing procedures have been changed to include critical parameters related to OCBs. 2. This process has been extended to 115kV and 38kV OCBs, leading to updated breaker maintenance criteria and procedures. LUMA has completed maintenance on 193 transformers and circuit breakers. 3. All of the 230kV breakers' vents have been inspected and cleaned. 109 115kV OCBs and 216 38kV OCBs have also been inspected and cleaned (some 38kV OCBs do not have vents). 4. Two Costa Sur 230kV OCBs have been replaced with more 230kV breakers placed on order. The plan has been developed to replace all OCBs through the system and this quantity of breakers has been ordered or is in the process of being ordered.

Cause	Corrective Action	Action Owner	Status (Provided by LUMA)
Root Cause 2: Ineffective PREPA operational management and risk decision-making resulting from not having a system stability model to assist in development load shedding schemes. In addition, the lack of transparency of PREPA and response to data requests by LUMA prevent LUMA from developing a model.	Update and revise the system stability model to include the following: Field testing and model development of each of the generation units. This should include the generator, the turbine, the exciter, the power system stabilizer, and the governor models. Review and update the protection system settings in the model, based on actual relays in the field. Extensive testing of the model against potential scenarios and observed system events. Review and update under frequency load shedding schemes	LUMA	In the absence of access to accurate generator data from PREPA, LUMA pursued a two-pronged approach to address similar events in the future: The first approach is a stop-gap measure that involved developing a dynamic system model based on old datasets. LUMA tuned the model based on few prior system events. Although this model is inaccurate and may misrepresent system behavior for future events, it is the best that can be done without access to accurate power plant dynamic data. The second and most robust measure involved developing a testing and model identification plan during Q4 2021, soliciting proposals, and contracting with a well-established third-party company to perform the testing. LUMA arranged few meetings with PREPA to discuss the testing process and schedule for the testing but has not received approval and access to visit the power plants and commence the testing process.

Cause	Corrective Action	Action Owner	Status (Provided by LUMA)
Contributing Cause 1: The synchronization protocols (roles and responsibilities) do not match the current organizational structure. Protocol required circuit breaker inspections to be performed prior to synchronization, and there was no evidence that PREPA performed this inspection or requested LUMA to perform this inspection.	Generation synchronization protocols should be reviewed and updated for all PREPA facilities relative to the change in operating structure for the electric system to ensure roles and responsibilities are well understood	PREPA / LUMA	LUMA added synchronizing relays in the switchyard on the breakers associated with the generators to provide an additional protection. In addition, LUMA has reached out to PREPA and is waiting for a continued discussion concerning upgrades to the procedure.
Contributing Cause 2: The state of the electric system was not stable and is often not able to prevent cascading events after the loss of major facilities. Addressing this issue will require a long-term effort by LUMA and transparency from PREPA	Develop a long-term plan for the overall electric system to identify vulnerabilities in system design and operation; and to define future mitigation actions.	LUMA	LUMA has performed system level study utilizing the steady-state model in accordance with CIP-14 standard as industry best practice to identify critical substations that are single points of failure on the Puerto Rico T&D system. These are due to past planning and design practices on the system – proposed mitigations include new substations as well as substation & Transmission line reconfigurations. In addition, LUMA has contracted to build a full system level dynamic model to perform critical system studies to support system stability.

Ongoing Actions and Improvements

Preventing future large-scale outages demands a clear and transparent explanation of the causes that contribute to such events. Based on the root cause analysis of the April 6th event, it is clear that the state of the grid that LUMA inherited remains a significant obstacle to providing the reliable energy our customers expect and deserve. To address this, LUMA is actively working on the improvement(s) needed to mitigate similar incidents from occurring in the future including a series of identified corrective short- and long-term actions. LUMA is also committed to not only being transparent about the causes of such events, but to working together with PREPA and other energy partners to take the necessary steps and actions that will help reduce the risk of an April 6th event from ever happening again.

Exhibit 2

(Root Cause Evaluation Report)

Engineering Sciences

Exponent®

Costa Sur Outage Event
April 6, 2022

Root Cause Evaluation

Exponent®

Costa Sur Outage Event April 6, 2022

Root Cause Evaluation

Prepared for:

DLA Piper LLP (US)

Prepared by:

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September 22, 2022

Contents

Figures

Tables

Limitations

At the request of DLA Piper LLP (US), Exponent conducted a root cause evaluation of the Costa Sur outage event on April 6, 2022. The purpose of this evaluation is to determine the root and contributing causes of this event and to define action to prevent recurrence. The results and conclusions of this evaluation are based on the information supplied by LUMA and public records. There was incomplete information received from Puerto Rico Electric Power Authority (PREPA) in response to various data requests, so some critical information is not available to the evaluation team. The opinions and comments formulated during this assessment are based on observations and information available at the time of this assessment.

The findings presented herein are made to a reasonable degree of engineering certainty. If new data becomes available or there are perceived omissions or misstatements in this report regarding any aspect of those conditions, we ask that they be brought to our attention as soon as possible so that we have the opportunity to address them fully.

1. Introduction

At 2042 hours on Wednesday, April 6th, 2022, a fault occurred in the 230 kV switchyard of the Costa Sur Steam Plant (SP). Phase B of Oil-Circuit Breaker (OCB) #0082 suffered a catastrophic failure. The failure affected four adjacent circuit breakers and several portions of the switchyard's lattice structures. Due to the circuit breaker's failure, the 230 kV circuits at Costa Sur SP needed to open to clear the fault, which disconnected EcoEléctrica Generating Facility from the grid and resulted in subsequent outage events that cascaded into a full blackout of Puerto Rico's electrical system. DLA Piper LLP (US) has retained Exponent to perform a root cause analysis of the incident. The objectives of this analysis are to determine the root and contributing causes of this event and define actions to reduce the potential for future events.[1]

This root cause analysis is performed with the following conditions:

- LUMA repeatedly requested information and event records from PREPA pertaining to the Costa Sur generating facility synchronization and was provided incomplete information. Therefore, a key limitation in the assessment is that Exponent has no access to the policies and procedures used in the performance of work by PREPA relative to plant operations at the time of the event. These policies and procedures are developed and maintained by PREPA and are needed to insure proper synchronization to the grid. Therefore, reasonable industry practice will be assumed in examining the cause of the incident.

- Exponent is relying on the recently completed analysis of this event relative to system protection performance, circuit breaker failure analysis, power generation assessment, and system stability analysis described in separate reports, which are included as references in this report.

[1] LUMA "Costa Sur Outage Event of 04/06/2022 Progress Report"; NEPR-IN-2022-04, dated July 2022

2. Problem Statement

The problem statement provides the focus of the root cause analysis to ensure that the appropriate issues are addressed. Exponent personnel reviewed the available documentation and defined the problem statement for the root cause analysis. The problem statement developed for performing this root cause analysis is:

On April 6, 2022, at 2042 hours, oil circuit breaker 0082 at the Costa Sur Steam Plant 230kV Switchyard failed while operating to connect and then disconnect the Costa Sur Steam Plant Unit #5 to the grid resulting in the failure of the circuit breaker and adjacent equipment and structures and resulting in outages to 1.5 million customers requiring five days to fully restore all customers.

The problem statement specifically addresses two major issues:

1. Determine the cause of the circuit breaker failure

2. Determine the cause of the system collapse (resulting from events at a single substation).

3. Event Description

The event description provides a discussion of the Costa Sur Steam Plant and the 230kV switchyard, which contains the failed circuit breaker, a summary of the event, and the event timeline. This information is utilized to identify the key findings that form the starting point of the causal analysis.

3.1 Costa Sur Steam Plant

The Costa Sur Steam Plant (SP) is a network of facilities involving the thermal generation plant and the electrical facilities, including the 230 kV Switchyard and 115/38 kV Switchyards (see Figure 1). Costa Sur's 230 kV switchyard has a breaker and a half configuration with five bays that include four (4) gas circuit breakers and 11 oil circuit breakers from circa 1969-1976. Figure 2 provides an aerial view of the 230 kV Costa Sur Switchyard.

The elevation of the switchyards for the Costa Sur SP has two different levels (Figure 1):

- The 230 kV switchyard's elevation is the highest of the switchyards and is located north of the road
- The 38/115 kV switchyard's elevation is the lowest of the switchyards and is located inside the plant's facilities.

The current protection and control panels for both switchyards are in the Control Room building of the power plant (see Figure 1).

The single line diagram for the Costa Sur Steam Plant Switchyards is shown in Figure 3, and the single line diagram for the Costa Sur 230 kV switchyard is shown in Figure 4.

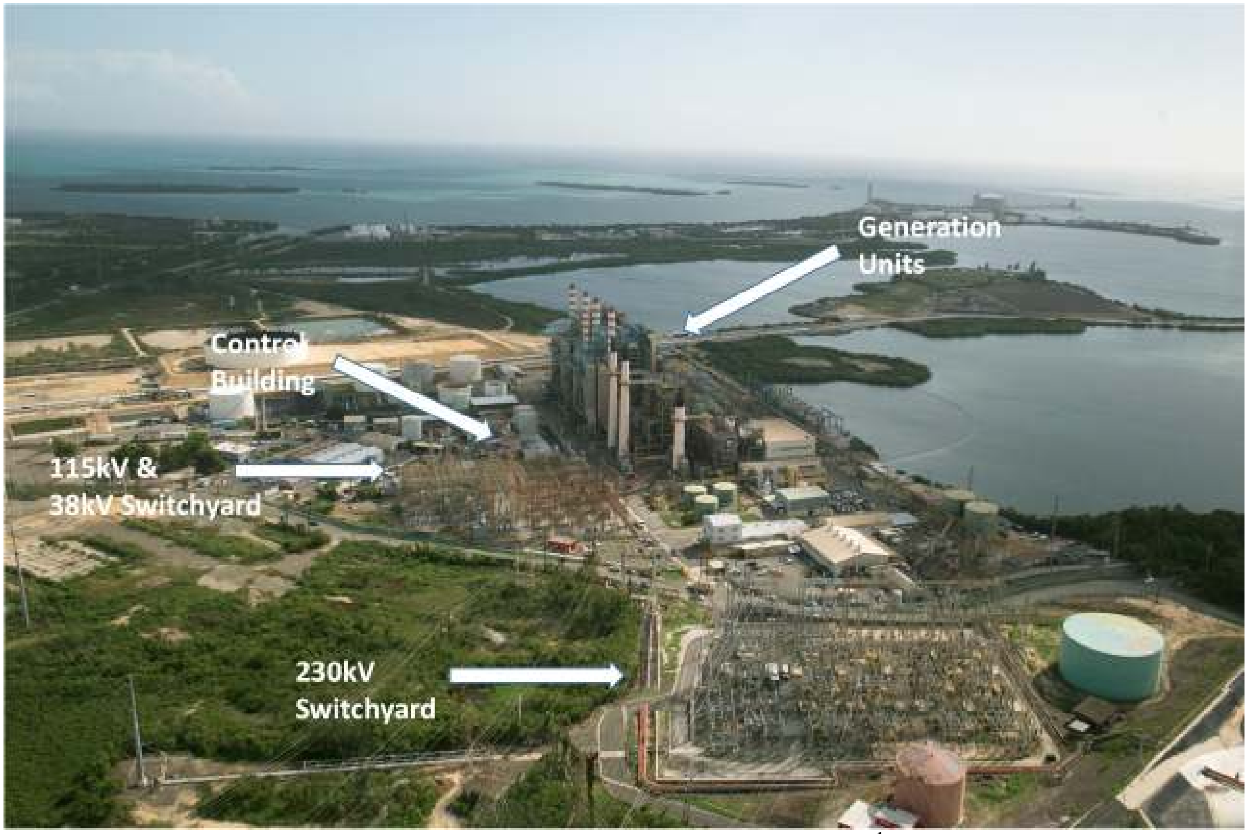

Figure 1: Aerial View of Costa Sur Steam Plant Prior to April 6th Event (switchyard is in foreground of photograph)

Figure 2: Costa Sur SP's 230 kV Switchyard (CB 0082 is in top right corner of photograph)

Redacted

Figure 3: Single Line Diagram for Costa Sur Steam Plant Switchyards

Redacted

Figure 4: Single-line Diagram of Costa Sur 230 kV Switchyard

3.2 Event Summary

At 2042 hours on Wednesday, April 6th, 2022, a fault occurred in the 230 kV switchyard of the Costa Sur Steam Plant (SP). Phase B of Oil-Circuit Breaker (OCB) #0082 suffered a catastrophic failure (see Figure 5).[1] A detailed description of the event is provided in LUMA's Outage Event Progress Report[1]. A summary of these analyses is described here.

OCB #0082 connects to Costa Sur SP's generation unit #5 to the transmission grid. After synchronizing unit #5 to the grid, the circuit breaker began to experience internal arcing, resulting in the generation protection system sending a trip command to OCB #0082. During the opening, phase B tank of the OCB # experienced a catastrophic failure followed by an explosion and flying debris that damaged bus #6 (see Figure 4 for reference). The failure affected four adjacent circuit breakers and several portions of the substation's lattice structures. Due to the circuit breaker's failure, the 230 kV circuits at Costa Sur SP needed to open to clear the fault, which disconnected EcoEléctrica from the grid and resulted in subsequent outage events that cascaded into a full blackout of Puerto Rico's electrical system. Under-frequency load shedding occurred but was insufficient to prevent total system collapse. By 2100 hours on Saturday, April 9th, 83.5% of customers impacted by this event had been restored, and by Sunday, April 10th at 0300 hours, 99% of customers impacted had been restored.[1]

Figure 5: Damaged OCB #0082

3.3 Event Timeline

The event scenario is determined based on an evaluation of the event information from the various operating and monitoring sources. The event scenario is summarized from the analysis in the event report[1], power generation assessment report[2] , and circuit breaker failure analysis[3] reports. More details of the event scenario are found in those references. Based on an assessment of this data, the following event scenario was determined:

- Costa Sur's generator unit #5 was connected to the transmission system by closing OCB #0082 Phase B.
- Approximately five seconds later, unit #5's protection system operated due to an unknown event. This sent a command to OCB #0082 to open.[4]
- While opening, a fault occurred within OCB #0082, causing a failure.
- This failure caused conductive gases and particles to engulf the surrounding area, resulting in multiple faults on the 230 kV system at Costa Sur.
- The breaker failure relay correctly isolated the fault as designed.
- These subsequent 230 kV line faults were correctly isolated from the system by line-fault protection at remote substations.
- The failure of the circuit breaker and the resulting subsequent faults caused the generators at Costa Sur and EcoEléctrica to be disconnected from the power system. This resulted in the removal of approximately 800 MW generation capacity from the system, corresponding to an approximate reduction of the system from 2,300 MW to 1,500 MW.
- The sudden generation reduction resulted in the remaining generators decelerating.

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[2] Puerto Rico Outage Investigation: Costa Sur Power Plant"; Exponent Report, dated September 9, 2022
[3] "Failure Analysis of Costa Sur Oil Circuit Breaker 082", Exponent Report, dated August 25, 2022
[4] LUMA has requested operating information on the initiating relay that issued the trip signal to the breaker from PREPA, but has not received any information from these requests. See Transmittal # LUMA-PREP-T-00267 "Response to PREPA's Letter Regarding Costa Sur OCB #0082 Event Investigation"; dated June 3, 2022

- The generation deceleration triggered under frequency load shedding, but this load shedding was not sufficient to prevent the Island from blacking out.

Based on the event timeline, the major findings related to this event are:

1. There was a trip signal sent to open OCB #0082 from an unknown source from Unit #5[5].

2. There was an unexpected failure of OCB #0082.

3. The protection system breaker failure relays performed as intended to clear the faults after the explosion. The performance of the bus differential protection scheme was limited by a faulty lock-out relay which prevented a signal to OCB #0082, and the bus differential protection did not clear the fault.

4. The overall system could not handle the failure at the Costa Sur 230V switchyard, the subsequent loss of load, and the inability of the under-frequency load shedding scheme to prevent system collapse.

3.4 Immediate and Interim Corrective Actions

After this event, LUMA took the following immediate corrective actions in preparation for restoring the 230 kV bus #6 and replacing damaged circuit breakers #0074 and #0082[6]:

- Electrical
  - Performed high-voltage auxiliary switch cleaning and adjustments on switches #51120A, #50320A, and #0019.
  - Performed maintenance on OCBs #51120 and #50220.
  - Re-energized the undamaged portion of Bus #6 after testing, commissioning, and connecting to PTs and OCB #50220.

[5] Repeated requests for this information was requested from PREPA, but information was never obtained.

[6] LUMA "Costa Sur Outage Event of 04/06/2022 Progress Report"; NEPR-IN-2022-04, dated July 2022

- Current transformers tested on high-voltage circuit breakers #51120, #50220, and #50320.
- The protective relays associated with affected breakers OCB #0082 and #0074 and bus differential were tested for proper operation.
- Removed high-voltage auxiliary switches #0082A and #0074A.
- Installed high-voltage PT and secondary PT disconnect switch and wire pulls.
- Replaced damaged portion of Bus #6 and wiring of protection in Control Room.
- Cable pulled for SCADA panel.

- Civil
  - Removed contaminated soil.
  - Replaced crushed stone.
  - Trench completed for PT secondary conduit.
  - Transferred extra material to material trailer.

4. Prior Maintenance Practices and System Deterioration

The background information provides a summary of the recent history and the condition of the electric system in Puerto Rico and the transition to LUMA's operation of the electric transmission and distribution system. While LUMA was aware of many maintenance and equipment condition issues, the severity of the deterioration of the maintenance and inspection program was not known as will be discussed below. This historical discussion is provided to indicate the state of the system prior to LUMA operations and to its effect on the incident.

4.1 Electric System Milestones

The electric system in Puerto Rico was operated by PREPA until the turnover of operations to LUMA in June 2021. Key milestones in the recent history of the system are shown in Figure 6.

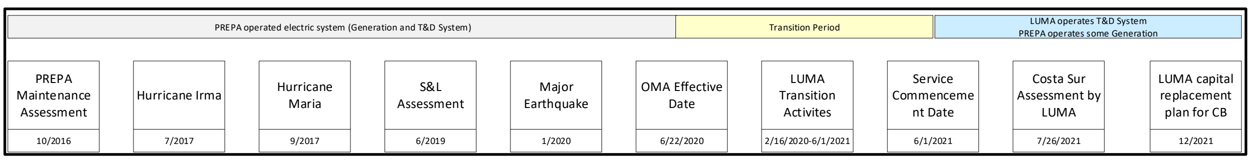

Figure 6: Puerto Rico Electric System History

The key milestone events of interest prior to the LUMA transition are:

- PREPA prepared an assessment of their maintenance program and staffing limitations in 2016 that indicated a significant and critical decline in their maintenance program.[7]

- The Island was subject to back-to-back hurricanes in 2017 that caused severe damage to the electric system infrastructure as well as all infrastructure systems (water, roads, buildings, etc.).

[7] PREPA Letter "Análisis Estadístico y Proyectado de la Conservación de Equipos Eléctricos de la Subdivisión de Conservación Eléctrica"; dated October 19, 2016.

- An independent assessment of the electric system was performed in 2019 to assess the system condition after the hurricanes and to inform electric system recovery plans.[8]

- A major earthquake occurred in 2020, which further damaged the electric infrastructure.

- The Puerto Rico Public-Private Partnerships Authority made a decision to issue a request for bid for an independent entity to take over operations of the electric transmission and distribution system. LUMA was selected as the operator and a transition period of approximately one year began in mid-2020 with the Operation and Maintenance Agreement (OMA).[9]

- LUMA began operations on June 1, 2021.

- LUMA completed its initial assessment of the major electric system substations to determine condition and needs. The Costa Sur assessment was completed in July 2021, shortly after the commencement of operations by LUMA.[10]

- LUMA also took over planned capital work that was proposed by PREPA as recovery from the hurricanes. There was a project proposed for the replacement of several of the circuit breakers at Costa Sur[11] that was submitted to PREB in February 2021.[12] This project was reevaluated and expanded by LUMA to include all the older

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[8] "Independent Engineering Report PREPA Transmission and Distribution System" prepared by Sargent & Lundy, Report No. SL-014468.TD, dated June 2019

[9] "Puerto Rico Transmission and Distribution System Operation and Maintenance Agreement" between PREPA, LUMA and the Puerto Rico Public-Private Partnerships Authority (Administrator); dated June 22, 2020

[10] LUMA "Substation Assessment Costa Sur"; dated July 26, 2021

[11] The proposal was for the replacement of four oil circuit breakers and three gas circuit breakers.

[12] DR-4339-PR Public Assistance "Project Scope of Work with Cost Estimates Submitted to COR and FEMA; Substations – Costa Sur SP TC – Equipment Repair and Replacement 169896, dated February 1, 2021.

breakers when it was also determined that the 115kV switchyard was in a flood zone. This project has been recently approved for funding by FEMA.[13]

These are key historical milestones leading up to the April 6, 2022, outage event. A description of the electric system condition leading up to these events is provided below.

4.2 Electric System Assessments

Electric systems are subject to various inspection and maintenance programs to ensure that the assets and systems are safe and reliable. In 2016 PREPA prepared an internal communication that discussed the current state of the maintenance program. This information, which indicated a severe decline in maintenance activity, was not provided to LUMA during the transition.[14] maintenance and inspection activities were greatly reduced. The electric system has been significantly impacted in the past several years by reduced preventive maintenance and by major external events (hurricanes and earthquakes).

In 2016, PREPA indicated that the status of their electric system inspection and maintenance program was deteriorating.[14] This information indicated that there were issues with both the maintenance program and the ability of PREPA to retain and recruit key personnel to manage the inspection and maintenance program effectively. PREPA indicated the following completion level of maintenance tasks, as shown in Figure 7. As indicated by the results in Figure 7, the effective maintenance completion declined continuously from 2008 to 2016 to the extent that only 24% of maintenance was being completed within its required time period. The impact of this condition is that asset condition deteriorates without the appropriate attention and leaves the system in a vulnerable state relative to equipment condition and reliability.

[13] Department of Homeland Security Federal Emergency Management Agency, Project 169896 Approval; dated July 28, 2022.

[14] PREPA Letter "Análisis Estadístico y Proyectado de la Conservación de Equipos Eléctricos de la Subdivisión de Conservación Eléctrica"; dated October 19, 2016.

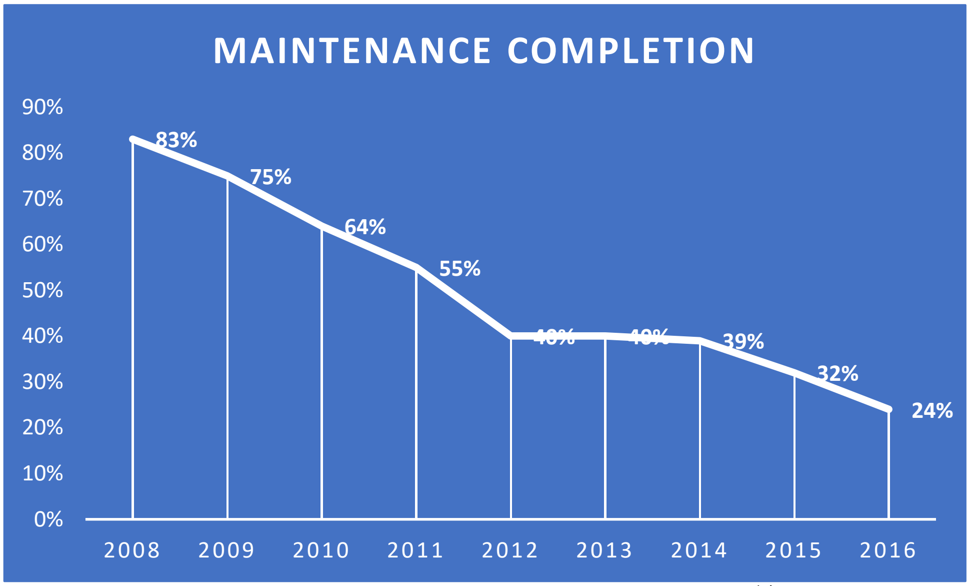

Figure 7: PREPA Maintenance Completion[14]

With the deteriorated maintenance conditions, two major hurricanes in the summer of 2017 impacted Puerto Rico and severely impacted the electric system. The entire Island was without electric power for a significant period of time (in addition to other negative impacts of the storms). As reported in a June 2019 independent report,[15]

"On September 6, 2017, the island of Puerto Rico was struck by Category 5 Hurricane Irma; two weeks later, it was hit by later by Category 4 Hurricane Maria. The 150+ miles per hour winds and heavy rains of Hurricane Maria caused extensive damage to Puerto Rico's infrastructure, including the electric grid. Damage from Hurricane Maria resulted in the entire island going into a black-out condition, with complete de-energization of the T&D system."

