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DEF's Supplemental Responses to OPC's First Set of Interrogatories No. 8

DEF's Supplemental Responses to OPC's First Set of Production of Documents

No. 4.

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

In re: Fuel and purchased power cost recovery clause with generating performance incentive factor	Docket No. 20210001-EI Dated: October 19, 2021

DUKE ENERGY FLORIDA, LLC'S SUPPLEMETNAL RESPONSE TO CITIZENS' FIRST SET OF INTERROGATORIES (NOS. 1-8)

Duke Energy Florida, LLC ("DEF") responds to the Citizens of the State of Florida, through the Office of Public Counsel's ("Citizens" or "OPC") First Set of Interrogatories to DEF (Nos. 1-8), specifically question 8, as follows:

INTERROGATORIES

Please reference the February 26, 2021 GPIF Actual Unit Performance data schedules for January 2021 in responding to interrogatories 1-8:

8. Please identify all documents related to any and all root cause analyses (or the functional equivalent, regardless of title), including drafts and related commentary correspondence, involving the forced outages occurring at Crystal River 4 in January 2021.

Answer:

Please see the documents provided in DEF's Response to OPC First Request for Production of Documents, question 4, bearing bates numbers 20210001-DEF-000048 through 20210001-DEF-000056 provided on April 9, 2021.

Please also see DEF's supplemental Response to OPC First Request for Production of Document, question 4, bearing bates numbers 20210001-DEF- 000156 through 20210001-DEF-000235.

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

In re: Fuel and Purchased Power Cost Recovery Clause and Generating Performance Incentive Factor	Docket No. 20210001-EI Filed: October 19, 2021

DUKE ENERGY FLORIDA, LLC'S SUPPLEMENTAL RESPONSE TO CITIZENS' FIRST REQUEST TO PRODUCE DOCUMENTS (NOS. 1-4)

Duke Energy Florida, LLC's ("DEF"), supplemental response to the Citizens of the State of Florida, through the Office of Public Counsel's ("Citizens" or "OPC") First Request to Produce Documents (Nos. 1-4), specifically question 4, as follows:

DOCUMENTS REQUESTED

4. Please provide the documents identified in Citizens' Interrogatory No. 8.

Response:
Please see the attached documents bearing bates numbers 20210001-DEF-000048 through 20210001-DEF-000056 provided on April 9, 2021.

Please also see the attached supplemental documents bearing bates numbers 20210001-DEF-0000156 through 20210001-DEF-000235.

Root Cause Analysis Report

CRN U4 Generator Out of Phase Synchronization 12/18/2020

Revision # 0.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: _____

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date:	1/21/2021
Date Report Completed:	2/16/2021
Root Cause Investigator(s):	Barbara Martinuzzi, Sr OE Specialist James C Winborne, Lead Engineer Joe Simpson, Manager Generation Engineering Doug Wood, Senior Engineer Gene Mullins, Interim Assignment - Leader Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16, 2020. Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump, when the turbine/generator tripped due to a boiler feed water pump control issue~~. Prior to returning to service on December 16, the unit 4 main boiler feed pump tripped due to low drum level. The MBFP doesn't trip due to low drum level. Also, the MBFP wouldn't be in service prior to the unit returning to service. The MBFP is put in service after the unit reaches about 250 MW.~~

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover unit 4.

~~The required NERC VAR-002 AVR Alarm Status PM had been completed on unit 4. Why is this relevant?~~

Operations closed the exciter field breaker, turbine auto sync was selected, set breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker and placed the sync switch in manual. The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchroscope rolled to the twelve o'clock position. The operator stated that they were not attempting to synchronize in manual rather attempting to reset the synchronization circuit to permit auto synchronization. Through interviews it was noted that the auto sync option has been

used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged causing the turbine/generator to attempt to sync to the grid out of phase at a 160-degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline (reference Plantview event #1100460).

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to latch closed as far out as fifty degrees from zero. The setpoint is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main generator field and the unit was placed in forced outage.

Timeline

December 16, 2020	22:53	Unit 4 returned to service
December 17, 2020	19:10	Turbine/generator tripped (boiler feed water pump control issue)
December 17, 2020	22:00:12.608	First attempt to auto sync (permissive 86A&B lockouts tripped)
December 17, 2020	22:00:16.924	Second attempt to auto sync (plant line 3AG & 3BG lockout relays tripped)
December 17, 2020	22:00:20.132	Third attempt to auto sync (cause for failed auto sync unknown)
December 17, 2020	22:11:47.708	Fourth attempt (red flagged the breaker - breaker closed)
December 17, 2020	22:11:44.7340	Citrus Combined Cycle PB1 tripped (breaker open)
December 17, 2020	22:11:47.7106	Unit 4 breaker 3233 tripped open (U4 placed in forced outage)
December 18, 2020		Meeting with Turbine Generator Services
December 21, 2020		Review of substation drawings, relay operational data
December 23, 2020		Beckwith manual sync check relay replaced
January 7, 2021		Unit 4 start attempt (ground on the main field)
January 20, 2021		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis
February 8, 2021		Beckwith completed repair evaluation report (confirmed onsite findings)

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was originally procured on February 28, 2002, and then relocated from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020. The relay was sent for failure analysis following the event. The sync check relay was verified with component failure that led to mis-operation of the device. The report is included as Attachment 2.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line lockout (3AG & AB) relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a unit trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown.

Prior to the 2017-2019 fiber optic outage, the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or sync selector switch occurred during this outage. There have been no changes to the synchronization hard panel since original panel construction in 2002.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay

event files and substation relay schemes were reviewed along with projects and configuration changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker control switches were also evaluated. The Beckwith Electric Company repair evaluation report was reviewed.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part

The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule

(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)

The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. Did the operator say why they didn't reposition the synch handle one more twist to OFF? i don't like the way this is worded. i think i know what you want to say but it isn't saying that. The breaker closed before the operator had a chance to touch the switch.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

~~**A3B2C02 – Signs to stop were ignored and step performed incorrectly**~~

~~*(Most activities generate indication of status (both positive and negative). The human tendency is to focus on the indications of success rather than all the indicators. The negative indicators are the "signs to stop.")*~~

~~Changing priorities regarding unit operation changed multiple times in less than two hours, adding time pressure to complete the tasks and move on to additional tasks. Station was attempting to respond to meet system requirements. (unit 4 running, start-up on unit 5, unit 4 tripped, put unit 5 on hold, start-up unit 4, out of phase sync event happened, start-up unit 5). Once U4 tripped it required immediate response. No choice but to change priority from U5 start-up to U4 recovery. Agreed that there were immediate changing priorities, but was there really time pressure during the synchronizing process?~~

A3B3C04 – LTA review based on assumption that process will not change

(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).

After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto. Were all three permissive lights illuminated? Is more adjustment needed once the light is illuminated? If so, why? Talk through with Joe's graphs.

A3B3C06 – Individual underestimated the problem by using past events as basis

(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)

Operations should have stopped when unit 4 initially tripped on low drum level and consulted the Generator Trip EOP 1. The EOP (which EOP; BFP Trip, Boiler Trip, Turbine Trip) provides steps for immediate operator response, protective relay targets, and associated alarms on the DCS alarm screen. Transformer, auxiliary transformers and relay trip schedules are also listed along with the lockout relay reset procedure. Through interviews it was noted that trips caused by the main boiler feed water pump were not uncommon and the EOP was typically not consulted for this type trip event.

Ops protocol states that we respond to unit emergencies, then refer to a procedure. "During a station transient or emergency situation (e.g. boiler leak, equipment tripping, fire, injury, etc.), Operators are expected to take prompt actions to ensure the safety of all personnel and place the station equipment in a safe and stable condition and then refer to appropriate procedures to verify correct actions have been taken." The plant had tripped three hours earlier and EOPs were never referenced. Start-up procedure was pulled, no documentation found for the sign off portions of the procedure.

My understanding is that a start-up procedure was pulled out to use as reference to return the unit to service. There will be an overall revision to the start-up procedure including detailed information on relay resetting including an attachment with pictures.

A6B2C01 – Practice or "hands-on" experience LTA
(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)
Additional training resources were not made available to provide adequate training for the newly restructured organization ~~as it moved through various tier levels.~~ ~~CRN moved from tier 3 to tier 2 status on October 7, 2020.~~ Experience of the OTS was less than adequate, consisting of shadowing for approximately three months and becoming full time in September 2020. Not sure how tiering impacted the event, unless you are referencing that CRN reduced supervisor positions from 11 to 6 prompting many experienced OTS to leave? The remaining and new supervisors are now responsible for Plant and FGD/WWT instead of being siloed in one area.

It isn't the OTS who is tasked with knowing how to synch the unit online. It is preferable, but not a requirement to know each technical aspect of the position being supervised.

A5B1C01 – Format deficiencies
(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)
The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 3.

A5B2C08 – Incomplete/situation not covered
(*Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)*
Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto sync mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(*Limits were not expressed clearly and concisely.)*
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the generator synchronization panel. The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint. Would like clarification on if the three permissive lights are illuminated, are adjustments still needed? That doesn't seem acceptable. Joe's graphs.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:

Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

VIII. Repeat Event Review:

There have been no similar generator events at Crystal River or in the Florida fleet within the last three years.

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee**	**Due/Completion Date**

	Evaluator **SHALL** obtain concurrence from assignee or supervisor	
Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with Fleet.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device.	Heath McDonald	5/1/2021
CAPR 2: Performance manage employees involved in the event as appropriate. Who was identified as requiring performance management by the team? What level? Not the RCA's team call.	Jamie Long	3/1/2021
CAPR 3: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/1/2021

Action to Correct the Contributing Cause(s)		
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Ensure that there is a specific lesson plan around generator synchronization and implement. Include methodical problem-solving techniques with unfamiliar situations. Two separate training tasks. Divide the problem solving training into a separate task with a later due date.	TJ Snodgrass	5/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021

Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency. OTS will be provided extended pay to attend all training sessions and simulator training with their crews. Extended pay to review procedures and shadow craft would be desired.	Jamie Long	5/1/2021

Action(s) to Correct the Contributing Cause(s)		
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/1/2021
Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action Describe specific actions required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due Date** 6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.	Barbara Martinuzzi	10/18/2021

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

20210001.EI Staff Hearing Exhibits 00193

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker.

