Docket No. 2020001-EI
Cross-Examination
Hearing Exhibit

Exhibit No.: 8

Proffered by: Public Counsel

Short title: FPL RCE - Public Version

Witness(s): FPL- COFFEY

St. Lucie Station

Unit 1 Main Generator Ground Fault Root Cause Evaluation Report

Event Date: 04/25/2019

CR Number: 02312208

Root Cause Team	Name	Dept/Group
Management Sponsor	Mark Jones	Engineering Director
Team Leader	Anas Bouchfaa	Engineering
RC Evaluator	Gary Arntson	Engineering
Team Members	Don Zoll	Maintenance
	Andy Terezakis	Operations

Root Cause Evaluator: GARY ARNTSON / [signature] **Date:** 8/19/19
Print/Sign

Management Sponsor: MARK JONES / [signature] **Date:** 8-19-19
Print/Sign

MRC Chair: Dan DeBoer / [signature] **Date:** 8/19/19
Print/Sign

Electronic Signature may be obtained by assigning actions in NAMS.
Refer to PI-AA-104-1000 for details.

The root cause process is designed to be self critical to drive improvement. As such, specific organizational and/or programmatic causes within the plant's span of control are identified. The root cause process determines a functional cause and not a legal or contractual cause.

1.0 Executive Summary

On 04/25/2019 St Lucie Unit 1 tripped due to a generator lockout during performance of a Reactive Power Lagging Capability Test. The lockout was initiated due to a ground fault in the generator. The fault condition was verified using electrical testing and determined to be in the C phase winding of the stator; however, the location could not be identified during less-intrusive inspections. After generator disassembly and rotor removal, the fault was located using electrical testing to a specific half-coil stator bar in the bottom of slot 17 (B17) in the stator. A decision was made to perform a generator rewind to address the fault.

The ground fault has been attributed to a small puncture through the ground wall insulation of stator bar B17. It has been demonstrated that a latent initiator for the failure was introduced in the stator during a 2012 generator rewind; the puncture developing through the insulation over the course of seven years. Examination and lab analysis has been performed on stator bar B17, however the specific failure mechanism could not be established definitively. Consequently the initiating occurrence in 2012, and its underlying cause, is indeterminate.

An extent of condition review of Unit 2 generator maintenance history has been completed. The Unit 2 generator completed high potential testing in September 2018 and the insulation successfully withstood the high potential test voltage. It can be concluded that a similar ground fault was not present and is not likely in the near term.

Causes

A small puncture developed through the ground wall insulation of stator bar B17 in the phase C Stator Winding resulting in a fault current path to ground.

The root cause of the puncture is indeterminate.

Corrective Action

Complete rewind of the Unit 1 generator to restore stator winding to serviceable condition.

2.0 Report

1. Event Description

On 04/25/2019 St Lucie Unit 1 Operators commenced performance of a Reactive Power Lagging Capability Test in accordance with procedure 0-OSP-53.01. Pre-requisite and risk mitigation activities for the test were completed including verification of generator H2 gas pressures, pre-test predictive maintenance checks, cooling water system performance reviews, securing all load threat work activities both in the plant and switchyard, staging personnel for monitoring exciter fuses and generator vibrations during the test, and establishing pre-planned operating conditions in accordance with St Lucie Unit 2 and Transmission System Operations (TSO).

At 0819 Unit 1 began reactive power ascension. At 0835 the Unit 1 generator reached the test reactive power of 255MVAR out and began a 1 hour hold as specified in the test procedure. Operators began manual logging of test data on 15 minute intervals with no abnormal indications. At 0918 the generator backup lockout was tripped. An automatic turbine and reactor trip occurred in response to the lockout as expected.

Initial investigations determined that the lockout was initiated by operation of backup ground protection relay 64GB/881. The relay's protection zone includes the Main Generator, Isolated Phase bus and associated potential transformers, the high voltage side of Main Transformers 1A and 1B, and the high voltage side of Aux Transformers 1A and 1B. A failure investigation team was chartered in accordance with EN-AA-108-1001 to investigate the ground fault. Digital Fault Recorder data captured for the event provided evidence that a valid ground fault condition was present and likely located on the C phase. After removal of generator flexible links to separate the generator from the isolated phase bus, and separation of each phase at the neutral bus, a ground was confirmed internal to the generator on phase C. Subsequent disassembly and testing confirmed the bottom stator bar in slot 17 of the generator (B17) had a low resistance ground.

2. Problem Statement

The Unit 1 Main Generator experienced a ground fault during performance of a reactive power lagging capability test. The ground fault resulted in a generator lockout and reactor trip.

3. Analysis

A. Background Information on Unit 1 Generator

The St Lucie Unit 1 Main Generator is an 1800rpm direct hydrogen inner-cooled synchronous unit originally supplied by the Westinghouse Electric Company with a rating 1000MVA. During the SL1-24 outage various modifications were performed by Siemens Energy, the current OEM, to achieve increased output for the Extended Power Uprate project. These modifications included rotor replacement and stator rewind to increase the rating from 1000MVA to 1200MVA [D19,D21,D22].

The ‘stator’ is the primary stationary component of the generator consisting of a stator core, three phase windings, and the generator leads which conduct the electrical power from the stator windings. Several images of the Unit 1 generator during rewind in SL1-24 are presented on the following pages to illustrate the stator construction. The core is constructed using laminations of steel with slots to receive the stator coils (Figure 1). The windings each consist of a series of distributed single turn coils. The coils are constructed using half coil ‘stator bars’ installed within slots in the core (Figure 2 and 3) and connected at the ends of the stator outside of the core (Figure 4).

Each stator bar contains conductor, hydrogen cooling tubes, and several layers of materials forming the insulation system (Figure 5 and 6). The conductor consists of copper strands that are individually insulated from each other to reduce losses and arranged close to the cooling tubes for heat removal. The ground wall insulation is ‘Thermalastic’; a trademarked insulation system originally developed by Westinghouse consisting of layers of inorganic mica tape impregnated with an organic epoxy resin.

Special conductive and semi-conductive layers are applied to protect the ground wall insulation from partial discharges (sometimes termed corona) which are damaging to the organic components of the insulation. The Inside Corona Protection (ICP) is applied around the conductor strands under the ground wall. The ICP layer incorporates a conductive copper strip connected to a strand at one end of the stator bar to provide a drain for excess electrical charge. The Outside Corona Protection (OCP) layer is applied over the ground wall insulation within the stator slot and extends for a short distance outside of the slot on both ends. The OCP is maintained in contact with the grounded core laminations to provide a drain path for excess electrical charge outside the ground wall. The OCP layer is terminated at each end of the bar outside of the slot with a semi-conductive End Corona Protection (ECP) layer, also referred to as gradient taping, used to control electrical stress at the OCP termination.