Additionally, the independent report indicated the following relative to the substations on the system:

"*As reported from PREPA, as of March 6, 2019, 332 of 342 distribution substations had been reenergized and 54 of 56 TCs had been re-energized. As with T&D elements, even though the system has been successfully restored to serve the vast majority of PREPA customers, it is not*

[15] "Independent Engineering Report PREPA Transmission and Distribution System" prepared by Sargent & Lundy, Report No. SL-014468.TD, dated June 2019

clear what level of reliability can be expected from the substations and TCs. Many sites experienced significant flooding which can degrade critical equipment. Equipment, such as transformers and circuit breakers and the associated control panels are sensitive to moisture intrusion, especially during periods of de-energization, which can lead to lower reliability. Once the emergency restoration effort has been completed, much of the substations and TCs will need to be revisited by crews in order to evaluate and make the required repairs to bring them up to industry standard levels of reliability."

Therefore, in 2019, the electric facilities were in operation, but required significant maintenance and potential replacement.

In January of 2020, a major earthquake struck the Island, and again electric power was lost for a significant period of time. While not sustaining the damage from the hurricanes, the electric infrastructure was further impacted and required remediation to restore customers to service.

The independent report provided the most current review of equipment and substation conditions prior to the LUMA transition. Key conclusions and excerpts[15] from this assessment are included below (emphasis added):

- *"Overall, most substations and TCs were operating and in decent condition. However, overall maintenance was a concern. While newer equipment was in good condition, older equipment exhibited its age indicative of inadequate maintenance practices. The condition of the wiring and lack of documentation represents a significant challenge to the stations' reliable performance."*

- *"PREPA indicates that due to lack of labor resources, they do not generally perform scheduled or planned maintenance of the TCs, substations, or T&D systems. However, scheduled and planned maintenance is generally performed on large power transformers, oil and gas circuit breakers, station batteries, and relays on a time basis."*

- *"In general, the substations, TCs, and T&D lines that we inspected are operational. The majority of the equipment observed is 30 years old or more, and maintenance of the* *equipment has been minimal due to limited resources and budget. PREPA's focus has been to address failed or damaged equipment as customers lose power. The lack of maintenance has contributed to continued reduced system reliability, increased outages, and safety concerns."*

- *"These TCs and substations are critical for system reliability. They allow for the integration of transmission voltage levels, and step power down to lower voltages at which customers can be served. They use breakers, switchgear, and relays to provide for the protection and control of the transmission lines and transformers, which is critical for reliable and safe operation. The majority of the relaying on PREPA's system is of the older, electro-mechanical type, and approximately 38% of the high voltage circuit breakers on the system are older oil-type circuit breakers."*

- *"As these systems age failures will become increasingly frequent, leading to crews spending more time in restoring and performing corrective maintenance, rather than focusing on preventative maintenance that increases reliability. Older sites also pose additional challenges as drawings may be outdated or inaccurate, and years of emergency repairs can lead to non-standard installations that are more difficult to troubleshoot."*

- *"… also recommends completing a full grid study, including load flow and dynamic stability studies, to quantify the transmission constraints on the system. Once the actual constraints are identified, PREPA will likely not only be able to dispatch their generators in a more efficient manner, but they could also develop a targeted plan for future grid improvements for the T&D Roadmap."*

The major observation from our assessment of the condition in the independent report is that the electric system remains fragile from years of lack of maintenance and inspections and damage from external events. These conditions already existed when LUMA executed the Operating and Maintenance Agreement (OMA) in June 2020.

4.3 LUMA Transition

LUMA signed the OMA[16] on June 22, 2020, which began a period of transition from PREPA to LUMA relative to taking over operations of the electric transmission and distribution system. The purpose of this document was to define the scope of the operating and maintenance services[17], the front-end transition services[18], and the back-end transition services[19]. After June 22, evaluate various documents, operating procedures, staffing requirements, record management, and other services. The result of this transition period was the beginning of service commencement by LUMA on June 1, 2021. After the service commencement date, LUMA took over the operations and maintenance activities for the electric transmission and distribution assets, including lines and substations.

LUMA indicated that their first major tasks relative to substations were to:

- Initiate the development of a computerized asset and maintenance database. The existing databases from PREPA were not consistent with current industry practices, and most of the prior asset and maintenance information was only available in paper records located at the various work centers. LUMA indicated that a significant effort was required to retrieve paper records to populate the computerized database.

- Perform visual inspections of facilities to determine where immediate work was required. LUMA performed walk-throughs and visual inspections of its large

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[16] "Puerto Rico Transmission and Distribution System Operation and Maintenance Agreement" between PREPA, LUMA and the Puerto Rico Public-Private Partnerships Authority (Administrator); dated June 22, 2020

[17] Per OMA, O&M services are generally defined as "Operator shall (i) provide management, operation maintenance, repair, restoration and replacement and other related services for the T&D System, in each case that are customary and appropriate for a utility transmission and distribution system service provider, including the services set forth in this Article 5 (O&M Services) (excluding the GenCo Shared Services) and Annex I (Scope of Services), and (ii) establish policies, programs and procedures with respect thereto (all such services, the "O&M Services"), in each case, in accordance with the Contract Standards.

[18] Per OMA, front-end services are generally defined as "services provided by Management Company under this Agreement prior to the Service Commencement Date in order to complete the transition and handover to Operator of the operation, management and other rights and responsibilities with respect to the T&D System."

[19] Per OMA, back-end transition services are generally defined as "services provided under this Agreement in order to complete the transition and handover of the O&M Services."

substations and documented these inspections. The Costa Sur 230kV switchyard was inspected in July 2021.[20] The report on OCB #0082 indicated it was close to its expected service life and showed signs of aging. This condition estimate was similar to other equipment at the 230kV switchyard.

- Evaluate major capital projects that were proposed by PREPA and continue or expand these projects based on assessments. As indicated earlier, a major capital program was proposed for Costa Sur 230kV station, and this capital project has been recently approved.[13] This capital program includes the replacement for OCB #0082. However, this program was identified earlier, but funding was not available for action prior to the April 6, 2022, outage event.

- Focused efforts on restoring equipment that was not operational as the primary initial focus, which diverted resources from the ongoing maintenance efforts.

A key observation is that LUMA's takeover of operations included the inheritance of a T&D system that was aged, deteriorated, significantly undermaintained, and had very poor asset and maintenance documentation. The T&D system would require significant effort to bring the assets to good health and high reliability.

[20] LUMA "Substation Assessment Costa Sur"; dated July 26, 2021

5. Observations and Event Analysis

This section details the various data collection and analysis activities associated with this root cause evaluation. The key analysis aspects of the assessment include:

- Protection analysis and performance during the event
- Evaluation of Costa Sur Steam Plant Unit #5 synchronization process
- Failure analysis of circuit breakers
- System analysis and operations related to under-frequency load shedding

This information will provide the basis for analysis of the event and the determination of findings to support the causal analysis.

5.1 System Protection Analysis

The system protection analysis is documented in a separate report.[1] The detailed analysis of the event and the protection response is described in the report and is summarized here. The analysis of this complex system event was impacted due to missing fault recorder data at the time of the event.

Table 1 provides an overview of the performance of all fault-protection elements during this event. The breaker failure relays operated properly to clear faults in the system after the explosion. There were a few elements that did not perform as planned. However, these elements likely had a limited impact on the overall event. A discussion of the performance of these protection elements follows.

Table 1: Summary of Protection Performance During April 6th Event

Event	Protection Element That Operated	Performed Correctly?	Comment
Initiating event	Generator protection	Unknown	No data received from PREPA
Initial fault on OCB #0082	Unit #5 differential	Yes	
Initial fault on OCB #0082	Bus #6 differential	Partial	One defect LOR
Initial fault on OCB #0082	Line 50200 Costa Sur terminal	No	No operation expected; LOP missing
Initial fault on OCB #0082	Line 50400 Costa Sur terminal	No	No operation expected; LOP missing
Initial fault on OCB #0082	Line 50100 both terminals	Yes	
Initial fault on OCB #0082	Breaker failure	Yes	
Subsequent fault on 50200 Manatí	Line 50200 Manatí terminal	Yes	
Subsequent fault on 50300 Aguirre	Line 50300 Aguirre terminal	Acceptable	67G operation
Subsequent fault on 50300 Aguirre	Line 51300 Ponce terminal	No	67G operation
Subsequent fault on 50400 Mayagüez	Line 50400 Mayagüez terminal	Yes	
Subsequent fault on 51200 Cambalache	Line 51200 both terminals	Yes	

LOR = Lock Out Relay; LOP = Loss of Potential

The initiating event caused the generator protection to issue a trip command to OCB #0082. At this time, it can be assumed that OCB #0082 was already closed for several seconds. What the cause of this initiating event was and why the generator protection issued a trip command are still under investigation as PREPA has not provided any insight into the trip command that opened the OCB.

When OCB #0082 opened could not be confirmed even though the SCADA alarm announced the circuit breaker was open 114 milliseconds after the trip command was issued. This is the moment where the B-ground faults begin. The unit #5 differential protection correctly issued a trip for this fault and started the breaker failure's timer. The high-impedance, bus-differential protection also issued a trip for this fault, but due to a defective lock-out relay,[21] only some of the circuit breakers were tripped. The fact, however, that the measuring coil of the B-phase was burned confirms that the lockout relay (LOR) that gives the alarm to SCADA, and that shortens the measurement coil to prevent the burnout was not working during this fault. One defective LOR was confirmed by a field test. The fault was correctly cleared by the breaker failure relay after 360 milliseconds.

Two cycles before the fault were cleared, the fault expanded into an AB-ground fault. At this time, the PT signals were lost. The line relaying for the Manatí line 50200 and Mayagüez line 50400 issued an incorrect Zone 1 operation for this reverse fault at this moment. Nonetheless, the operation from the Manatí line relay did not have any impact on the event, as the breaker failure operation was already in the opening sequence of these circuit breakers. The functionality was reviewed with the relays' manufacturer, Schweitzer Engineering Laboratories (SEL), as the expected response of blocking Zone 1 by a loss of potential logic was not working. SEL explained that the missing loss of potential signal in both line relays was due to the firmware of this relay (R112) having a logic/timing error that caused this malfunction. To mitigate this problem, firmware R113 must be used. The impact of the incorrect operation from the Mayagüez terminal can also be ignored since the Mayagüez line was tripped late based on a subsequent fault.

All subsequent faults on different lines were cleared by the associated protection correctly, apart from the fault on Aguirre line 50300. The line relaying at the Aguirre line terminal detected the subsequent fault and tripped the fault with an instantaneous over-current element (67G). Concurrently, the line relaying at the Ponce line terminal detected the same fault and also operated with an instantaneous over-current element (67G). The setting philosophy was reviewed and found to be correct. However, the settings of elements cannot consider this type of multiple contingency event. The operation on the Aguirre terminal is acceptable as the fault was indeed on the Aguirre line, but the operation from the Ponce terminal is undesirable. It should

[21] Regular maintenance and testing of the relay had the potential to identify and prevent this defect.

be noted that the system is already in an abnormal condition as the Costa Sur bus #6 is isolated from the 230 kV system and the Mayagüez line tripped. For the development of the 67G pick-up settings, only a n-1 or n-2 contingency is considered.

5.2 Power Generation Assessment

An attempt has been made to understand and analyze the circumstances associated with the synchronization of the Costa Sur Unit 5 turbine-generator unit just prior to the failure of OCB #0082 on April 6, 2022, and the Unit 5 synchronization on April 22, 2022. This assessment is documented in the Exponent Power Generation Assessment Report, which provides a detailed assessment.[22,23] A summary of the power generation assessment is provided here.

At the time of this incident, the Unit 5 generator was being synchronized to the 230 kV grid. After investigation, it appears that the synchronization occurred for about five seconds.[24] At this point, an electrical anomaly was detected, followed by the Unit 5 protection system issuing a trip command to Breaker #0082. Breaker #0082 catastrophically failed while attempting to open.

There are reported discrepancies associated with the synchronizing activities at the time the Unit 5 generator was being connected to the 230 kV grid. Because the PREPA plant operator reported the breaker status indicator lights did not show a change of breaker state (open-to-close) and reported that the synchroscope hand was still moving, he thought the unit had not synchronized to the system when, in fact, it had. The generator began picking up load; approximately 5 seconds later, the unit tripped offline. Review of the preliminary events and alarms from Mark VI shows that the electrical anomaly occurred about 5 seconds after synchronization, and this started a sequence that led to the breaker failing. This also initiated a Breaker #0082 trip by the generator protection group. The transient fault recorder data could

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[22] "Puerto Rico Outage Investigation: Costa Sur Power Plant"; Exponent Report, dated September 9, 2022

[23] This effort has been hampered by the lack of information provided by the PREPA plant personnel. This report has identified the need for detailed information pertaining to startup procedures, unit protection (mechanical and electrical), and unit monitoring and unit control.

[24] Oscillography data from the Manati substation showed no anomalies from the time of synchronization for about five seconds. At this point a waveform anomaly occurred and persisted for about 200 ms until the generator unit protection issued an open command to Breaker #0082.

have provided valuable insight during these first 5 seconds, but was offline at the time of the incident. Specifically, the data from the transient fault recorder would have provided pre-fault and fault current and voltage measurements at the location of the fault. This would have provided valuable information about the performance of the generator.

On April 21, 2022, several problems were revealed when Unit 5 was subsequently synchronized to the 230 kV grid. This was the first time after the April 6 event, and had to use breaker #0012 to connect to Bus #5 (breaker 0084 was still OOS). Bus #6 was out of service as a result of the damage incurred during the breaker 0082 failure incident.

In the steps leading up to unit synchronization (on 6/21/22), sequential trip simulations were conducted by PREPA. During these pre-synchronization tests, PREPA's personnel jumpered the valve trips. This allows the 20X sequential trip circuit to be activated without disturbing the valve circuit. Under these circumstances, a defective limit switch can go undetected.

It was determined that during this Incident a malfunctioning limit switch prevented the sequential trip circuit from initiating a unit trip, and elements in the trip circuit could not be asserted. Shortly after the unit was synchronized to the system, arcing was visually observed on the B phase of the unit 5's #0019 motor-operated disconnect (MOD). PREPA personnel had to intervene and manually trip the #0012-circuit breaker. It is suspected that the condition found with MOD #0019, B-phase contacts, might have existed prior to the April 6 event. It is further suspected that the defective limit switch problem may also have existed prior to the April 6 event. The defective limit switch would have prevented several trip criteria from initiating a sequential unit trip.

Additionally, the operating procedures that PREPA utilized for synchronization of the generators to the grid have not been updated for the current operations with LUMA.[25] There are requirements in this procedure requiring PREPA, as the generation operator, to take specific actions to ensure that OCB #0082 is ready for the synchronization process. These actions

[25] PREPA Operating Procedure Number 401-C.S.5&6, dated September 1, 1977.

include verification by the engineer of the shift (plant operator) prior to the operation of the following elements on the circuit breaker:

- DC current circuit
- AC circuit for air compressor power
- Compressed air system
- Oil level
- Manual discs
- Key locking
- No mechanical earths.

There was no evidence uncovered by the assessment team that these checks were performed by PREPA or that LUMA was asked to perform these checks.

During this investigation, a number of discrepancies, issues, and questions have arisen, the analyses of, and answers to which remain unresolved due to a lack of transparent communications and lack of sharing of relevant information by PREPA to LUMA. LUMA has repeatedly requested information from PREPA, and PREPA has been nonresponsive to many of these requests. Many of the open questions from this report about the performance of the generators could have been answered had PREPA been more responsive. In addition, additional lessons learned could have been gleaned from this event. For example, PREPA did not provide the protection function that sent the trip signal to the circuit breaker. This and the lack of a functional transient fault recorder very much limited any data available from the plant during the first few seconds of this event.

5.3 Circuit Breaker Analysis

5.3.1 Breaker Asset Information

OCB-82 is a 230 kV oil circuit breaker that was manufactured by ITE in 1970. ITE was later sold to ABB, who later sold it to Hitachi Energy. The only requirements for operation and maintenance were included in the original instruction manual.[26]

5.3.2 Breaker Maintenance History

Maintenance recommendations begin on Page 8 of the Instruction Manual[26]. This included pre-inspection safety checks, an external and internal inspections. The circuit breakers are on a four-year maintenance cycle. For the specific breaker that failed, OCB #0082, the maintenance history is summarized in Figure 8.

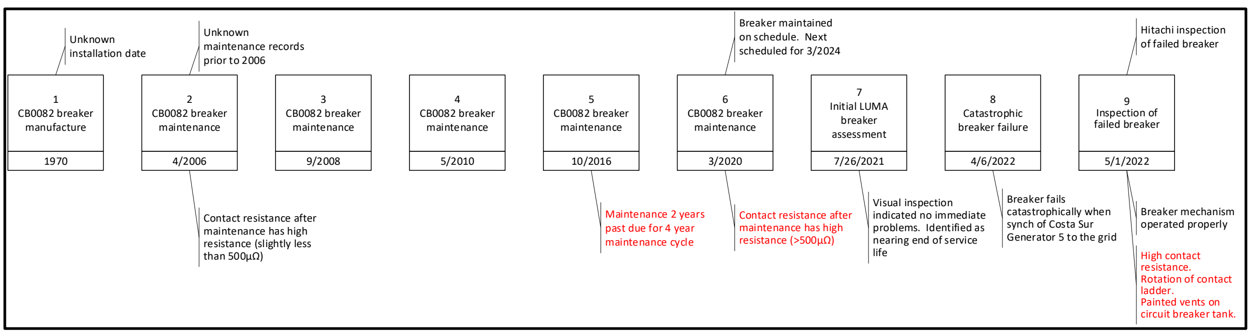

Figure 8: OCB #0082 Maintenance History Timeline

The circuit breaker maintenance was documented for 2006, 2010, 2016, and 2020. The next scheduled maintenance would be 2024. All of the breaker maintenance was performed by PREPA. Key findings from the review of the maintenance data are:

- There was overdue maintenance in 2016 as this passed the four-year inspection interval.

[26] ITE Imperial Corporation: "Instruction Manual for Power Circuit Breakers Type 230kV Transmission Class"; Issue C.

- The maintenance results for contact resistance were recorded after maintenance, as shown in Table 2.

Table 2: OCB #0082 Maintenance Results

Maintenance Year	Contact Resistance after Maintenance (μ-ohms)		
	A Phase	B Phase	C Phase
2006[27]	454	490	472
2010[28]	432	463	470
2016[29]	487	274	488
2020[30]	556	956	608

Based on discussions with the Hitachi representative, contact resistance after maintenance is ideally less than 300 μ-ohms, but should never be more than 500 μ-ohms. Therefore, this circuit breaker has been marginal for some time, and clearly, in 2020, PREPA should not have placed this breaker back into service without a breaker overhaul to address the high contact resistance.

A key observation is that the breaker was inspected in 2020, which would require its next maintenance in 2024. LUMA's visual inspection in 2021 as part of its transition would not have identified issues related to contact resistance.

5.3.3 Breaker Failure Analysis

The circuit breaker failure analysis is described in a separate report.[31] The summary of the failure analysis conclusions is provided here.

It is impossible to know precisely what happened in this event due to two factors. First, Tank B of the circuit breaker OCB #0082 failed catastrophically, destroying all internal tank evidence that would otherwise have provided valuable information (e.g., internal tank arcing, and contact

[27] OCB 0082_MAINTENANCE AND INSPECTION REPORT_SEPTEMBER 2008

[28] OCB 0082_MAINTENANCE AND INSPECTION REPORT_MAY 2010

[29] OCB 0082_MAINTENANCE AND INSPECTION REPORT_OCTOBER 2016

[30] OCB 0082_MAINTENANCE AND INSPECTION REPORT_MARCH 2020

[31] "Failure Analysis of Costa Sur Oil Circuit Breaker 082", Exponent Report, dated August 25, 2022

condition). Second, the digital fault recorder was inoperable at the time of the Incident, making waveform data that would provide fault current information unavailable.

Although it is impossible to know precisely what happened in this event, there is a likely scenario that is consistent with all of the facts in the record. This likely scenario consists of the following sequence of events.

1. Prior to the synchronization of Unit 5, the contact resistance in Tank B of OCB #0082 (Tank B) was too high.
2. When OCB #0082 was closed to connect Unit 5, the synchronization was successful.
3. After synchronization, the current flow through the contacts of Tank B resulted in excessive heating due to the high contact resistance.
4. The excessive heating of the Tank B contacts results in thermal runaway[32], causing extreme temperatures in the contacts and vaporization of the surrounding oil, and the rapid buildup of hydrogen gas.
5. About 5 seconds after synchronization, vaporization of the internal tank oil around the Tank B contact reduces the dielectric strength from the Tank B contacts to grounded components within the tank, resulting in arcing from Phase B to ground.
6. The arcing from B Phase to ground results in:
    a. A ground potential rise in the switchyard grounding grid. This ground potential rise results in arcing at several locations in-and-around the Costa Sur switchyard.
    b. The combination of high Phase B impedance and arcing results in waveform distortion.
7. After about 213 milliseconds of distorted waveforms, a trip command is sent to OCB #0082 by the Unit 5 generator protection system.

[32] The resistance of metallic conductors increases with temperature. Since heat generation is proportional to resistance, a conductor with excessive current can cause a significant increase in conductor temperature. This increase in conductor temperature will further increase conductor resistance, which further increases heat generation. This situation can create a positive feedback loop where conductor temperatures continue to increase until the conductor melts, referred to as thermal runaway.

8. The operating mechanism of OCB #0082 functioned properly during the trip operation. However, the compromised gas within OCB #0082 resulted in sustained arcing across the opening contacts, resulting in further hydrogen gas buildup.
9. The hydrogen gas generated by the internal arcing could not be vented since the vent filters had been painted over.
10. After about 700 milliseconds of internal arcing, Tank B catastrophically fails due to the ignition of combustible gases.

There are no guidelines in the Instruction Manual with regard to contact resistance. Interviews with former PREPA maintenance personnel indicate a maximum acceptable contact resistance of 500 $\mu\Omega$. The Hitachi Energy report (not the instruction manual) states the following:[33]

> *"Contact resistance after maintenance should ideally be less than 300μΩ but never more than 500μΩ."*

Contact resistance measurements were made during scheduled PREPA maintenance activities in both 2016 and 2020, consistent with the 4-year PREPA maintenance cycle. Results are shown in Table 3 (data taken from scanned paper maintenance records (see Appendix A)).