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization check relay to perform as designed.

5. Why did the synchronization check relay not support the operators training and experience, and not perform as designed?
5a. The synchronization check relay had failed allowing an out of phase event.

Attachment 2: Beckwith Electric Company Repair Evaluation Report

RMA 21184 DUKE ENERGY EVALUATION

Attachment 3: CRN Startup Procedure #CRNOP/00/TBD/0004

CR Unit Start-Up Procedure OI-1 CRNC

Attachment 4: Barrier(s) that should have precluded or reduced the likelihood or significance of the incident

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 o'clock position on the synchroscope	Synchronization to the grid should occur as close to 12 o'clock as possible, but within the zone of 11 to 1 on the synchronization scope.	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Time pressure	Priorities changed multiple times in a short period as the station was attempting to respond to meet system requirements.	Operations should have stopped and evaluated the situation prior to continuing to attempt synchronization (contributed to).	Signs to stop were not recognized and step performed incorrectly

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Turbine speed of 3602 RPM was considered a setpoint and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the turbine speed.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	Less than adequate review based on assumption that process will not change
Operations should have stopped when unit 4 initially tripped on low drum level and consulted the Emergency Operating Procedure (EOP).	Using the startup procedure does not direct the operator to consult the EOP which provides steps for immediate operator response, protective relay targets and associated alarms on the DCS alarm screen.	Not being directed to utilize the EOP placed the operator in a skill-based scenario, outside the scope of the startup procedure, and with only knowledge to rely on. (contributed to).	Individual underestimated the problem by using past events as basis
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	Operations team supervisor experience consisted of shadowing for approximately three months. Shadowing only provides training on conditions that exist during the shadowing. (contributed to).	Practice or "hands-on" experience less than adequate

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not setpoints.	Operator and Operations team supervisor could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised

Root Cause Analysis Report

CRN U4 Generator Out of Phase Synchronization 12/18/2020

Revision # 0.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: _____

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date:	1/21/2021
Date Report Completed:	2/16/2021
Root Cause Investigator(s):	Barbara Martinuzzi, Sr OE Specialist James C Winborne, Lead Engineer Joe Simpson, Manager Generation Engineering Doug Wood, Senior Engineer Gene Mullins, Interim Assignment - Leader Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16, 2020. Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump, when the turbine/generator tripped due to a boiler feed water pump control issue. Prior to returning to service on December 16, the unit 4 main boiler feed pump tripped due to low drum level. The MBFP doesn't trip due to low drum level. Also, the MBFP wouldn't be in service prior to the unit returning to service. The MBFP is put in service after the unit reaches about 250 MW.

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover unit 4.

The required NERC VAR-002 AVR Alarm Status PM had been completed on unit 4. Why is this relevant?

Operations closed the exciter field breaker, turbine auto sync was selected, set breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker and placed the sync switch in manual. The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchroscope rolled to the twelve o'clock position. The operator stated that they were not attempting to synchronize in manual rather attempting to reset the synchronization circuit to permit auto synchronization. Through interviews it was noted that the auto sync option has been

used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged causing the turbine/generator to attempt to sync to the grid out of phase at a 160-degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline (reference Plantview event #1100460).

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to latch closed as far out as fifty degrees from zero. The setpoint is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main generator field and the unit was placed in forced outage.

Timeline

December 16, 2020	22:53	Unit 4 returned to service
December 17, 2020	19:10	Turbine/generator tripped (boiler feed water pump control issue)
December 17, 2020	22:00:12.608	First attempt to auto sync (permissive 86A&B lockouts tripped)
December 17, 2020	22:00:16.924	Second attempt to auto sync (plant line 3AG & 3BG lockout relays tripped)
December 17, 2020	22:00:20.132	Third attempt to auto sync (cause for failed auto sync unknown)
December 17, 2020	22:11:47.708	Fourth attempt (red flagged the breaker)
December 17, 2020	22:11:44.7340	Citrus Combined Cycle PB1 tripped
December 17, 2020	22:11:47.7106	Unit 4 breaker 3233 tripped open (U4 placed in forced outage)
December 18, 2020		Meeting with Turbine Generator Services
December 21, 2020		Review of substation drawings, relay operational data
December 23, 2020		Beckwith manual sync check relay replaced
January 7, 2021		Unit 4 start attempt (ground on the main field)
January 20, 2021		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis
February 8, 2021		Beckwith completed repair evaluation report (confirmed onsite findings)

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was originally procured on February 28, 2002, and then relocated from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020. The relay was sent for failure analysis following the event. The sync check relay was verified with component failure that led to mis-operation of the device. The report is included as Attachment 2.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line lockout (3AG & AB) relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a unit trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown.

Prior to the 2017-2019 fiber optic outage, the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or sync selector switch occurred during this outage. There have been no changes to the synchronization hard panel since original panel construction in 2002.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay

event files and substation relay schemes were reviewed along with projects and configuration changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker control switches were also evaluated. The Beckwith Electric Company repair evaluation report was reviewed.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part

The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule

(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)

The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. Did the operator say why they didn't reposition the synch handle one more twist to OFF? i don't like the way this is worded. i think i know what you want to say but it isn't saying that.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

A3B2C02 – Signs to stop were ignored and step performed incorrectly

(Most activities generate indication of status (both positive and negative). The human tendency is to focus on the indications of success rather than all the indicators. The negative indicators are the "signs to stop.")

~~Changing~~ priorities regarding unit operation changed multiple times in less than two hours, adding time pressure to complete the tasks and move on to additional tasks. Station was attempting to respond to meet system requirements. (unit 4 running, start-up on unit 5, unit 4 tripped, put unit 5 on hold, start-up unit 4, out of phase sync event happened, start-up unit 5). Once U4 tripped it required immediate response. No choice but to change priority from U5 start-up to U4 recovery. Agreed that there were immediate changing priorities, but was there really time pressure during the synchronizing process?

A3B3C04 – LTA review based on assumption that process will not change

(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).

After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto. Were all three permissive lights illuminated? Is more adjustment needed once the light is illuminated? If so, why?

A3B3C06 – Individual underestimated the problem by using past events as basis

(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)

Operations should have stopped when unit 4 initially tripped on low drum level and consulted the EOP. The EOP (which EOP; BFP Trip, Boiler Trip, Turbine Trip) provides steps for immediate operator response, protective relay targets, and associated alarms on the DCS alarm screen. Transformer, auxiliary transformers and relay trip schedules are also listed along with the lockout relay reset procedure. Through interviews it was noted that trips caused by the main boiler feed water pump were not uncommon and the EOP was typically not consulted for this type trip event.

Ops protocol states that we respond to unit emergencies, then refer to a procedure. "During a station transient or emergency situation (e.g. boiler leak, equipment tripping, fire, injury, etc.), Operators are expected to take prompt actions to ensure the safety of all personnel and place the station equipment in a safe and stable condition and then refer to appropriate procedures to verify correct actions have been taken."

My understanding is that a start-up procedure was pulled out to use as reference to return the unit to service. There will be an overall revision to the start-up procedure including detailed information on relay resetting including an attachment with pictures.

A6B2C01 – Practice or "hands-on" experience LTA
(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)
Additional training resources were not made available to provide adequate training for the newly restructured organization as it moved through various tier levels. CRN moved from tier 3 to tier 2 status on October 7, 2020. Experience of the OTS was less than adequate, consisting of shadowing for approximately three months and becoming full time in September 2020. Not sure how tiering impacted the event, unless you are referencing that CRN reduced supervisor positions from 11 to 6 prompting many experienced OTS to leave? The remaining and new supervisors are now responsible for Plant and FGD/WWT instead of being siloed in one area.

It isn't the OTS who is tasked with knowing how to synch the unit online. It is preferable, but not a requirement to know each technical aspect of the position being supervised.

A5B1C01 – Format deficiencies
(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)
The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 3.

A5B2C08 – Incomplete/situation not covered
(*Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)*
Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto sync mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(*Limits were not expressed clearly and concisely.)*
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the generator synchronization panel. The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint. Would like clarification on if the three permissive lights are illuminated, are adjustments still needed? That doesn't seem acceptable.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:
Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

VIII. Repeat Event Review:
There have been no similar generator events at Crystal River or in the Florida fleet within the last three years.

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**

Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with Fleet.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device.	Heath McDonald	5/1/2021
CAPR 2: Performance manage employees involved in the event as appropriate. Who was identified as requiring performance management by the team? What level?	Jamie Long	3/1/2021
CAPR 3: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/1/2021

Action to Correct the Contributing Cause(s)		
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Ensure that there is a specific lesson plan around generator synchronization and implement. Include methodical problem-solving techniques with unfamiliar situations. Two separate training tasks. Divide the problem solving training into a separate task with a later due date.	TJ Snodgrass	5/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021
Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency. OTS will be provided extended pay to attend all training sessions and	Jamie Long	5/1/2021

simulator training with their crews. Extended pay to review procedures and shadow craft would be desired.		

Action(s) to Correct the Contributing Cause(s)		
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/1/2021
Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action Describe specific actions required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due Date** 6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.	Barbara Martinuzzi	10/18/2021

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker.

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization check relay to perform as designed.

5. Why did the synchronization check relay not support the operators training and experience, and not perform as designed?
5a. The synchronization check relay had failed allowing an out of phase event.