Figure 1 – Stator Core prior to Coil Installation

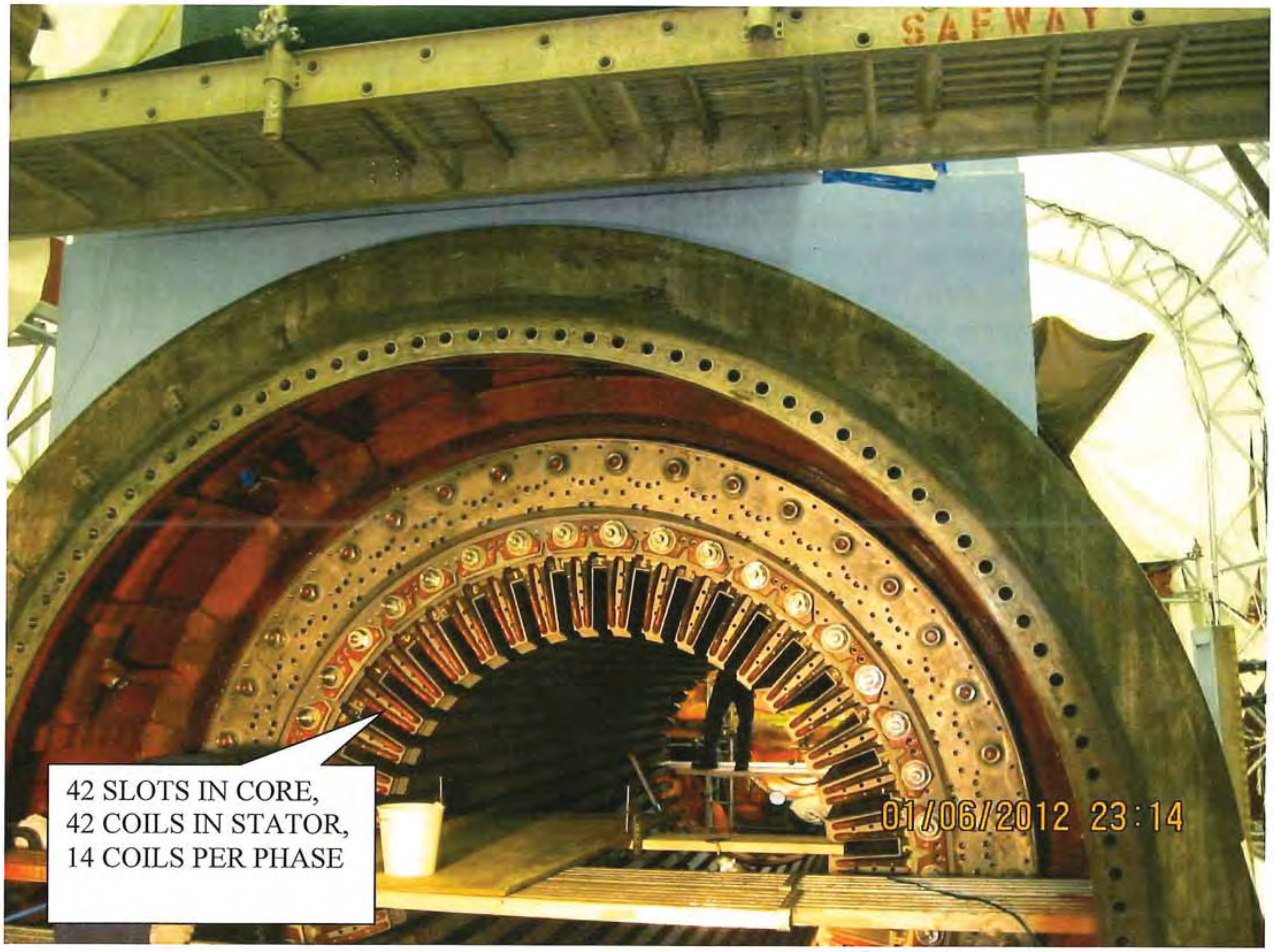


Figure 2 – Bottom Half-Coil installation

Figure 3 – Top Half-Coil Installation

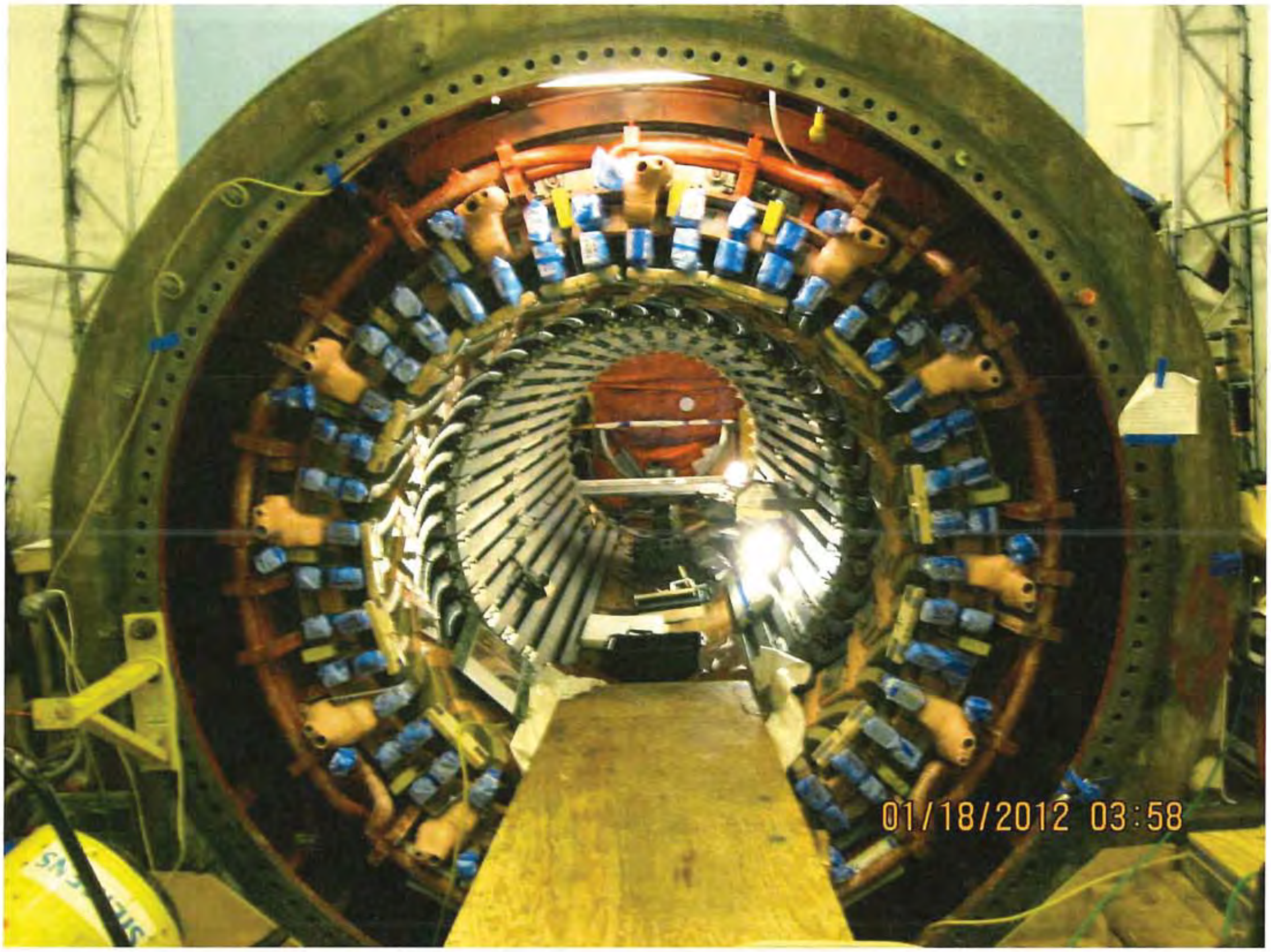


Figure 4 – Coil End Connections

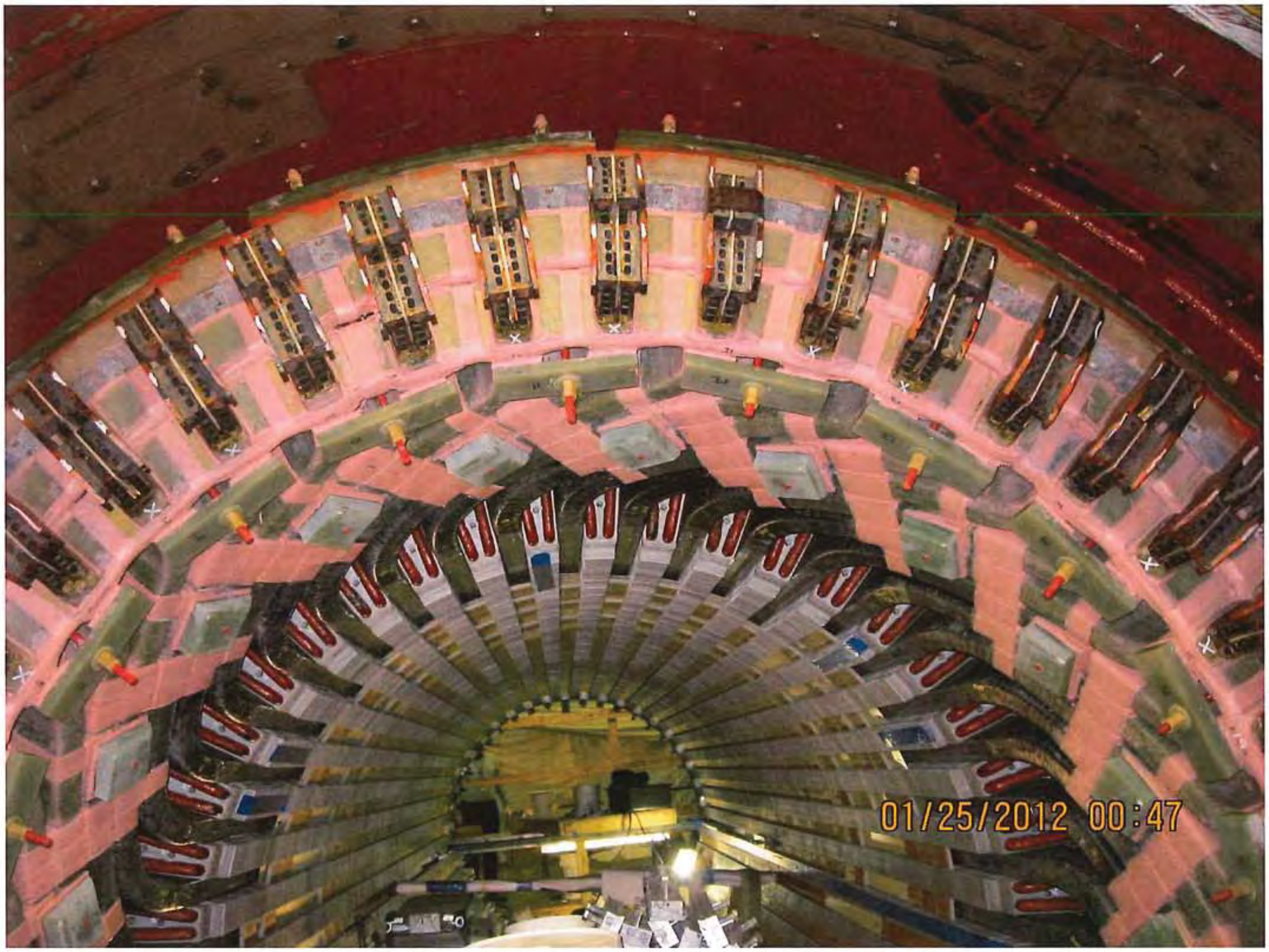


Figure 5 – Stator Bar Section

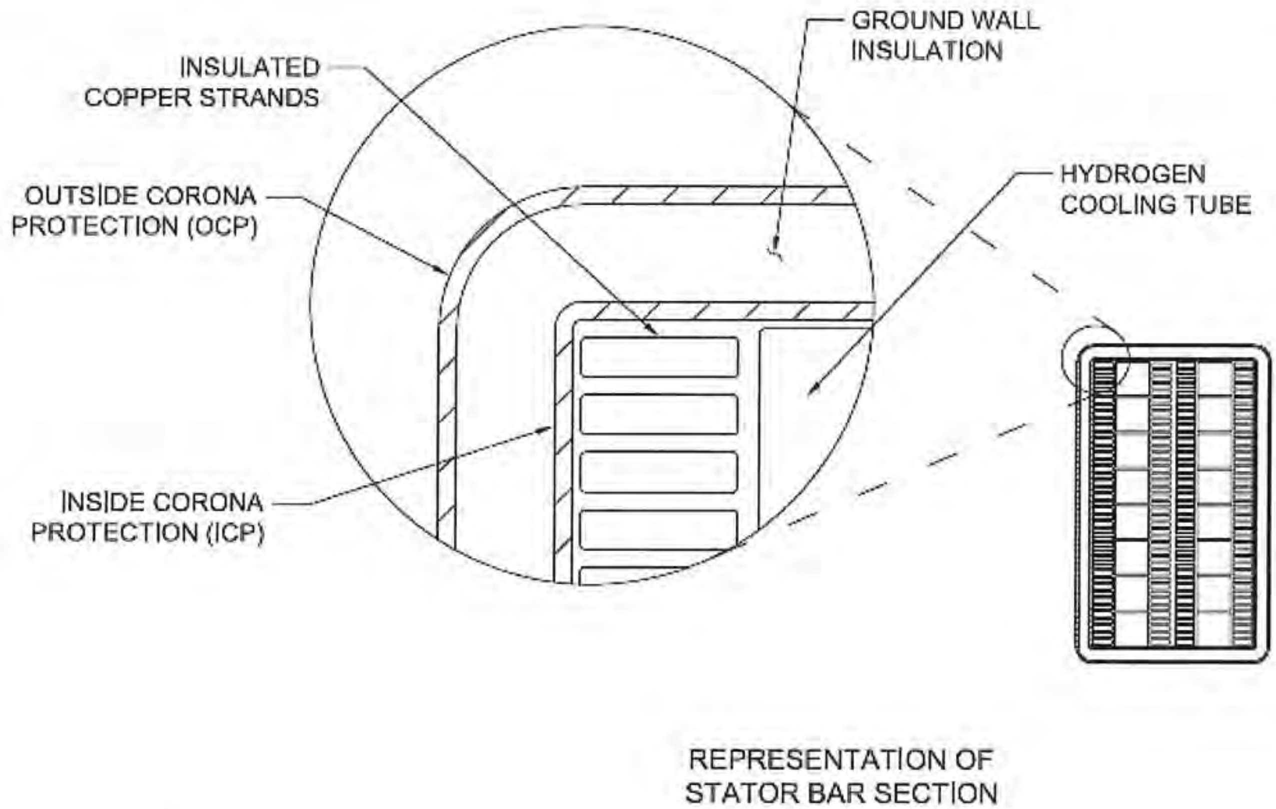


Figure 6 – Section of Stator Bar Removed from Unit 1 Generator 2019 Rewind

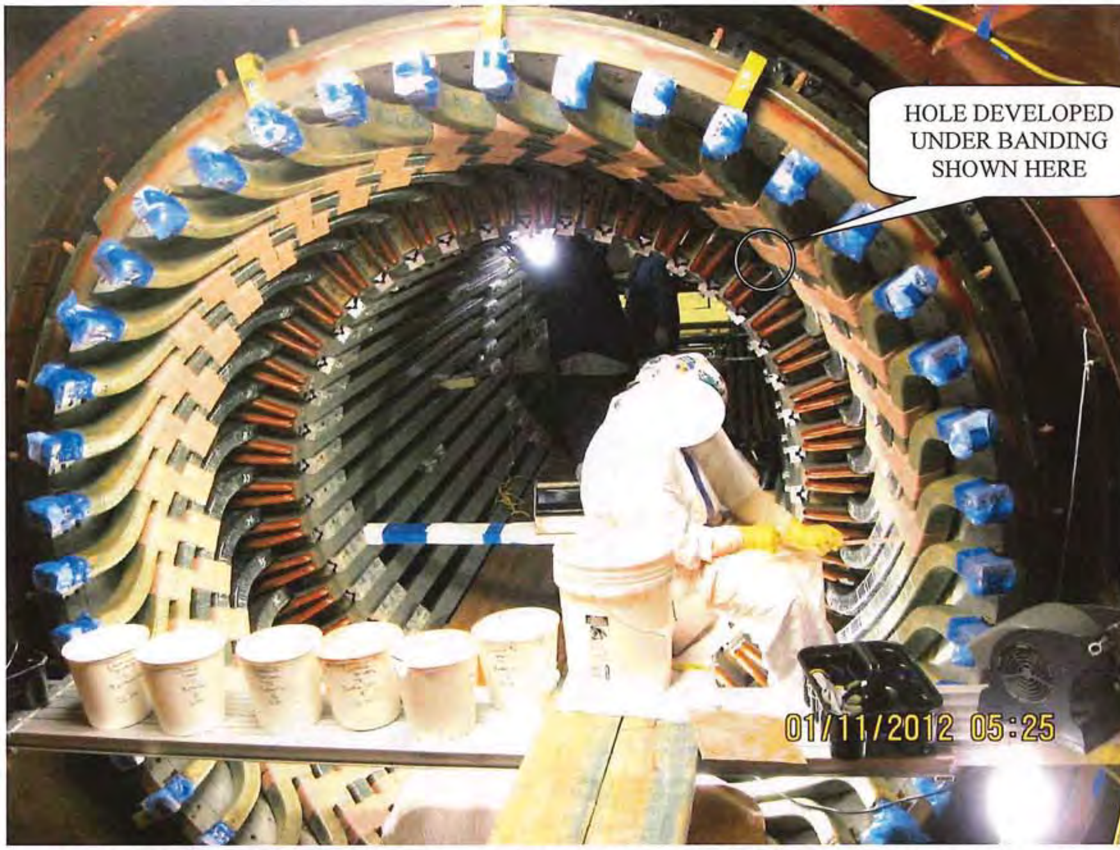
B. Fault Tree Analysis and Support Refute Matrix

The Fault Tree presented in Attachment B was developed to investigate a range of possible causes for insulation failure. The fault tree reflects input from relevant EPRI and IEEE publications on rotating electrical machines and their insulation systems [D16,D17,D20]. Evidence supporting or refuting each failure was captured in the Support Refute Matrix presented in Attachment C.