Table 3: B Phase Contact Resistance Measurements

Year	B Phase Contact Resistance (μΩ)	
	Before Maintenance	After Maintenance
2016	2047	274
2020	2112	956

As can be seen, OCB-082 was put back in service, by PREPA, after 2020 maintenance with a B Phase contact resistance of 956 $\mu\Omega$. This is over three times the 300 $\mu\Omega$ recommenced value by Hitachi Energy and almost twice the internal PREPA criterion of 500 $\mu\Omega$. Furthermore, the B Phase contact resistance had a history of increasing to very high levels between maintenance cycles: 2047 $\mu\Omega$ in 2016 and 2112 $\mu\Omega$ in 2020.

[33] Hitachi Energy, *Luma OCB Circuit Breaker Failure: Field Service Inspection Report*, 2022-06-27, p14.

There is no question that the B Phase contact resistance of OCB-82 was unacceptably high at the time of the Incident. Based on contact resistance measurements alone, PREPA should never have put OCB-82 back in service after the 2020 maintenance was performed without reducing the high contact resistance to recommended values.

Additionally, a post-incident site inspection of the Costa Sur 230 kV switchyard found that some circuit breaker tanks of similar vintage to OCB-82 had their tank breathers painted over.[34] Tank breathers exist to vent excess gas accumulation and painting them over can result in an accumulation of combustible gases within the tank. The Hitachi report concludes the following:[35]

> *The catastrophic failure of the tank can only happen if the hydrogen pressure builds up fast enough to cause the arcing inside the breaker from the fault to ignite the hydrogen gas causing the oil tank to fail. This scenario is consistent with the painted-over vents preventing the release of hydrogen from the tank.*

Tank B ruptured in a violent explosion, resulting in a complete separation along the vertical seam weld. This is consistent with hydrogen gas buildup within the tank, which is then ignited by internal arcing.

If both of the OCB-82 tank breathers were painted over, internal arcing would have resulted in hydrogen gas generation that was not able to be vented out of the tank. However, the generation of hydrogen gases occurs rapidly during a long-duration arcing event and may not have time to escape during this time. This hydrogen gas would have been ignited when the contacts attempted to open, resulting in a high-temperature electrical arc within the tank. This scenario is consistent with the damage that occurred to the Phase B tank.

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[34] "Failure Analysis of Costa Sur Oil Circuit Breaker 082", Exponent Report, dated August 25, 2022

[35] Hitachi Energy, *Luma OCB Circuit Breaker Failure: Field Service Inspection Report*, 2022-06-27, p14.

5.4 Power System Stability

The power system stability assessment is described in the LUMA Transmission Reliability Standards and Critical Infrastructure Report.[36] A summary of the results is included here. This report is focused on the event analysis based on the dynamic system stability model. Dynamic stability models have been used for decades throughout the electric power industry. They are used to assess the response of the power system to various events, including faults and equipment outages. Dynamic models are routinely utilized by utilities and regional operators in transmission planning, reliability compliance assessments (e.g., NERC), reconstruction of event sequence, renewable interconnection studies, tuning of generator controls or transmission equipment, and the design of mitigations to prevent load interruptions and cascading outages.

Dynamic stability models include a detailed representation of the time response of each component in the power system. The model components include:

- Turbine-generators models and associated protection and controls (e.g., relays, excitation system, and governor),
- Inverters and associated control of renewable resources (e.g., wind, solar, and storage),
- Load controls and sensitivity to variation in frequency and voltage, and
- Grid protection includes under frequency, under voltage load shedding, and out of step.

At the time of the Incident, there was not a useful power system stability model of the system. LUMA has repeatedly requested the necessary information from PREPA to build this model and still does not have a complete and accurate model because of this. The model that was provided to LUMA from PREPA did not conform to accepted industry practices and was unable to replicate the recordings of the actual system response during two historical outage events from 2019 and essentially used default generation parameters instead of actual parameters provided by the generation facilities. The two events were:

[36] LUMA "Transmission Reliability Standards and Critical Infrastructure", dated July 12, 2022

- Event 1: Two generating units – AES 2 (generating 254 MW) and ECO CT 1 (generating 180 MW) – trip offline on March 19, 2019 at 1613 hours.

- Event 2: Aguirre Unit 1 (generating 300 MW) trips offline on August 2, 2019 at 1350 hours.

The LUMA team embarked on an effort to update the dynamic stability model and to benchmark its performance against the recordings of the two events in 2019, and the recent event on April 6th, 2022. Best industry practices use generator performance data, the actual response to events data, transmission system details and protection, and load profiles in a mathematical simulation. This simulation is then validated against actual system performance. The process being used at this time is missing the performance and specifications of the PREPA generators, and relies on only partial information and includes the following steps:

- The existing model was initially simulated and compared to the 2019 event recordings. This was a necessary step to ensure that the available model is the same that PREPA and its consultant used for the 2019 benchmarking report.

- Detailed analysis of the recordings of the first event in 2019 revealed the need to add load-shedding relays to the model and also to tune the response of the governors of some of the generation units. After incorporating these adjustments into the model, the dynamic model's performance improved. However, these adjustments would then need to be made in the generator and the system.

- Similar detailed analysis and tuning were performed utilizing the recordings of the second recorded event in 2019.

- The third step of the model tuning leveraged the recordings of the Costa Sur event on April 6th, 2022. Being a complete blackout scenario, the recordings showed the timing and system frequency at which several of the generators on the system tripped. This information was utilized to augment the dynamic model with generator protection systems.

- The fourth step utilized good industry practice to reflect more additional protection system representation in the model and tune its settings.

After adjustments to the model that utilized the best available information, the performance of the dynamic stability model improved. However, it is still not deemed to be accurate enough to enable LUMA to design full mitigation measures that reduce the probability of future cascading outage events on the system, or to properly assess the impact of future tranches of renewable procurements on system operation. PREPA needs to collaborate with LUMA to develop the most accurate system model possible by providing the data requested and to help improve the reliability of the electric system on the Island and allow Luma to do performance testing and model development of each of the generating units.

6. Causal Analysis

6.1 Findings and Observations

The evaluation of the various event data, asset history, failure analysis, system protection analysis, system stability analysis, and power generation analysis leads to the following key findings and observations:

- The T&D system that LUMA took over for operations had suffered from deterioration of its maintenance program and severe damage from hurricane and earthquake events.

- Circuit breaker OCB #0082 failed from arcing in the B Phase tank resulting in rupture of the tank.

- Maintenance on OCB #0082 indicated issues with contact resistance and should not have been placed back into service after its 2020 maintenance by PREPA.

- Generation synchronization was performed with several "unknowns" due to a lack of information from the generator data systems; however, the generator appeared to synchronize with the grid for five seconds prior to the generator sending a trip signal to the breaker OCB #0082.

- The protection breaker failure scheme operated appropriately to clear the faults at Costa Sur after the explosion and throughout the system. However, there were several protection element issues that did not perform as intended due to equipment obsolescence and likely lack of maintenance and testing.

- The load shedding scheme failed to prevent the collapse of the system. Evaluation of the system stability model used by PREPA was unable to recreate the event, and the model includes deficiencies relative to assessing system performance.

Based on these key findings, a causal analysis was performed.

6.2 Causal Analysis

The causal analysis was performed using a causal chart in the form of a 5-Whys approach. The events are assessed based on the available data that drives potential root and contributing causes. There are two starting points for the causal analysis:

1. Failure of OCB #0082: The direct cause of the breaker failure was very high contact resistance in the B Phase of the OCB. This resulted in a fault upon opening that led to the creation of gases and subsequent explosion. The failure mode was also influenced by the painted breather holes, which did not allow the escape of gas and the pressure build-up. However, the rapid build-up of gasses and pressure due to high fault energy likely would not have allowed the gases to escape quickly to prevent the explosion. Additionally, while not considered a cause of the event, the protection scheme exhibited some deficiencies due to equipment obsolescence.

2. Response of the system did not prevent system collapse: The system on the Island is very dependent on the generation capacity in Costa Sur complex (Costa Sur and EcoElectrica). The system design and lack of a validated system stability model do not provide sufficient tools to predict the response of the system under significant conditions properly.

The causal analysis is shown in Figure 9 for the circuit breaker failure and Figure 10 for the electric system collapse.

The causal chain for the circuit breaker failure is based on the following:

- The causal chain has two major paths:
    - The first major path is related to maintenance performed by PREPA in 2020.
        - The evidence from the maintenance forms shows very high contact resistance. The past maintenance has also indicated high readings prior to maintenance and then high readings above the desired 300μΩ level.

        - There was a lack of maintenance limits in the PREPA maintenance procedures. A good maintenance practice would be to know and/or determine what an acceptable limit.
        - With maintenance staffing issues, the lack of specific acceptance criteria is problematic as this places extensive weight on the experience of the individual personnel to make effective decisions.
        - Finally, there was a lack of management effectiveness by PREPA in assessing maintenance program risk and decision-making to place the circuit breakers back into service. This is considered a root cause since taking the breaker out of service or overhauling the breaker would have prevented the event.
    - The second major path is related to LUMA's lack of identification of the OCB #0082 condition
        - The LUMA visual inspections in July 2021 did not identify the major problems with the Costa Sur breaker. There was limited ability to retrieve maintenance data for these breakers, and the visual inspection would not identify issues with the contact resistance.
        - The initial assessment by LUMA was intended to identify a major visible problem and was not directed at internal assessment. This assessment would be possible once LUMA completes the retrieval of paper maintenance forms and the development of its computerized maintenance management database. Therefore, this assessment is not considered a potential cause.

The causal chain for the system response not preventing the system collapse is based on the following:

- The causal chain has four "major" paths:
    - The first major path is related to the load shedding scheme.
        - The evidence from the operation is that the under-frequency load shedding scheme is inadequate to handle a major event at the Costa Sur

Steam Plant. Costa Sur and EcoEletrica provide a significant amount of power to the grid, and any issues with these generators carry a risk to system stability.

- There is one causal chain below this:
  - There is an inability to define a proper load shedding scheme.
    - The system stability model does not exist to evaluate and predict events on in the system adequately.[37]
    - There was ineffective PREPA operational management of risk and decision-making by not having a functional system model. This is considered a root cause as a viable system analysis tool would allow the definition of effective load shedding schemes and could have prevented the system collapse.

- The second major path is related to generation synchronization. In this case, the synchronization was less than adequate, and two paths are applicable.
  - The first path is based on the reliance on manual operation and verbal communication and was based on an operating procedure[38] from 1977 that has not been updated and does not reflect the current organizational structure with LUMA as the operator. This path is considered a contributing cause since there is limited information on the generation aspects of this event.
  - The second path is related as there were pre-synchronization inspections required by the generation operator at Costa Sur, and there is no evidence that these inspections were performed by the operator or requested on LUMA. This is also related to the outdated operating procedure and is considered a contributing cause.
- The third major path is related to system protection performance. The protection scheme performed as intended, and there were no incorrect operations of

[37] LUMA "Transmission Reliability Standards and Critical Infrastructure", dated July 12, 2022

[38] Operating Procedure Number 401-C.S.5&6, dated September 1, 1977.

protection that impacted this event in a negative manner[39]. There is no potential cause for this path.

- o The fourth major path is related to system design. The overall design of the system is not modeled adequately, and there appears to be an inability of the system to cope with events on the south side of the Island from Costa Sur. There appear to be insufficient contingencies and generation capacity to handle these issues. Since the system is dependent on Costa Sur, the system design should protect against the contingencies that could take out multiple generators. The Costa Sur Substation has been identified as a NERC CIP 14 Substation from planning studies and therefore must be designed to account for multiple events occurring at a single substation. For this event, this is considered a contributing cause to the event since this condition is not capable of being addressed in the near term and must be part of a long-term plan.

Based on the causal chain, the root and contributing causes of April 6, 2022, outage event are listed below. Root causes are those causes that, if they were removed, then the event would have a high probability of not occurring. Contributing causes are those causes that, if they were removed, had some chance of reducing the likelihood of the event.

- Root Cause 1 (RC1): Ineffective PREPA maintenance management and decision-making, which led to OCB #0082 being placed into service with undocumented maintenance limits, and that resulted in breaker failure due to arcing across the contacts. There were no maintenance guidelines for contact resistance in the PREPA work procedures. This resulted in the circuit breaker being returned to service with high contact resistance. This circuit breaker should not have been returned to service by PREPA with this level of contact resistance.

- Root Cause 2 (RC2): Ineffective PREPA operational management and risk decision-making resulting from not having a system stability model to assist in development load shedding schemes. The lack of a proper model prevented PREPA from developing and

[39] LUMA "Costa Sur Outage Event of 04/06/2022 Progress Report"; NEPR-IN-2022-04, dated July 2022

implementing an effective load shedding scheme. In addition, the lack of transparency of PREPA and response to data requests by LUMA prevent LUMA from developing a model.

- Contributing Cause 1 (CC1): The synchronization protocols (roles and responsibilities) do not match the current organizational structure. The PREPA procedures were developed prior to LUMA, and these procedures were not updated to reflect LUMA operation of the electric transmission and distribution system. This protocol required circuit breaker inspections to be performed prior to synchronization, and there was no evidence that PREPA performed this inspection or requested LUMA to perform this inspection.

- Contributing Cause 2 (CC2): The state of the electric system was not stable and is often not able to prevent cascading events after the loss of major facilities. Addressing this issue will require a long-term effort and transparency from PREPA

These are the primary drivers for the outage event due to the equipment failure at Costa Sur.

Figure 9: Causal Analysis of Failed Circuit Breaker

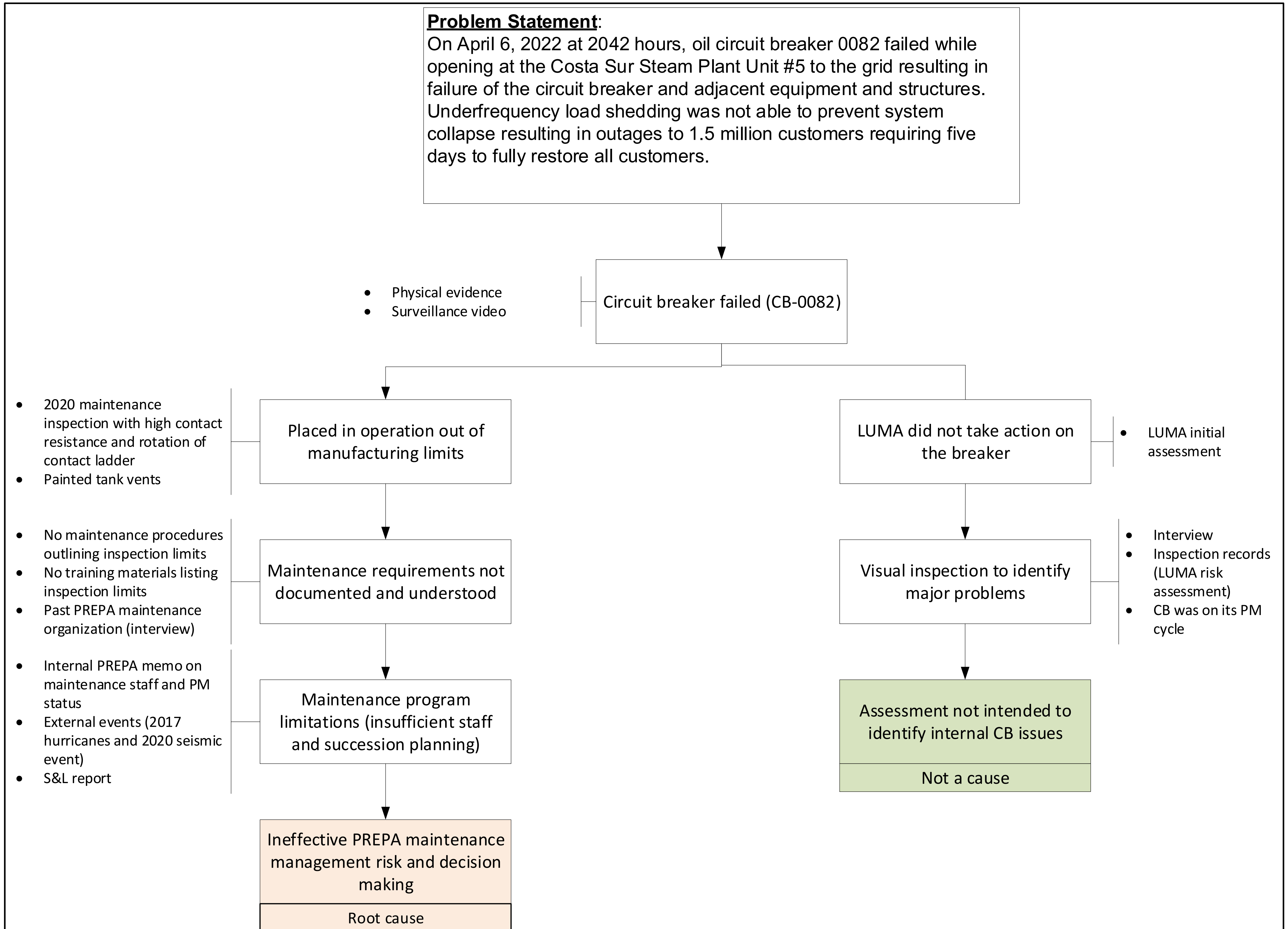
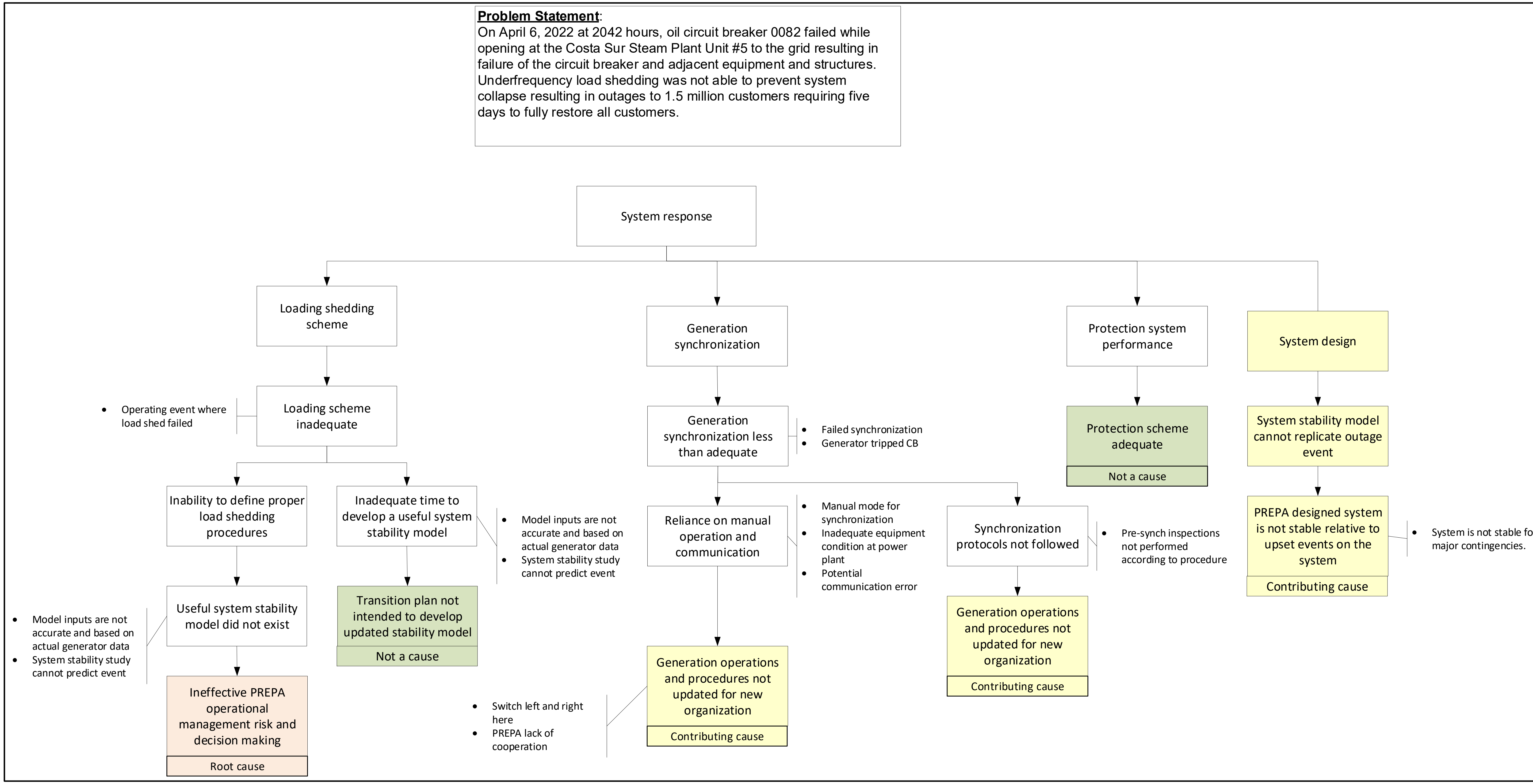


Figure 10: Causal Analysis : System Response



7. Recommended Corrective Actions

The key to a successful causal evaluation is the identification of corrective actions to prevent the recurrence of the event. The recommendations for the causes identified are listed below.

Table 4: Recommended Corrective Actions

Cause	Recommended Corrective Action	Action Owner
Root Cause 1 (RC1): Ineffective PREPA maintenance management and decision-making, which led to OCB #0082 being placed into service with undocumented maintenance limits, and that resulted in breaker failure due to arcing across the contacts. There were no maintenance guidelines for contact resistance in the PREPA work procedures. This resulted in the circuit breaker being returned to service with high contact resistance. This circuit breaker should not have been returned to service by PREPA with this level of contact resistance.	CA1: Complete maintenance bases for circuit breakers and update maintenance procedures to include limits for pass/fail for inspection and maintenance. CA2: Extend maintenance bases to other critical assets and update maintenance procedures accordingly. CA3: Evaluate ITT oil circuit breakers for similar issues relative to OCB #0082 and perform maintenance and overhauls as needed. CA4: Expedite Costa Sur capital program based on recent funding approvals.	LUMA
Root Cause 2 (RC2): Ineffective PREPA operational management and risk decision-making resulting from not having a system stability model to assist in development load shedding schemes. The lack of a proper model prevented PREPA from developing and implementing an effective load shedding scheme. In addition, the	CA5: Update and revise the system stability model to include the following: • Field testing and model development of each of the generation units. This should include the generator, the turbine, the exciter, the power system stabilizer, and the governor models.	LUMA

lack of transparency of PREPA and response to data requests by LUMA prevent LUMA from developing a model.	• Review and update the protection system settings in the model, based on actual relays in the field. • Extensive testing of the model against potential scenarios and observed system events. • Review and update under frequency load shedding schemes	
Contributing Cause 1 (CC1): The synchronization protocols (roles and responsibilities) do not match the current organizational structure. The PREPA procedures were developed prior to LUMA, and these procedures were not updated to reflect LUMA operation of the electric transmission and distribution system. This protocol required circuit breaker inspections to be performed prior to synchronization, and there was no evidence that PREPA performed this inspection or requested LUMA to perform this inspection.	CA6: Generation synchronization protocols should be reviewed and updated for all PREPA facilities relative to the change in operating structure for the electric system to ensure roles and responsibilities are well understood	PREPA / LUMA
Contributing Cause 2 (CC2): The state of the electric system was not stable and is often not able to prevent cascading events after the loss of major facilities. Addressing this issue will require a long-term effort by LUMA and transparency from PREPA	CA7: Develop a long-term plan for the overall electric system to identify vulnerabilities in system design and operation; and to define future mitigation actions.	LUMA

8. Conclusions

At 2042 hours on Wednesday, April 6th, 2022, a fault occurred in the 230 kV switchyard of the Costa Sur Steam Plant (SP). Phase B of Oil-Circuit Breaker (OCB) #0082 suffered a catastrophic failure. The failure affected four adjacent circuit breakers and several portions of the substation's lattice structures. Due to the circuit breaker's failure, the 230 kV circuits at Costa Sur SP needed to open to clear the fault, which disconnected EcoEléctrica Generating Facility from the grid and resulted in subsequent outage events that cascaded into a full blackout of Puerto Rico's electrical system. LUMA has retained Exponent to perform a root cause analysis of the incident. The objectives of this analysis are to determine the root and contributing causes of this event and to define the actions to reduce the potential for future events.[40]

The evaluation of the various event data, asset history, failure analysis, system protection analysis, system stability analysis, and power generation analysis leads to the following key findings and observations:

- The system that LUMA took over for operations had suffered from deterioration of its maintenance program and severe damage from hurricane and earthquake events.