Attachment 2: Beckwith Electric Company Repair Evaluation Report

RMA 21184 DUKE ENERGY EVALUATION

Attachment 3: CRN Startup Procedure #CRNOP/00/TBD/0004

CR Unit Start-Up Procedure OI-1 CRNC

Attachment 4: Barrier(s) that should have precluded or reduced the likelihood or significance of the incident

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 o'clock position on the synchroscope	Synchronization to the grid should occur as close to 12 o'clock as possible, but within the zone of 11 to 1 on the synchronization scope.	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Time pressure	Priorities changed multiple times in a short period as the station was attempting to respond to meet system requirements.	Operations should have stopped and evaluated the situation prior to continuing to attempt synchronization (contributed to).	Signs to stop were not recognized and step performed incorrectly

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Turbine speed of 3602 RPM was considered a setpoint and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the turbine speed.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	Less than adequate review based on assumption that process will not change
Operations should have stopped when unit 4 initially tripped on low drum level and consulted the Emergency Operating Procedure (EOP).	Using the startup procedure does not direct the operator to consult the EOP which provides steps for immediate operator response, protective relay targets and associated alarms on the DCS alarm screen.	Not being directed to utilize the EOP placed the operator in a skill-based scenario, outside the scope of the startup procedure, and with only knowledge to rely on. (contributed to).	Individual underestimated the problem by using past events as basis
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	Operations team supervisor experience consisted of shadowing for approximately three months. Shadowing only provides training on conditions that exist during the shadowing. (contributed to).	Practice or "hands-on" experience less than adequate

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not setpoints.	Operator and Operations team supervisor could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised

Root Cause Analysis Report

CRN U4 Generator Out of Phase Synchronization 12/18/2020

Revision # 0.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: _____

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date: 1/21/2021
Date Report Completed: 2/16/2021
Root Cause Investigator(s): Barbara Martinuzzi, Sr OE Specialist
James C Winborne, Lead Engineer
Joe Simpson, Manager Generation Engineering
Doug Wood, Senior Engineer
Gene Mullins, Interim Assignment - Leader
Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16, 2020. Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump, when the turbine/generator tripped due to a boiler feed water pump control issue. Prior to returning to service on December 16, the unit 4 main boiler feed pump tripped due to low drum level. The MBFP doesn't trip due to low drum level. Also, the MBFP wouldn't be in service prior to the unit returning to service. The MBFP is put in service after the unit reaches about 250 MW.

Commented [WJJC1]: None of this information is relevant to our problem statement or the event under review for the RCA.

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover unit 4.

Commented [WJJC2]: Reword. Some such as Unit 5 was in startup operations at the time of the Unit 4 turbine/generator trip. The station only hs one standby boiler feed pump; shared by both units thus only one unit can be in startup at a time. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover uit 4.

The required NERC VAR-002 AVR Alarm Status PM had been completed on unit 4. Why is this relevant?

Commented [WJJC3]: Remove. This is not relavant.

Operations closed the exciter field breaker, turbine auto sync was selected, set breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker and placed the sync switch in manual. The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchroscope rolled to the twelve o'clock position. The operator stated that they were not attempting to synchronize in manual rather attempting to reset the synchronization circuit to permit auto synchronization. Through interviews it was noted that the auto sync option has been

used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged causing the turbine/generator to attempt to sync to the grid out of phase at a 160-degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline (reference Plantview event #1100460).

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to latch closed as far out as fifty degrees from zero. The setpoint is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main generator field and the unit was placed in forced outage.

Timeline

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December 21, 2020		Review of substation drawings, relay operational data
December 23, 2020		Beckwith manual sync check relay replaced
January 7, 2021		Unit 4 start attempt (ground on the main field)
January 20, 2021		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis
February 8, 2021		Beckwith completed repair evaluation report (confirmed onsite findings)

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was originally procured on February 28, 2002, and then relocated from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020. The relay was sent for failure analysis following the event. The sync check relay was verified with component failure that led to mis-operation of the device. The report is included as Attachment 2.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line lockout (3AG & AB) relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a unit trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown.

Prior to the 2017-2019 fiber optic outage, the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or sync selector switch occurred during this outage. There have been no changes to the synchronization hard panel since original panel construction in 2002.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay

event files and substation relay schemes were reviewed along with projects and configuration changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker control switches were also evaluated. The Beckwith Electric Company repair evaluation report was reviewed.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part
The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule
(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)
The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. Did the operator say why they didn't reposition the synch handle one more twist to OFF? i don't like the way this is worded. i think i know what you want to say but it isn't saying that.

Commented [WJJC4]: The operator red flagged breaker 3233 expecting a failed synchronization per normal (past) function of the synchronizer relay. Operator stated it did not matter because if permissives are not met the synchronizing relay would block breaker closure.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

A3B2C02 – Signs to stop were ignored and step performed incorrectly
(Most activities generate indication of status (both positive and negative). The human tendency is to focus on the indications of success rather than all the indicators. The negative indicators are the "signs to stop.")
~~Changing~~ priorities regarding unit operation changed multiple times in less than two hours, adding time pressure to complete the tasks and move on to additional tasks. Station was attempting to respond to meet system requirements. (unit 4 running, start-up on unit 5, unit 4 tripped, put unit 5 on hold, start-up unit 4, out of phase sync event happened, start-up unit 5). Once U4 tripped it required immediate response. No choice but to change priority from U5 start-up to U4 recovery. Agreed that there were immediate changing priorities, but was there really time pressure during the synchronizing process?

Commented [WJJC5]: I understand what Plant Manager is saying. Priority change concern was resolved well ahead of the actions that caused the event. Is this truly time pressure??? Also I am a little unsure if what we wrote herein conincides with the cause code. Our wording should have included information about the 4 futile attempts and the signal a halt to this effort until a gameplan was developed based on results.

A3B3C04 – LTA review based on assumption that process will not change
(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).
After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto. Were all three permissive lights illuminated? Is more adjustment needed once the light is illuminated? If so, why?

Commented [WJJC6]: All three permissive lights were only illuminated when Sync Scope reached 12:00. That is a function of the synch circuitry. No more adjusts are needed once all 3 lights light between 11 and 1.

A3B3C06 – Individual underestimated the problem by using past events as basis
(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)
Operations should have stopped when unit 4 initially tripped on low drum level and consulted the EOP. The EOP (which EOP; BFP Trip, Boiler Trip, Turbine Trip) provides steps for immediate operator response, protective relay targets, and associated alarms on the DCS alarm screen. Transformer, auxiliary transformers and relay trip schedules are also listed along with the lockout relay reset procedure. Through interviews it was noted that trips caused by the main boiler feed water pump were not uncommon and the EOP was typically not consulted for this type trip event.
Ops protocol states that we respond to unit emergencies, then refer to a procedure. "During a station transient or emergency situation (e.g. boiler leak, equipment tripping, fire, injury, etc.), Operators are expected to take prompt actions to ensure the safety of all personnel and place the station equipment in a safe and stable condition and then refer to appropriate procedures to verify correct actions have been taken."
My understanding is that a start-up procedure was pulled out to use as reference to return the unit to service. There will be an overall revision to the start-up procedure including detailed information on relay resetting including an attachment with pictures.

A6B2C01 – Practice or "hands-on" experience LTA
(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)
Additional training resources were not made available to provide adequate training for the newly restructured organization as it moved through various tier levels. CRN moved from tier 3 to tier 2 status on October 7, 2020. Experience of the OTS was less than adequate, consisting of shadowing for approximately three months and becoming full time in September 2020. Not sure how tiering impacted the event, unless you are referencing that CRN reduced supervisor positions from 11 to 6 prompting many experienced OTS to leave? The remaining and new supervisors are now responsible for Plant and FGD/WWT instead of being siloed in one area.

It isn't the OTS who is tasked with knowing how to synch the unit online. It is preferable, but not a requirement to know each technical aspect of the position being supervised.

Commented [WJJC7]: The information after referencing is true. The last sentence is how plants/industry Management thinks TODAY.

A5B1C01 – Format deficiencies
(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)
The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 3.

A5B2C08 – Incomplete/situation not covered
(Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)
Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto sync mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(Limits were not expressed clearly and concisely.)
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the generator synchronization panel. The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint. Would like clarification on if the three permissive lights are illuminated, are adjustments still needed? That doesn't seem acceptable.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:

Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

VIII. Repeat Event Review:

There have been no similar generator events at Crystal River or in the Florida fleet within the last three years.

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**

Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with Fleet.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device.	Heath McDonald	5/1/2021
CAPR 2: Performance manage employees involved in the event as appropriate. Who was identified as requiring performance management by the team? What level?	Jamie Long	3/1/2021
CAPR 3: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/1/2021

Action to Correct the Contributing Cause(s)		
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Ensure that there is a specific lesson plan around generator synchronization and implement. Include methodical problem-solving techniques with unfamiliar situations. Two separate training tasks. Divide the problem solving training into a separate task with a later due date.	TJ Snodgrass	5/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021
Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency. OTS will be provided extended pay to attend all training sessions and	Jamie Long	5/1/2021

simulator training with their crews. Extended pay to review procedures and shadow craft would be desired.		

Action(s) to Correct the Contributing Cause(s)		
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/1/2021
Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action Describe specific actions required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due Date** 6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.	Barbara Martinuzzi	10/18/2021

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker.

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization check relay to perform as designed.

5. Why did the synchronization check relay not support the operators training and experience, and not perform as designed?
5a. The synchronization check relay had failed allowing an out of phase event.