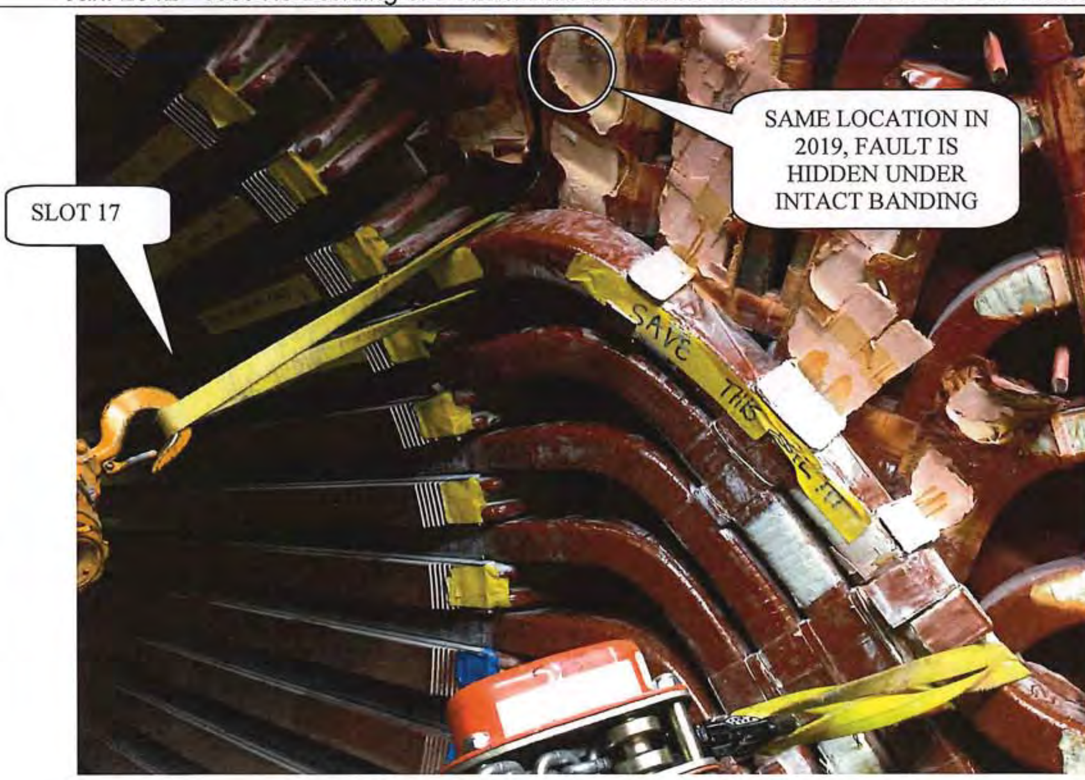
Examination of the fault current track and the insulation breach demonstrates that the fault was caused by a small puncture through the insulation. This small puncture is located on the turbine end outside of the stator slot and underneath a layer of structural banding material at the first diamond spacer. Available data is insufficient to determine a singular cause for the presence of this puncture; three possible causes hypothesized under the fault tree were neither refuted nor adequately supported:

- Ferromagnetic particle introduced during installation of the stator bar
- Impact damage during handling, or installation of the stator bar
- A contaminant or small object introduced in the stator bar insulation during its manufacture or construction

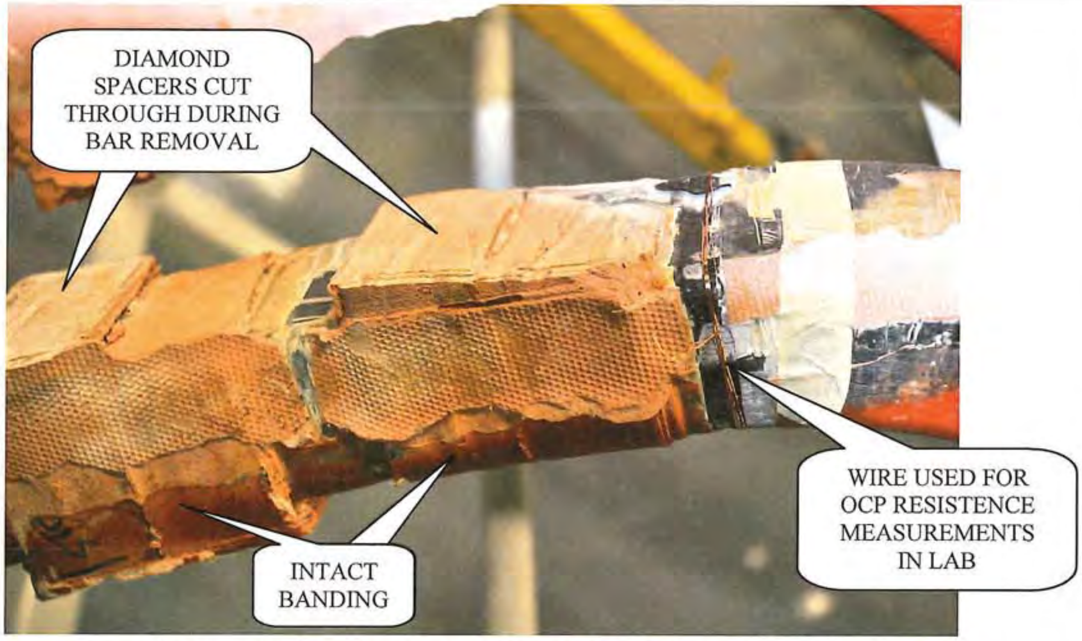
The small puncture in the insulation was located under banding material that was found intact and had been in place since the stator rewind in 2012. Therefore, all of these possible causes involve some occurrence prior to completion of the stator rewind in 2012. The stator was qualified with a high potential test after the rewind was completed. The unit subsequently operated for over 7 years.



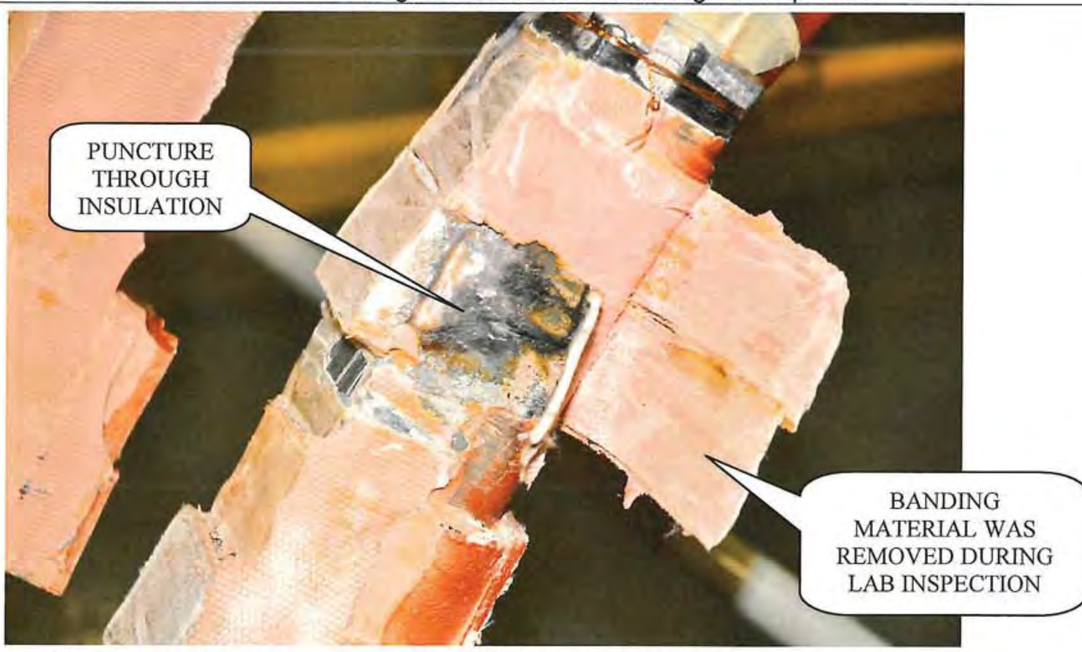
Jan. 2012 - Wet Tie Banding of Bottom Bars at Turbine end of St Lucie Unit 1 Generator.



May 2019 – Removal of Top Bar in Slot 17.



June 2019 – Intact banding material over B17 during lab inspection.



June 2019 – Small puncture through insulation of B17 located during lab inspection.

C. Event and Causal Factors Analysis

The Event and Causal Factors Chart is presented in Attachment D. The chart includes documented history of the Unit 1 main generator since the generator rewind completed in 2012 for Extended Power Uprate (EPU), refueling outage SL1-24.

All of the possible causes that have not been refuted on the Fault Tree analysis involve some initiating occurrence prior to completion of the stator rewind in 2012. All of these involve in some manner the manufacture and assembly services procured for the EPU project. A specific causal factor(s) within the manufacture and/or assembly processes of service providers in 2012 remains indeterminate.

In 2013 a temperature instrument replacement activity was completed during refueling outage SL1-25. This activity is unrelated to the April 2019 ground fault; however, it involved more than routine maintenance and testing. A High Potential Test of the generator was completed after reassembly in SL1-25 with satisfactory results.

No other significant generator maintenance activities have been performed since the rewind in 2012. Routine crawl through inspections were performed in 2015, 2016, 2018 outages. During the SL1-27 outage in 2016 a ground condition was measured during insulation resistance testing; this was caused by water intrusion in the neutral ground transformer bushing and is unrelated to the April 2019 ground fault. [D28,D29].

4. Causal Factor Categorization

A. Address each category - People, Programmatic, Organizational and Equipment based on the analysis.

Equipment:

Sufficient evidence has been provided to demonstrate that the generator ground resulted from a small puncture through the ground wall insulation on the turbine end of stator bar B17 in the phase C stator winding.

There are three potential causes for the equipment failure which could not be refuted (ferromagnetic particle, impact damage, contaminant in insulation). It has been demonstrated that the initiating occurrence for producing this puncture happened before completion of the generator rewind for EPU in 2012. However, the failure mechanism that resulted in a puncture of the ground wall insulation is indeterminate.

The ground fault occurred coincident with the performance of a Reactive Power Lagging Capability Test. This test is one of several tests designed to demonstrate the St Lucie Plant generators can reliably achieve specified values of reactive power used for operation, maintenance, planning and modeling for the bulk electric system. The generator was operated at 255MVAR lagging for the test which produced a modest increase in voltage from 22kV nominal to 22.7kV. The generator was maintained below its operating limits of 23.1kV for voltage and 510MVAR reactive power capability.

The occurrence of the fault provides no indication that the stated generator capability is unreliable. No deficiencies in operation, maintenance, specification or design of the St Lucie Unit 1 generator, or its excitation equipment, were noted. Rather, the mechanism producing a singular small puncture in the insulation of stator bar B17 slowly degraded the insulation capability over the course of 7 years in service. The condition was sufficiently degraded to a point of marginal performance such that the small additional voltage stress during performance of the test exceeded the remaining insulation capability.

People:

It remains unclear if any legacy task performance error, during manufacture and/or assembly of the generator, played a role in initiating a puncture in the insulation. Therefore analysis of human performance causal factors relating to the ground fault is not possible.

Coincidence of the generator lockout to the performance of a Reactive Power Lagging Capability Test was reviewed. No operator error was found to play a role in the ground fault. Additionally, there is no evidence that human intervention during performance of the test was possible to prevent, mitigate, or minimize the effects from the ground fault. Though the generator is provided with various diagnostic instruments, there were no alarms or abnormal indications noted leading up to generator lockout. Continuous monitoring of the generator by operations and maintenance staff provided no leading indication of a problem.

Organizational and Programmatic:

The failure mechanism that resulted in a puncture of the ground wall insulation is indeterminate; therefore any underlying organizational and programmatic causal factors remain unclear.

The possible causal factors that underlie each of three possible failure mechanisms are unique. The only clear commonalities between these failures are that 1) the causal factor was present prior to completion of the 2012 stator rewind, and 2) the causal factor generally involves manufacture and assembly of the generator stator.

Basic expectations for packaging, handling, cleanliness, foreign material exclusion, inspection and testing requirements, etc. applicable for performing the generator manufacture and assembly service activities were established in the project specification. Responsibility for implementation was assumed contractually by providers performing such activities (Siemens and its subcontractors) under the providers' processes and procedures, which are not within the scope of the plant.

The organizational interface between the station and Siemens was reviewed to the extent practicable. Contract requirements for Quality Assurance were imposed in accordance with industry standard. These included expectations for inspection, testing, packaging, shipping, non-conformance process, customer communication and facilities access for mutually agreed upon witness points. An FPL project team was established for coordination and oversight of turbine and generator activities under the EPU project. The project team implemented oversight activities including tracking project milestones, review of deliverables and witness/inspection activities. No direct relation to any of the three potential causal factors was noted. Due to the latent nature of the condition, and the inability to identify it with testing, it can be concluded that external oversight could not have reasonably prevented the generator stator ground.

Siemens produced a customer report for the generator rewind and core replacement which summarized the onsite work activities. The specific Siemens processes used in the performance of the onsite activities are proprietary; therefore investigation beyond what is available in the customer report and plant records is outside the scope of this analysis. Siemens is performing its own internal root cause analysis in parallel with this effort.

Whichever specific initiating condition occurred, it was not detected during the generator assembly activities. The customer report includes descriptions for the activities completed, and lists deficiencies, issues, questions etc. (identified as PCM Clarifications/WRITs/CAPAs) encountered in the field and how these were addressed. Review of the customer report provides no indication of any assembly problems affecting stator bar B17. Instances of stator bar damage identified in the field were noted. A request for clarification from Siemens on these specific issues was satisfied and it was shown that they did not involve either B17 or adjacent stator bars. The damage was attributed to installation activities and repaired. No issues of cleanliness, foreign/native materials or contamination were noted. Generator testing during and after assembly was in accordance with industry standards and manufacturer recommendations. Testing was completed with satisfactory results and St Lucie Unit 1 was placed in service in April 2012. While the identification of damage to certain stator bars during installation is of note, there is no information provided in the customer report attributable to any initiating condition of insulation failure in stator bar 17.

The condition remained undetected for 7 years until it was self-revealed when the generator ground fault occurred in April 2019. During this time the manufacturer's routine maintenance recommendations were performed approximately every 18 months during refueling outages. This maintenance, including crawl through inspection, was performed by Siemens. The crawl through scope includes inspection of turbine end turn blocking and banding, and was found in satisfactory condition during each inspection. These inspections had no opportunity for finding the developing puncture through stator bar B17 due to its location on a bottom bar and underneath banding. In addition, supplemental work was performed in 2013 to repair generator Resistance Temperature Detectors (RTDs). This work included a maintenance high potential test of the stator, which was completed with satisfactory results. It can only be concluded that the developing puncture through stator bar B17 had not sufficiently damaged the insulation after approximately 18 months in service to have been revealed from this test. The manufacturer also recommends major maintenance scope including rotor out inspection and high potential testing at approximately 7 year intervals. This major maintenance scope was scheduled for implementation in September 2019 during the SL1-29 refueling outage.