- Circuit breaker OCB #0082 failed from arcing in the B Phase tank resulting in rupture of the tank.

- Maintenance on OCB #0082 indicated issues with contact resistance and should not have been placed back into service after its 2020 maintenance by PREPA.

[40] LUMA "Costa Sur Outage Event of 04/06/2022 Progress Report"; NEPR-IN-2022-04, dated July 2022

- Generation synchronization was performed with several “unknowns” due to a lack of information from the generator data systems; however, the generator appeared to synchronize with the grid for five seconds prior to the generator sending a trip signal to the breaker OCB #0082. No data exists to show if there were any issues during this synchronization with the grid.

- The protection scheme operated appropriately to clear the faults at Costa Sur and throughout the system.

- The load shedding scheme failed to prevent the collapse of the system.

- Evaluation of the system stability model used by PREPA was unable to recreate the event, and the model includes deficiencies relative to assessing system performance.

The root and contributing causes of the April 6, 2022, outage event are listed below. Root causes are those causes that, if removed, the event would have a high probability of not occurring. Contributing causes are those causes that, if they were removed, had some chance of reducing the likelihood of the event.

- Root Cause 1 (RC1): Ineffective PREPA maintenance management and decision-making, which led to OCB #0082 being placed into service with undocumented maintenance limits, and that resulted in breaker failure due to arcing across the contacts. There were no maintenance guidelines for contact resistance in the PREPA work procedures. This resulted in the circuit breaker being returned to service with high contact resistance. This circuit breaker should not have been returned to service by PREPA with this level of contact resistance.

- Root Cause 2 (RC2): Ineffective PREPA operational management and risk decision-making resulting from not having a system stability model to assist in development load shedding schemes. The lack of a proper model prevented PREPA from developing and implementing an effective load shedding scheme. In addition, the lack of transparency of PREPA and response to data requests by LUMA prevent LUMA from developing a model.

- Contributing Cause 1 (CC1): The synchronization protocols (roles and responsibilities) do not match the current organizational structure. The PREPA procedures were developed prior to LUMA, and these procedures were not updated to reflect LUMA operation of the electric transmission and distribution system. This protocol required circuit breaker inspections to be performed prior to synchronization, and there was no evidence that PREPA performed this inspection or requested LUMA to perform this inspection.

- Contributing Cause 2 (CC2): The state of the electric system was not stable and is often not able to prevent cascading events after the loss of major facilities. Addressing this issue will require a long-term effort by LUMA and transparency from PREPA

Corrective actions have been recommended to address these causes, including:

- CA1: Complete maintenance bases for circuit breakers and update maintenance procedures to include limits for pass/fail for inspection and maintenance.

- CA2: Extend maintenance bases to other critical assets and update maintenance procedures accordingly.

- CA3: Evaluate oil circuit breakers for similar issues relative to OCB #0082

- CA4: Expedite Costa Sur capital program based on recent funding approvals.

- CA5: Update and revise the system stability model to include the following:

    - Field testing and model development of each of the generation units. This should include the generator, the turbine, the exciter, the power system stabilizer, and the governor models.

    - Review and update the protection system settings in the model, based on actual relays in the field.

    - Extensive testing of the model against potential scenarios and observed system events.

    - Review and update under frequency load shedding schemes

- CA6: Generation synchronization protocols should be reviewed and updated for all PREPA facilities relative to the change in operating structure for the electric system to ensure roles and responsibilities are well understood.

- CA7: Develop a long-term plan for the overall electric system to identify vulnerabilities in system design and operation; and to define future mitigation actions.

9. References

1. LUMA "Costa Sur Outage Event of 04/06/2022 Progress Report"; NEPR-IN-2022-04, dated July 2022

2. "Puerto Rico Outage Investigation: Costa Sur Power Plant"; Exponent Report, dated September 9, 2022

3. "Failure Analysis of Costa Sur Oil Circuit Breaker 082", Exponent Report, dated August 25, 2022

4. Transmittal # LUMA-PREP-T-00267 "Response to PREPA's Letter Regarding Costa Sur OCB #0082 Event Investigation"; dated June 3, 2022

5. PREPA Letter "Análisis Estadístico y Proyectado de la Conservación de Equipos Eléctricos de la Subdivisión de Conservación Eléctrica"; dated October 19, 2016.

6. "Independent Engineering Report PREPA Transmission and Distribution System" prepared by Sargent & Lundy, Report No. SL-014468.TD, dated June 2019

7. "Puerto Rico Transmission and Distribution System Operation and Maintenance Agreement" between PREPA, LUMA and the Puerto Rico Public-Private Partnerships Authority (Administrator); dated June 22, 2020

8. LUMA "Substation Assessment Costa Sur"; dated July 26, 2021

9. DR-4339-PR Public Assistance "Project Scope of Work with Cost Estimates Submitted to COR and FEMA; Substations – Costa Sur SP TC – Equipment Repair and Replacement 169896, dated February 1, 2021.

10. Department of Homeland Security Federal Emergency Management Agency, Project 169896 Approval; dated July 28, 2022.

11. PREPA Operating Procedure Number 401-C.S.5&6, dated September 1, 1977.

12. ITE Imperial Corporation: "Instruction Manual for Power Circuit Breakers Type 230kV Transmission Class"; Issue C.

13. OCB 0082_MAINTENANCE AND INSPECTION REPORT_SEPTEMBER 2008

14. OCB 0082_MAINTENANCE AND INSPECTION REPORT_MAY 2010

15. OCB 0082_MAINTENANCE AND INSPECTION REPORT_OCTOBER 2016

16. OCB 0082_MAINTENANCE AND INSPECTION REPORT_MARCH 2020

17. Hitachi Energy, *LUMA OCB Circuit Breaker Failure: Field Service Inspection Report*, 2022-06-27, p14.

18. LUMA "Transmission Reliability Standards and Critical Infrastructure", dated July 12, 2022

Appendix A

Oil Circuit Breaker #0082 Maintenance Records

Costa Sur Steam Plant Transmission Center 230kV OCB-0082

Maintenance Record -- 2010

AEE 015.4-55
REV.6/81

PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE **091-00-00-07**

JOB NO. ________ A.D. ( ) S.D. ( )	DATE 10-14/Mayo/2010
LOCATION Central Costa Sur	DISPATCHER ORDER NO.
EQUIPMENT OCB 0082 de 230 kv	MANUFACTURER I.T.E.
REQUESTED BY *Ing. Ricardo L. Tristani Serrano*	EQUIPMENT S.N. 41-30125-1085
WORK TO BE PERFORMED Pruebas y Conservación	SCHEDULE YES (X) NO ( )

INSPECTION OR WORK PERFORMED	MAN- HOURS
Equipo fuera de servicio para conservación. Se realizaron pruebas preliminares de las cuales se acompaña copia y cuyos resultados obtenidos estan dentro de los límites permitidos para operación. Se tomaron las medidas exteriores del mecanímo.	187.5 *H.Regs.*
Se procedió a bajar el nivel de aceite aprox. 1960 gls del tanque #1 con la maquina baron 3-6646. Se procedió a recircular el mismo para filtrarlo. Se sacaron las cámaras interuptoras y se desmontaron afuera. Se encontraron los contactos movibles desgastados, se limpiaron y se reacondicionaron.	37.5 *H.Extra* 225 *H.Total*
Se limpiaron rigurosamente en su interior. Se ensamblaron y se instalaron en el tanque. Se verificó la aislación auxiliar interna y está en perfectas condiciones. Se tomaron todas las medidas correspondientes. Se limpió el tanque en su interior. Se devolvió el aceite ya filtrado.	
Se procedió a bajar el nivel de aceite aprox. 1960 gls del tanque #2 con la maquina baron 3-6646. Se procedió a recircular el mismo para filtrarlo. Se sacaron las cámaras interuptoras y se desmontaron afuera. Se encontraron los contactos movibles desgastados, se limpiaron y se reacondicionaron.	
Se limpiaron rigurosamente en su interior. Se ensamblaron y se instalaron en el tanque. Se verificó la aislación auxiliar interna y está en perfectas condiciones. Se tomaron todas las medidas correspondientes. Se limpió el tanque en su interior. Se devolvió el aceite ya filtrado.	
Se procedió a bajar el nivel de aceite aprox. 1960 gls del tanque #3 con la maquina baron 3-6646. Se procedió a recircular el mismo para filtrarlo. Se sacaron las cámaras interuptoras y se desmontaron afuera. Se encontraron los contactos movibles desgastados, se limpiaron y se reacondicionaron.	
Se remplazó bareta principal por estar agrietada.	
Se limpiaron rigurosamente en su interior. Se ensamblaron y se instalaron en el tanque. Se verificó la aislación auxiliar interna y está en perfectas condiciones. Se tomaron todas las	
medidas correspondientes. Se limpió el tanque en su interior. Se devolvió el aceite ya filtrado.	***Regular:*** $6,070.16
Se limpiaron los bushings con collinite.	***Extra:*** $1,516.12
Se lubricó el mecanismo exterior y se inspeccionó el mecanismo inerior y no se encontró	***Dietas:*** $200.00
nada anormal.	***Total:*** $7,785.28

R.V.
R.Díaz, S.Miranda, J.Anés
WORK PERFORMED BY

14/Mayo/2010
DATE

Ing. Eddie William Rivera
SUPERVISOR

AEE 015.4-65
REV.6/81

PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE **091-00-00-07**

JOB NO. ________ A.D. ( ) S.D. ( )

DATE 10-14/Mayo/2010

LOCATION Central Costa Sur

DISPATCHER ORDER NO. ________

EQUIPMENT OCB 0082 de 230 kv

MANUFACTURER I.T.E.

REQUESTED BY *Ing. Ricardo L. Tristani Serrano*

EQUIPMENT S.N. 41-30125-1085

WORK TO BE PERFORMED Pruebas y Conservación

SCHEDULE YES (X) NO ( )

INSPECTION OR WORK PERFORMED | **MAN- HOURS**

MEDIDAS

LIMITES	*DIMENSIÓN*	*TANQUE#1*	*TANQUE#2*	*TANQUE#3*
3 1/8, 1/32	*L*	3 1/2 IN	3 9/16 IN	3 1/2 IN
1 ½,1/32	*J (1 17/32 IN)*	N/A	N/A	N/A
3 ½, 1/8	*D*	1) 3 7/16, 2)3 5/8	3)3 3/8, 4)3 3/8	5)3 1/2,6)3 9
5/32, 1/32	*T*	1) 5/32, 2) 5/32	3) 5/32, 4) 5/32	5) 5/32, 6)5/3
2 5/8, 1/4	*O.L. DASHPOT*	2 5/8 IN	2 1/2 IN	2 1/2 IN
3/32, 1/8	*C*	1) 3/32, 2) 1/16	3) 3/32, 4)3/32	5)5/64, 6)3/32
20, 3/4	*A (STOKE)*	19 3/4 IN	19 13/16 IN	20 in
15/16, 3/16	*C.WIPE*	5/8 IN	13/16 IN	5/8 IN
	RESISTORS	1)2446, 2)2434	3) 2412, 4) 2382	5)2512, 6)24

Se realizaron pruebas de velocidad y se ajustó la velocidad de disparo.

Se recomienda el equipo para servicio.

R.Ve...
R.Di... S.Miranda, J.Anés
WORK PERFORMED BY

14/Mayo/2010
DATE

Ing. Eddie William Rivera
SUPERVISOR

DOBLE Test Assistant - Oil Circuit Breaker

Nameplate - Oil Circuit Breaker

Company	PREPA	Serial Number	41-30125-1085
Location	COSTA SUR 230KV	Special ID	091-00-00-07
Division	C.E.P.S.E.	Circuit Designation	OCB-0082
Manufacturer	ITE	Type	230-KM-20000-20
Yr. Manufactured	1970	Class	
Mfr. Location	USA	Mech. Type	P-45A
Oil Volume	1960 UG	BIL	900 kV
Weight	84060	Interrupting Rating	43.0 kA
# of Tanks	3	Counter	
Control Volts	125	Amps	2000
kV	242		
Note	TESTED BEFORE MAINTENANCE:		

Test Date	5/10/2010	Test Time	1:19:06 PM	Weather	SUNNY
Air Temperature	31 °C	Tank Temp.	38 °C	RH.	48 %
Tested by		Work Order #		Last Test Date	7/18/2001
Checked by		Test Set Type		Retest Date	
Checked Date		Set Top S/N		Reason	BRKR MAINT.
Last Sheet #		Set Bottom S/N			

Bushing Namplate

Dsg	Serial	Mfr	Type	C1 % PF	C1 Cap	C2 % PF	C2 Cap	kV	Amps	Year
1	1687361	GE	U	.27	459		4223	146	2000	1970
2	1687345	GE	U	.25	453		4282	146	2000	1970
3	1686334	GE	U	.26	460		4285	146	2000	1970
4	1686332	GE	U	.25	458		4552	146	2000	1970
5	1686333	GE	U	.25	459		4235	146	2000	1970
6	1686329	GE	U	.26	457		4408	146	2000	1970

Overall Tests

Energize	Bus Ft	Ins. #	Ph.	Test kV	mA	Watts	%PF corr	Corr Fctr	TLI	IR_{auto}	IR_{man}
1	15	6	C	10.003	2.888	0.2420	0.80	0.95			
2	15	6	C	10.003	2.873	0.2210	0.74	0.96		G	
3	15	6	B	10.003	2.877	0.2550	0.85	0.95		G	
4	15	6	B	10.003	2.848	0.1990	0.67	0.96		G	
5	15	6	A	10.002	2.880	0.2520	0.84	0.95		G	
6	15	6	A	10.003	2.883	0.2040	0.68	0.96		G	
1,2	30	12	C	10.004	5.530	0.4090	0.74	1.00		G	
3,4	30	12	B	10.003	5.559	0.4430	0.80	1.00	-0.054	G	
5,6	30	12	A	10.002	5.549	0.4230	0.76	1.00	-0.011	G	
									-0.033	G	

Bushing C1

ID	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
1	10.003	1.718	0.0680	0.39	0.97	455.64	G	
2	10.003	1.700	0.0920	0.52	0.96	450.85	D	
3	10.005	1.734	0.0940	0.52	0.97	460.03	D	
4	10.004	1.717	0.0730	0.42	0.97	455.40	G	
5	10.004	1.735	0.0830	0.47	0.97	460.31	G	
6	10.004	1.709	0.0650	0.37	0.97	453.25	G	

Bushing C2

ID	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
1	0.5000	15.973	0.6280	0.39	1.00	4237.0	G	
2	0.4990	16.252	0.6480	0.40	1.00	4311.0	G	
3	0.4990	16.190	0.8400	0.52	1.00	4294.4	G	
4	0.5000	16.073	0.8710	0.54	1.00	4263.4	G	
5	0.5000	16.318	0.8140	0.50	1.00	4328.3	G	
6	0.4990	16.611	0.7800	0.47	1.00	4406.2	G	

Insulating Fluid Tests

Sample Location	Deg C	Test kV	mA	Watts	%PF corr.	Corr Fact	IR_{auto}	IR_{man}
TANK#1	36	10.003	0.9000	0.0150	0.08	0.48	G	
TANK#2	36	10.003	0.9080	0.0070	0.04	0.48	G	
TANK#3	36	10.002	0.9040	0.0400	0.21	0.48	G	

Oil Quality Tests

Desc.	Color	ASTM D1816	ASTM D877	Total part. per 10ml	Water Content	Neutral Number
Tank 1	1.0		26.0			
Tank 2	1.0		24.0			
Tank 3	1.0		16.0			

Insulation Resistance

Mfr.		Serial #			
Open Breaker Tests					
Volts	Connection		T1	T2	PI

Contact Resistance

Mfr.		Serial #			
Closed Breaker Tests					
Volts	Connection	T1(Mohms)	T2(Mohms)	PI	Contact Res.(μOhms)

	Tank 1					864
	Tank 2					933
	Tank 3					935
Note						

Nameplate - Oil Circuit Breaker

Company	PREPA	**Serial Number**	41-30125-1085
Location	COSTA SUR 230KV	**Special ID**	091-00-00-07
Division	C.E.P.S.E.	**Circuit Designation**	OCB-0082
Manufacturer	ITE	**Type**	230-KM-20000-20
Yr. Manufactured	1970	**Class**	
Mfr. Location	USA	**Mech. Type**	P-45A
Oil Volume	1960 UG	**BIL**	900 kV
Weight	84060	**Interrupting Rating**	43.0 kA
# of Tanks	3	**Counter**	
Control Volts	125	**Amps**	2000
kV	242		
Note	TESTED AFTER MAINTENANCE:		

Test Date	5/14/2010	**Test Time**	10:00:37 AM	**Weather**	SUNNY
Air Temperature	37 °C	**Tank Temp.**	32 °C	**RH.**	37 %
Tested by		**Work Order #**		**Last Test Date**	5/10/2010
Checked by		**Test Set Type**		**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	BRKR MAINT.
Last Sheet #		**Set Bottom S/N**			

Bushing Namplate

Dsg	Serial	Mfr	Type	C1 % PF	C1 Cap	C2 % PF	C2 Cap	kV	Amps	Year
1	1687361	GE	U	.27	459		4223	146	2000	1970
2	1687345	GE	U	.25	453		4282	146	2000	1970
3	1686334	GE	U	.26	460		4285	146	2000	1970
4	1686332	GE	U	.25	458		4552	146	2000	1970
5	1686333	GE	U	.25	459		4235	146	2000	1970
6	1686329	GE	U	.26	457		4408	146	2000	1970

Overall Tests

Energize	Bus Ft	Ins. #	Ph.	Test kV	mA	Watts	%PF corr	Corr Fctr	TLI	IR_{auto}	IR_{man}
1	15	6	C	10.003	2.853	0.1470	0.50	0.96			
2	15	6	C	10.003	2.875	0.1650	0.55	0.96		G	
3	15	6	B	10.003	2.869	0.1940	0.65	0.96		G	
4	15	6	B	10.002	2.844	0.1480	0.50	0.96		G	
5	15	6	A	10.003	2.872	0.1880	0.62	0.96		G	
6	15	6	A	10.003	2.874	0.1480	0.49	0.96		G	
1,2	30	12	C	10.002	5.517	0.2860	0.52	0.96		G	
3,4	30	12	B	10.003	5.520	0.3230	0.59	1.00	-0.026	G	
5,6	30	12	A	10.003	5.524	0.3060	0.55	1.00	-0.019	G	
								1.00	-0.030	G	

Insulating Fluid Tests

Sample Location	Deg C	Test kV	mA	Watts	%PF corr.	Corr Fact	IR_{auto}	IR_{man}
TANK # 1	31	10.003	0.9020	0.0080	0.05	0.61	G	
TANK # 2	31	10.003	0.9010	0.0120	0.08	0.61	G	
TANK # 3	31	10.003	0.9010	0.0130	0.09	0.61	G	

Oil Quality Tests

Desc.	Color	ASTM D1816	ASTM D877	Total part. per 10ml	Water Content	Neutral Number
Tank 1	1		30			
Tank 2	1		31			
Tank 3	1		31			

Insulation Resistance

Mfr.		Serial #				
Open Breaker Tests						
Volts	Connection			T1	T2	PI

Contact Resistance

Mfr.		Serial #			
Closed Breaker Tests					
Volts	Connection	T1(Mohms)	T2(Mohms)	PI	Contact Res.(μOhms)
	Tank 1				432
	Tank 2				463
	Tank 3				470
Note					

BREAKER PERFORMANCE REPORT
TDR9000 Version: RE 4.01

Manufacturer : I.T.E.
Model Number : 230-KM-20000-20
Serial Number: 41-30125-1085
Instr Book # :
Mechanism # : PA-45A
Mech Instr # :
Special ID : 091-00-00-07
:

Location: Sample Location 1
Circuit : OCB 0082
Operator: ING.E.W.RIVERA

Operation Counter :
:

Test Type : TRIP-FREE

Test Plan Name :

Test was performed on 5/14/2010 at 11:19:09.

Motion Channels 1-3 Transfer Function
1.000 in Travel at the contacts is 1.000 in Travel at the transducer.

Command Parameters	Trip Pulse 390.00 cy	Delay 1 0.50 cy	Close Pulse (Standing)	8.00 cy
Command Currents	Trip Current	7.86 A pk	Close Current	0.03 A pk

OCB CONTACT TIMING
TRIP-FREE OPERATION

Trip-Free Dwell Time Within a Phase

Specifications	Test results			Compare
Maximum******** cy	Phase A		cy	
Minimum********	Phase B	2.06		
	Phase C	2.08		

Trip-Free Dwell Time Within the Breaker

Specifications	Test results		Compare
	Breaker	cy	

Main Contact Closing Time Measured From Test Initiation

Specifications	Test results			Travel	Velocity	Compare
Maximum******** cy	CONTACT1		cy	******* in	****** ft/s	
Minimum********	CONTACT2	15.87		*******	******	
	CONTACT3	15.82		*******	******	

Delta Main Contact Closing Time Within the Breaker

Specifications	Test results		Compare
Maximum******** cy	Breaker	0.05 cy	

Main Contact Opening Time Measured From Test Initiation

Specifications		Test results		Travel	Velocity	Compare
Maximum******** cy	CONTACT1		cy	******* in	****** ft/s	
Minimum********	CONTACT2	17.93		*******	******	
	CONTACT3	17.90		*******	******	

Delta Main Contact Opening Time Within the Breaker

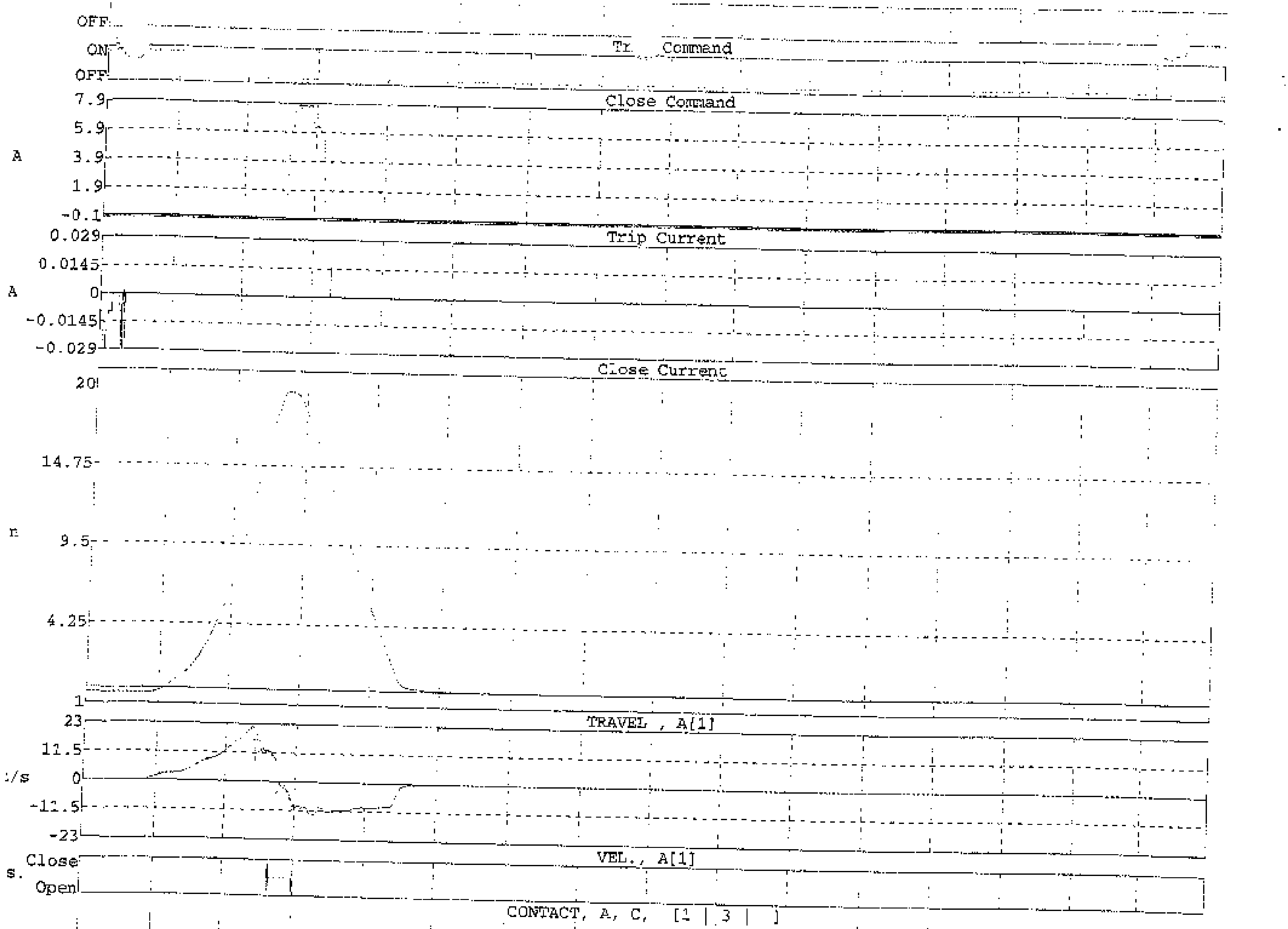
Specifications	Test results		Compare
Maximum******** cy	Breaker	0.02 cy	

User Notes

Page 1

Page 2

Page 3



OFF
ON
OFF
Tr Command
Close Command
7.9
5.9
A
3.9
1.9
-0.1
0.029
Trip Current
0.0145
A
0
-0.0145
-0.029
Close Current
20
14.75
9.5
4.25
1
23
TRAVEL , A[1]
11.5
0
-11.5
-23
Close
Open
VEL., A[1]
CONTACT, A, C, [1 | 3 |]
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96

BREAKER PERFORMANCE REPORT
TDR9000 Version: RE 4.01

Manufacturer : I.T.E.
Model Number : 230-KM-20000-20
Serial Number: 41-30125-1085
Instr Book # :
Mechanism # : PA-45A
Mech Instr # :
Special ID : 091-00-00-07
:

Location: Sample Location 1
Circuit : OCB 0082
Operator: ING.E.W.RIVERA

Operation Counter :
:

Test Type : TRIP

Test Plan Name :

Test was performed on 5/14/2010 at 11:31:15.