Attachment 2: Beckwith Electric Company Repair Evaluation Report

RMA 21184 DUKE ENERGY EVALUATION

Attachment 3: CRN Startup Procedure #CRNOP/00/TBD/0004

CR Unit Start-Up Procedure OI-1 CRNC

Attachment 4: Barrier(s) that should have precluded or reduced the likelihood or significance of the incident

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 o'clock position on the synchroscope	Synchronization to the grid should occur as close to 12 o'clock as possible, but within the zone of 11 to 1 on the synchronization scope.	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Time pressure	Priorities changed multiple times in a short period as the station was attempting to respond to meet system requirements.	Operations should have stopped and evaluated the situation prior to continuing to attempt synchronization (contributed to).	Signs to stop were not recognized and step performed incorrectly

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Turbine speed of 3602 RPM was considered a setpoint and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the turbine speed.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	Less than adequate review based on assumption that process will not change
Operations should have stopped when unit 4 initially tripped on low drum level and consulted the Emergency Operating Procedure (EOP).	Using the startup procedure does not direct the operator to consult the EOP which provides steps for immediate operator response, protective relay targets and associated alarms on the DCS alarm screen.	Not being directed to utilize the EOP placed the operator in a skill-based scenario, outside the scope of the startup procedure, and with only knowledge to rely on. (contributed to).	Individual underestimated the problem by using past events as basis
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	Operations team supervisor experience consisted of shadowing for approximately three months. Shadowing only provides training on conditions that exist during the shadowing. (contributed to).	Practice or "hands-on" experience less than adequate

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not setpoints.	Operator and Operations team supervisor could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised

Root Cause Analysis Report

CRN U4 Generator Out of Phase Synchronization 12/18/2020

Revision # 1.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: 2/24/2021

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date:	1/21/2021
Date Report Completed:	2/16/2021
Root Cause Investigator(s):	Barbara Martinuzzi, Sr OE Specialist James C Winborne, Lead Engineer Joe Simpson, Manager Generation Engineering Doug Wood, Senior Engineer Gene Mullins, Interim Assignment - Leader Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16, 2020. Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump, when the turbine/generator tripped due to a boiler feed water pump control issue.

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover unit 4.

Operations closed the exciter field breaker, turbine auto sync was selected, set breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker and placed the sync switch in manual. The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchroscope rolled to the twelve o'clock position. The operator stated that they were not attempting to synchronize in manual rather attempting to reset the synchronization circuit to permit auto synchronization. Through interviews it was noted that the auto sync option has been used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged causing the turbine/generator to attempt to sync to the grid out of phase at a 160-degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline (reference Plantview event #1100460).

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to latch closed as far out as fifty degrees from zero. The setpoint is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main generator field and the unit was placed in forced outage.

Timeline

December 16, 2020	22:53	Unit 4 returned to service
December 17, 2020	19:10	Turbine/generator tripped (boiler feed water pump control issue)
December 17, 2020	22:00:12.608	First attempt to auto sync (permissive 86A&B lockouts tripped)
December 17, 2020	22:00:16.924	Second attempt to auto sync (plant line 3AG & 3BG lockout relays tripped)
December 17, 2020	22:00:20.132	Third attempt to auto sync (cause for failed auto sync unknown)
December 17, 2020	22:11:44.7340	Citrus Combined Cycle PB1 tripped (breaker open)
December 17, 2020	22:11:47.7080	Fourth attempt (red flagged the breaker - breaker closed)
December 17, 2020	22:11:47.7106	Unit 4 breaker 3233 tripped open (U4 placed in forced outage)
December 18, 2020		Meeting with Turbine Generator Services
December 21, 2020		Review of substation drawings, relay operational data
December 23, 2020		Beckwith manual sync check relay replaced
January 7, 2021		Unit 4 start attempt (ground on the main field)
January 20, 2021		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis
February 8, 2021		Beckwith completed repair evaluation report (confirmed onsite findings)

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was originally procured on February 28, 2002, and then relocated from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020. The relay was sent for failure analysis following the event. The sync check relay was verified with component failure that led to mis-operation of the device. The report is included as Attachment 2.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line lockout (3AG & AB) relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a unit trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown.

Prior to the 2017-2019 fiber optic outage, the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or sync selector switch occurred during this outage. There have been no changes to the synchronization hard panel since original panel construction in 2002.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay event files and substation relay schemes were reviewed along with projects and configuration changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker control switches were also evaluated. The Beckwith Electric Company repair evaluation report was reviewed.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part
The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule
(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)
The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. Proper operational procedure would be to remove the red flag from the breaker prior to repositioning the synchronization switch handle.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

A3B3C04 – LTA review based on assumption that process will not change
(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).
After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto.

A3B3C06 – Individual underestimated the problem by using past events as basis
(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)
During the 17-minute time frame of the event, the operations crew attempted unsuccessfully to synchronize to the grid four times without a questioning attitude and without consulting the Operations Superintendent and/or Station Manager.

A6B2C01 – Practice or "hands-on" experience LTA
(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)
Additional training resources are needed to fully train the shifts for the newly restructured organization.

A5B1C01 – Format deficiencies
(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)
The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 3.

A5B2C08 – Incomplete/situation not covered
(*Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)*
Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto sync mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(*Limits were not expressed clearly and concisely.)*
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the generator synchronization panel. The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:

Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

VIII. Repeat Event Review:

There have been no similar generator events at Crystal River or in the Florida fleet within the last three years.

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with Fleet.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device.	Heath McDonald	5/1/2021
CAPR 2: Performance manage employees involved in the event as appropriate.	Jamie Long	3/15/2021
CAPR 3: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/31/2021

Action to Correct the Contributing Cause(s)			
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*		
Corrective Action Describe specific actions taken or required		**Assignee**	**Due/Completion Date**

	Evaluator **SHALL** obtain concurrence from assignee or supervisor	
Ensure that there is a specific lesson plan around generator synchronization and implement.	TJ Snodgrass	5/1/2021
Ensure that the lesson plan includes methodical problem-solving techniques with unfamiliar situations.	TJ Snodgrass	6/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021
Issue Standing Order "maximum of two attempts at synchronization in start-up procedure" until identified procedural changes are complete.	Jamie Long	3/15/2021
Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency. *OTS will be provided extended pay to attend all training sessions and simulator training with their crews. Extended pay to review procedures and shadow craft would be desired.* (Discuss with Tara - added per Wayne)	Jamie Long	5/1/2021

Action(s) to Correct the Contributing Cause(s)		
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/1/2021
Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action	**Assignee**	**Due Date**

Describe specific actions required	Evaluator **SHALL** obtain concurrence from assignee or supervisor	6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.	Barbara Martinuzzi	10/18/2021

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker.

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization check relay to perform as designed.

5. Why did the synchronization check relay not support the operators training and experience, and not perform as designed?
5a. The synchronization check relay had failed allowing an out of phase event.

Attachment 2: Beckwith Electric Company Repair Evaluation Report


RMA 21184 DUKE ENERGY EVALUATION

Attachment 3: CRN Startup Procedure #CRNOP/00/TBD/0004


CR Unit Start-Up Procedure OI-1 CRNC

Attachment 4: Barrier(s) that should have precluded or reduced the likelihood or significance of the incident

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 o'clock position on the synchroscope	Synchronization to the grid should occur as close to 12 o'clock as possible, but within the zone of 11 to 1 on the synchronization scope.	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Turbine speed of 3602 RPM was considered a setpoint and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the turbine speed.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	Less than adequate review based on assumption that process will not change

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	Operations team supervisor experience consisted of shadowing for approximately three months. Shadowing only provides training on conditions that exist during the shadowing. (contributed to).	Practice or "hands-on" experience less than adequate
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not setpoints.	Operator and Operations team supervisor could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised

Root Cause Analysis Report

CRN U4 Generator Out of Phase Synchronization 12/18/2020

Revision # 1.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: 2/24/2021

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date:	1/21/2021
Date Report Completed:	2/16/2021
Root Cause Investigator(s):	Barbara Martinuzzi, Sr OE Specialist James C Winborne, Lead Engineer Joe Simpson, Manager Generation Engineering Doug Wood, Senior Engineer Gene Mullins, Interim Assignment - Leader Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16, 2020. Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump, when the turbine/generator tripped due to a boiler feed water pump control issue.

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover unit 4.

Operations closed the exciter field breaker, turbine auto sync was selected, set generator output breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker and placed the sync switch in manual. The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchroscope rolled to the twelve o'clock position. The operator stated that they were not attempting to synchronize in manual rather attempting to reset the synchronization circuit to permit auto synchronization. Through interviews it was noted that the auto sync option has been used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged causing the turbine/generator to attempt to sync to the grid out of phase at a 160-degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline (reference Plantview event #1100460).

Commented [SJ1]: Were these relays verified to not be tripped prior to the sync attempt? If so, I think we should add that.

Commented [MBJ2R1]: No. The operators did not reference any of the Emergency Operating Procedures (which list all of the relays) and the startup procedure does not address the permissives, so after each attempt, they thought that particular relay was the problem and stopped looking.

Commented [MBJ3R1]:

Commented [SJ4]: Were these relays verified to not be tripped prior to the second sync attempt? If so, I think we should add that.

Commented [MBJ5R4]: Same comment as above.

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to latch closed as far out as fifty degrees from zero. The setpoint is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main generator field and the unit was placed in forced outage.

Timeline

December 16, 2020	22:53	Unit 4 returned to service
December 17, 2020	19:10	Turbine/generator tripped (boiler feed water pump control issue)
December 17, 2020	22:00:12.608	First attempt to auto sync (permissive 86A&B lockouts tripped)
December 17, 2020	22:00:16.924	Second attempt to auto sync (plant line 3AG & 3BG lockout relays tripped)
December 17, 2020	22:00:20.132	Third attempt to auto sync (cause for failed auto sync unknown)
December 17, 2020	22:11:44.7340	Citrus Combined Cycle PB1 tripped (breaker open)
December 17, 2020	22:11:47.7080	Fourth attempt (red flagged the breaker - breaker closed)
December 17, 2020	22:11:47.7106	Unit 4 breaker 3233 tripped open (U4 placed in forced outage)
December 18, 2020		Meeting with Turbine Generator Services
December 21, 2020		Review of substation drawings, relay operational data
December 23, 2020		Beckwith manual sync check relay replaced
January 7, 2021		Unit 4 start attempt (ground on the main field)
January 20, 2021		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis
February 8, 2021		Beckwith completed repair evaluation report (confirmed onsite findings)

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was originally procured on February 28, 2002, and then relocated from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020. The relay was sent for failure analysis following the event. The sync check relay was verified with component failure that led to mis-operation of the device. The report is included as Attachment 2.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line lockout (3AG & AB) relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a unit trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown.