The maintenance and testing program for the Unit 1 generator was in accordance with industry practice and the manufacturer's recommendations. Due to the nature of the developing puncture and its location, detection by either routine maintenance inspections or testing was very unlikely. Even after the fault, its location was not apparent from any field inspections performed onsite prior to disassembly and rewind activities. Hypothetically, had the fault not occurred in April, it can be reasonably concluded that the winding would have failed during high potential testing in the SL1-29 outage.

B. Based upon the above documentation, categorize the results using the Causal Factor Characterization Matrix below.

The Unit 1 main generator stator ground fault was the result of a small puncture through the ground wall insulation of stator bar B17. The puncture hole was located underneath banding that was found intact. Several possible fault mechanisms which could have produced the hole were identified. The specific mechanism could not be proved as there is insufficient factual evidence to do so. The nature of these possible failure mechanisms is such that the causal factor lies within the manufacture and/or assembly processes for the stator. The causal factor is outside of the scope of the station; no gaps in station processes or external oversight were identified. The root cause is indeterminate.

Causal Factor Characterization (Each causal factor identified is listed and classified in the appropriate People, Programmatic, Organizational and Equipment categories.)		
Cause Type	**Cause Statement**	**Category**
Direct Cause	A small puncture developed through the ground wall insulation of stator bar B17 in the phase C Stator Winding resulting in a fault current path to ground.	Equipment
Root Cause	Indeterminate*	Indeterminate

*In accordance with PI-AA-100-1005:

"If the lack of cause identification is beyond the scope of the plant, the team will issue a final report listing the cause as indeterminate. In these cases, assignment of corrective actions to preclude repetition is not required."

Supporting Information:

1) The St Lucie Unit 1 Main Generator is a Siemens/Westinghouse hydrogen intercooled unit rated 1200MVA. [D22]

2) A complete rewind and rotor replacement was completed for the St Lucie Unit 1 Generator for Extended Power Uprate (EPU) during the SL1-24 refueling outage [D19]. The uprated generator was required to meet a new output of 1200 MVA, 22 kV, 1800 rpm at 75 psig hydrogen pressures [D21,D22]

3) The St Lucie Unit 1 Generator Ratings are as follows [D22]:

Generator Rating	
Apparent Power (MVA)	1200
Power Output (MW)	1080
Power Factor (lagging)	0.9
Speed (RPM)	1800
Frequency (Hz)	60
Terminal Voltage (kV)	22
Stator Current @ 22 kV (A)	31492
Field Current (A)	7924
Field Voltage (V)	616
Number of Poles	4
Insulation Class	F
H2 Pressure (psig)	75

4) The EPU generator upgrade specification [D21] addressed an expected 40 year service life:

The uprated main generator, refurbished/rewound exciter rotor as well as the hydrogen coolers, exciter coolers, main leads, bushings and current transformers shall be designed for suitable operation for a minimum service life of 40 years under power uprate conditions.

5) The EPU generator upgrade specification [D21] describes technical requirements for the stator windings and insulation:

The stator coils shall be gas inner-cooled, single turn, half coils wound in open slots and secured in place by Kevlar coated molded glass-epoxy wedges. Each stator coil shall be made up of two half coils shaped on a former and joined together after assembly in the slots.

The stator coils shall be composed of solid copper strands in insulated ventilation tubes. Each stator coil strand shall be made of annealed tough pitch copper wire. All individual strands shall be insulated with a double thickness of continuous filament Dacron-Glass fibers having suitable thermal properties, high thermal stability and high abrasion resistance.

The coils shall utilize the latest stator coil construction materials, which include internal and external voltage grading material to improve the dielectric performance.

A glass backed mica paper tape and epoxy resin, rated for Class F insulation (155°C hot spot temperature limit) and working to Class B (130°C hot spot temperature limit) shall be used to provide the ground wall insulation of the stator coils superior dielectric and mechanical properties. The vacuum-pressure-impregnation (VPI) process shall be utilized.

The glass-backed mica paper tape shall be machine-applied over the entire length of the coil, straight part and end arms.

Prior to vacuum pressure impregnation, each coil shall be subject to a pre-heat cycle that removes residual moisture.

The coils shall be placed into an impregnation pan that shall be inserted into a tank, where a vacuum shall be drawn prior to introduction of the epoxy impregnation resin. Following impregnation, the coils shall be wrapped with a release film barrier and then placed into presses for curing in an oven.

6) The Siemens generator documentation [D22] includes a topical description of the Armature Coils:

[redacted]

7) Division of responsibility for EPU generator modification activities was specified within EC 246457 [D19]. The OEM was selected to perform various activities including the generator rewind and testing:

The work performed by the OEM is as follows:

1. *Replacement of the Main Generator Rotor and all associated removal including:*
   a. *Removing existing rotor from the 62 foot elevation to a transporter located at the 19.5 foot elevation by use of the turbine gantry crane.*
   b. *Lifting the replacement rotor from the 19.5 foot elevation to the 62 foot elevation by use of turbine gantry crane.*
2. *Rewinding of the Main Generator Stator and associated tests.*
3. *Replacement of the Exciter rotor and modification of Exciter and Generator coupling*
4. *Design and installation of new terminal board, TB-57*
5. *Removal of existing RTDs and installation of replacement RTDs.*
6. *Wiring of RTDs to the terminal strip in RTD Terminal Board TB-57 for customer interface.*
7. *Removal of existing FOVM vibration sensors and installation of replacement FOVM vibration sensors.*
8. *Removal of existing FOVM conduit boxes and installation of replacement FOVM conduit boxes internal to the Main Generator skirt.*
9. *Removal of existing stator slot couplers and installation of replacement stator slot couplers and associated wiring for IRIS partial discharge system.*
10. *Removal of existing termination box and installation of the external termination box for IRIS on the Main Generator housing.*
11. *Removal of the existing flux probe and associated wiring and installation of one replacement flux probe and one new flux probe and associated wiring.*
12. *Installation of the casing glands and the BNC connectors for the flux probes.*

8) The EPU modification activities to upgrade the St Lucie Unit 1 Generator were performed onsite between November 2011 and April 2012. [D10,D13,D23] Siemens performed the rewind and core replacement modification activities. Siemens work processes and procedures were used. As described in the customer report [D23] activities were grouped into "modules":

[redacted]

9) The 2012 customer report [D23] summarizes the process for inspecting, installing, and testing the bottom coils into the stator during Module 06 of the rewind. Two bottom coils (#35 and #42) were noted with minor damage during this process and were repaired. High potential test at 84kVdc was performed on the bottom coils after installation (before top coil install) with satisfactory results:

[redacted]

10) Minor damage to the insulation of two stator bars was noted after installation of bottom coils for the EPU modification [D23]. The coils with damage were located in slot #35 and slot #42 and repaired in place [D41]. No mention of any damage to bottom coil 17 was found.

11) IEEE standard 95 [D43] describes the recommended practice for testing the insulation of AC machines using high direct voltage (hipot), including acceptance proof testing for new equipment and maintenance proof testing equipment that has been in service:

[redacted]

12) ANSI C50.10 [D44] specifies the standard test voltages for acceptance testing:

[redacted]

13) The 2012 customer report [D23] summarizes the final testing performed on the stator during Module 13 after the rewind, which included dc high potential testing. The test was performed consistent with IEEE 95 using a test voltage of 76.5kVdc:

[redacted]

14) The testing performed on the Unit 1 generator windings during the 2012 rewind process subjected the insulation of stator bar B17 to an initial installation high potential test of 84 kVdc with satisfactory results, and a final high potential test of 76.5kVdc with satisfactory results. The final test satisfies IEEE 95 using a test voltage of 76.5kVdc based on (2E+1)*1.7 as described in ANSI C50.10 for dc test voltage, where E=22kV (rated line-to-line voltage of the generator). Therefore, the Unit 1 acceptance proof testing met the applicable industry standards for acceptance testing new equipment.

15) Warranty replacement of RTDs was performed during the Fall 2013 refueling outage. This scope included a maintenance high potential test in addition to routine Generator Crawl-Through Inspection.

[redacted]

16) Routine Generator Crawl-Through Inspection was performed by Siemens during refueling outages in Spring 2015, Fall 2016, and Spring 2018. These each included inspection of the turbine end winding.

Spring 2015 Inspection [D33]:

[redacted]

Fall 2016 Inspection [D34]:

[redacted]

Spring 2018 Inspection [D35]:

[redacted]

17) The Unit 1 generator ground fault lockout occurred on 04/25/2019 during the performance of a reactive capability test of the generator. The testing was being performed in accordance with procedure 0-OSP-53.01. The unit was operating at 100% reactor power. The generator was producing 1055MWe (gross) with 255MVAR (lagging) when the lockout occurred. During the test, Unit 2 was operating at -100MVAR (leading) to compensate for the excess reactive output from Unit 1. Generator terminal voltage was 22.7kV. [D1,D4, D6]

18) Insulation resistance testing of the generator was performed by site maintenance electricians during the post event investigations to verify the ground condition. The generator failed the initial 500Vdc test attempt after achieving only 9Vdc test voltage, demonstrating a ground internal to the generator. The ground resistance was measured as 1.88kOhm using a Digital Multimeter. Separation of the generator neutral connections was then performed and the testing repeated on each phase. This testing confirmed C Phase of the generator was grounded. [D13,D14]

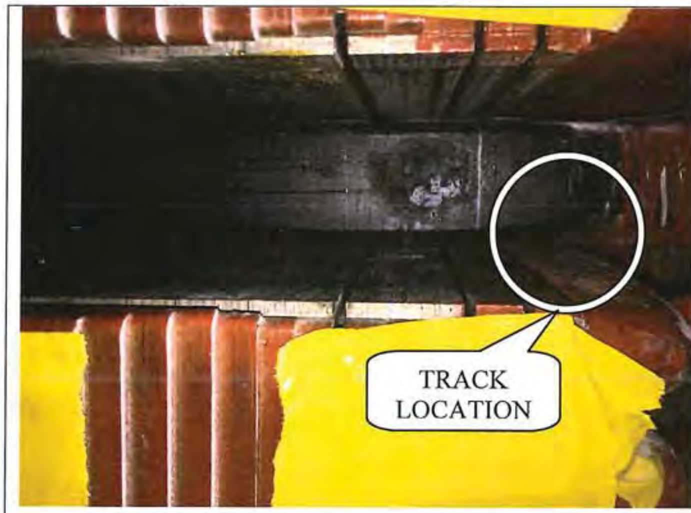
19) Internal inspection of the generator Lead Box was performed with no findings. Siemens staff performed internal disassembly to isolate the C Phase generator leads from the respective line and neutral bushings for additional Insulation Resistance tests. This testing demonstrated that the ground was located in the generator stator. Insulation Resistance Tests performed on the bushings were satisfactory. [O1,D14,D15].

20) Generator crawl through inspection was performed with no findings. Siemens staff performed a voltage drop test from each end of the C Phase Stator winding to ground. The purpose of the test was to determine the relative location of the ground fault from interpretation of the voltage drops as a function of the circuit length through the stator. This test indicated the fault was likely in a particular coil close to the turbine end of the stator. After breaking connections between individual Stator Bars it was determined the Bottom Bar in Slot 17 of the stator was grounded. [O3]

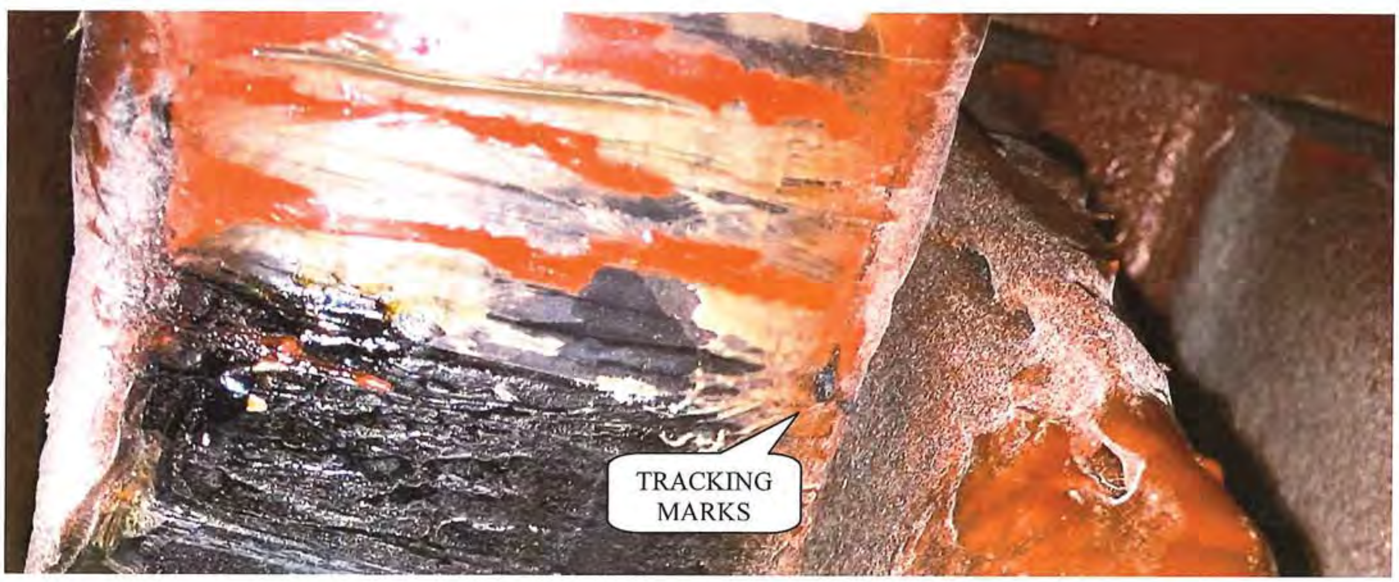
21) Additional testing of Stator Bar B17 insulation layers was performed to characterize the ground condition. The ICP layer in the stator bar contains a drain conductor that is connected to a strand at one end of the stator bar such that the individual strand insulation is bypassed. The drain conductor was disconnected and low voltage insulation resistance testing was performed. An insulation resistance test between the OCP and ICP layers confirmed a low resistance through the ground wall insulation. An insulation resistance test between the ICP and copper conductor strands confirmed that the strand insulation was intact. [O3]

22) Stator Bar T17 was removed allowing in-situ inspection of bar B17 in the slot. At the time of inspection there was on obvious indication of the fault. [O2]

Several pictures taken during the inspection show an area subsequently confirmed to be the location of the fault current track to ground just outside of the slot in the stator core laminations. Subtle tracking marks are evident from close review as shown below, though they are somewhat obscured by the armor layer taping and paint applied at the end winding area.