Motion Channels 1-3 Transfer Function
1.000 in Travel at the contacts is 1.000 in Travel at the transducer.

Command Parameters Trip Pulse 4.00 cy

Command Currents Trip Current 7.86 A pk

MECHANICAL MOTION CHANNELS 1-3
TRIP OPERATION

Specifications	Test results	Compare
Average velocity in Open zone 1		
Maximum 12.00 ft/s Minimum 10.00 Zone 1 1.000 in to 5.000 in	VEL.1 10.90 ft/s	Pass
Total Travel		
Expected 20.000 inches Tolerance + 0.750 - 0.750	TRAVEL 1 19.915 inches TRAVEL 2 TRAVEL 3	Pass
Overtravel		
Expected 0.000 inches Tolerance + 0.032 - 0.000	TRAVEL 1 0.014 inches TRAVEL 2 TRAVEL 3	Pass
Rebound		
Expected 0.063 inches Tolerance + 0.000	TRAVEL 1 0.059 inches TRAVEL 2	Pass

- 0.063 | TRAVEL 3

OCB CONTACT TIMING - MOTION CHANNELS 1-3
TRIP OPERATION

Main Contact Opening Time Measured From Test Initiation

Specifications	Test results		Travel	Velocity	Compare
Maximum******** cy	CONTACT1	2.03 cy	******* in	****** ft/s	
Minimum********	CONTACT2	2.21	*******	******	
	CONTACT3	2.08	*******	******	

Delta Main Contact Opening Time Within the Breaker

Specifications	Test results		Compare
Maximum******** cy	Breaker	0.18 cy	

Insertion Resistor Duration Time

Specifications	Test results		Compare
Maximum******** cy	CONTACT1	0.04 cy	
Minimum********	CONTACT2	0.01	
	CONTACT3	0.07	

Resistor Switch Opening Time Measured From Test Initiation

Specifications	Test results		Travel	Velocity	Compare
	CONTACT1	2.07 cy	******* in	****** ft/	
	CONTACT2	2.21	*******	******	
	CONTACT3	2.15	*******	******	

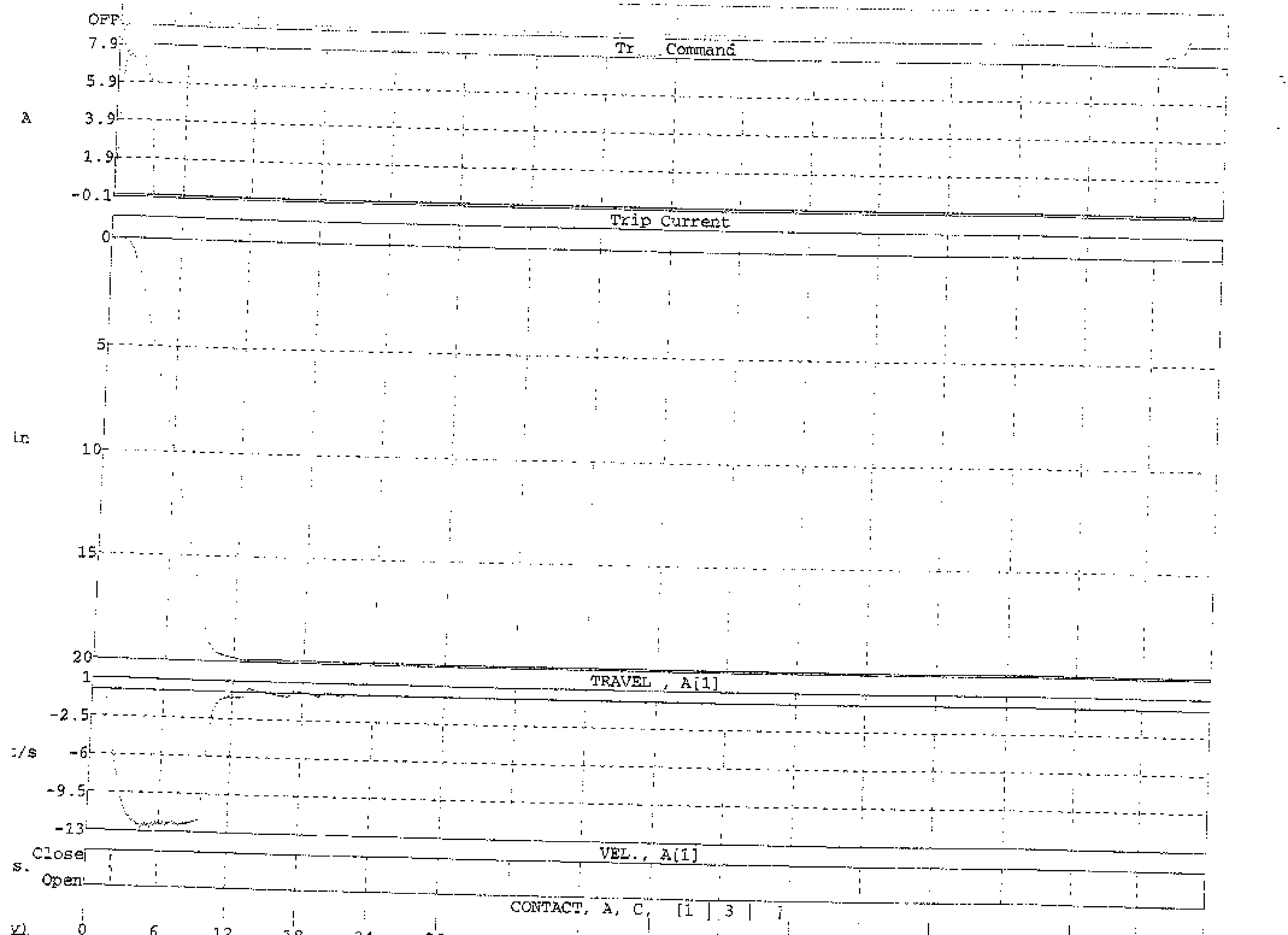
Delta Resistor Switch Opening Time Within the Breaker

Specifications	Test results		Compare
Maximum******** cy	Breaker	0.14 cy	

Resistor Value

Specifications	Test results		Compare
Maximum ****** ohms	CONTACT1	ohms	
Minimum ******	CONTACT2		
	CONTACT3		

User Notes



R9000 Sample Location 1 230-KM-20000-20 091-00-00-07 5/14/2010 11:31 - 091-00-00-07 41-30125-1085 230-KM-20000-20 Trip Page 1

BREAKER PERFORMANCE REPORT
TDR9000 Version: RE 4.01

Manufacturer : I.T.E.
Model Number : 230-KM-20000-20
Serial Number: 41-30125-1085
Instr Book # :
Mechanism # : PA-45A
Mech Instr # :
Special ID : 091-00-00-07
:

Location: Sample Location 1
Circuit : OCB 0082
Operator: ING.E.W.RIVERA

Operation Counter :
:

Test Type : CLOSE

Test Plan Name :

Test was performed on 5/14/2010 at 11:32:02.

Motion Channels 1-3 Transfer Function
1.000 in Travel at the contacts is 1.000 in Travel at the transducer.

Command Parameters Close Pulse 8.00 cy

Command Currents Close Current 0.03 A pk

MECHANICAL MOTION CHANNELS 1-3
CLOSE OPERATION

Specifications	Test results	Compare
Average velocity in Close zone 1		
Maximum 20.00 ft/s Minimum 12.00 Zone 1 5.000 in to 1.000 in	VEL.1 13.86 ft/s	Pass
Total Travel		
Expected 20.000 inches Tolerance + 0.750 - 0.750	TRAVEL 1 19.920 inches TRAVEL 2 TRAVEL 3	Pass
Overtravel		
Expected 0.250 inches Tolerance + 0.125 - 0.250	TRAVEL 1 0.243 inches TRAVEL 2 TRAVEL 3	Pass
Rebound		
Expected 0.125 inches Tolerance + 0.125	TRAVEL 1 0.081 inches TRAVEL 2	Pass

- 0.125	TRAVEL 3		

Contact Wipe

Expected 0.625 inches Tolerance + 0.250 - 0.125	TRAVEL 1 0.635 inches TRAVEL 2 TRAVEL 3		Pass

OCB CONTACT TIMING - MOTION CHANNELS 1-3
CLOSE OPERATION

Main Contact Closing Time Measured From Test Initiation

Specifications	Test results		Travel	Velocity	Compare
Maximum******** cy	CONTACT1	15.44 cy	******* in	****** ft/s	
Minimum********	CONTACT2	15.46	*******	******	
	CONTACT3	15.44	*******	******	

Delta Main Contact Closing Time Within the Breaker

Specifications	Test results		Compare
Maximum******** cy	Breaker	0.02 cy	

Insertion Resistor Duration Time

Specifications	Test results		Compare
Maximum******** cy	CONTACT1	0.01 cy	
Minimum********	CONTACT2	0.02	
	CONTACT3	0.07	

Resistor Switch Closing Time Measured From Test Initiation

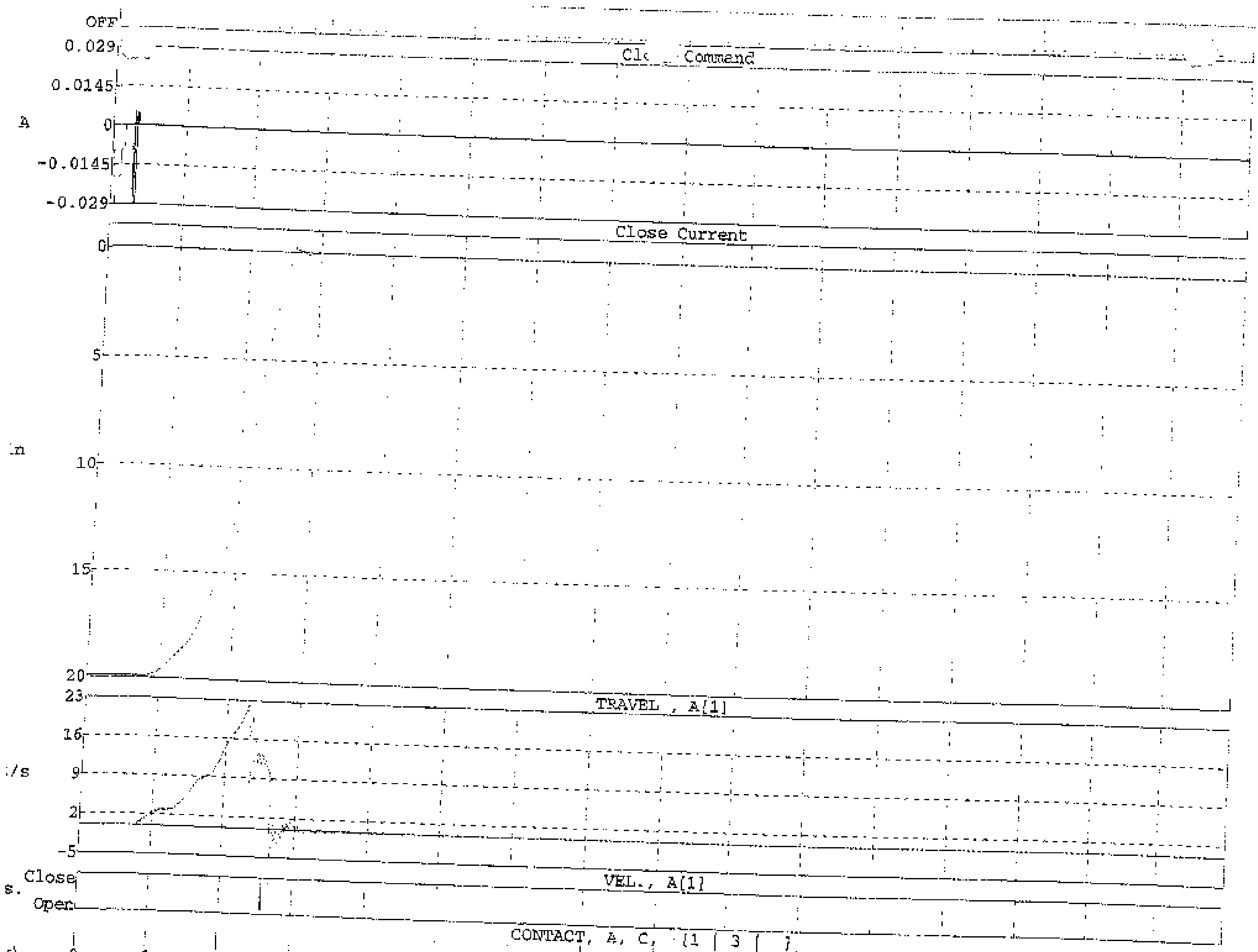
Specifications	Test results		Travel	Velocity	Compare
	CONTACT1	15.43 cy	******* in	****** ft/	
	CONTACT2	15.43	*******	******	
	CONTACT3	15.38	*******	******	

Delta Resistor Switch Closing Time Within the Breaker

Specifications	Test results		Compare
Maximum******** cy	Breaker	0.05 cy	

Resistor Value

Specifications	Test results	Compare



R9000 Sample Location 1 230-KM-20000-20 091-00-00-07 5/14/2010 11:31 - 091-00-00-07 41-30125-1085 230-KM-20000-20 Close Page 1

Costa Sur Steam Plant Transmission Center 230kV OCB-0082

Maintenance Record -- 2016

AEE 015.4-55
REV. 6/81

PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE **091-00-000-007**

JOB NO.		A.D. ☐ S.D. ☐	DATE 1 Y 2 OCTUBRE 2016
LOCATION	CENTRAL COSTA SUR PATIO 230 KV	DISPATHER ORDER NO.	1@10
EQUIPMENT	OCB 0082T	MANUFACTURER	ITE
REQUISTED	ING. EDDIE W. RIVERA BERMUDEZ	EQUIPMENT S.N.	41-30125-1085
WORK TO BE PERFORMED	CONSERVACIÓN	SCHEDULE	YES ☒ NO ☐

INSPECTION OR WORK PERFORMED	MAN - HOURS
EQUIPO FUERA DE SERVICIO CON AUXILIARES ABIERTOS.	HR-150.00
SE REALIZARON PRUEBAS PRELIMINARES SATISFACTORIAS.	
PRUEBA DE " CONTACT RESISTANCE " CON VALORES SUMAMENTE ALTOS .	
POLO 1 = 949 POLO 2 = 2047 POLO 3 = 1067	
SE BAJÓ NIVEL DE LOS **TANQUES** RECIRCULANDO EL ACEITE EN LOS	
TANQUEROS DE 3,000 GALONES . SE ABRIERON LAS TAPAS ENCONTRANDO LAS	
JUNTAS EN BUENAS CONDICIONES Y CANTIDAD MODERADA DE CARBÓN Y SLUGE	
EN LOS COMPARTIMIENTOS . SE REMOVIERON LOS " UPPER AND LOWER SHIELDS " .	
SE REMOVIERON LAS RESISTENCIAS Y SE LIMPIARON .	
SE REMOVIERON LAS CÁMARAS INTERRUPTIVAS DESARMÁNDOLAS EN SUS PARTES,	
SE PULIERON LOS CONTACTOS FIJOS E INTERMEDIOS CON LIJA Y PAÑOS .	
SE LIMPIARON LOS " SPACERS " , LAS JUNTAS EN " O-RING " , LOS " BAFFLES "	
Y SE PULIERON LOS CONTACTOS MOVIBLES EN LAS CÁMARAS .	
SE PULIERON LOS CONTACTOS FIJOS EN LOS " BUSHINGS ADAPTERS " Y LOS	
MOVIBLES EN LAS VARETAS (ANCLAS) . SE CAMBIO TAPON ROTO DASHPOT TK#3.	
SE TOMARON LAS MEDIDAS QUE RECOMIENDA EL FABRICANTE PARA UNA	
OPERACIÓN SATISFACTORIA .	
SE NORMALIZARON LOS COMPONENTES Y SE INSTALARON LAS CÁMARAS .	
SE LIJARON LOS BUFFERS CON LIJADORA PARA SUAVIZAR SU ENTRADA .	
SE FABRICARON JUNTAS PARA LOS UST TAPS .	
SE LLENARON LOS UST TAPS CON ACEITE LIMPIO . SE LLENARON LOS TANQUES	HR$5,280.00
	DIET$168.00
CON EL ACEITE FILTRADO.	TOT$5,448.00

RICHARD, JULIO,LUIS
NOEL , JAVIER, GERALD
WORK PERFORMED BY

2 OCTUBRE 2016
DATE

ING. JORGE SANTIAGO
SUPERVISOR

AEE 015.4-55
REV. 6/81

PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE **091-00-000-007**

JOB NO.	A.D. [ ] S.D. [ ]	DATE	1 Y 2 OCTUBRE 2016
LOCATION	CENTRAL COSTA SUR PATIO 230 KV	DISPATHER ORDER NO.	1@10
EQUIPMENT	OCB 0082T	MANUFACTURER	ITE
REQUISTED	ING. EDDIE W. RIVERA BERMUDEZ	EQUIPMENT S.N.	41-30125-1085
WORK TO BE PERFORMED	CONSERVACIÓN	SCHEDULE	YES [X] NO [ ]

INSPECTION OR WORK PERFORMED — MAN - HOURS

MEDIDAS RECOMENDADAS POR EL FABRICANTE :

		TANQUE # 1	TANQUE # 2	TANQUE # 3
TRAVEL		19 - 3/4	19 - 3/4	19 - 3/4
WIPE		5/8	3/4	5/8
DASHPOT		2-5/8	2-5/8	2-5/8
DIMENSIÓN	L	3-1/8	3-1/8	3-1/8
	T	5/32,1/8	5/32,1/8	1/8,1/8
	D	3-1/2,31/2	3-9/16,3-1/2	3-1/2,3-1/2
RESISTENCIA (Kohms)		1.850 , 1.870	1.891 , 1.800	1.840 , 1.880

SE PULIERON LOS BUSHINGS CON COLLINITE.

SE REALIZARON PRUEBAS FINALES SATISFACTORIAS.

SE REALIZARON PRUEBAS DE VELOCIDAD CON RESULTADOS SATISFACTORIOS .

" CONTACT RESISTANCE " SATISFACTORIO (microohms) :

POLO 1 = 487 **POLO 2 = 274** **POLO 3 = 488**

SE RECOMENDÓ EL EQUIPO PARA SERVICIO .