Commented [SJ6]: I'm not clear on what the purpose of this paragraph is...were the 3AG&AB relays tripped for both the first and second sync attempts? Above we have that these were found tripped after the second sync attempt. Still not sure what we're trying to do with this paragraph though...

Commented [MBJ7R6]: Yes. The operators did not complete a thorough walkdown after each trip, therefore each time they attempted to sync there was another item holding them out. This particular item was missed on the first attempt by the operators due to the change in the light sequence and the operators not aware of the modification. The OTS discovered.

Prior to the 2017-2019 fiber optic outage, the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or sync selector switch occurred during this outage. There have been no changes to the synchronization hard panel since original panel construction in 2002.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay event files and substation relay schemes were reviewed along with projects and configuration changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker control switches were also evaluated. The Beckwith Electric Company repair evaluation report was reviewed.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part
The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule
(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)
The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. Proper operational procedure would be to remove the red flag from the breaker prior to repositioning the synchronization switch handle.

Commented [SJ8]: Does the procedure specify to do this?

Commented [MBJ9R8]: There is no guidance in the procedure for unit 4, but for unit 5 it states " IF closing the generator breaker on unit 5,
THEN RED FLAG SET (CLOSE) generator output breaker 1660.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

A3B3C04 – LTA review based on assumption that process will not change
(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).
After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto.

Commented [SJ10]: Why would the amber permissive lights show unit was ready to sync if more adjustments were needed to allow it to sync in auto? What would trigger operator to make adjustments if all the lights indicated he was good to sync? This contributing cause doesn't make sense to me

Commented [MBJ11R10]: When you exceed 3600 RPM all three lights will flicker and illuminate every time when the synchroscope reaches 12 o'clock, however it will not sync if the frequency and voltage angle are not aligned. The only way to do this is to increase speed.

A3B3C06 – Individual underestimated the problem by using past events as basis
(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)
During the 17-minute time frame of the event, the operations crew attempted unsuccessfully to synchronize to the grid four times without a questioning attitude and without consulting the Operations Superintendent and/or Station Manager.

A6B2C01 – Practice or "hands-on" experience LTA
(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)
Additional training resources are needed to fully train the shifts for the newly restructured organization.

A5B1C01 – Format deficiencies
(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)
The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 3.

A5B2C08 – Incomplete/situation not covered
(*Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)*
Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto sync mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(*Limits were not expressed clearly and concisely.)*
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the generator synchronization panel. The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint.

Commented [SJ12]: It's not clear why this contributing cause is listed - are we saying we need the same operator aid for unit 4? What would have triggered operator to know an adjustment was needed if all the lights indicated ready to sync?

Commented [MBJ13R12]: Please see the information above regarding the 'ready to sync'. The operator aid is inaccurate regarding the RPM.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:

Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

Commented [SJ14]: I suspect only Joe and relay experts understand this paragraph - is there a way to write this so the audience of this RCA will understand this paragraph?

Commented [MBJ15R14]: I will work with Joe on the language. We have since found that both Anclote units and CRN Unit 5 already have this fail safe mechanism so only applies to CRN unit 4. Transmission is already moving forward with the corrective action.

VIII. Repeat Event Review:

There have been no similar generator events at Crystal River or in the Florida fleet within the last three years.

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with Fleet.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device.	Heath McDonald	5/1/2021
CAPR 2: Performance manage employees involved in the event as appropriate.	Jamie Long	3/15/2021
CAPR 3: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/31/2021

Action to Correct the Contributing Cause(s)		
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*	
Corrective Action Describe specific actions taken or required	**Assignee**	**Due/Completion Date**

	Evaluator **SHALL** obtain concurrence from assignee or supervisor	
Ensure that there is a specific lesson plan around generator synchronization and implement.	TJ Snodgrass	5/1/2021
Ensure that the lesson plan includes methodical problem-solving techniques with unfamiliar situations.	TJ Snodgrass	6/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021
Issue Standing Order "maximum of two attempts at synchronization in start-up procedure" until identified procedural changes are complete.	Jamie Long	3/15/2021
Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency.	Jamie Long	5/1/2021

Deleted: *OTS will be provided extended pay to attend all training sessions and simulator training with their crews. Extended pay to review procedures and shadow craft would be desired.* (Discuss with Tara - added per Wayne

Action(s) to Correct the Contributing Cause(s)		
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/1/2021
Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action Describe specific actions required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due Date** 6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat	Barbara Martinuzzi	10/18/2021

events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.		

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker.

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization check relay to perform as designed.

5. Why did the synchronization check relay not support the operators training and experience, and not perform as designed?
5a. The synchronization check relay had failed allowing an out of phase event.

Attachment 2: Beckwith Electric Company Repair Evaluation Report

RMA 21184 DUKE ENERGY EVALUATION

Attachment 3: CRN Startup Procedure #CRNOP/00/TBD/0004

CR Unit Start-Up Procedure OI-1 CRNC

Attachment 4: Barrier(s) that should have precluded or reduced the likelihood or significance of the incident

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 o'clock position on the synchroscope	Synchronization to the grid should occur as close to 12 o'clock as possible, but within the zone of 11 to 1 on the synchronization scope.	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Turbine speed of 3602 RPM was considered a setpoint and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the turbine speed.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	Less than adequate review based on assumption that process will not change

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	Operations team supervisor experience consisted of shadowing for approximately three months. Shadowing only provides training on conditions that exist during the shadowing. (contributed to).	Practice or "hands-on" experience less than adequate
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not setpoints.	Operator and Operations team supervisor could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised

Root Cause Analysis Report

CRN U4 Generator Out of Phase Synchronization 12/18/2020

Revision # 2.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: 2/24/2021

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date:	1/21/2021
Date Report Completed:	2/16/2021
Root Cause Investigator(s):	Barbara Martinuzzi, Sr OE Specialist James C Winborne, Lead Engineer Joe Simpson, Manager Generation Engineering Doug Wood, Senior Engineer Gene Mullins, Interim Assignment - Leader Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16, 2020. Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump, when the turbine/generator tripped due to a boiler feed water pump control issue.

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover unit 4.

Operations closed the exciter field breaker, turbine auto sync was selected, set generator output breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker in auto and placed the sync switch in manual. The operator then red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchroscope rolled to the twelve o'clock position. The operator stated that they were not attempting to synchronize in manual rather attempting to reset the synchronization circuit to permit auto synchronization. Through interviews it was noted that the auto sync option has been used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged causing the turbine/generator to attempt to sync to the grid out of phase at a 160-degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline (reference Plantview event #1100460).

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to latch closed as far out as fifty degrees from zero. The setpoint is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main generator field and the unit was placed in forced outage.

Timeline

December 16, 2020	22:53	Unit 4 returned to service
December 17, 2020	19:10	Turbine/generator tripped (boiler feed water pump control issue)
December 17, 2020	22:00:12.608	First attempt to auto sync (permissive 86A&B lockouts tripped)
December 17, 2020	22:00:16.924	Second attempt to auto sync (plant line 3AG & 3BG lockout relays tripped)
December 17, 2020	22:00:20.132	Third attempt to auto sync (cause for failed auto sync unknown)
December 17, 2020	22:11:44.7340	Citrus Combined Cycle PB1 tripped (breaker open)
December 17, 2020	22:11:47.7080	Fourth attempt (red flagged the breaker - breaker closed)
December 17, 2020	22:11:47.7106	Unit 4 breaker 3233 tripped open (U4 placed in forced outage)
December 18, 2020		Meeting with Turbine Generator Services
December 21, 2020		Review of substation drawings, relay operational data
December 23, 2020		Beckwith manual sync check relay replaced
January 7, 2021		Unit 4 start attempt (ground on the main field)
January 20, 2021		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis
February 8, 2021		Beckwith completed repair evaluation report (confirmed onsite findings)

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was originally procured on February 28, 2002, and then relocated from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020. The relay was sent for failure analysis following the event. The sync check relay was verified with component failure that led to mis-operation of the device. The report is included as Attachment 2.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line lockout (3AG & AB) relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a unit trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown. Detailed information on relay trip schedules along with the lockout relay reset procedure would have assisted Operations during the multiple attempts to synchronize.

Prior to the 2017-2019 fiber optic outage, the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or sync selector switch occurred during this outage. There have been no changes to the synchronization hard panel since original panel construction in 2002.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay event files and substation relay schemes were reviewed along with projects and configuration changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker

control switches were also evaluated. The Beckwith Electric Company repair evaluation report was reviewed.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part
The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule
(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)
The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. Proper operational procedure would be to green flag the breaker placing the unit in a safe condition prior to repositioning the synchronization switch handle.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

A3B3C04 – LTA review based on assumption that process will not change
(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).
After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto.

A3B3C06 – Individual underestimated the problem by using past events as basis
(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)
During the 17-minute time frame of the event, the operations crew attempted unsuccessfully to synchronize to the grid four times without a questioning attitude and without consulting the Operations Superintendent and/or Station Manager.

A6B2C01 – Practice or "hands-on" experience LTA
(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)
Additional training resources are needed to fully train the shifts for the newly restructured organization.

A5B1C01 – Format deficiencies
(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)
The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 3.

A5B2C08 – Incomplete/situation not covered
(*Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)*
Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto sync mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(*Limits were not expressed clearly and concisely.)*
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the generator synchronization panel. The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:

Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

VIII. Repeat Event Review:

There have been no similar generator events at Crystal River or in the Florida fleet within the last three years.