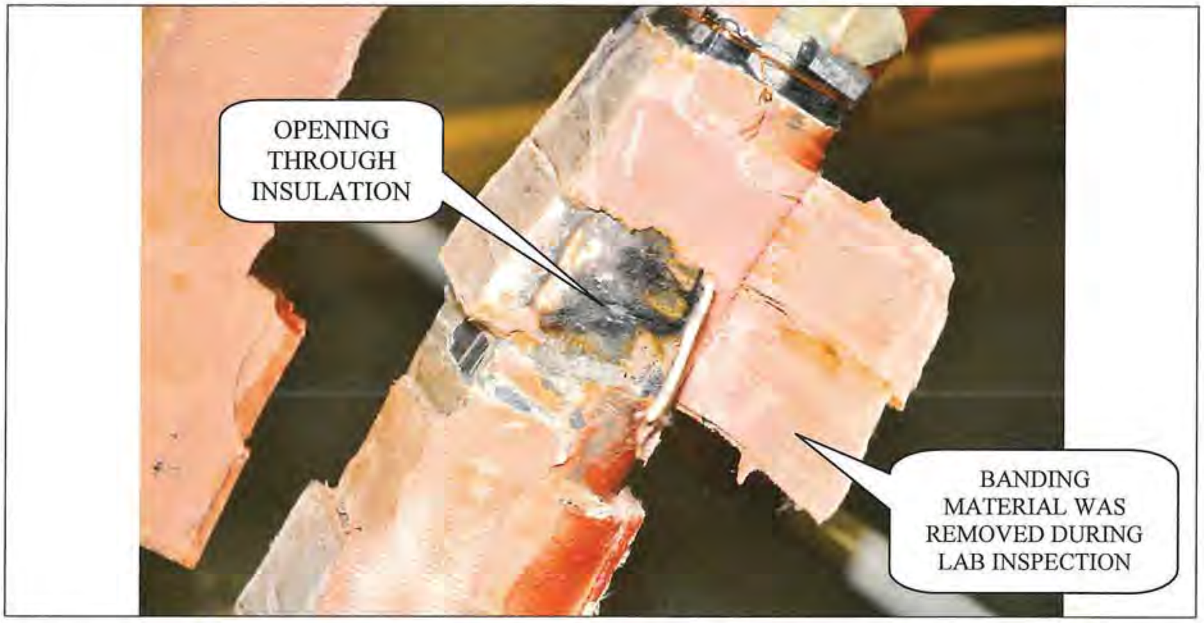
Close-up View:



23) After stator bar B17 was carefully removed from the generator the area of the fault current track to ground was apparent from visual inspection [O3]

24) Various materials removed from the stator were retained and transferred to Siemens for further testing and analysis in accordance with a testing plan [D31]. These materials included stator bar B17 and four additional stator bars that were removed whole to serve as test specimens.

After examination of B17 it was observed [D38, O5] that the fault current track to ground followed a path along the OCP layer originating at a small opening through the insulation that was located under spacer banding material:



The bar was cut approximately 9" on either side of the fault area and a CT scan was performed on the specimen. The CT imaging shows that the opening to a narrowing hole straight through the insulation to the ICP layer with no obvious involvement of the underlying copper strands.

[redacted]

25) A review of the ground fault [D42] was provided by FPL Power Generation Division staff supporting the St Lucie Unit 1 generator rewind and investigation activities. The PGD staff concluded that a "magnetic termite" was the most likely cause for the fault, but this conclusion was not definitive.

> *Based on the extent of core work performed during the 2012 rewind, the most likely root cause is an introduction of ferrous foreign material*
>
> ...
>
> *No definitive root cause was identified due to the damage at the failure location*

The opinion was based on visual characteristics of the fault in comparison with similar events after consultation with peers, but could not be claimed as definitive. This evidence supporting the presence of a magnetic terminate is circumstantial. No remains of any metallic or ferrous object (foreign or native) were found at the puncture site. Additionally, the location of the puncture under banding material applied using an epoxy provides conflicting evidence against the presence of a magnetic termite. The damaging activity of a ferromagnetic particle is generally prevented when the particle is captured / restrained by epoxy.

26) A Siemens internal analysis of the St Lucie stator ground fault is in progress. Siemens has shared a root cause statement [D45] based on this analysis work to date.

[redacted]

5. Evaluation Attributes

A. Previous Occurrences

The generator ground fault is not similar to past issues and is has not been determined to be either a repeat event or repeat occurrence in accordance with PI-AA-104-1000.

B. Extent of Condition

Identified Problem: The Extent of Condition (EOC) reviews for generator ground failures.

Object: St Lucie Unit 1 Main Generator

Defect: Grounded stator winding

Consequence: protective relay actuation and generator lockout

Same / Similar Analysis

Same Object: Unit Main Generator	**Same Defect:** Grounded stator winding	**Same / Same:** St Lucie Unit 2 Main Generator
	Similar Defect: Stator Winding insulation failures: Phase to Ground Phase to Phase	**Same / Similar:** Other types of fault paths through insulation failures to the stator are considered
Similar Object: Generators and Motors with similar stator configurations		**Similar / Similar:** Emergency Diesel Generators and other large motors used on site are subject to insulation failures.

The extent of condition reviews the St Lucie Unit 2 Main Generator for present insulation condition to ensure there is no current vulnerability for a fault. The Unit 1 and 2 Generators are provided with ground protective relays that will lockout the unit in the event of a ground fault. The units are also provided with differential protective relays that will lockout the unit in the event of a phase to phase type fault.

Although the electrical insulation system of any motor or generator could have a failure resulting in a fault, the extent of condition for this event will be limited to the Unit 2 Main Generator. Due to size and scale the Unit Main Generator stator designs and protection system arrangements are unique. These generators have stators constructed using half coil bars and complex arrangements for cooling. The Emergency Diesel Generators and all Medium Voltage motors used on site are relatively simple air cooled machines using form wound coils for stator windings. None of these machines have a stator construction similar to the Unit generators. In addition, the electrical systems (6.9 and 4.16kV) these machines are connected to have high impedance grounding with alarm, but no automatic tripping in the event of a ground fault.

Extent of Condition Review

EOC Action: review most recent insulation condition tests for the Unit 2 generator to determine if adequate confidence is provided for the current condition of the stator winding insulation. If necessary, ensure insulation condition tests are scheduled for next opportunity.

An inspection of the St Lucie Unit 2 generator was performed during the most recent SL2-24 refueling outage in 2018. This work included a generator crawl-through inspection, tuning weight inspection, exciter rotor swap out and electrical inspection, and rotor radial lead hardware upgrade. The generator was partially disassembled for this inspection and the rotor was removed [D18]. Electrical tests were performed including, insulation resistance test, polarization index test, and high potential test to 48,000Vdc. To the extent that the Unit 2 generator passed these tests and insulation successfully withstood the high potential test voltage it can be concluded there that a similar ground fault was not present and is not likely in the near term.

C. Extent of Cause

No causes within the scope of the station have been identified. Extent of cause is not applicable.

D. Safety Culture Evaluation

No causes within the scope of the station have been identified.

E. Risk/Consequence

The main generator and its protection systems are not safety related. However, a generator lockout initiates a turbine trip. Upon a turbine trip an automatic reactor trip is initiated by Loss of Load actuation in the Reactor Protection System (RPS) when reactor power >15%.

The operational crew entered 1-EOP-01, Standard Post Trip Actions, and then transitioned to 1-EOP-02, Post Trip Recovery. All CEAs fully inserted into the core and the trip was uncomplicated with all safety functions satisfied. The plant established in Mode 3 Hot Standby. Nuclear Regulatory Commission (NRC) was notified of the event per 10CFR 50.72(b)(2) due to RPS Actuation.

The ground fault was located in an inaccessible location of the generator stator and the affected stator bar assessed as unrepairable in place. An emergent Generator rewind was undertaken. This evolution has resulted in over 30 days of unplanned energy loss (UEL) beginning 4/25/19.

The event did not impact the environment and there were no radiological or security related implications

6. Operating Experience

An INPO OE search was completed for generator ground faults.

INPO TR4-38 July 2004	Topical Report - Review of Main Generator Failures
OE #102142 November 1990	South Texas Unit 1 Reactor Trip Due to a Generator Ground Fault Relay Actuation Caused by a Stator Coil End Turn Failure
OE #103441 December 1990	Braidwood Unit 1 REACTOR TRIP CAUSED BY MAIN GENERATOR PHASE C GROUND FAULT
[redacted]	
OE #287412 November 1988	Sequoyah Unit 1 TURBINE TRIP (POWER> 50%) A MAIN GENERATOR GROUND FAULT CAUSED A TURBINE TRIP WHICH CAUSED A REACTOR TRIP BECAUSE REACTOR POWER WAS ABOVE 50%. THE GROUND FAULT WAS CAUSED BY INSULATION BREAKDOWN ON THE "C" PHASE STATOR BAR T-17
OE #312004 (WANO) February 2014	Novovoronezh 5 Protection Actuation on a Ground Fault in Turbine Generator Stator Winding Caused a Main Generator Trip and Subsequent Unit Load Reduction
[redacted]	

Additional External OE was identified by PGD staff. Two presentations regarding generator failures having some similarity to the St Lucie Unit 1 ground fault were reviewed.

Detroit Edison (DTE) "Inleakage of H2 into Stator Water Cooling" [D36] September 2009	Fermi 2 generator shutdown due to H2 leakage into water cooled stator. Caused by magnetic termite wormhole discovered in stator produced by small steel particle.
Electrabel Belgium "EPRI Generation Workshop Rome, April 2013"	500MW Jeumont generator (Westinghouse design) trip via earth fault relay after failure of stator winding bottom bar. Although no physical evidence presence of domestic or foreign object cannot be eliminated.

Brief review of certain OE is provided below. Based on the information reviewed to date there is no OE directly relevant to the event.

[redacted]

INPO IER L2-11-2 Scram Analysis:

The Main Generator is an SPV component, therefore Recommendation 2 of IER L2-11-2 pertaining to SPV elimination and mitigation strategies is directly applicable. The Main Generator has been classified as an SPV/FID1. The St. Lucie scram analysis response has credited SPV mitigating strategies including preventive maintenance, replacement, and design modification.

SPV elimination is not credible for the generator, however the uprate completed in 2012 addressed both replacement and modernization improvements. Various preventive maintenance activities address the generator. By its nature the activities for the stator are limited to monitoring (inspect and test) activities, however these are consistent with industry practice. No gaps in this area are apparent.

7. Lessons Learned - An important opportunity of the root cause evaluation process is the identification of lessons learned for organizational learning. These lessons learned can be shared with the organization through formal communications, department briefings or training.

The St Lucie Unit 1 Generator ground fault occurred in 2019, but it was initiated in 2012 during an onsite generator upgrade. It is to be recognized that there exists some unavoidable assumed risks when undertaking the manufacture and onsite assembly of a generator stator.

- The conditions under which activities are performed onsite cannot be optimized to the level of a manufacturing facility. Unless and until a change in the state of the art is developed, such that a 1200MVA size stator could be fully manufactured and assembled offsite under controlled conditions and then installed at the station, then complex onsite assembly activities are necessary.
- Accepted methods of testing will not reliably detect certain minor but significant deficiencies during the manufacture and assembly of a stator. Minor damage to insulation, introduction of a contaminant, or very small particle internal to a generator, can remain undetected. The minor deficiency can result in significant damage to stator insulation overtime and ultimately may take years to materialize as a fault.