RICHARD, JULIO,LUIS
NOEL , JAVIER, GERALD

WORK PERFORMED BY

2 OCTUBRE 2016

DATE

ING. JORGE SANTIAGO

SUPERVISOR

41-30125-1085_BO(1)

Report Source	OilCircuitBreaker
Session Test Date	10/2/2016 1:30:37 PM

Nameplate - Oil Circuit Breaker

Company	P.R.E.P.A.	**Serial Number**	41-30125-1085
Location	SOUCO	**Special ID**	091-000-000-007
Division	GEN;C.E.P.S.E.	**Circuit Designation**	O.C.B.#0082 T
Manufacturer	I.T.E.	**Type**	230-KM-20000-20
Year Manufactured	1970	**Class**	OilCircuitBreaker
Mfr Location	U.S.A.	**Mechanism Type**	P-45A
Interrupting Rating	43.0 kA	**BIL**	900 kV
Oil Volume	1960.0 UG	Interrupting Rating	43.0 kA
# of Tanks	3	**Counter**	
Control Volts	125	**Amps**	2000
kV	242		

Administration

Test Date	10/2/2016	Test Time:	1:30 PM	**Weather**	Sunny
Air Temperature	32°C	**Apparatus Temperature**	36°C	Humidity	100 %
Tester	R.DIAZ	**Work Order**	9	**Date Last Tested**	
Verified		**Test Set Type**	M4000	**Date Retested**	
Verification Date	10/2/2016	**Set Top Serial #**		**Reason**	BRKR MAINT.
Last Sheet #		**Set Bottom Serial #**		**Travel Time**	
Purchase Order		Ins. Book #		**Duration**	
Copies		**Sheet #**		**Crew Size**	3

Bushing Nameplate

Designation	Serial #	Manufacturer	Type	C1 %PF	C1 Cap	C2 %PF	C2 Cap	Rated kV	Amps
1	1687361	General Electric	U	0.27	459	*	4223	146	2000
2	1687345	General Electric	U	0.25	453	*	4282	146	2000
3	1686334	General Electric	U	0.26	460	*	4285	146	2000
4	1686332	General Electric	U	0.25	458	*	4552	146	2000
5	1686333	General Electric	U	0.25	459	*	4235	146	2000
6	1686329	General Electric	U	0.26	457	*	4408	146	2000

Bushing Additional Details -1

Designation 1	Voltage	Serial # 1687361	
Catalog #	Amps 2000 A	BIL 900 kV	Tap Y
Class	Year 1970	Drawing	
Style	Other	S.O. Number	
Physical Dimensions			
Creep Distance *	Overall Length *	Inner Seal Dia. *	Eff. Gnd Sleeve *
Total Weight *	Recess Depth *	Outer Seal Dia. *	Slot Size *
Units			
Flange Dimensions			
To Bottom *	# Bolts *	Max. Diameters	Draw Lead
To Top *	Bolt Size *	Below Flange *	Tube ID *
	Circle Diameter *	Above Flange *	To Pin *

Bushing Additional Details -2

Designation	2	Voltage		Serial #	1687345		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Bushing Additional Details -3

Designation	3	Voltage		Serial #	1686334		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Bushing Additional Details -4

Designation	4	Voltage		Serial #	1686332		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Bushing Additional Details -5

Designation	5	Voltage		Serial #	1686333		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Bushing Additional Details -6

Designation	6	Voltage		Serial #	1686329		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Overall Tests

Energize	Bus Ft	Ins. #	Ph.	Test kV	mA	Watts	% PF Corr.	Corr Fctr	Cap (pF)	TLI	FRANK™	Manual
1	0	0	A	10.010	2.612	0.085	0.316	0.968	692.769	*	Good	Good
2	0	0	A	10.009	2.621	0.127	0.468	0.968	695.289	*	Good	Good
3	0	0	B	10.010	2.628	0.099	0.364	0.968	697.060	*	Good	Good
4	0	0	B	10.008	2.625	0.101	0.373	0.968	696.345	*	Good	Good
5	0	0	C	10.004	2.654	0.116	0.422	0.968	703.901	*	Good	Good
6	0	0	C	10.003	2.659	0.164	0.597	0.968	705.354	*	Good	Good
1 or 2	0	0	A	10.004	5.089	0.277	0.528	0.968	1349.821	0.065	Deteriorated	Good
3 or 4	0	0	B	10.009	5.101	0.242	0.460	0.968	1353.003	0.042	Good	Good
5 or 6	0	0	C	10.011	5.165	0.308	0.578	0.968	1369.993	0.029	Good	Good

LSR	mA: 2.612/2.612, 1/1	Watts: 0.085/0.085, 1/1	Cap (pF): 692.769/692.769, 1/1
LSR	mA: 2.621/2.621, 1/1	Watts: 0.127/0.127, 1/1	Cap (pF): 695.289/695.289, 1/1
LSR	mA: 2.628/2.628, 1/1	Watts: 0.099/0.099, 1/1	Cap (pF): 697.060/697.060, 1/1
LSR	mA: 2.625/2.625, 1/1	Watts: 0.101/0.101, 1/1	Cap (pF): 696.345/696.345, 1/1
LSR	mA: 2.654/2.654, 1/1	Watts: 0.116/0.116, 1/1	Cap (pF): 703.901/703.901, 1/1
LSR	mA: 2.659/2.659, 1/1	Watts: 0.164/0.164, 1/1	Cap (pF): 705.354/705.354, 1/1
LSR	mA: 5.089/5.089, 1/1	Watts: 0.277/0.277, 1/1	Cap (pF): 1349.821/1349.821, 1/1
LSR	mA: 5.101/5.101, 1/1	Watts: 0.242/0.242, 1/1	Cap (pF): 1353.003/1353.003, 1/1
LSR	mA: 5.165/5.165, 1/1	Watts: 0.308/0.308, 1/1	Cap (pF): 1369.993/1369.993, 1/1
FRANK™ Message	7 (Deteriorated) - According to the general TLI analysis the calculated TLI is slightly higher than normal. Doble recommends the breaker be retested on a more frequent basis. Increasing TLI's usually indicate deterioration in either the lift-rod, tank oil, and auxiliary contact support insulation. Please Note: There is limited information to rate this test. Since there are no previous tests or limits for this breaker, a general TLI analysis was applied. The general TLI analysis may not apply for all breakers. If this is the first test, the Identification Panel must be reviewed carefully to ensure that all of the required fields are present. The required fields are Manufacturer, Breaker Type, Bushing Nameplate, and kV Rating. Once this information is filled in, use the F9 key to recalculate the ratings for this breaker. Contact your supervisor or Doble Engineer if further analysis is required.		

Insulation Resistance

Manufacturer					
Serial Number					
Voltage					
	Volts	T1	T2	PI	Manual
Open Breaker Tests					
Bushing 1	*	*	*	*	
Bushing 2	*	*	*	*	
Bushing 3	*	*	*	*	
Bushing 4	*	*	*	*	
Bushing 5	*	*	*	*	
Bushing 6	*	*	*	*	
Closed Breaker Tests					
A	*	*	*	*	
B	*	*	*	*	
C	*	*	*	*	

Insulating Fluid Tests

Sample Location	Deg C	Test kV	mA	Watts	% PF Corr.	Corr Fctr	FRANK™	Manual
TK#1	35	10.010	0.902	0.014	0.077	0.508		Good
TK#2	35	10.003	0.902	0.014	0.078	0.508		Good
TK#3	35	10.002	0.902	0.014	0.079	0.508		Good

Contact Resistance

Manufacturer	MEGGER		
Serial			
Amps	100		
		Contact Res. (uOhms)	Manual
Closed Breaker Tests			
	A	487	
	B	274	
	C	488	

[Header]

Oil Quality Tests

	Color	Sp. Gravity	ASTM-D1816	ASTM-D877	%PF @25°C	%PF @100°C	Water Content	Neutral #	IFT	Total Parts/10ml
Tank1	1.5	*	*	29.4	*	*	*	*	*	*
Tank2	1.5	*	*	28.5	*	*	*	*	*	*
Tank3	1.5	*	*	27.9	*	*	*	*	*	*

[Header]

Report Source **OilCircuitBreaker**

Session Test Date 10/1/2016 8:04:13 AM

Nameplate - Oil Circuit Breaker

Company	P.R.E.P.A.	Serial Number	41-30125-1085
Location	SOUCO	Special ID	091-000-000-007
Division	GEN;C.E.P.S.E.	Circuit Designation	O.C.B.#0082 T
Manufacturer	I.T.E.	Type	230-KM-20000-20
Year Manufactured	1970	Class	OilCircuitBreaker
Mfr Location	U.S.A.	Mechanism Type	P-45A
Interrupting Rating	43.0 kA	BIL	900 kV
Oil Volume	1960.0 UG	Interrupting Rating	43.0 kA
# of Tanks	3	Counter	
Control Volts	125	Amps	2000
kV	242		

Administration

Test Date	10/1/2016	Test Time:	8:04 AM	Weather	Sunny
Air Temperature	35°C	Apparatus Temperature	37°C	Humidity	100 %
Tester	R.DIAZ	Work Order	8	Date Last Tested	
Verified		Test Set Type	M4000	Date Retested	
Verification Date	10/1/2016	Set Top Serial #		Reason	BRKR MAINT.
Last Sheet #		Set Bottom Serial #		Travel Time	
Purchase Order		Ins. Book #		Duration	
Copies		Sheet #		Crew Size	3

Bushing Nameplate

Designation	Serial #	Manufacturer	Type	C1 %PF	C1 Cap	C2 %PF	C2 Cap	Rated kV	Amps
1	1687361	General Electric	U	0.27	459	*	4223	146	2000
2	1687345	General Electric	U	0.25	453	*	4282	146	2000
3	1686334	General Electric	U	0.26	460	*	4285	146	2000
4	1686332	General Electric	U	0.25	458	*	4552	146	2000
5	1686333	General Electric	U	0.25	459	*	4235	146	2000
6	1686329	General Electric	U	0.26	457	*	4408	146	2000

Bushing Additional Details -1

Designation 1	**Voltage**	**Serial #** 1687381	
Catalog #	**Amps** 2000 A	**BIL** 900 kV	**Tap** Y
Class	**Year** 1970	**Drawing**	
Style	**Other**	**S.O. Number**	
Physical Dimensions			
Creep Distance *	**Overall Length** *	**Inner Seal Dia.** *	**Eff. Gnd Sleeve** *
Total Weight *	**Recess Depth** *	**Outer Seal Dia.** *	**Slot Size** *
Units			
Flange Dimensions			
To Bottom *	**# Bolts** *	**Max. Diameters**	**Draw Lead**
To Top *	**Bolt Size** *	**Below Flange** *	**Tube ID** *
	Circle Diameter *	**Above Flange** *	**To Pin** *

Bushing Additional Details -2

Designation 2	**Voltage**	**Serial #** 1687345	
Catalog #	**Amps** 2000 A	**BIL** 900 kV	**Tap** Y
Class	**Year** 1970	**Drawing**	
Style	**Other**	**S.O. Number**	
Physical Dimensions			
Creep Distance *	**Overall Length** *	**Inner Seal Dia.** *	**Eff. Gnd Sleeve** *
Total Weight *	**Recess Depth** *	**Outer Seal Dia.** *	**Slot Size** *
Units			
Flange Dimensions			
To Bottom *	**# Bolts** *	**Max. Diameters**	**Draw Lead**
To Top *	**Bolt Size** *	**Below Flange** *	**Tube ID** *
	Circle Diameter *	**Above Flange** *	**To Pin** *

Bushing Additional Details -3

Designation	3	Voltage		Serial #	1666334		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Bushing Additional Details -4

Designation	4	Voltage		Serial #	1666332		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Bushing Additional Details -5

Designation	5	Voltage		Serial #	1686333		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Bushing Additional Details -6

Designation	6	Voltage		Serial #	1686329		
Catalog #		Amps	2000 A	BIL	900 kV	Tap	Y
Class		Year	1970	Drawing			
Style		Other		S.O. Number			
Physical Dimensions							
Creep Distance	*	Overall Length	*	Inner Seal Dia.	*	Eff. Gnd Sleeve	*
Total Weight	*	Recess Depth	*	Outer Seal Dia.	*	Slot Size	*
Units							
Flange Dimensions							
To Bottom	*	# Bolts	*	Max. Diameters		Draw Lead	
To Top	*	Bolt Size	*	Below Flange	*	Tube ID	*
		Circle Diameter	*	Above Flange	*	To Pin	*

Overall Tests

Energize	Bus Ft	Ins. #	Ph.	Test kV	mA	Watts	% PF Corr.	Corr Fctr	Cap (pF)	TLI	FRANK™	Manual
1	0	0	A	10.002	2.623	0.124	0.453	0.960	695.844	*	Good	Good
2	0	0	A	10.002	2.652	0.189	0.685	0.960	703.504	*	Good	Good
3	0	0	B	10.002	2.621	0.130	0.477	0.960	695.321	*	Good	Good
4	0	0	B	10.002	2.630	0.146	0.532	0.960	697.755	*	Good	Good
5	0	0	C	10.002	2.663	0.140	0.504	0.960	706.290	*	Good	Good
6	0	0	C	10.001	2.650	0.181	0.656	0.960	702.941	*	Good	Good
1 or 2	0	0	A	10.002	5.094	0.287	0.541	0.960	1351.139	-0.026	Good	Good
3 or 4	0	0	B	10.000	5.105	0.255	0.479	0.960	1354.179	-0.021	Good	Good
5 or 6	0	0	C	10.002	5.166	0.283	0.525	0.960	1370.304	-0.036	Good	Good

LSR	mA: 2.623/2.623, 1/1	Watts: 0.124/0.124, 1/1	Cap (pF): 695.844/695.844, 1/1
LSR	mA: 2.652/2.652, 1/1	Watts: 0.189/0.189, 1/1	Cap (pF): 703.504/703.504, 1/1
LSR	mA: 2.621/2.621, 1/1	Watts: 0.130/0.130, 1/1	Cap (pF): 695.321/695.321, 1/1
LSR	mA: 2.630/2.630, 1/1	Watts: 0.146/0.146, 1/1	Cap (pF): 697.755/697.755, 1/1
LSR	mA: 2.663/2.663, 1/1	Watts: 0.140/0.140, 1/1	Cap (pF): 706.290/706.290, 1/1
LSR	mA: 2.650/2.650, 1/1	Watts: 0.181/0.181, 1/1	Cap (pF): 702.941/702.941, 1/1
LSR	mA: 5.094/5.094, 1/1	Watts: 0.287/0.287, 1/1	Cap (pF): 1351.139/1351.139, 1/1
LSR	mA: 5.105/5.105, 1/1	Watts: 0.255/0.255, 1/1	Cap (pF): 1354.179/1354.179, 1/1
LSR	mA: 5.166/5.166, 1/1	Watts: 0.283/0.283, 1/1	Cap (pF): 1370.304/1370.304, 1/1

Bushing C1

ID	Serial #	NP %PF	NP Cap	Test kV	mA	Watts	% PF Corr.	Corr Fctr	Cap(pF)	FRANK™	Manual
1	1687361	0.27	459	10.002	1.726	0.073	0.405	0.960	457.829	Good	Good
2	1687345	0.25	453	10.002	1.699	0.104	0.588	0.960	450.621	Investigate	Good
3	1686334	0.26	460	10.000	1.731	0.070	0.390	0.960	459.160	Good	Good
4	1686332	0.25	456	10.001	1.721	0.084	0.467	0.960	456.412	Deteriorated	Good
5	1686333	0.25	459	10.003	1.722	0.062	0.345	0.960	456.698	Good	Good
6	1686329	0.26	457	10.002	1.709	0.071	0.401	0.960	453.232	Good	Good

LSR	mA: 1.726/1.726, 1/1	Watts: 0.073/0.073, 1/1	Cap (pF): 457.829/457.829, 1/1
LSR	mA: 1.699/1.699, 1/1	Watts: 0.104/0.104, 1/1	Cap (pF): 450.621/450.621, 1/1
LSR	mA: 1.731/1.731, 1/1	Watts: 0.070/0.070, 1/1	Cap (pF): 459.160/459.160, 1/1
LSR	mA: 1.721/1.721, 1/1	Watts: 0.084/0.084, 1/1	Cap (pF): 456.412/456.412, 1/1
LSR	mA: 1.722/1.722, 1/1	Watts: 0.062/0.062, 1/1	Cap (pF): 456.698/456.698, 1/1
LSR	mA: 1.709/1.709, 1/1	Watts: 0.071/0.071, 1/1	Cap (pF): 453.232/453.232, 1/1

FRANK™ Message

2 (Investigate) - Power Factor is high compared to Nameplate.

Power Factor is high compared to limit.

4 (Deteriorated) - Power Factor is high compared to Nameplate.

Bushing C2

ID	Serial #	NP %PF	NP Cap	Test kV	mA	Watts	%PF Corr.	Corr Fctr	Cap(pF)	FRANK™	Manual
1	1687361	*	4223	2.000	15.922	0.552	0.347	1	4223.475	Good	Good
2	1687345	*	4282	2.000	16.167	0.680	0.421	1	4288.255	Good	Good
3	1686334	*	4285	2.000	16.130	0.650	0.403	1	4278.577	Good	Good
4	1686332	*	4552	2.000	16.010	0.807	0.504	1	4246.592	Deteriorated	Good
5	1686333	*	4235	2.000	16.303	0.821	0.504	1	4324.457	Good	Good
6	1686329	*	4408	2.000	16.601	0.922	0.556	1	4403.386	Good	Good

LSR	mA: 15.922/15.922, 1/1	Watts: 0.552/0.552, 1/1	Cap (pF): 4223.475/4223.475, 1/1
LSR	mA: 16.167/16.167, 1/1	Watts: 0.680/0.680, 1/1	Cap (pF): 4288.255/4288.255, 1/1
LSR	mA: 16.130/16.130, 1/1	Watts: 0.650/0.650, 1/1	Cap (pF): 4278.577/4278.577, 1/1
LSR	mA: 16.010/16.010, 1/1	Watts: 0.807/0.807, 1/1	Cap (pF): 4246.592/4246.592, 1/1
LSR	mA: 16.303/16.303, 1/1	Watts: 0.821/0.821, 1/1	Cap (pF): 4324.457/4324.457, 1/1
LSR	mA: 16.601/16.601, 1/1	Watts: 0.922/0.922, 1/1	Cap (pF): 4403.386/4403.386, 1/1

FRANK™ Message 4 (Deteriorated) - Capacitance is low compared to Nameplate.

Insulation Resistance

Manufacturer

Serial Number

Voltage *

	Volts	T1	T2	PI	Manual
Open Breaker Tests					
Bushing 1	*	*	*	*	
Bushing 2	*	*	*	*	
Bushing 3	*	*	*	*	
Bushing 4	*	*	*	*	
Bushing 5	*	*	*	*	
Bushing 6	*	*	*	*	
Closed Breaker Tests					
A	*	*	*	*	
B	*	*	*	*	
C	*	*	*	*	

Insulating Fluid Tests

Sample Location	Deg C	Test kV	mA	Watts	% PF Corr.	Corr Fctr	FRANK™	Manual
TK#1	35	10.002	0.901	0.012	0.068	0.508		Good
TK#2	35	10.001	0.901	0.013	0.073	0.508		Good
TK#3	35	10.001	0.901	0.013	0.073	0.508		Good

Contact Resistance

Manufacturer	MEGGER		
Serial			
Amps	100		
		Contact Res. (uOhms)	Manual
Closed Breaker Tests			
	A	949	
	B	2047	
	C	1067	

Oil Quality Tests

	Color	Sp. Gravity	ASTM-D1816	ASTM-D877	%PF @25°C	%PF @100°C	Water Content	Neutral #	IFT	Total Parts/10ml
Tank1	1.5	*	*	24.2	*	*	*	*	*	*
Tank2	1.5	*	*	23.5	*	*	*	*	*	*
Tank3	1.5	*	*	22.8	*	*	*	*	*	*

T-Doble Test Details Report

Nameplate

Type	Oil Breaker	**Description**	O.C.B.
Manufacturer	I.T.E.	**Circuit Number**	0082-T
Model no.	230-KM-20000-20	**Mechanism Type**	PA-45A
Company	P.R.E.P.A.	**Mechanism Book no.**	
Location	SOUCO	**Instruction Book no.**	
Division	Gen;C.E.P.S.E.	**Operation Counter**	
Serial no.	41-30125-1085	**Line Frequency**	60 Hz
Special ID	091-000-000-007	**Operator**	R.DIAZ
		<custom label 1>	
		<custom label 2>	
Plan Type	Test Result	**Test Run**	Oct 2, 2016 14:42:27
	Instrument Details:	**Instrument Model**	TDR 900
		Serial Number	
		Calibrated	

Main Contact Results: Trip

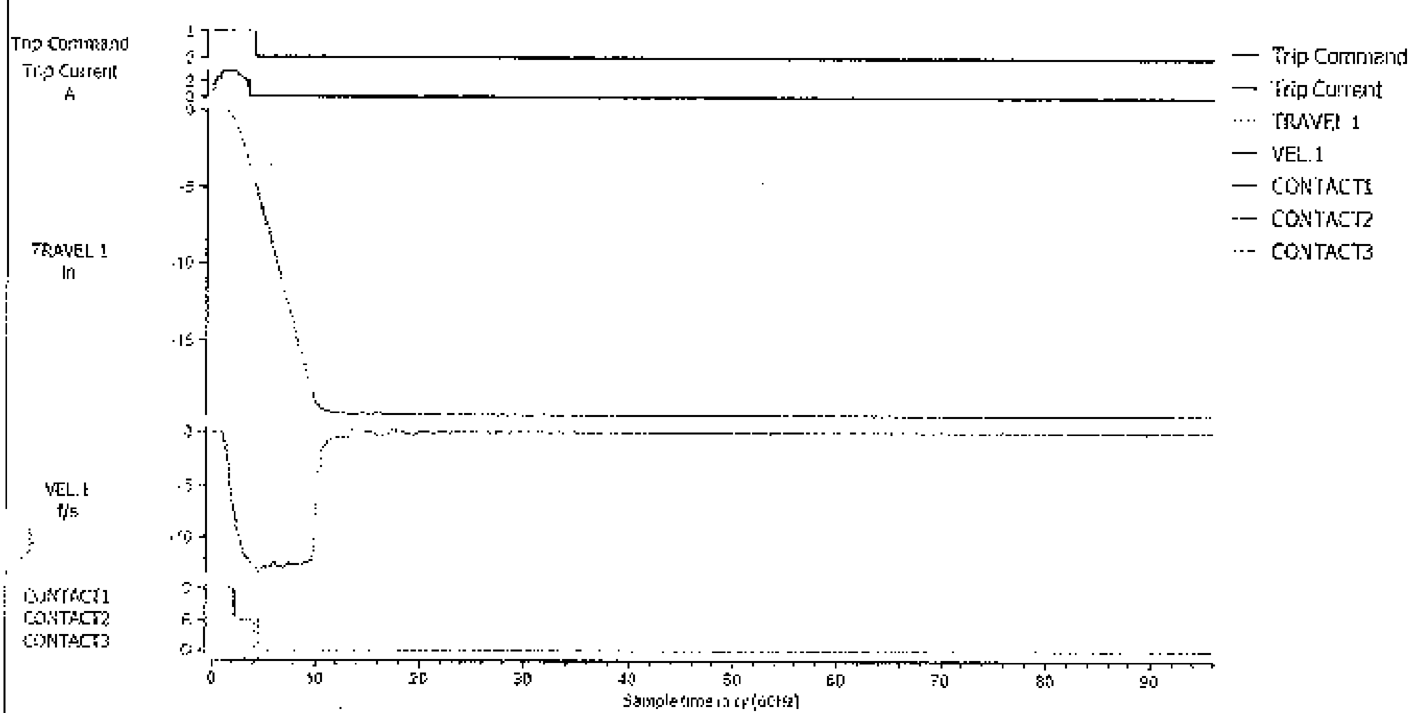
Main Contact Timing / ***Synchronization***

Channel	Label	Phase	Time	Status	In Breaker	
OCB-A	CONTACT1	Phase A	2112.00 cy	Pass	252.00 cy	No status
OCB-B	CONTACT2	Phase B	2316.00 cy	Pass		
OCB-C	CONTACT3	Phase C	2064.00 cy	Pass		

Motion Measurements

Channel		Velocity Zone 1	Velocity Zone 2	Total Travel	Overtravel	Travel Rebound	Contact Wipe	Damping
Motion-1	Zone Type	Distance; Distance	Distance; Distance					
(TRAVEL 1)	Measured	3.206 m/s		19.880 in	0.016 in	0.056 in		3546.00 cy
Phase Undefined	Limits - Max	3.658 m/s	3.658 m/s	20.750 in	0.500 in	0.500 in		
	Limits - Min	3.048 m/s		19.250 in	0.000 in	0.000 in		

Result Plot



Breaker Test Details

Test Style	OCB	Include Resistors	NO

Main Contact Channel Setup

Channel	Enable	Label	Phase
OCB-A	YES	CONTACT1	Phase A
OCB-B	YES	CONTACT2	Phase B
OCB-C	YES	CONTACT3	Phase C

Filename E:\O.C.B.#0082-T SOUCO\091-000-000-007_10-2-2016_144227_Trip.tdrx

T-Doble Test Details Report

Nameplate

Type	Oil Breaker	Description	O.C.B.
Manufacturer	I.T.E.	Circuit Number	0062-T
Model no.	230-KM-20000-20	Mechanism Type	PA-45A
Company	P.R.E.P.A.	Mechanism Book no.	
Location	SOUCO	Instruction Book no.	
Division	Gen;C.E.P.S.E.	Operation Counter	
Serial no.	41-30125-1085	Line Frequency	60 Hz
Special ID	091-000-000-007	Operator	R.DIAZ
		<custom label 1>	
		<custom label 2>	
Plan Type	Test Result	Test Run	Oct 2, 2016 14:56:58
	Instrument Details:	Instrument Model	TDR 900
		Serial Number	
		Calibrated	