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with peers.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device.	Heath McDonald	5/1/2021
CAPR 2: Revise Crystal River Start-Up Procedure to include detailed information on resetting relays.	TJ Snodgrass	4/1/2021
CAPR 3: Performance manage employees involved in the event as appropriate.	Jamie Long	3/15/2021
CAPR 4: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/31/2021

Action to Correct the Contributing Cause(s)	
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*

Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Ensure that there is a specific lesson plan around generator synchronization and implement.	TJ Snodgrass	5/1/2021
Ensure that the lesson plan includes methodical problem-solving techniques with unfamiliar situations.	TJ Snodgrass	6/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021
Issue Standing Order "maximum of two attempts at synchronization in start-up procedure" until identified procedural changes are complete.	Jamie Long	3/15/2021
Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency.	Jamie Long	5/1/2021

Action(s) to Correct the Contributing Cause(s)	
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*

Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/15/2021
Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action Describe specific actions required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due Date** 6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.	Barbara Martinuzzi	10/18/2021

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker.

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization check relay to perform as designed.

5. Why did the synchronization check relay not support the operators training and experience, and not perform as designed?
5a. The synchronization check relay had failed allowing an out of phase event.

Attachment 2: Beckwith Electric Company Repair Evaluation Report


RMA 21184 DUKE ENERGY EVALUATION

Attachment 3: CRN Startup Procedure #CRNOP/00/TBD/0004


CR Unit Start-Up Procedure OI-1 CRNC

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The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 o'clock position on the synchroscope	Synchronization to the grid should occur as close to 12 o'clock as possible, but within the zone of 11 to 1 on the synchronization scope.	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Turbine speed of 3602 RPM was considered a setpoint and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the turbine speed.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	Less than adequate review based on assumption that process will not change

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	Operations team supervisor experience consisted of shadowing for approximately three months. Shadowing only provides training on conditions that exist during the shadowing. (contributed to).	Practice or "hands-on" experience less than adequate
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not setpoints.	Operator and Operations team supervisor could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised

Root Cause Analysis Report

CRN U4 Generator Out of Phase Synchronization 12/18/2020

Revision # 0.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: _____

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date:	1/21/2021
Date Report Completed:	2/16/2021
Root Cause Investigator(s):	Barbara Martinuzzi, Sr OE Specialist James C Winborne, Lead Engineer Joe Simpson, Manager Generation Engineering Doug Wood, Senior Engineer Gene Mullins, Interim Assignment - Leader Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16, 2020. Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump, when the turbine/generator tripped due to a boiler feed water pump control issue. Prior to returning to service on December 16, the unit 4 main boiler feed pump tripped due to low drum level.

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to put unit 5 on hold in a safe condition and recover unit 4.

The required NERC VAR-002 AVR Alarm Status PM had been completed on unit 4.

Operations closed the exciter field breaker, turbine auto sync was selected, set breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchroscope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker and placed the sync switch in manual. The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchroscope rolled to the twelve o'clock position. The operator stated that they were not attempting to synchronize in manual rather attempting to reset the synchronization circuit to permit auto synchronization. Through interviews it was noted that the auto sync option has been used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged causing the turbine/generator to attempt to sync to the grid out of phase at a 160-

degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline (reference Plantview event #1100460).

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to latch closed as far out as fifty degrees from zero. The setpoint is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main generator field and the unit was placed in forced outage.

Timeline

December 16, 2020	22:53	Unit 4 returned to service
December 17, 2020	19:10	Turbine/generator tripped (boiler feed water pump control issue)
December 17, 2020	22:00:12.608	First attempt to auto sync (permissive 86A&B lockouts tripped)
December 17, 2020	22:00:16.924	Second attempt to auto sync (plant line 3AG & 3BG lockout relays tripped)
December 17, 2020	22:00:20.132	Third attempt to auto sync (cause for failed auto sync unknown)
December 17, 2020	22:11:47.708	Fourth attempt (red flagged the breaker)
December 17, 2020	22:11:44.7340	Citrus Combined Cycle PB1 tripped
December 17, 2020	22:11:47.7106	Unit 4 breaker 3233 tripped open (U4 placed in forced outage)
December 18, 2020		Meeting with Turbine Generator Services
December 21, 2020		Review of substation drawings, relay operational data
December 23, 2020		Beckwith manual sync check relay replaced
January 7, 2021		Unit 4 start attempt (ground on the main field)
January 20, 2021		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis
February 8, 2021		Beckwith completed repair evaluation report (confirmed onsite findings)

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was originally procured on February 28, 2002, and then relocated from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020. The relay was sent for failure analysis following the event. The sync check relay was verified with component failure that led to mis-operation of the device. The report is included as Attachment 2.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a unit trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown.

Prior to the 2017-2019 fiber optic outage, the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or sync selector switch occurred during this outage. There have been no changes to the synchronization hard panel since original panel construction in 2002.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay event files and substation relay schemes were reviewed along with projects and configuration changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and

the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker control switches were also evaluated. The Beckwith Electric Company repair evaluation report was reviewed.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part

The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule

(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)

The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

A3B2C02 – Signs to stop were ignored and step performed incorrectly

(Most activities generate indication of status (both positive and negative). The human tendency is to focus on the indications of success rather than all the indicators. The negative indicators are the "signs to stop.")

Changing priorities regarding unit operation changed multiple times in less than two hours, adding time pressure to complete the tasks and move on to additional tasks. Station was attempting to respond to meet system requirements. (unit 4 running, start-up on unit 5, unit 4 tripped, put unit 5 on hold, start-up unit 4, out of phase sync event happened, start-up unit 5).

A3B3C04 – LTA review based on assumption that process will not change

(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).

After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto.

A3B3C06 – Individual underestimated the problem by using past events as basis

(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)

Operations should have stopped when unit 4 initially tripped on low drum level and consulted the EOP. The EOP provides steps for immediate operator response, protective relay targets, and associated alarms on the DCS alarm screen. Transformer, auxiliary transformers and relay trip schedules are also listed along with the lockout relay reset procedure. Through interviews it was noted that trips caused by the main boiler feed water pump were not uncommon and the EOP was typically not consulted for this type trip event.

A6B2C01 – Practice or "hands-on" experience LTA

(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)

Additional training resources were not made available to provide adequate training for the newly restructured organization as it moved through various tier levels. CRN moved from tier 3 to tier 2 status on October 7, 2020. Experience of the OTS was less than adequate, consisting of shadowing for approximately three months and becoming full time in September 2020.

A5B1C01 – Format deficiencies

(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)

The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 3.

A5B2C08 – Incomplete/situation not covered

(*Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)*

Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto sync mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(*Limits were not expressed clearly and concisely.)*
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the generator synchronization panel. The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:

Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

VIII. Repeat Event Review:

There have been no similar generator events at Crystal River or in the Florida fleet within the last three years.

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with Fleet.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device.	Heath McDonald	5/1/2021

CAPR 2: Performance manage employees involved in the event as appropriate.	Jamie Long	3/1/2021
CAPR 3: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/1/2021

Action to Correct the Contributing Cause(s)		
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Ensure that there is a specific lesson plan around generator synchronization and implement. Include methodical problem-solving techniques with unfamiliar situations.	TJ Snodgrass	5/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021
Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency.	Jamie Long	5/1/2021

Action(s) to Correct the Contributing Cause(s)		
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/1/2021
Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action Describe specific actions required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due Date** 6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.	Barbara Martinuzzi	10/18/2021

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to synchronize (sync) with the system when breaker closed, resulting in an out of phase event.

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker.

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization check relay to perform as designed.

5. Why did the synchronization check relay not support the operators training and experience, and not perform as designed?
5a. The synchronization check relay had failed allowing an out of phase event.

Attachment 2: Beckwith Electric Company Repair Evaluation Report


RMA 21184 DUKE ENERGY EVALUATION

Attachment 3: CRN Startup Procedure #CRNOP/00/TBD/0004


CR Unit Start-Up Procedure OI-1 CRNC

Attachment 4: Barrier(s) that should have precluded or reduced the likelihood or significance of the incident

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 o'clock position on the synchroscope	Synchronization to the grid should occur as close to 12 o'clock as possible, but within the zone of 11 to 1 on the synchronization scope.	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Time pressure	Priorities changed multiple times in a short period as the station was attempting to respond to meet system requirements.	Operations should have stopped and evaluated the situation prior to continuing to attempt synchronization (contributed to).	Signs to stop were not recognized and step performed incorrectly

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Turbine speed of 3602 RPM was considered a setpoint and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the turbine speed.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	Less than adequate review based on assumption that process will not change
Operations should have stopped when unit 4 initially tripped on low drum level and consulted the Emergency Operating Procedure (EOP).	Using the startup procedure does not direct the operator to consult the EOP which provides steps for immediate operator response, protective relay targets and associated alarms on the DCS alarm screen.	Not being directed to utilize the EOP placed the operator in a skill-based scenario, outside the scope of the startup procedure, and with only knowledge to rely on. (contributed to).	Individual underestimated the problem by using past events as basis
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	Operations team supervisor experience consisted of shadowing for approximately three months. Shadowing only provides training on conditions that exist during the shadowing. (contributed to).	Practice or "hands-on" experience less than adequate

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of **actual** consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not setpoints.	Operator and Operations team supervisor could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised

(1) Synchro should ... two words instead of one.

(2) Sync vs Synchronize throughout

DUKE ENERGY.

Root Cause Analysis Report

CRN U4 Generator Sync Out of Phase 12/18/2020

Revision # 0.0

PlantView Event Number: 1100300

Prepared By: Barbara Martinuzzi Date: 2/2/2021

Sponsor Approval: Wayne Toms Date: _____

Regional Review Committee date: _____

This cause analysis evaluates important conditions adverse to quality through the use of a structured evaluation process. The information identified in this report was discovered using all the data available to the root cause evaluation team at the time of writing using the benefit of hindsight. Cause analyses performed after the fact for Duke Energy have been established as a responsive means to document and assure that conditions adverse to quality are promptly identified and corrected and, as required, to assure that actions are taken to reduce the risk of repetition of the event or condition adverse to quality.