Organizations performing significant generator maintenance should review this evaluation for the Unit 1 generator ground fault as a case study. This review should be used as a tool to challenge processes and work plans for enhancement opportunities beyond current industry standards.

8. Corrective Actions

Area	Corrective Action/Assignment	Responsible	Assignment Type	Due Date
Direct Cause - A small puncture developed through the ground wall insulation of stator bar B17 in the phase C Stator Winding resulting in a fault current path to ground.	Complete rewind of the Unit 1 generator to restore stator winding to serviceable condition.	Maintenance Programs	CA	COMPLETE
Interim – Forensics Testing	Track completion of forensics testing as prescribed in Attachment E	RCE Sponsor Mark Jones	MA	COMPLETE
	Re-establish Root Cause Team to complete final Evaluation based on findings of forensics testing. Revise RCE Charter with updated team scope and schedule	RCE Sponsor Mark Jones	MA	COMPLETE
Extent of Condition- Unit 2 Generator	Review maintenance history for Unit 2 Generator to determine near term risk for stator insulation resistance	Root Cause Team	CA	COMPLETE
Enhancement – Lessons Learned	Complete a Self-Assessment of Siemens implementation plans (material handling, FME plans, cleanliness and housekeeping requirements) against the lessons learned from the Unit 1 Generator Ground Fault for enhancement opportunities beyond current industry standards.	Maintenance Programs	MA	10/11/19
External Root Cause – Siemens	Document Completion of Siemens internal Root Cause Analysis.	RCE Sponsor Mark Jones	MA	10/11/19

9. Deferral Justification

There are no CAPR and CA actions deferred.

10. Effectiveness Review Plan

No causes within the scope of the station have been identified. As such there is no specific CAPR to be addressed in an EFR plan.

11. Sources Cited

Documents:

#	Document Title
D1.	AR 02312208 UNIT 1 AUTOMATIC REACTOR TRIP
D2.	AR 02312219 NRC Notification
D3.	AR 02312560 LER
D4.	0-OSP-53.01 "Reactive Power Lagging Capability Test" performed 4/25/19
D5.	Turbine Generator Vibration Summary for Lagging Test 4/25/19
D6.	U1 Ops Narrative Logs April 25, 2019
D7.	Enterprise Wide Information System (EWIS) St Lucie Data / PI Process Book
D8.	8770-B-327 sh890
D9.	8770-B-327 sh1250
D10.	WO 40066477 SL1-248 Generator Rewind (EPU)
D11.	WO 40168563 SL1-25 Rotor Inspection
D12.	WO 40272487 SL1-25 Generator High Pot
D13.	WO 40661261-10 U1 GEN MAIN ACCESS LEAD BOX FOR MEGGER - FAR 10
D14.	Summary of Failure Investigation Process Field Actions and Results
D15.	WO 40661017-18 U01 GENERATOR MEGGER TEST FIP - FAR 3
D16.	EPRI EL-5036 "Power Plant Electrical Reference Series, Volume 1 Electric Generators"
D17.	EPRI EL-5036 "Power Plant Electrical Reference Series, Volume 16 Handbook to Assess Insulation"
D18.	Siemens Customer Report for St Lucie Unit 2 Generator September 2018
D19.	EC 246457 "UNIT 1 GENERATOR ROTOR REPLACEMENT AND STATOR REWIND"
D20.	IEEE Press "Electrical Insulation for Rotating Machines" by Stone, Boulter, Culbert, Dhirani
D21.	Specification SPEC-E-037 Rev. 3 "Main Generator and Exciter Upgrade"
D22.	Manual 8770-4139 Rev. 17 "Siemens Hydrogen Inter-cooled Turbine Generator"
D23.	Siemens Customer Report for St Lucie Unit 1 Generator Rewind and Core Replacement completed February 2012
D24.	WO 40011327 SL1-24 Generator Rewind
D25.	Siemens Customer Report for St Lucie Unit 1 Generator October 2013
D26.	PSDS Field Data

#	Document Title
D27.	WO 40503468-01 SL1-28 Generator Grounding and Testing
D28.	WO 40391932-01 SL1-27 Generator Grounding and Testing
D29.	AR 02167611-01 CE SUPPLEMENT TO AR 2167433 LOW GEN MEGGER
D30.	Understanding Generator Ground Faults
D31.	Siemens Testing Summary and Acceptance Criteria [proprietary data]
D32.	WO 40168563-01 SL1-25 Rotor Insp.
D33.	Siemens Customer Report for St Lucie Unit 1 Generator 2015
D34.	Siemens Customer Report for St Lucie Unit 1 Generator 2016
D35.	Siemens Customer Report for St Lucie Unit 1 Generator 2018
D36.	"Inleakage of H2 into Stator Water Cooling" DTE presentation on Fermi 2 experience, 2000 International Joint Power Generation Conference & Exposition
D37.	Electrobel/GDF Suez presentation on fault attributed to magnetic termite, EPRI Generation Workshop Rome 2013
D38.	Siemens Document ID: DPTRP-0005707601 "TGME Materials Laboratory Testing as Part of St. Lucie Ground Fault RCA Investigation" dated 18-July-2019 Siemens Confidential and Siemens proprietary information
D39.	Unit 1 Fiber Optic Vibration Monitor Routine Data through March 2014
D40.	FME Plan for Siemens Turbine Generator Work Scope at St. Lucie Dated 26 August 2013 (Following EPU)
D41.	St Lucie RCA Follow Up - Email Correspondence regarding Siemens PCM responses to noted minor damage to bottom coils during installation.
D42.	AR 2151217
D43.	IEEE 95 "IEEE Recommended Practice for Insulation Testing of AC Electric Machinery (2300 V and Above) With High Direct Voltage"
D44.	ANSI C50.10-1990 "Rotating Electrical Machinery – Synchronous Machines"
D45.	St Lucie U1 Stator Ground Fault Root Cause Statement Siemens Letter dated June 24, 2019

Observations:

#	Observation
O1.	Generator Crawl through field notes/pictures
O2.	Top Coil Removal and slot inspection field notes/pictures
O3.	Slot 17 Bottom Coil Removal and field notes/pictures
O4.	Photo documentation of EPU Generator Rewind, Nov.-Jan. 2012, St Lucie Unit 1
O5.	Photo documentation of Laboratory Testing June-July 2019, Siemens Energy Charlotte, NC

Interviews:

#	Interview
I1.	Former FPL FME Coordinator

12. Attachments

A. Root Cause Charter

B. Fault Tree Analysis

C. Support Refute Matrix

D. Event and Causal Factors Chart

ROOT CAUSE CHARTER

Facility: St. Lucie Nuclear
Condition Report: 2312208
Manager Sponsor: Mark Jones (Engineering)

Event Description
At approximately 0918 on 4/25/2019, Unit 1 reactor and turbine automatically tripped due to a Main Generator ground.

Preliminary Problem Statement
Object: U1 Main Generator
Defect: experienced a phase to ground electrical fault
Consequence: resulting in an automatic reactor and turbine trip.

Preliminary Extent of Condition
Extent of condition preliminarily defined as U2 Main Generator.
Extent of cause preliminarily defined as U1/U2 Main Turbine and U1/U2 Main Generator

Investigation Scope and Methodology
At a minimum, the RCE shall address the following:

- Root and Contributing Causes
- Extent of Condition and Extent of Cause
- Corrective Actions and Effectiveness Measures

The following investigation methodologies shall be considered for use by the RCE team:

- Hazard/Barrier/Target Analysis
- Event and Causal Factor Charting
- Organizational and Programmatic Failure Analysis

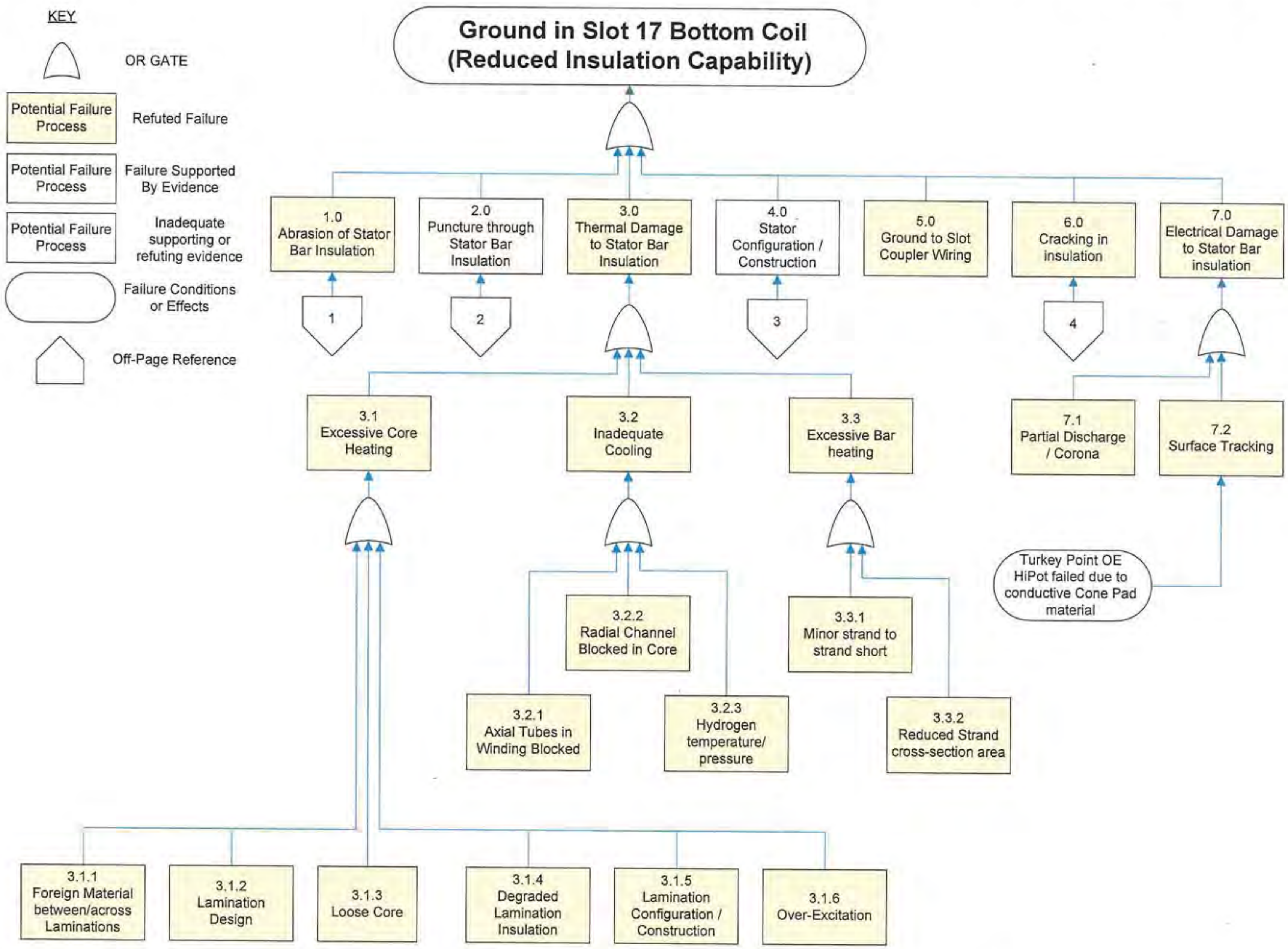
Team Members
Team Leader: A. Bouchfaa (Engineering)
Team Root Cause Evaluator: Gary Arntson (Engineering)
Team Member: Andy Terezakis (Operations)
Team Member: Don Zoll (Electrical Maintenance)