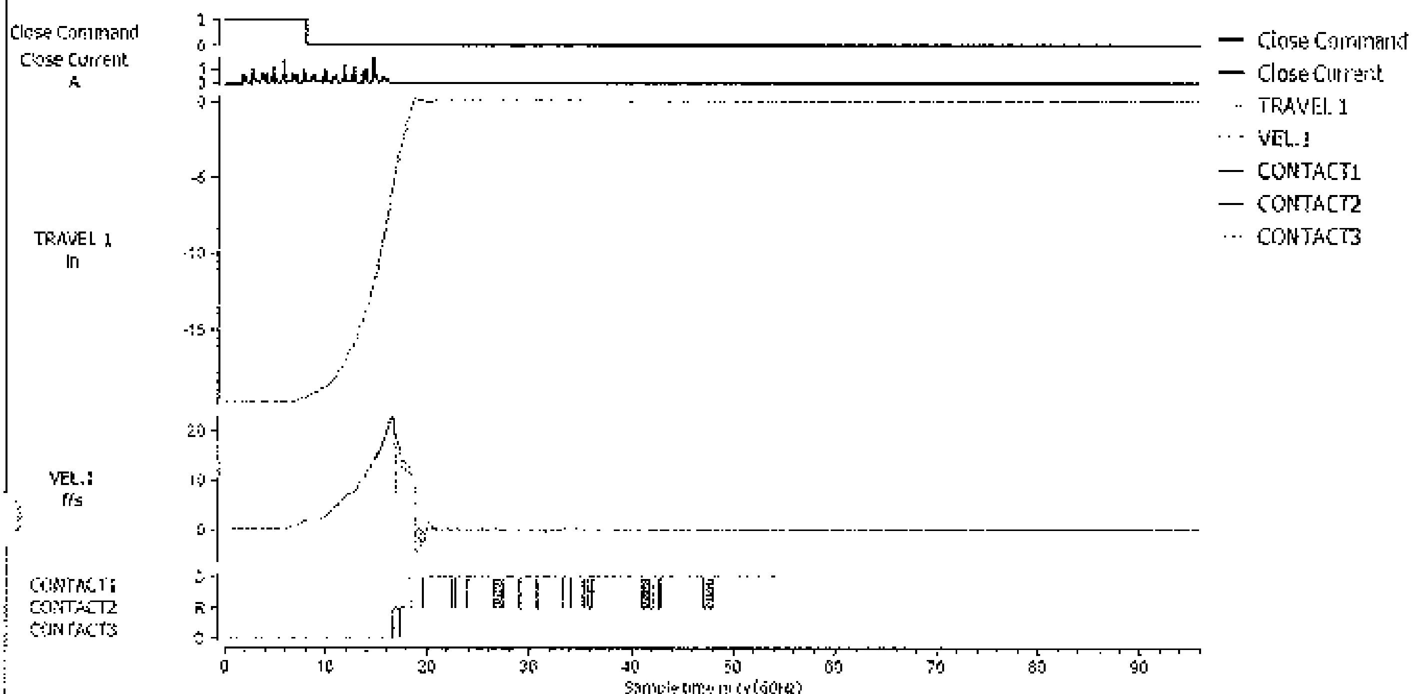
Main Contact Results: Close

Main Contact Timing					*Synchronization*
Channel	Label	Phase	Time	Status	In Breaker
OCB-A	CONTACT1	Phase A	18376.00 cy	Pass	66.00 cy No status
OCB-B	CONTACT2	Phase B	18330.00 cy	Pass	
OCB-C	CONTACT3	Phase C	18396.00 cy	Pass	

Motion Measurements

		Velocity				Travel		
Channel		Zone 1	Zone 2	Total Travel	Overtravel	Rebound	Contact Wipe	Damping
Motion-1	Zone Type	Distance; Distance	Distance; Distance					
(TRAVEL 1)	Measured	4.069 m/s		19.874 in	0.292 in	0.062 in	0.662 in	
Phase Undefined	Limits - Max	4.420 m/s	4.420 m/s	20.750 in	0.375 in	0.250 in	1.000 in	
	Limits - Min	3.658 m/s		19.250 in	0.000 in	0.000 in	0.500 in	

Result Plot



Breaker Test Details

Test Style	OCB	Include Resistors	NO

Main Contact Channel Setup

Channel	Enable	Label	Phase
OCB-A	YES	CONTACT1	Phase A
OCB-B	YES	CONTACT2	Phase B
OCB-C	YES	CONTACT3	Phase C

Filename E:\O.C.B.#0082-T SOUCO\091-000-000-007_10-2-2016_145658_Close.tdrx

Costa Sur Steam Plant Transmission Center 230kV OCB-0082

Maintenance Record -- 2020

AEE 015.4-55
REV. 6/81

PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE 091-00-00-07

JOB NO.	A.D. [ ] S.D. [ ]	DATE	3 - 5, 7 / MARZO / 2020
LOCATION	CENTRAL COSTA SUR	DISPATHER ORDER NO.	11 @ 15
EQUIPMENT	OCB 0082	MANUFACTURER	I.T.E.
REQUISTED BY	ING. EDDIE W. RIVERA	EQUIPMENT S.N.	41-30125-1085
WORK TO BE PERFORMED	CONSERVACIÓN	SCHEDULE	YES [X] NO [ ]

	MAN-HOURS
EQUIPO FUERA DE SERVICIO PARA CONSERVACIÓN CON SUS AUXILIARES	
ABIERTOS. UNIDAD 5 FUERA DE SERVICIO A CONSECUENCIA DE TERREMOTO.	
	95 H. REGS.
SE PROBÓ EL ÁREA DE TRABAJO SIN VOLTAJE Y SE INSTALARON TIERRAS.	32.5 H. EXTRAS
	127.5 H. TOTAL
SE DESCONECTARON LOS CONECTORES EN LA PARTE SUPERIOR DE LOS	
BUSHINGS. SE LEVANTARON LAS BARRAS Y SE AISLARON UTILIZANDO MANTAS.	
LAS BARRAS NO SE RETIRARON.	
SE LIMPIARON LOS BUSHINGS CON COLLINITE.	
SE REALIZARON PRUEBAS PRELIMINARES DE OVERALL, BUSHINGS (C1 & C2),	
CONTACT RESISTANCE Y ACEITES (PF). SE OBTUVIERON RESULTADOS	
SATISFACTORIOS. ADJUNTO SE INCLUYE COPIA DE LOS MISMOS.	
CONTACT RESISTANCE PRELIMINAR (MICRO-OHMS)	
POLO 1 = 699, POLO 2 = 2112, POLO 3 = 581	
TODO ESTO FUE REALIZADO POR SUP. GERALD VERA. A PARTIR DE ESTE	
MOMENTO, ING. ARNALDO NAZARIO CONTINUÓ LOS TRABAJOS.	
SE REALIZÓ CONSERVACIÓN A CADA UNO DE LOS TANQUES.	
TANQUE 1	
SE BAJO NIVEL DE ACEITE Y SE RECIRCULÓ EN EL TANQUERO (APROX. 5 HRS).	
SE ABRIÓ LA TAPA PRINCIPAL DEL TANQUE. SE ENCONTRÓ LA JUNTA EN	
BUEN ESTADO. SE LE DIÓ UN FLUSH AL TANQUE Y TODOS LOS COMPONENTES	
INTERNOS CON ACEITE LIMPIO Y A PRESIÓN.	
SE ENCONTRÓ CANTIDAD CONSIDERABLE DE CARBÓN EN EL INTERIOR DEL	
TANQUE. SE LE PASARON PAMPERS A TODO EL INTERIOR DEL TANQUE Y PAÑOS	Regular: $ 2,577.47
LIMPIOS A TODOS LOS COMPONENTES INTERNOS.	Extra: $ 847.17
	Dietas: $ 192.00
*Incluye Beneficios Marginales	*Total: $ 3,616.64

R. DIAZ, J. ORTIZ, J. RAMÍREZ
L. FELICIANO, L. RODRÍGUEZ
WORK PERFORMED BY

7 / MARZO / 2020
DATE

ING. ARNALDO NAZARIO MATTEI
SUPERVISOR

AEE 015.4-55
REV. 6/81

PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE 091-00-00-07

JOB NO.		A.D. ☐ S.D. ☐ DATE	3 - 5, 7 / MARZO / 2020
LOCATION	CENTRAL COSTA SUR	DISPATHER ORDER NO.	11 @ 15
EQUIPMENT	OCB 0082	MANUFACTURER	I.T.E.
REQUISTED BY	ING. EDDIE W. RIVERA	EQUIPMENT S.N.	41-30125-1085
WORK TO BE PERFORMED	CONSERVACIÓN	SCHEDULE	YES ☒ NO ☐

	MAN- HOURS
SE REMOVIERON LOS "UPPER & LOWER SHIELDS" Y LAS RESISTENCIAS. SE	
LIMPIARON PASANDOLE PAÑOS LIMPIOS PARA REMOVER TODOS LOS RESIDUOS	
DE CARBÓN. LAS RESISTENCIAS SE MIDIERON Y SE APUNTARON SUS LECTURAS.	95 H. REGS.
SE DESACOPLARON LAS CÁMARAS INTERRUPTIVAS ("INTERRUPTER TUBES") Y	32.5 H. EXTRAS
SE DESMONTARON, SE SACARON DEL TANQUE Y SE LLEVARON A LA MESA DE	127.5 H. TOTAL
TRABAJO. SE REMOVIERON TODOS SUS COMPONENTES INTERNOS INCLUYENDO	
"BAFFLES", CONTACTOS ESTACIONARIOS BAJOS E INTERMEDIOS, "SPACERS" Y	
"MOVING CONTACT ASSEMBLY". SE PULIERON LOS CONTACTOS FIJOS	
UTILIZANDO "SCOTCHBRITE" INCLUYENDO SUS ROMPE ARCOS. DE IGUAL FORMA	
SE PULIERON LOS CONTACTOS MOVIBLES. SE ROTARON PARA EL LADO CON	
MENOS DESGASTE PARA MEJOR OPERACIÓN. EN EL INTERIOR DEL TANQUE SE	
LIMPIARON Y PULIERON LOS CONTACTOS FIJOS EN LOS "BUSHING ADAPTERS".	
ADEMÁS SE PULIERON LOS MOVIBLES DEL "CROSSBAR ASSEMBLY".	
SE VERIFICÓ EL FUNCIONAMIENTO DEL DASHPOT. SE TOMARON LAS MEDIDAS	
RECOMENDADAS POR EL FABRICANTE. SE NORMALIZARON TODOS LOS	
COMPONENTES LIMPIOS Y REACONDICIONADOS. SE INSTALARON NUEVAMENTE	
LAS CÁMARAS INTERRUPTIVAS, LAS RESISTENCIAS Y LOS "SHIELDS". SE CERRÓ	
LA TAPA PRINCIPAL Y SE LLENÓ EL TANQUE CON EL ACEITE FILTRADO.	
TANQUE 2 Y TANQUE 3 SE LE REALIZÓ LA MISMA CONSERVACIÓN QUE LA	
DEL TANQUE 1. TODOS LOS CONTACTOS FIJOS Y MOVIBLES SE ENCONTRARON	
EN BUEN ESTADO. ACEITE DE CADA TANQUE SE RECIRCULÓ POR ESPACIO DE	
5 HORAS CADA UNO.	
SE LLENARON TODOS LOS UST TAPS CON ACEITE NUEVO Y LIMPIO.	
	Regular: $ 2,577.47
	Extra: $ 847.17
	Dietas: $ 192.00
*Incluye Beneficios Marginales	*Total: $ 3,616.64

R. DIAZ, J. ORTIZ, J. RAMÍREZ
L. FELICIANO, L. RODRÍGUEZ
WORK PERFORMED BY

7 / MARZO / 2020
DATE

ING. ARNALDO NAZARIO MATTEI
SUPERVISOR

AEE 015.4-55
REV. 6/81

PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE 091-00-00-07

A.D. ☐
S.D. ☐

JOB NO.
LOCATION CENTRAL COSTA SUR
EQUIPMENT OCB 0082
REQUISTED BY ING. EDDIE W. RIVERA
WORK TO BE PERFORMED CONSERVACIÓN

DATE 3 - 5, 7 / MARZO / 2020
DISPATHER ORDER NO. 11 @ 15
MANUFACTURER I.T.E.
EQUIPMENT S.N. 41-30125-1086
SCHEDULE YES ☒ NO ☐

MEDIDAS RECOMENDADAS POR EL FABRICANTE:	TANQUE 1	TANQUE 2	TANQUE 3	MAN- HOURS	
TRAVEL	19 3/4"	19 7/8"	19 7/8"	95	H. REGS.
CONTACT WIPE	1/2"	13/16"	1/2"	32.5	H. EXTRAS
DASHPOT	OK	OK	OK	127.5	H. TOTAL
DASHPOT OIL LEVEL	2 5/8"	2 11/16"	2 1/2" ***		
DIMENSIÓN "L"	3 1/8"	3 3/16"	3 1/8"		
DIMENSIÓN "T"	3/16", 3/16"	5/32", 1/4"	5/32", 5/32"		
DIMENSIÓN "D"	3 1/2", 3 7/16"	3 1/2", 3 1/2"	3 1/2", 3 1/2"		
RESISTENCIA (K-OHMS)	1.855, 1.846	1.901, 1.794	1.812, 1.906		
CONT. RESISTANCE (INTERNO)	198	314	165 (μ-OHMS)		
NIVEL DE ACEITE	OK	OK	OK		

*** SE AJUSTÓ AL VALOR QUE APARECE EN LA TABLA (MEDIDA ESTABA EN 3")

SE REALIZARON PRUEBAS FINALES DE OVERALL, CONTACT RESISTANCE,
Y ACEITES OBTENIENDO RESULTADOS SATISFACTORIOS.

CONTACT RESISTANCE FINAL (MICRO-OHMS)

POLO 1 = 556, POLO 2 =956, POLO 3 = 605

NOTA: PROBLEMAS DE LA PRUEBAEN POLO 2 ES EXTERNO. AL
MOMENTO DE CONECTAR SE VERIFICARÁ CONECTOR EN EL "STUD".
PRUEBA INTERNA FUÉ SATISFACTORIA.

- PRUEBA BREAKDOWN ACEITES:

TANQUE 1 - 28.2 KV COLOR - 1.5
TANQUE 2 - 24.8 KV COLOR - 1.5
TANQUE 3 - 26.6 KV COLOR - 1.5

Regular:	$ 2,577.47
Extra:	$ 847.17
Dietas:	$ 192.00
*Total:	$ 3,616.64

*Incluye Beneficios Marginales

R. DIAZ, J. ORTIZ, J. RAMÍREZ
L. FELICIANO, L. RODRÍGUEZ
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SUPERVISOR

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PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE 091-00-00-07

JOB NO.	A.D. [ ] S.D. [ ]	DATE	3 - 5, 7 / MARZO / 2020
LOCATION	CENTRAL COSTA SUR	DISPATHER ORDER NO.	11 @ 15
EQUIPMENT	OCB 0082	MANUFACTURER	I.T.E.
REQUISTED BY	ING. EDDIE W. RIVERA	EQUIPMENT S.N.	41-30125-1085
WORK TO BE PERFORMED	CONSERVACIÓN	SCHEDULE	YES [X] NO [ ]

	MAN- HOURS
SEPROCEDE A REALIZAR PRUEBAS DE VELOCIDAD. SE REALIZÓ PRUEBA DE	
CLOSE Y DE TRIP OBTENIENDO RESULTADOS SATISFACTORIOS.	
ADJUNTO SE INCLUYE COPIA DE LAS MISMAS.	95 H. REGS.
	32.5 H. EXTRAS
SE RECONECTA NUEVAMENET EQUIPO AL SISTEMA. SE LE DIÓ LIMPIEZA A LOS	127.5 H. TOTAL
PUNTOS DE CONEXIÓN.	
SE REMUEVEN LAS TIERRAS.	
SE LIMPIA EL ÁREA DE TRABAJO. SE ENTREGA EQUIPO DISPONIBLE PARA	
SERVICIO.	
NO SE PUDO VERIFICAR OPERACIÓN REMOTA DEL BREAKER YA QUE EL	
BREAKER DE SALIDA DE UNIDAD Y NO TENÍA CONDICIONES YA QUE LA U5	
ESTABA FUERA DE SERVICIO.	
	Regular: $ 2,577.47
	Extra: $ 847.17
	Dietas: $ 192.00
*Incluye Beneficios Marginales	*Total: $ 3,616.64

R. DIAZ, J. ORTIZ, J. RAMÍREZ
L. FELICIANO, L. RODRÍGUEZ
WORK PERFORMED BY

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DATE

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SUPERVISOR

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PUERTO RICO ELECTRIC POWER AUTHORITY

SUBSTATION MAINTENANCE AND INSPECTION REPORT

EQUIPMENT CODE 091-00-00-07

JOB NO. ______ A.D. [ ] S.D. [ ]
DATE 3 - 5, 7 / MARZO / 2020
LOCATION CENTRAL COSTA SUR
DISPATHER ORDER NO. 11 @ 15
EQUIPMENT OCB 0082
MANUFACTURER I.T.E.
REQUISTED BY ING. EDDIE W. RIVERA
EQUIPMENT S.N. 41-30125-1085
WORK TO BE PERFORMED CONSERVACIÓN
SCHEDULE YES [X] NO [ ]

INFORME DE GASTOS

EMPLEADO	SALARIO	HORAS REG	COSTO CON B.M.	HORAS EXTRAS	COSTO CON B.M.
A. NAZARIO	$ 22.13	19	$ 668.55	3.5	$ 85.98
R. DIAZ	$ 18.96	19	$ 602.99	6.5	$ 216.02
J. ORTIZ	$ 19.21	11.5	$ 351.25	5	$ 159.92
L. FELICIANO	$ 13.27	19	$ 400.89	6.5	$ 143.61
J. RAMÍREZ	$ 13.03	19	$ 393.64	6.5	$ 141.02
L. RODRÍGUEZ	$ 13.43	7.5	$ 160.15	4.5	$ 100.62
TOTAL		95.00	$ 2,577.47	32.50	$ 847.17

EMPLEADO	NÚM. EMPLEADO	DIETAS
A. NAZARIO	23462	$ 32.00
R. DIAZ	12431	$ 32.00
J. ORTIZ	12392	$ 32.00
L. FELICIANO	23722	$ 32.00
J. RAMÍREZ	24130	$ 32.00
L. RODRÍGUEZ	23950	$ 32.00
TOTAL		$ 192.00

Total = $ 3,616.64

NOTA:

R. DIAZ, J. ORTIZ, J. RAMÍREZ
L. FELICIANO, L. RODRÍGUEZ
WORK PERFORMED BY

7 / MARZO / 2020
DATE

ING. ARNALDO NAZARIO MATTEI
SUPERVISOR

Pruebas OCB 0082

OMICRON

Client		OCB 0082	
Execution date	2/11/2020	Reason of the job	Routine
Tested by	R.DIAZ	Location	O.C.B#0082 SOUCO
Approved by		Asset	Circuit breaker
Report ID	2	Asset type	Dead tank oil breaker (OCB)
Report issue date	3/6/2020 12:51:11 PM	Asset serial number	41-30125-1086
Work order	6	Manufacturer	I.T.E.

Summary

Performed tests	Assessment
Circuit Breaker PF & CAP Preliminares	Not assessed
Insulating Fluids PF & CAP Preliminares	Not assessed
Bushing PF & CAP - C1	Not assessed
Bushing PF & CAP - C2	Not assessed
Circuit Breaker PF & CAP Finales	Not assessed
Insulating Fluids PF & CAP Finales	Not assessed

Overall Assesement	Not assessed

Tested by: ________________

Approved by: ________________

Location & company information

Location	
Name	O.C.B#0082 SOUCO
Region	PONCE
Division	T.D.C.E.P.S.E.
Area	SUBESTACIONES
Plant	SOUCO
Address	
City	GUAYANILLA
State/Province	P.R.
Postal code	
Country	

Company	
Company	P.R.E.P.A.
Department	Subestaciones
Address	Ave. HOSTOS
City	Ponce
State/Province	P.R.
Postal code	
Country	
Phone No.	787-521-8647
Fax No.	
E-mail	

Geo coordinates	

Contact person	
Name	
Phone No. 1	
Phone No. 2	
Fax No.	
E-mail	

Comment

Dead tank oil breaker (OCB) nameplate data

Serial number	41-30125-1085
Manufacturer	I.T.E.
Manufacturing year	1970
Manufacturer type	230-KM-20000-20
Asset system code	
Apparatus ID	091-000-000-007
Feeder	
No. of phases	3

No. of interrupters p. phase	1
Pole operation	Ganged
Pre-insertion resistors	No
PIR value	Ω
Grading capacitors	No
Capacitor value	pF
Interrupting medium	Oil
Tank type	Dead tank

Comment

TESTED BEFORE MAINTENANCE AND TO INSPECT.

Ratings	
Rated frequency	60.00 Hz
Rated voltage L-L	242.0 kV
Rated current	2000.0 A
Rated SC breaking current	43.0 kA
Short-circuit nominal duration	s
Rated insul. level L-G (BIL)	900.0 kV
Rated interrupting time	ms
Interrupting duty cycle	
Rated power at closing	W
Rated power at opening	W
Rated power at motor charge	W

Contact system	
Total travel	in
Damping time	ms

Others	
Total weight with oil	84060 lbs
Weight of oil	lbs
Volume of oil	1960.0 gals

Pneumatic Operating mechanism nameplate data	
Serial No.	41-30125-1085
Manufacturer	I.T.E.
Manufacturer type	P-45A
Manufacturing year	1970
Asset system code	

Component	Rated voltage	Rated current	Frequency	
Trip coil 1	V	A	Hz	DC
Close coil 1	V	A	Hz	DC
Auxiliary circuits	V	A	Hz	DC
Motor	V	A	Hz	DC

Rated operating pressure	psi @ °C

Bushings nameplate data

Pos.	Serial No.	Manufact.	Man. year	Voltage L-ground	Max. system voltage	Rated current	Insul. level LL
1	1687361	General Electric	1970	kV	242.0 kV	2000.0 A	900 kV
2	1687345	General Electric	1970	kV	242.0 kV	2000.0 A	900 kV
3	1686334	General Electric	1970	kV	242.0 kV	2000.0 A	900 kV
4	1686332	General Electric	1970	kV	242.0 kV	2000.0 A	900 kV
5	1686333	General Electric	1970	kV	242.0 kV	2000.0 A	900 kV
6	1686329	General Electric	1970	kV	242.0 kV	2000.0 A	900 kV

Pos.	Cap. (C1)	PF (C1)	Cap. (C2)	PF (C2)	Insulation type	Tap type

Pos.	Cap. (C1)	PF (C1)	Cap. (C2)	PF (C2)	Insulation type	Tap type
1	459.00 pF	0.270 %	4223.00 pF	0.270 %		With test tap
2	453.00 pF	0.250 %	4262.00 pF	0.250 %		With test tap
3	460.00 pF	0.260 %	4285.00 pF	0.260 %		With test tap
4	458.00 pF	0.250 %	4552.00 pF	0.250 %		With test tap
5	459.00 pF	0.260 %	4236.00 pF	0.250 %		With test tap
6	457.00 pF	0.260 %	4408.00 pF	0.260 %		With test tap

Test set information

Model	Serial number	Calibration date
TESTRANO 600	DK297Y	2019-03-06
CP TD1	SC306Z	2019-03-27

Global test conditions

Weather	Clear	Humidity	78 %
Unit location	Outside	Ambient temperature	38 °C

Operations counter

Counter reading found	
Counter reading left	

Circuit Breaker PF & CAP Preliminares

Ambient temperature	36 °C		Weather	
			Humidity	78 %

Comments

Standard test

Corr. factor	1
* Reference voltage	10.0 kV

Meas.	Position	Test mode	Freq.	V out	* I out	* Watt losses	PF meas	PF corr	Cap. meas	Assessment
C1G	Open	GST	60.00 Hz	10.00 kV	2.65 mA	175.12 mW	0.6611 %	0.6611 %	699.6 pF	Not ass.
C2G	Open	GST	60.00 Hz	10.00 kV	2.65 mA	114.91 mW	0.4341 %	0.4341 %	699.1 pF	Not ass.
C3G	Open	GST	60.00 Hz	10.00 kV	2.65 mA	146.53 mW	0.5526 %	0.5526 %	700.4 pF	Not ass.
C4G	Open	GST	60.00 Hz	10.00 kV	2.70 mA	157.34 mW	0.5832 %	0.5832 %	712.7 pF	Not ass.
C5G	Open	GST	60.00 Hz	10.00 kV	2.65 mA	163.44 mW	0.6158 %	0.6158 %	700.9 pF	Not ass.
C6G	Open	GST	60.00 Hz	10.00 kV	2.74 mA	553.02 mW	2.0149 %	2.0149 %	724.8 pF	Not ass.
C1G+C2G	Closed	GST	60.00 Hz	10.00 kV	5.13 mA	276.91 mW	0.5397 %	0.5397 %	1358.1 pF	Not ass.
C3G+C4G	Closed	GST	60.00 Hz	10.00 kV	5.20 mA	374.01 mW	0.7197 %	0.7197 %	1375.4 pF	Not ass.
C5G+C6G	Closed	GST	60.00 Hz	10.00 kV	5.22 mA	706.91 mW	1.3540 %	1.3540 %	1381.7 pF	Not ass.