As such, this cause analysis is not intended to make a determination as to whether any of the actions taken or the decisions made by management, vendors, internal organizations, or individual personnel prior to or at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any individual statement or conclusion included in the evaluation as to whether errors may have been made or improvements are warranted is based solely upon information the root cause team considered, including information and results learned after-the-fact. Nothing in this evaluation should be construed as an admission of negligence, liability, or imprudence.

Team Kick-Off Meeting Date: 1/21/2021
Date Report Completed: 2/16/2021
Root Cause Investigator(s): Barbara Martinuzzi, Sr OE Specialist
James C Winborne, Lead Engineer
Joe Simpson, Manager Generation Engineering
Doug Wood, Senior Engineer
Gene Mullins, Interim Assignment - Leader
Dana Christensen, Supervisor Operations

I. Problem Statement:

Crystal River Unit 4 generator failed to align (synchronize) with the system when breaker closed, resulting in an out of phase event.

II. Description of Incident/Issue:

Crystal River Unit 4 had been in an extended outage returning to service on December 16 (2020). Unit 4 had been operating at near minimum load, having just completed the swapping from the standby boiler feed pump to the main boiler feed pump when the turbine/generator tripped due to a boiler feed water pump control issue. Prior to returning to service on December 16, the governor on unit 4 main boiler feed pump was replaced and set at 60 percent capacity rather than 100 percent, restricting water flow and causing the unit trip due to low drum level.

Is the 60% vs 100° an issue in CAP?

Unit 5 was in startup operations at the time of the unit 4 turbine/generator trip. The station only has one standby boiler feed pump that is shared by both units. Since unit 5 was still one day away from being online, the decision was made to take the ignitors out and put unit 5 on hold and recover unit 4.

The required NERC VAR-002 AVR Alarm Status PM had been completed on unit 4.

Operations closed the exciter field breaker, turbine auto sync was selected, set breaker 3233 to close, turbine speed was set at 3602 RPM, and generator voltage verified to be within 2KV of system voltage. When the synchro scope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid. A walkdown was performed and Operations found permissive 86A&B lockout relays tripped. The permissive lockout relays were reset, and a second attempt to synchronize in auto was initiated.

On the second auto attempt, when the synchro scope (A) rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid a second time. Another walkdown was performed and Operations found plant lines lockout relays 3AG & AB tripped. The plant line lockout relays were reset, and a third attempt to synchronize in auto was initiated.

On the third auto attempt, when the synchro scope rolled to the twelve o'clock position, all conditions were met (sync slip frequency OK, sync volts OK, sync phase angle OK), amber lights were lit, but breaker 3233 did not close and unit 4 failed to sync to the grid for the third time in auto.

The operator green flagged the breaker and placed the sync switch in manual. The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto. The operator expected nothing to happen until the auto option was selected and the synchro scope rolled to the twelve o'clock position. The operator stated that they were not attempting to sync in manual rather attempting to reset the sync circuit to ~~auto~~ permit auto synchronization. Through interviews it was noted that the auto sync option has been used since 2017 and use of the manual option would be rare. Unknown to Operations was that the manual sync check relay 25A1 had failed. The circuit was completed when breaker 3233 was red flagged

(A) Synchroscope is one word

causing the turbine/generator to attempt to ~~sync~~ synchronize to the grid out of phase at a 160-degree angle. This resulted in significant damage to the generator rotor. The event also caused enough grid instability on the 230KV to trip Citrus Combined Cycle PB1 station offline. (Ref PV 1100460)

The Beckwith Manual sync check relay model M-0359 (25A1) failed to pass bench testing. The failure mode allowed the closing contact to close as far out as fifty degrees from zero. The set point is fifteen degrees. This relay monitors the slip frequency, voltage, and phase angle. When all three conditions are satisfied, the relay closes permitting synchronization to the grid. The relay was sent for failure analysis and a spare relay was removed from Crystal River Unit 2, bench tested and installed.

The drift is an issue but larger issue is the A/B contact latching.

No damage was initially found to the machine during inspection, all electrical tests were satisfied, and the station went into a forced outage. During attempted start-up on January 7, a low speed centrifugal ground was found on the main ~~electrical~~ generator field and the unit was placed in forced outage.

Timeline

December 16	22:53	Unit 4 returned to service
December 17	19:10	Turbine/generator tripped (boiler feed water pump control issue)
December 17	22:00:12.608	First attempt to auto sync (permissive 86A&B lockouts tripped)
December 17	22:00:16.924	Second attempt to auto sync (plant line 3AG & 3BG lockout relays tripped)
December 17	22:00:20.132	Third attempt to auto sync (cause for failed auto sync unknown)
December 17	22:11:47.708	Fourth attempt (red flagged the breaker)
December 17	22:11:44.7340	Citrus Combined Cycle PB1 tripped
December 17	22:11:47.7106	Unit 4 breaker 3233 tripped open (U4 placed in forced outage)
December 18		Meeting with Turbine Generator Services
December 21		Review of substation drawings, relay operational data
December 23		Beckwith manual sync check relay replaced
January 7		Unit 4 start attempt (ground on the main field)
January 20		Beckwith manual sync check relay model M-0359 (25A1) sent for failure analysis

III. Extent of Condition:

The Beckwith Manual Sync Check Relay model M-0359 (25A1) is typically a very solid device with little to no history of failure in decades of operation. Relay 25A1, serial #1711 was ~~acquired~~ purchased on February 28, 2002 from the retired 230KV Crystal River substation and reinstalled in the new 230KV substation terminal house as part of the 2017-2019 fiber optic communication upgrades. The relay was last functionally tested in April 2020 and has been sent for failure analysis. As of this writing, two bad boards and manual contacts failed closed have been discovered. update

Do we want to mention the report from Beckwith that they have very low return rate?

It was made in 2002 but relocated in 2019.

The Beckwith model M-0193 and M-0189 auto sync check relays were tested and passed.

The plant line relay panels were modified during 2017 and completed in 2019 as part of Transmission substation upgrade project, making units 4 and 5 panel light sequence and visual cues identical. Before this project, the plant line relay panel light sequence, which indicates a ~~unit~~ line/breaker trip, was different for both units. The Operations Team Supervisor (OTS) was aware of this modification, but several operators on shift were not and did not check the plant line relay panels on initial walkdown.

Is this different than p2?

Prior to the 2019 Spring outage (upgrading fiber optics), the preferred method to sync unit 4 was in manual when syncing to the grid. Following the outage, the preferred method was modified to auto. It has been verified that no changes to the wiring or switch selector occurred during this outage. There have been no changes to the synchronization hard panel since original plant construction.

IV. Analysis:

The team utilized interviews, shift logs, shift turnover documents and the pre-job brief. Status updates and correspondence from Transmission and TGS, developed immediately after the event were examined as part of the analysis. Station electrical drawings, digital fault recorder, relay event files and substation relay schemes were reviewed along with projects and configuration

changes occurring between 2017 and 2020. The Start-up procedure and Emergency Operating Procedure (EOP) were reviewed along with the generator synchronizing guide instructions and the General Electric (GE) contact table for breaker 3233/3234 control switch. Unit 5 breaker control switches were also evaluated.

V. Summary of Root Cause(s):

Note: Not necessarily listed in order of significance.

A2B6C01 – Damaged, Defective or failed part
The Beckwith Manual sync check relay model M-0359 (25A1) failed in the closed position which left the circuit armed on manual operation.

A3B2C04 – Previous successes in use of rule reinforced continued use of rule
(Successful use of a rule in the past led to the wrong use of the rule or the rule being incorrectly applied.)
The operator red flagged breaker 3233 expecting a failed synchronization allowing reposition of the sync switch handle back to auto.

VI. Summary of Contributing Cause(s):

Note: Not necessarily listed in order of significance.

A3B2C02 – Signs to stop were ignored and step performed incorrectly
(Most activities generate indication of status (both positive and negative). The human tendency is to focus on the indications of success rather than all the indicators. The negative indicators are the "signs to stop.")
Changing priorities regarding unit operation changed multiple times in less than two hours, adding time pressure to complete the tasks and move on to additional tasks. Station was attempting to respond to meet system requirements. (unit 4 running, start-up on unit 5, unit 4 tripped, put unit 5 on hold, start-up unit 4 event happened, start-up unit 5).

A3B3C04 – LTA review based on assumption that process will not change
(Individual believed that no variability existed in the process and thus overlooked the fact that a change had occurred, leading to different results than normally realized).
After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle. Adjusting the turbine speed may have allowed the generator voltage and system voltage to align and the unit to sync to the grid in auto.

A3B3C06 – Individual underestimated the problem by using past events as basis
(Based on stored knowledge of past events, the individual underestimated problems with the existing event and planned for fewer contingencies than would be needed.)
Operations should have stopped when unit 4 initially tripped on low drum level and consulted the EOP. The EOP provides steps for immediate operator response, protective relay targets, and associated alarms on the DCS alarm screen. Transformer, auxiliary transformers and relay trip schedules are also listed along with the lockout relay reset procedure. Through interviews it was noted that trips caused by the main boiler feed water pump were not uncommon and the EOP was typically not consulted for this type trip event.