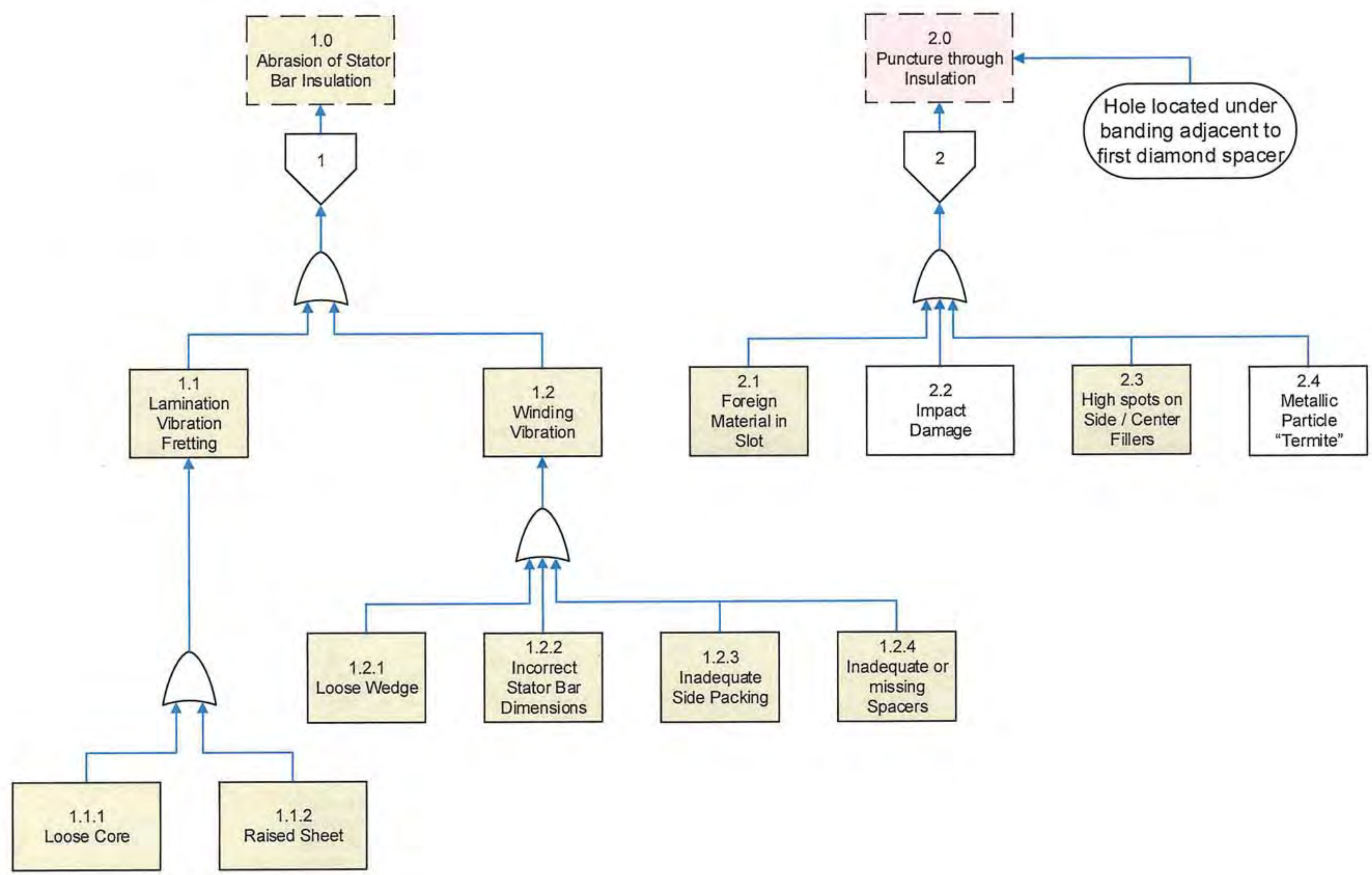
Milestones
Date Assigned: 05/06/2019
Status Update: 05/20/2019
Draft Report Date: 05/31/2019
Final Report Date: 06/05/2019

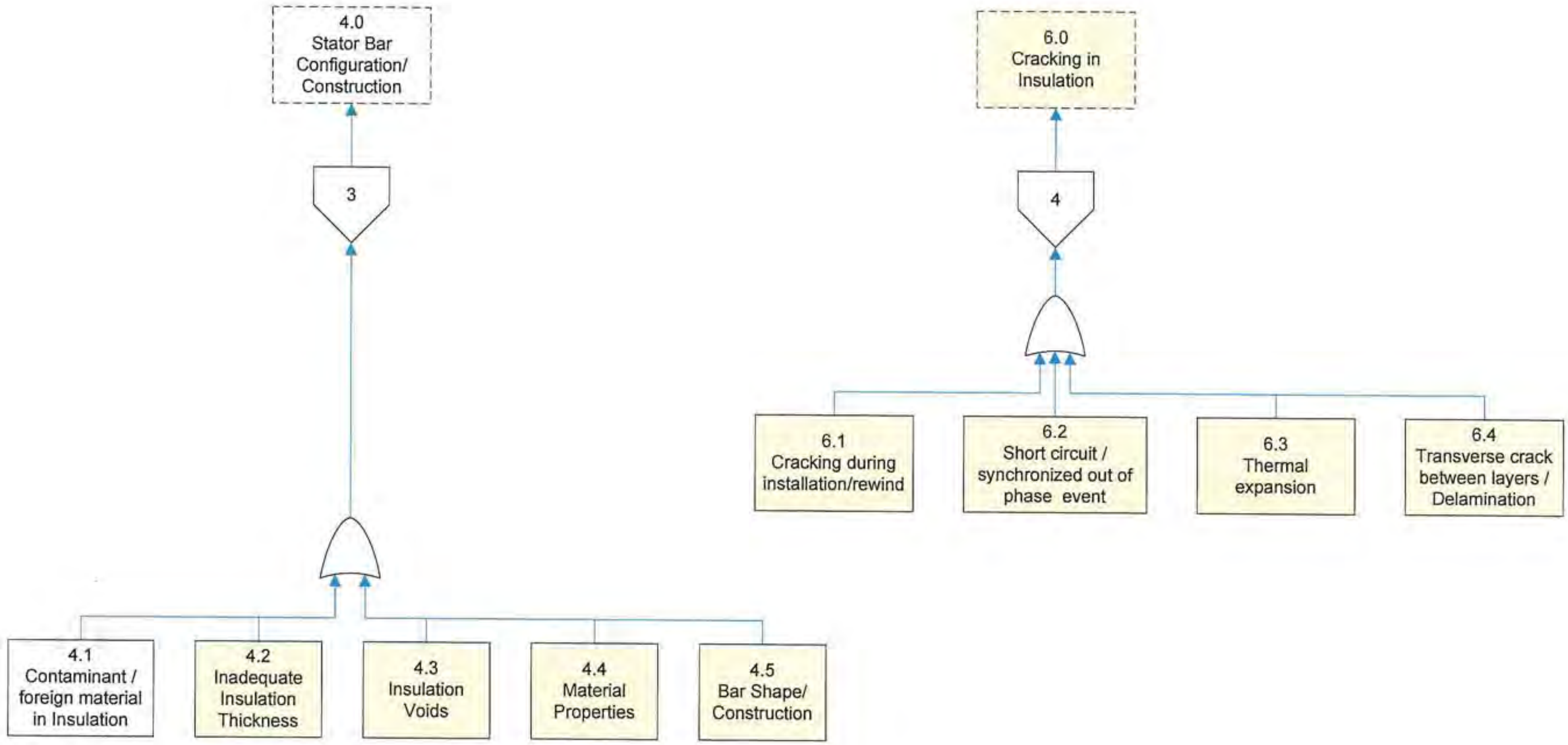
Communications Plan: Weekly updates to MRC. Daily updates will be provided during the early, critical discovery phase of deconstruction and repairs.

Sponsor Approval: [signature] Jones **Date:** 5/30/2019

MRC Approval: [signature] **Date:** 5/30/19


KEY
OR GATE
Potential Failure Process
Refuted Failure
Potential Failure Process
Failure Supported By Evidence
Potential Failure Process
Inadequate supporting or refuting evidence
Failure Conditions or Effects
Off-Page Reference
Ground in Slot 17 Bottom Coil (Reduced Insulation Capability)
1.0 Abrasion of Stator Bar Insulation
2.0 Puncture through Stator Bar Insulation
3.0 Thermal Damage to Stator Bar Insulation
4.0 Stator Configuration / Construction
5.0 Ground to Slot Coupler Wiring
6.0 Cracking in insulation
7.0 Electrical Damage to Stator Bar insulation
1
2
3
4
3.1 Excessive Core Heating
3.2 Inadequate Cooling
3.3 Excessive Bar heating
7.1 Partial Discharge / Corona
7.2 Surface Tracking
Turkey Point OE HiPot failed due to conductive Cone Pad material
3.2.2 Radial Channel Blocked in Core
3.3.1 Minor strand to strand short
3.2.1 Axial Tubes in Winding Blocked
3.2.3 Hydrogen temperature/ pressure
3.3.2 Reduced Strand cross-section area
3.1.1 Foreign Material between/across Laminations
3.1.2 Lamination Design
3.1.3 Loose Core
3.1.4 Degraded Lamination Insulation
3.1.5 Lamination Configuration / Construction
3.1.6 Over-Excitation


1.0
Abrasion of Stator Bar Insulation
1
1.1
Lamination Vibration Fretting
1.2
Winding Vibration
1.1.1
Loose Core
1.1.2
Raised Sheet
1.2.1
Loose Wedge
1.2.2
Incorrect Stator Bar Dimensions
1.2.3
Inadequate Side Packing
1.2.4
Inadequate or missing Spacers
2.0
Puncture through Insulation
Hole located under banding adjacent to first diamond spacer
2
2.1
Foreign Material in Slot
2.2
Impact Damage
2.3
High spots on Side / Center Fillers
2.4
Metallic Particle "Termite"


4.0
Stator Bar
Configuration/
Construction
3
4.1
Contaminant /
foreign material
in Insulation
4.2
Inadequate
Insulation
Thickness
4.3
Insulation
Voids
4.4
Material
Properties
4.5
Bar Shape/
Construction
6.0
Cracking in
Insulation
4
6.1
Cracking during
installation/rewind
6.2
Short circuit /
synchronized out of
phase event
6.3
Thermal
expansion
6.4
Transverse crack
between layers /
Delamination

1.0	**Failure Process # 1 – Abrasion of Stator Bar insulation** Description: Abrasive wear through the surface of the ground wall insulation					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
1.1	Lamination Vibration Fretting	Determine if fretting of insulation is present on stator bar insulation: 1. Field visual inspection of slot 17 stator bars before and after removal 2. Field visual inspection of slot 17 after stator bars and fillers are removed	No significant evidence of insulation damage due to fretting as indicted by greasing or dusting indications on bars or in slot	External inspection of the top and bottom bars from slot 17 was completed. Inspection of stator slot 17 was completed after bar removal. No evidence of fretting was identified and no indications were found for a raised lamination [O2,O3]	This failure mode can be refuted. No evidence supporting lamination vibration has been noted.	Initial Visual observation of bottom 17 bar shows indication of ground fault outside of the slot area on turbine end. Confirmed during Siemens Lab Testing [D38]
1.1.1	Loose Core	See 3.1.3				
1.1.2	Raised Sheet (lamination)	Perform visual inspection with check by feel for raised lamination in slot 17	Sheets properly aligned in core stack			
1.2	Stator Bar Vibration	Determine if indications of insulation abrasion due to vibration are present: 1. Field visual inspection of slot 17 stator bars before and after removal	No significant evidence of rubbing or wear through insulation damage due to vibration of the bar within the slot or out of slot at the end turns	Field inspection of the top and bottom bars from slot 17 was completed. There were no obvious indications of insulation abrasion.	This failure mode is refuted. There has been no abrasive damage identified and no supporting evidence was found for any of the various causes of vibration. Identification of the fault location under banding for the end arm [D38]	

1.0	**Failure Process # 1 – Abrasion of Stator Bar insulation** Description: Abrasive wear through the surface of the ground wall insulation					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
1.2.1	Loose Wedge	Perform PSDS (pre stress driving strip) Wedge Tightness	PSDS Wedge Tightness within specification	Review of as-found PSDS deflection data shows the slot 17 wedges were generally consistent for all the wedges and with those of the adjacent wedges [D26]. Inspection of slot 17 wedges, PSDS and filler materials did not show any abnormalities. Material testing of wedge and PSDS samples from slot 17 was normal and consistent with expectations for in service components.	No supporting evidence for loose wedging.	Outliers in PSDS deflection were identified. The outlier data points were consistent with bad micrometer readings (inadequate depth measurement rather than loose wedging) and have been discounted.
1.2.2	Incorrect Bar Dimensions	Validate bar dimensions after stator bar removal	Stator Bar dimensions within Siemens specifications	Dimensions in the cell region were consistent along the length of the bar and measured within expected tolerances.[D38]	No supporting evidence for irregular bar dimensions	
1.2.3	Inadequate Side Packing	Inspect prior to removal and check for bar loose fit in the slot during removal from stator	Assess fit during bar removal from Slot 17. Inspect removed bar and side packing materials for evidence of abrasion	Side packing appeared tight during bar removal.[O3] Inspection of slot 17 side filler materials did not show any abnormalities. Material testing of side filler material was normal.[D38]	No supporting evidence for inadequate side packing.	

1.0	**Failure Process # 1 – Abrasion of Stator Bar insulation** Description: Abrasive wear through the surface of the ground wall insulation					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
1.2.4	Inadequate or Missing Spacers	Validate all spacers in place during bar removal from slot	All spacer in place in accordance with Siemens specifications Inspect removed stator bar and spacer materials for evidence of abrasion	Inspection did not reveal any missing spacers. All center fillers were accounted for between top and bottom bars in slot 17.[O2,O3,D38] Review of original bump test data indicated no resonances. [D23] Initial readings by FOVM were low and further readings were suspended. [D39] Inspection of slot 17 center filler materials did not show any abnormalities.[D38]	No supporting evidence for inadequate or missing spacers.	