Phase	Tank loss index	Assessment
A	-0.01	Not ass.
B	0.07	Not ass.
C	-0.01	Not ass.

Insulating Fluids PF & CAP Preliminares

Ambient temperature	26 °C
Oil temperature	24 °C

Comments

Standard test

Corr. factor	1
* Reference voltage	10.0 kV

No.	Specimen	Test mode	Freq.	V out	* I out	* Watt losses	PF meas	PF corr	Cap. meas	Assessment
1	TANK 1	UST-A	60.00 Hz	10.00 kV	0.91 mA	7.57 mW	0.0833 %	0.0833 %	241.3 pF	Not ass.
2	TANK 2	UST-A	60.00 Hz	10.00 kV	0.91 mA	8.04 mW	0.0880 %	0.0880 %	242.4 pF	Not ass.
3	TANK 3	UST-A	60.00 Hz	10.00 kV	0.92 mA	6.41 mW	0.0699 %	0.0699 %	243.0 pF	Not ass.
4	Sample 4	UST-A	60.00 Hz	kV	mA	mW	%	%	pF	Not ass.

Bushing PF & CAP - C1

Ambient temperature	36 °C

Weather	Clear
Humidity	76 %

Comments

Standard test

Corr. factor	1
* Reference voltage	10.0 kV

No.	Meas.	Test mode	Freq.	V out	* I out	* Watt losses	PF meas	PF corr	Cap. meas	Assessment
1	Bushing 1	UST-A	60.00 Hz	10.00 kV	1.72 mA	68.56 mW	0.3975 %	0.3975 %	457.5 pF	Not ass.
2	Bushing 2	UST-A	60.00 Hz	10.00 kV	1.70 mA	113.68 mW	0.6698 %	0.6698 %	450.2 pF	Not ass.
3	Bushing 3	UST-A	60.00 Hz	10.00 kV	1.74 mA	104.65 mW	0.6000 %	0.6000 %	462.7 pF	Not ass.
4	Bushing 4	UST-A	60.00 Hz	10.00 kV	1.71 mA	164.79 mW	0.9617 %	0.9617 %	454.5 pF	Not ass.
5	Bushing 5	UST-A	60.00 Hz	10.00 kV	1.73 mA	90.77 mW	0.5237 %	0.5237 %	459.8 pF	Not ass.
6	Bushing 6	UST-A	60.00 Hz	10.00 kV	1.71 mA	68.79 mW	0.4022 %	0.4022 %	453.7 pF	Not ass.

Bushing PF & CAP - C2

Ambient temperature	36 °C	Weather	Clear
		Humidity	73 %

Comments

Standard test

Corr. factor	1
* Reference voltage	10.0 kV

No.	Meas.	Test mode	Freq.	V out	* I out	* Watt losses	PF meas	PF corr	Cap. meas	Assessment
1	Bushing 1	GSTg-A	60.00 Hz	0.50 kV	15.97 mA	112.77 mW	0.0706 %	0.0706 %	4233.4 pF	Not ass.
2	Bushing 2	GSTg-A	60.00 Hz	0.50 kV	16.20 mA	538.29 mW	0.3322 %	0.3322 %	4295.0 pF	Not ass.
3	Bushing 3	GSTg-A	60.00 Hz	0.50 kV	16.16 mA	547.32 mW	0.3387 %	0.3387 %	4283.4 pF	Not ass.
4	Bushing 4	GSTg-A	60.00 Hz	0.50 kV	16.02 mA	644.23 mW	0.4022 %	0.4022 %	4246.0 pF	Not ass.
5	Bushing 5	GSTg-A	60.00 Hz	0.50 kV	16.31 mA	291.70 mW	0.1788 %	0.1788 %	4324.0 pF	Not ass.
6	Bushing 6	GSTg-A	60.00 Hz	0.50 kV	16.56 mA	656.19 mW	0.3962 %	0.3962 %	4380.2 pF	Not ass.

Circuit Breaker PF & CAP Finales

Ambient temperature	34 °C		Weather	Clear
			Humidity	65 %

Comments

CONTACT RESISTANT AFTER MAINTENANCE:
PHASE #1= 556 microhms
PHASE#2 =956 microhms
PHASE #3 =605 microhms

Standard test

Corr. factor	1
* Reference voltage	10.0 kV

Meas.	Position	Test mode	Freq.	V out	* I out	* Watt losses	PF meas	PF corr	Cap. meas	Assessment
C1G	Open	GST	60.00 Hz	10.00 kV	2.71 mA	328.27 mW	1.2112 %	1.2112 %	715.9 pF	Not ass.
C2G	Open	GST	60.00 Hz	10.00 kV	2.64 mA	215.11 mW	0.8161 %	0.8161 %	696.1 pF	Not ass.
C3G	Open	GST	60.00 Hz	10.00 kV	2.71 mA	278.97 mW	1.0307 %	1.0307 %	714.9 pF	Not ass.
C4G	Open	GST	60.00 Hz	10.00 kV	2.68 mA	275.95 mW	1.0294 %	1.0294 %	708.1 pF	Not ass.
C5G	Open	GST	60.00 Hz	10.00 kV	2.66 mA	198.82 mW	0.7467 %	0.7467 %	703.1 pF	Not ass.
C6G	Open	GST	60.00 Hz	10.00 kV	2.65 mA	160.98 mW	0.6074 %	0.6074 %	699.9 pF	Not ass.
C1G+C2G	Closed	GST	60.00 Hz	10.00 kV	5.13 mA	334.53 mW	0.6525 %	0.6525 %	1356.8 pF	Not ass.
C3G+C4G	Closed	GST	60.00 Hz	10.00 kV	5.19 mA	431.09 mW	0.8314 %	0.8314 %	1372.5 pF	Not ass.
C5G+C6G	Closed	GST	60.00 Hz	10.00 kV	5.13 mA	317.91 mW	0.6200 %	0.6200 %	1357.2 pF	Not ass.

Phase	Tank loss index	Assessment
A	-0.21	Not ass.
B	-0.12	Not ass.
C	-0.04	Not ass.

Insulating Fluids PF & CAP Finales

Ambient temperature	34 °C
Oil temperature	20 °C

Comments

BREAKDOWN:
TK#1=28.2 kv
TK#2=24.8 kv
TK#3=26.6 kv

Standard test

Corr. factor	1
* Reference voltage	10.0 kV

No.	Specimen	Test mode	Freq.	V out	* I out	* Watt losses	PF meas	PF corr	Cap. meas	Assessment
1	TANK#1	UST-A	60.00 Hz	10.00 kV	0.91 mA	11.72 mW	0.1288 %	0.1288 %	241.5 pF	Not ass.
2	TANK# 2	UST-A	60.00 Hz	10.00 kV	0.91 mA	9.56 mW	0.1053 %	0.1053 %	240.8 pF	Not ass.
3	TANK# 3	UST-A	60.00 Hz	10.00 kV	0.91 mA	11.34 mW	0.1245 %	0.1245 %	241.7 pF	Not ass.
4	Sample 4	UST-A	60.00 Hz	kV	mA	mW	%	%	pF	Not ass.

Prueba Velocidad OCB 0082 - Trip

Nameplate

Type	Oil Breaker	**Description**	O.C.B.
Manufacturer	ITE	**Circuit Number**	0082
Model no.	230KM20000-20	**Mechanism Type**	P-45A
Company	P.R.E.P.A.	**Mechanism Book no.**	
Location	SOUCO	**Instruction Book no.**	
Division	T&D.C.E.P.S.E.	**Operation Counter**	
Serial no.	091-000-000-007	**Line Frequency**	60 Hz
Special ID		**Operator**	R.DIAZ
		<custom label 1>	
		<custom label 2>	
Plan Type	Test Result	**Test Run**	Mar 5, 2020 10:44:01
	Instrument Details:	**Instrument Model**	TDR 900
		Serial Number	
		Calibrated	

Main Contact Results: Trip

Main Contact Timing					***Synchronization***	
Channel	**Label**	**Phase**	**Time**	**Status**	**In Breaker**	
OCB-A		Phase A	2208.00 cy	Pass	102.00 cy	No status
OCB-B		Phase B	2202.00 cy	Pass		
OCB-C		Phase C	2190.00 cy	Pass		

Basic Limits

Breaking Timing Limits

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Main Contacts	Open	16.7 ms	41.7 ms	0.0 ms	0.0 ms	0.0 ms
	Close	166.7 ms	333.3 ms	0.0 ms	0.0 ms	0.0 ms
	Reclose	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	TripFree Dwell Time	16.7 ms	50.0 ms			
	Reclose Open-Close Time	0.0 ms	0.0 ms			

Resistor Timing Limits

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Rel. to Test Initiation	Open	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	Close	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
Rel. to Main	Open	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	Close	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	Resistor Debounce	200 us				

Resistance Limits

	Minimum	Maximum
Open Resistence	0.0 Ω	0.0 Ω
Close Resistence	0.0 Ω	0.0 Ω

Capacitance Limits

	Minimum	Maximum
Capacitance Limits	0.0 pF	0.0 pF

Motion Measurements

		Velocity				Travel		
Channel		Zone 1	Zone 2	Total Travel	Overtravel	Rebound	Contact Wipe	Damping
Motion-1	Zone Type	Distance; Distance	Distance; Distance					
(TRAVEL 1)	Measured	3.222 m/s		19.929 in	0.021 in	0.045 in		7410.00 cy
Phase Undefined	Limits - Max	3.658 m/s	3.658 m/s	20.750 in	0.500 in	0.500 in		
	Limits - Min	3.048 m/s		19.250 in	0.000 in	0.000 in		

Motion Measurements, Main Contacts Open/Close

			At Main Contact Open			
Channel	Label	Phase	Travel from Start Position	Average Velocity	Time from Initiation	Motion Reference Channel
OCB-A	OCB-A	Phase A	0.739 in	2.258 m/s	2208.00 cy	Motion-1
OCB-B	OCB-B	Phase B	0.866 in	2.364 m/s	2292.00 cy	Motion-1
OCB-C	OCB-C	Phase C	0.712 in	2.187 m/s	2190.00 cy	Motion-1

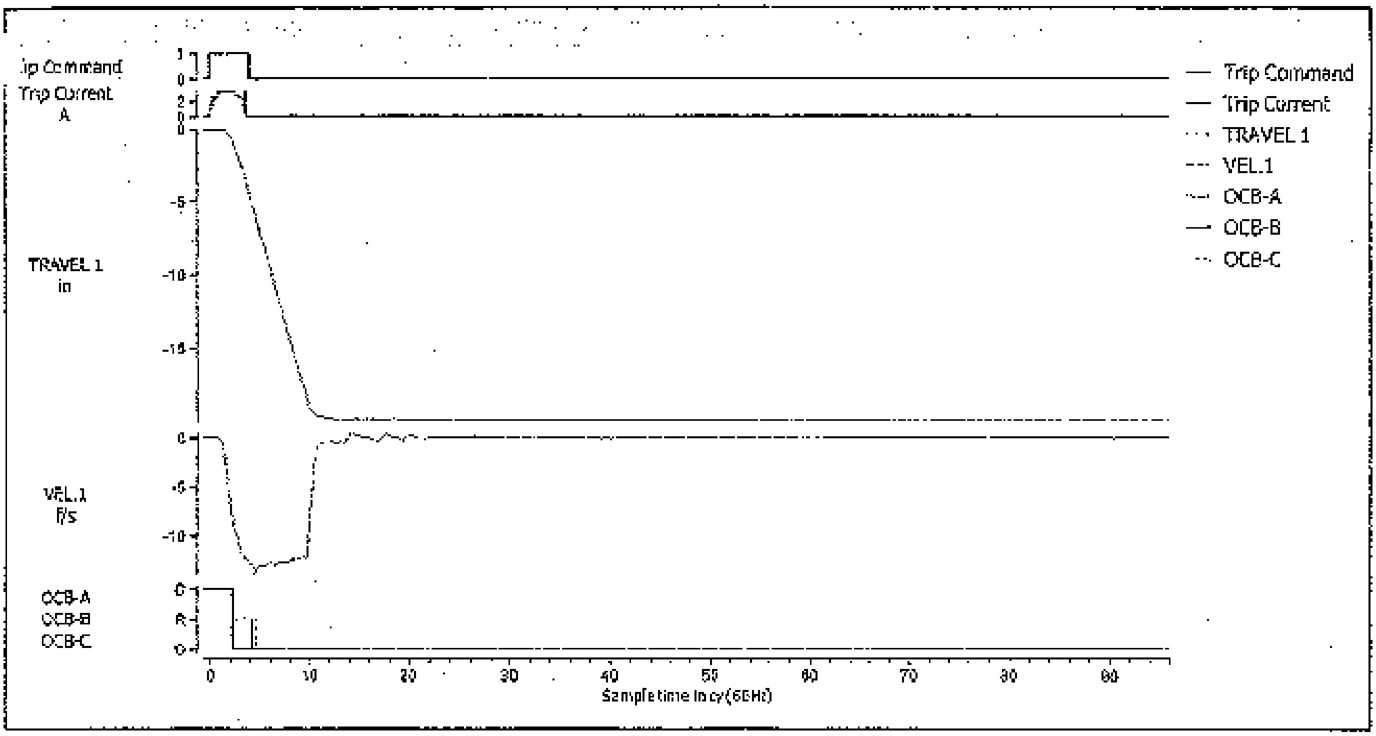
Travel Limits

	Travel Type	Label		Total Travel	Overtravel		Rebound		Contact Wipe
					Open	Close	Open	Close	
Limits Set #1	Linear								
			Expected	20.000 in	0.250 in	0.250 in	0.250 in	0.125 in	0.750 in
			Tolerance -	0.750 in	0.250 in	0.250 in	0.250 in	0.125 in	0.125 in
			Tolerance +	0.750 in	0.250 in	0.125 in	0.250 in	0.125 in	0.250 in

Average Velocity Limits

				Zone Details		Velocity	
	Action	Zone	Zone Type	From	To	Minimum	Maximum
Limits Set #1 (Linear)							
	Open	1	Distance; Distance	1.000 in	4.000 in	3.048 m/s	3.658 m/s
	Open	2	Distance; Distance	0.000 in	0.000 in	0.000 m/s	0.000 m/s
	Close	1	Distance; Distance	5.000 in	1.000 in	3.658 m/s	4.420 m/s
	Close	2	Distance; Distance	0.000 in	0.000 in	0.000 m/s	0.000 m/s

Result Plot



Breaker Test Details

Test Style	OCB	Include Resistors	NO

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Prueba Velocidad OCB 0082 - Close

Nameplate

Type	Oil Breaker	**Description**	O.C.B.
Manufacturer	ITE	**Circuit Number**	0082
Model no.	230KM20000-20	**Mechanism Type**	P-45A
Company	P.R.E.P.A.	**Mechanism Book no.**	
Location	SOUCO	**Instruction Book no.**	
Division	T&D.C.E.P.S.E.	**Operation Counter**	
Serial no.	091-000-000-007	**Line Frequency**	60 Hz
Special ID		**Operator**	R.DIAZ
		<custom label 1>	
		<custom label 2>	
Plan Type	Test Result	**Test Run**	Mar 5, 2020 10:40:03
	Instrument Details:	**Instrument Model**	TDR 900
		Serial Number	
		Calibrated	

Main Contact Results: Close

Main Contact Timing					*Synchronization*
Channel	**Label**	**Phase**	**Time**	**Status**	**In Breaker**
OCB-A		Phase A	17646.00 cy	Pass	42.00 cy No status
OCB-B		Phase B	17604.00 cy	Pass	
OCB-C		Phase C	17646.00 cy	Pass	

Basic Limits

Breaking Timing Limits

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
	Open	16.7 ms	41.7 ms	0.0 ms	0.0 ms	0.0 ms
Main Contacts	Close	166.7 ms	333.3 ms	0.0 ms	0.0 ms	0.0 ms
	Reclose	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	TripFree Dwell Time	16.7 ms	60.0 ms			
	Reclose Open-Close Time	0.0 ms	0.0 ms			

Resistor Timing Limits

		Timing		Synchronization		
		Minimum	Maximum	In Breaker	In Phase	In Module
Rel. to Test Initiation	Open	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	Close	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
Rel. to Main	Open	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	Close	0.0 ms	0.0 ms	0.0 ms	0.0 ms	0.0 ms
	Resistor Debounce	200 us				

Resistance Limits

	Minimum	Maximum
Open Resistence	0.0 Ω	0.0 Ω
Close Resistence	0.0 Ω	0.0 Ω

Capacitance Limits

	Minimum	Maximum
Capacitance Limits	0.0 pF	0.0 pF

Motion Measurements

		Velocity		Travel				
Channel		**Zone 1**	**Zone 2**	**Total Travel**	**Overtravel**	**Rebound**	**Contact Wipe**	**Damping**
Motion-1	**Zone Type**	Distance; Distance	Distance; Distance					
(TRAVEL 1)	**Measured**	4.030 m/s		19.934 in	0.279 in	0.101 in	0.679 in	
Phase Undefined	**Limits - Max**	4.420 m/s	4.420 m/s	20.750 in	0.375 in	0.250 in	1.000 in	
	Limits - Min	3.658 m/s		19.250 in	0.000 in	0.000 in	0.625 in	

Motion Measurements, Main Contacts Open/Close

			At Main Contact Close			
Channel	**Label**	**Phase**	**Travel from Start Position**	**Average Velocity**	**Time from Initiation**	**Motion Reference Channel**
OCB-A	OCB-A	Phase A	19.255 in	3.387 m/s	17646.00 cy	Motion-1
OCB-B	OCB-B	Phase B	19.160 in	3.563 m/s	17604.00 cy	Motion-1
OCB-C	OCB-C	Phase C	19.255 in	3.387 m/s	17646.00 cy	Motion-1

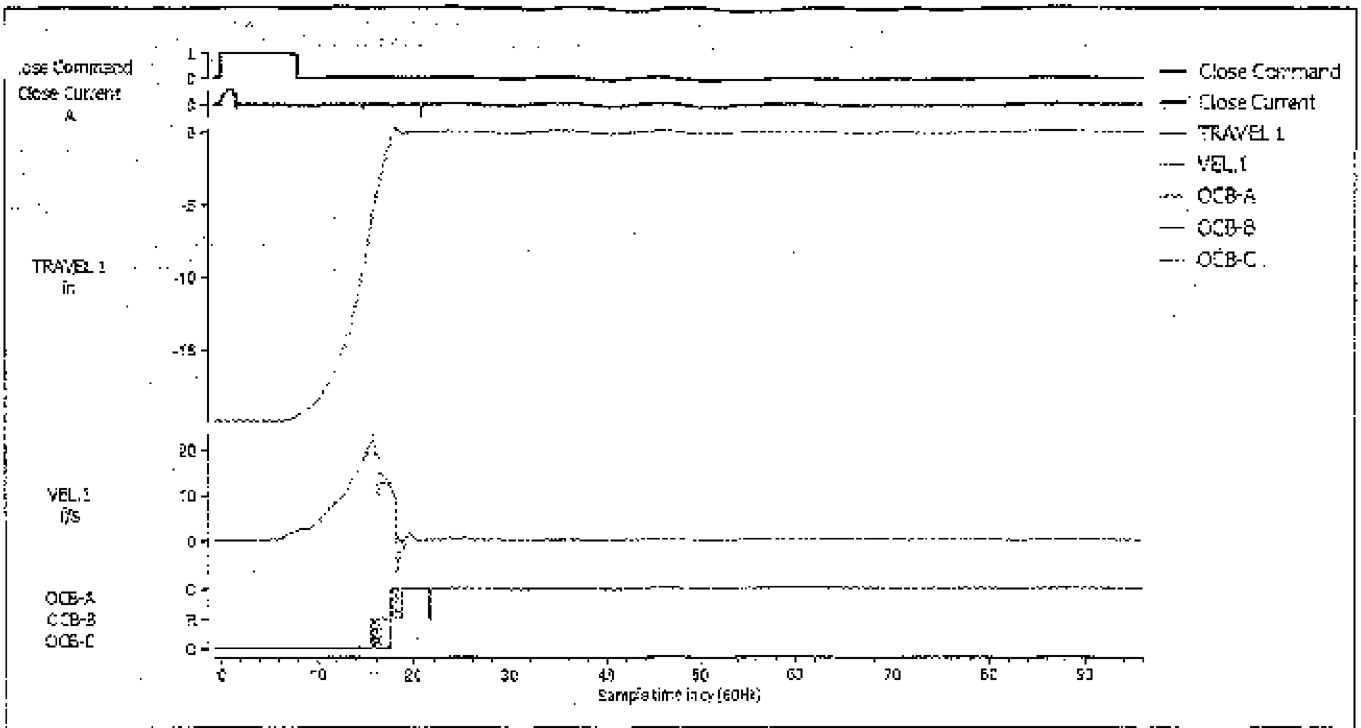
Travel Limits

	Travel Type	**Label**		**Total Travel**	**Overtravel**		**Rebound**		**Contact Wipe**
					Open	**Close**	**Open**	**Close**	
Limits Set #1	Linear								
			Expected	20.000 in	0.250 in	0.250 in	0.250 in	0.125 in	0.750 in
			Tolerance -	0.750 in	0.250 in	0.250 in	0.250 in	0.125 in	0.125 in
			Tolerance +	0.750 in	0.250 in	0.125 in	0.250 in	0.125 in	0.250 in

Average Velocity Limits

			Zone Details			Velocity	
	Action	**Zone**	**Zone Type**	**From**	**To**	**Minimum**	**Maximum**
Limits Set #1 (Linear)							
	Open	1	**Distance; Distance**	1.000 in	4.000 in	3.048 m/s	3.658 m/s
	Open	2	**Distance; Distance**	0.000 in	0.000 in	0.000 m/s	0.000 m/s
	Close	1	**Distance; Distance**	5.000 in	1.000 in	3.658 m/s	4.420 m/s
	Close	2	**Distance; Distance**	0.000 in	0.000 in	0.000 m/s	0.000 m/s

Result Plot



Breaker Test Details

Set Style	OCB	Include Resistors	NO

Filename E:\Update\Informes\Año 2020\Marzo 2020\Costa Sur\OCB 0082_3-5-2020_104003_Close.tdrx