A6B2C01 – Practice or "hands-on" experience LTA
(The on-the-job training did not provide opportunities to learn skills necessary to perform the job. There was not enough practice, or hands-on, time allotted.)
Additional training resources were not made available to provide adequate training for the newly restructured organization as it moved through various tier levels. **CRN moved from tier 3 to tier 2 status on October 7, 2020.** Experience of the OTS was less than adequate, consisting of shadowing for approximately three months and becoming full time in September 2020. **This amount of training did not adequately address normal, abnormal, and emergency working conditions.**

A5B1C01 – Format deficiencies
(The layout of the written communication made it difficult to follow. The steps of the procedure were not logically grouped.)
The unit 4 and unit 5 steps are intertwined even though the start-up process and unit configuration are different. CRN Startup Procedure #CRNOP/00/TBD/0004 is included as Attachment 2.

A5B2C08 – Incomplete/situation not covered
(Details of the written communication were incomplete. Insufficient information was presented. The written communication did not address situations likely to occur during the completion of the procedure.)
Page 75 of the Start-up procedure notes 'two methods of generator synchronization on Unit 4: Auto synch mode and Manual mode. Automatic is the normal mode'.
Page 76, section 13.2.2 states 'If Auto synchronization is inoperable on unit 4, then use manual sync listed in Enclosure 5'. Enclosure 5 instructions are incomplete, stopping mid step.

A5B2C01 – Limit inaccuracies
(Limits were not expressed clearly and concisely.)
A generator synchronizing guide (operator aid) for unit 5 is laminated and attached to the ~~generator output breaker.~~ The guide states 'Ensure the turbine speed is at least 3600 RPM (3602 is recommended)." Quite often, turbine speed needs to be adjusted up and down for synchronization. 3602 RPM should be a target, and not a specific setpoint.

~~Unit 5~~ hard panel where sync controls reside.

A4B5C09 – Change-related documents not developed or revised
(Changes to processes resulted in the need for new forms of written communication, which were not created.)
Laminated generator synchronizing guidance (operator aid) did not exist for unit 4.

VII. Extent of Cause:

Cases where the plant line breakers also serve as the Generator Synchronizing Breakers should be reviewed for output contact supervision with 25A1/A2 elements. Modifying SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks will provide a fail-safe mechanism that allows performance only one way.

VIII. Repeat Event Review:

There have been no similar events at Crystal River or in the Florida fleet within the last three years.

– Should we mention the pulverizer good catch

Corrective Actions:

Immediate & Interim Corrective Actions *A4B5C09 – Change-related documents not developed or revised*		
Corrective Action Describe specific actions taken or required.	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Develop a generator synchronizing guide (operator aid) for unit 4, laminate and attach to the generator output breaker.	Jamie Long	Complete

Corrective action for Extent of Condition		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Create PMs to check synchronizing relays on a six-year period based on industry standard.	Heath McDonald	Complete
Share technical document on lessons learned with Fleet.	Joe Simpson	5/1/2021

Action(s) to Correct the Root Cause(s)		
Root Cause(s):	*A2B6C01 – Damaged, Defective or failed part* *A3B2C04 – Previous successes in use of rule reinforced continued use of rule*	
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**

CAPR 1: Replace the Beckwith Manual Sync Check Relay model M-0359 (25A1) with a new device (Work Order #).	Heath McDonald	5/1/2021
CAPR 2: Performance manage employees involved in the event as appropriate.	Jamie Long	3/1/2021
CAPR 3: Share this Root Cause Analysis with all employees at the station.	Wayne Toms	3/1/2021

Action to Correct the Contributing Cause(s)	
Contributing Cause(s):	*A3B3C04 – LTA review based on assumption that process will not change* *A4B2C04 – Resources not provided to assure adequate training was provided/ maintained* *A3B3C06 – Individual underestimated the problem by using past events as basis* *A6B2C01 – Practice or "hands-on" experience LTA*

Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Ensure that there is a specific lesson plan around generator synchronization and implement. Include methodical problem-solving techniques with unfamiliar situations.	TJ Snodgrass	5/1/2021
Provide instructor led training for Operations and OTSs upon completion of the Start-up procedure and synchronizing guide revisions.	TJ Snodgrass	5/1/2021
Evaluate OTS training (technical, command and control) and consider increased shadowing time and rotation to improve proficiency.	Jamie Long	5/1/2021

Action(s) to Correct the Contributing Cause(s)	
Contributing Cause (s):	*A5B1C01 – Format deficiencies* *A5B2C08 – Incomplete/situation not covered* *A5B2C01 – Limit inaccuracies*

Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Revise Crystal River Start-Up Procedure to add enclosures for unit specific activities.	TJ Snodgrass	4/1/2021
Revise Crystal River Start-Up Procedure to reference the EOP ensuring EOP steps have been satisfied.	TJ Snodgrass	4/1/2021
Update generator synchronizing guides (operator aids) on both units to reference 3602 RPM should be a target, and not a specific setpoint.	TJ Snodgrass	4/1/2021

Corrective action for Extent of Cause		
Corrective Action Describe specific actions taken or required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due/Completion Date**
Modify SEL-351S Breaker 3233/3234 logic to supervise output contact equation 102 with 25A1/A2 synchronizing checks.	Jezzel Martinez (Transmission)	3/1/2021

Review existing facilities in Florida for extent of cause.	Joe Simpson	4/1/2021

Effectiveness Review Action Insert rows for additional EREV such as interim effectiveness review		
Corrective Action Describe specific actions required	**Assignee** Evaluator **SHALL** obtain concurrence from assignee or supervisor	**Due Date** 6 months or earlier after all actions have been completed
EREV: Perform effectiveness review on event #1100300. Document no repeat events, procedures revised as described in the corrective actions, training completed, and Transmission corrective actions complete.	Barbara Martinuzzi	6/18/2021

Attachments

Attachment 1: Five (5) Why Staircase
Problem Statement: Crystal River Unit 4 generator failed to align with the system when breaker closed, resulting in an out of phase event.

1. Why did Crystal River Unit 4 generator have an out of phase synchronization to the grid?
1a. The operator red flagged the breaker at the wrong point in the synchronization process.

2. Why did the operator red flag the breaker at the wrong point in the synchronization process?
2a. The operator thought that it didn't matter when you red flagged the breaker. → or was he counting on sych check saving him

3. Why did the operator think that it didn't matter when you red flagged the breaker?
3a. The operator understood that the synchronizing relay would not allow an out of phase synchronization.

4. Why did the operator understand that the synchronizing relay would not allow an out of phase synchronization?
4a. The operators training and experience supported this position.
4b. The operator expected the synchronization relay to perform as designed.
check

5. Why did the synchronization relay not support the operators training and experience, and not perform as designed?
5a. The synchronization relay had failed allowing an out of phase event.
check

Attachment 2: CRN Startup Procedure #CRNOP/00/TBD/0004


CR Unit Start-Up Procedure OI-1 CRNC

Attachment 3: Barrier(s) that should have precluded or reduced the likelihood or significance of the incident

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of actual consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
The Beckwith Manual sync check relay model M-0359 (25A1)	Relay failed in the closed position.	The relay failure armed the circuit on manual operation (directly led).	Damaged, defective or failed part
Operator red flagged the breaker at the 9 position	Synchronization to the grid should occur as close to 12 as possible, but within the zone of 11 to 1 on the synchronization scope. (±5°)	The operator expected a failed synchronization allowing reposition of the sync switch handle back to auto. Operator was unaware that the sync check relay failed (directly led).	Previous successes in use of rule reinforced continued use of the rule
Time pressure	Priorities changed multiple times in a short period as the station was attempting to respond to meet system requirements.	Operations should have stopped and evaluated the situation prior to continuing to attempt synchronization (contributed to).	Signs to stop were ignored and step performed incorrectly

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	BARRIER ASSESSMENT (HOW THE BARRIER FAILED) (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	CONSEQUENCES OF BARRIER FAILURE (Careful consideration of actual consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	REASON(s) for BARRIER FAILURE (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Turbine speed of 3602 RPM was considered a set point and not a target.	After initial voltage adjustment and verifying generator speed of 3602 RPM, no other adjustments were made to the frequency or voltage angle.	Adjusting the turbine speed greater than 3602 RPM may have allowed the generator voltage and system voltage to align and the unit to sync in auto (contributed to).	LTA review based on assumption that process will not change
Operations should have stopped when unit 4 initially tripped on low drum level and consulted the EOP.	The EOP provides steps for immediate operator response, protective relay targets and associated alarms on the DCS alarm screen.	The EOP was typically not consulted for main boiler feed water pump trips as they were not uncommon (contributed to).	Individual underestimated the problem by using past events as basis
On the job training	The amount of training did not adequately address normal, abnormal, and emergency working conditions.	OTS experience consisted of shadowing for approximately three months (contributed to).	Practice or "hands-on" experience less than adequate

BARRIER(s) THAT SHOULD HAVE PRECLUDED, OR REDUCED THE LIKELIHOOD OR SIGNIFICANCE OF, THE INCIDENT (Barriers that should have precluded the incident may be part of the Root Causal Train. Barriers that should have reduced the incident may be part of a Contributing Causal Train.)	**BARRIER ASSESSMENT (HOW THE BARRIER FAILED)** (Identify whether, and in what specific manner, the barrier was missing, weak, or ineffective. Note that a barrier may fail in several different ways in the same incident. Each failure of the barrier should be considered separately.)	**CONSEQUENCES OF BARRIER FAILURE** (Careful consideration of actual consequences of specific barrier failure is needed to help determine whether a specific failure is part of the Root Causal Train or a Contributing Causal Train.) Indicate if Barrier Failure directly led to or contributed to the Event.	**REASON(s) for BARRIER FAILURE** (Identify immediate cause(s) of Barrier failure.) As appropriate, identify additional barrier(s) that should have prevented this Barrier failure. Apply "WHY STAIRCASE" as appropriate.
Procedure was not of adequate quality and did not provide clear instructions.	The unit steps are intertwined even though the start-up process and unit configuration are different. Enclosure instructions are incomplete, and limits should be a target and not set points.	Operator and OTS could not rely on the procedure for guidance during the event (contributed to).	Format deficiencies Incomplete/situation not covered Limit inaccuracies Change related documents not developed or revised