2.0	**Failure Process # 2 – Puncture through insulation** Description: A hole is punctured through the ground wall insulation resulting in fault					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
	Puncture [hole] through insulation	Identify location of fault and examine for any direct evidence that insulation was punctured. 1. Non Destructive CT exam of bar 2. Visual and Microscopic Exam of fault area surface	Insulation is free from indications of puncture damage	The ground wall insulation was breached through a small hole in the insulation apparent from visual inspection. The hole was located adjacent to the first set of diamond spacers on the end arm underneath a layer of banding material. The banding material covering the breach was not punctured. [D38]	It is concluded that the insulation breach occurred due to puncture through the ground wall insulation.	The hole has an opening at the OCP surface of approximately 15mm long x 2mm wide, with elongated conical shape through the insulation ending at a small point where the inner most insulation layers interface with the ICP layer.
2.1	Foreign Material in Slot	Inspect stator bar and slot after removal for evidence of Foreign Material Additional exam and testing as described in 4.1	No foreign materials found in slot during visual inspections	No visually identifiable foreign materials have been found after bar removal from Slot 17. Confirmed Fault location is not in the cell/slot area of the stator bar.	Damage to the insulation due to a foreign material in the stator slot is refuted	

2.0	Failure Process # 2 – Puncture through insulation Description: A hole is punctured through the ground wall insulation resulting in fault					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
2.2	Impact Damage [mechanical puncture, chip, or gouge in insulation that progresses through remainder of insulation over time]	Impact damage to insulation 1. Visual and Microscopic Exam of fault area surface for puncture with adjacent area cracking or crazing 2. Section Bar and perform visual and microscopic exam of insulation at fault for evidence of puncture with adjacent area cracking or crazing 3. Non Destructive CT exam of bar	No puncture of insulation with evidence of cracking or partial discharge damage in surrounding insulation.	Puncture through the ground wall insulation identified under banding material adjacent to diamond spacer. Puncture was through full depth of the ground wall insulation but did not penetrate the ICP [D38].	Location demonstrates that any impact damage could only have occurred before application of banding during rewind. Pre-existing impact damage at the time of installation cannot be refuted. However, there is no additional evidence for a propagating mechanism such as cracking.	The coils passed initial High Potential testing at 76500Vdc. Any significant pre-existing damage would have resulted in failed preoperational testing. This mechanism is only credible for a minor puncturing through a small % of the ground wall which then propagates over time by another mechanism.
2.3	High spot or anomaly on side fillers or center filler	Visual Exam of stator bar and middle and side fillers from slot 17	No evidence of localized insulation damage from nonconforming filler materials.	The fault location was identified after bar removal from Slot 17. Insulation damage was identified in a location outside of the slot [D38]	Puncture of the insulation by some anomaly of slot filler materials can be refuted due to the location of the insulation damage	

2.0	Failure Process # 2 – Puncture through insulation Description: A hole is punctured through the ground wall insulation resulting in fault					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
2.4	Metallic Particle / "Magnetic Termite" [small ferromagnetic object wears through insulation producing a hole due to combined effects of magnetic attraction and vibration due to eddy currents]	Fault occurs though hole straight through the insulation [sometimes referred to as a wormhole due to appearance], Presence of metallic or ferrous object in insulation 1. Visual and Microscopic Exam of fault area surface 2. Section Bar and perform visual and microscopic exam of insulation at fault 3. Non Destructive CT exam of bar 4. Electron Dispersion Spectroscopy (EDS) of fault area for metallic / ferrous contaminants	No evidence of puncture straight through the insulation No metallic or ferrous object or contaminants	Puncture through the ground wall insulation identified under banding material adjacent to diamond spacer. Fault was straight through the insulation.[D38] No remains of any macro metallic object were found in the hole. EDS identified Fe and Mn contaminants in materials adjacent to fault location indicating presence of carbon steel, origin of contaminants is unclear as cross contamination during sample preparation can't be ruled out.[D38]	The shape and direction of the hole are consistent with a magnetic termite. [D36,D37] Though no object was found in the hole to allow a definitive identification, it is feasible the object would vaporize or melt and be ejected during the fault. Evidence supporting the presence of a magnetic termite is circumstantial.	Based on the fault location under banding materials, any termite must have been introduced in the stator during the 2012 rewind. The presence of a termite would not result in failure of High Potential Testing performed on the new stator after rewind. Subsequent High Potential Testing may or may not fail depending on the progress of the terminate into the insulation If a ferromagnetic particle is captured within insulation material this may restrain the particle and prevent vibration leading to it termite effect. This is a potentially counter point for presence of a termite under the banding material. However, there was a large void in the binding epoxy over the fault area and it remains unproven whether epoxy binding resin could permanently restrain a termite.

3.0	**Failure Process # 3 – Thermal Damage to insulation** Description: Insulation is continuously operated above its design temperature. Significant accelerated aging leads to failure					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
	Thermal Damage to Insulation	Section Bar 17 at various locations and perform visual and microscopic exam of insulation for direct evidence of overheated / aged condition in fault location as compared to non-fault locations	Consistent satisfactory condition in all insulation sections, no signs of overheating / aging	Various sections of insulation on bar B10 (control sample) and B17 were inspected with no indications of overheating.	All failure processes for thermal damage are refuted. No other evidence supporting thermal damage has been noted. This failure mode is refuted.	
3.1	Excessive Core Heating					
3.1.1	Foreign Material between/ across Lamination [localized heating due to shorted laminations]	1. Perform field inspection of slot 17 laminations 2. Perform core imperfection test (EL-CID/SMCAS) 3. Remove and insect affected laminations (if warranted)	No heating or tracking indications on slot 17 laminations No significant indications in slot 17 laminations	No evidence of FME or in the core [O3] Initial SMCAS after fault does not show significant indications at slot 17 The core was found in generally serviceable condition after generator stripping. Disassembly for inspection and repair was not necessary.	Core faults due to FME in slot 17 can be refuted.	No faults found in these locations by SMCAS and Loop tests after 2011 rewind

3.0	Failure Process # 3 – Thermal Damage to insulation Description: Insulation is continuously operated above its design temperature. Significant accelerated aging leads to failure					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
3.1.2	Lamination Design	1. Perform field inspection of slot 17 laminations 2. Perform core Loop test at rated flux	Consistent satisfactory condition in all redial sections of laminations adjacent to 17, no systemic indications	The core was found in generally serviceable condition after generator stripping. No evidence of overheating [O3] Initial SMCAS after fault does not show any systemic indications. A Loop test has been also been performed finding a consistent thermal response to rated flux and no thermal anomalies present	Design of the laminations can be refuted as a cause.	Reactive Capability Testing was underway during the fault. The voltage was only raised by 2.3% and the reactive power was well within the capability curve
3.1.3	Loose Core	1. As-found SMCAS 2. Visual inspection after removal 3. Knife test 4. Post-Removal SMCAS (Core Loop Test if indicated) 5. Through bolt tightness checks, visual inspection of belleville washers	SMCAS/Knife test within Siemens specifications Visual inspection with no anomalies Bolts tightened to Siemens specification	Some end iron issues were noted that were clearly due to generator stripping activities. No loose core lamination issues for slot 17. [O3] Initial SMCAS after fault does not show any systemic indications. A Loop test has been also been performed and no thermal anomalies were present	Core looseness can be refuted as a cause.	

3.0	**Failure Process # 3 – Thermal Damage to insulation** Description: Insulation is continuously operated above its design temperature. Significant accelerated aging leads to failure					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
3.1.4	Degraded Lamination Insulation [localized heating due to shorted laminations]	See 3.1.1	No heating or tracking indications on slot 17 laminations No indications in stator core laminations Lamination insulation is intact with no signs of degraded condition or overheating	The core was found in generally serviceable condition after generator stripping. No evidence of overheating from surface inspection. [O3] Initial SMCAS after fault does not show any systemic indications. A Loop test has been also been performed finding a consistent thermal response to rated flux and no thermal anomalies present Disassembly for inspection and repair was not necessary.	Cause is refuted. Satisfactory inspections and testing demonstrates lamination insulation is not degraded	
3.1.5	Lamination Configuration / Construction	See 3.1.1	Lamination configuration, (shape, size, thickness etc.) is per specifications.	The core was found in generally serviceable condition after generator stripping. [O3] Initial SMCAS after fault does not show any systemic indications. A Loop test has been also been performed finding a consistent thermal response to rated flux and no thermal anomalies present Disassembly for inspection and repair was not necessary.	Satisfactory inspections and testing demonstrates core configuration problem is refuted.	

3.0	**Failure Process # 3 – Thermal Damage to insulation** Description: Insulation is continuously operated above its design temperature. Significant accelerated aging leads to failure					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
3.1.6	Over-excitation of generator	Review generator data recorded during reactive capability test	Generator Reactive Load (MVAR) and Exciter Amps within capability ratings	Generator was maintained at 255MVAR during the reactive load test.[D4]	Over-excitation is refuted. Generator was maintained within excitation limits	The generator capability limit for the test conditions was 510MVA
3.2	Inadequate Cooling					
3.2.1	Ventilation Tubes in Bar Blocked	1. Perform inspection of cooling tubes 2. Review hot gas temperature history data	cooling tubes are open and free of any debris no outlier in hot gas temperatures prior to fault event, consistent temperature response during reactive capability testing	Cooling tube inspection completed on various sections with no distortion or blocking observed [D38] Generator temperatures maintained well within specifications and generally consistent at all RTD locations leading up to generator lockout [D7]	Blocked cooling tube in stator bar B17 is refuted.	
3.2.2	Cooling Channel Blocked in Core (Axial Channels, plus additional radial channels in step iron)	Perform field inspection of cooling channels in slot 17 and adjacent slots for blockage	Stator cooling channels are open and free of any debris	No evidence of cooling tube blockage was observed. [O1,O2] The fault location was identified after bar removal from Slot 17. Insulation damage was identified in a location outside of the slot [D38]	Blockage of H2 cooling in core is refuted.	

3.0	**Failure Process # 3 – Thermal Damage to insulation** Description: Insulation is continuously operated above its design temperature. Significant accelerated aging leads to failure					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
3.2.3	Inadequate Hydrogen Temperature / Pressure	Review hot gas temperature history data.	H2 pressure and hot gas temperatures prior to fault event within specifications, consistent temperature response during reactive capability testing	Pressures and temperatures continuously monitored and checked within limits shifty. Pressures validated prior to testing, consistent temperature response at recorded RTD locations leading up to generator lockout [D4,D7]	Inadequate Hydrogen system performance is refuted.	
3.3	Excessive Bar Heating					
3.3.1	Strand to Strand Shorts	Section Bar and perform visual inspection of strand insulation for overheating / evidence of shorted strands	Consistent appearance of strand insulation, no signs of overheating or shorts between strands	Sections of Bar B17 adjacent to the fault area were polished and inspected. No evidence of shorting between strands was found.	Overheating due to strand to strand shorts is refuted	
3.3.2	Reduced strand cross-section area [localized ampacity issue]	Section Bar and perform visual inspection of strands	Consistent cross section shape and size of strands in cross section	Sections of Bar B17 adjacent to the fault area were polished and inspected. Strands were of consistent shape/size and no deformation noted, no indication of overheating in strand insulation or adjacent material was found.	Overheating due to inadequate conductor cross section is refuted.	

4.0	**Failure Process # 4 – Stator Bar Configuration** Description: The construction of the bar does not conform to design specifications. Loss of margin to a critical design characteristic resulted in premature failure.					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
4.1	Contaminants / Foreign Material in Insulation	1. Microscopic Exam of fault area surface 2. Section Bar and perform Microscopic Examination of insulation at fault 3. Spectroscopy if warranted by inspections	Insulation layer is free of any foreign material or contaminants	Various sections of bar B10 (control sample) and B17 were polished and inspected visually and microscopically, including section of bar on either side of the faulted area sample. No indications of foreign material within the ground wall insulation were noted. [D38] Spectroscopy performed on surface of (FTIR and EDS) fault location did not support the presence of a contaminant in the insulation; however EDS identified some copper and ferrous contaminants on the surface outside of the fault area. Origin of these contaminants is unclear as cross contamination during sample preparation can't be ruled out.[D38]	No gross contamination of the insulation was found. Though unlikely, the presence of a contaminant / object at the singular location of the fault can't be factually refuted. Due to loss of material from the fault location the existence of any contaminant in this material prior to the fault is indeterminate.	The coils passed multiple initial High Potential tests including final test at 76500Vdc. Significant pre-existing contamination would likely have resulted in failed preoperational testing. This mechanism is only credible for a small amount of material affecting a small % of the ground wall (possibly on between one half lapped layer) of which then propagates over time by another mechanism.

4.0	**Failure Process # 4 – Stator Bar Configuration** Description: The construction of the bar does not conform to design specifications. Loss of margin to a critical design characteristic resulted in premature failure.					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
4.2	Inadequate Insulation Thickness	1. Section Bar and perform visual and microscopic exam of insulation at fault 2. dimensional measurements of insulation thickness	Verify lapping configuration and insulation dimensions Configurations and copper and insulation sizes conform with drawings (Siemens)	Bar dimensions were measured and verified to specification. Various sections of bar B10 (control sample) and B17 were polished and inspected visually and microscopically, including section of bar on either side of the faulted area sample. Consistent and acceptable Insulation configuration and condition in all samples. High Voltage Breakdown test of B10 and B17 samples exceeded specifications. [D38]	Insulation Thickness is refuted	B17 sample withstood equivalent of 99kVac for 1 minute prior to flashover during High Voltage breakdown test.

4.0	**Failure Process # 4 – Stator Bar Configuration** Description: The construction of the bar does not conform to design specifications. Loss of margin to a critical design characteristic resulted in premature failure.					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
4.3	Insulation Voids	1. Perform tap test on bar 2. Section Bar and perform visual exam of insulation at fault for voids	Verify lapping configurations conform with drawings (Siemens) Insulation is free from voids	Some void areas were noted during tap testing, including areas around fault area. This was considered inconclusive due to the mechanical armor layer applied to the end arm areas where the fault was located. Various sections of bar B10 (control sample) and B17 were polished and inspected visually and microscopically, including section of bar on either side of the faulted area sample. Insulation was well consolidated and No substantive voids were noted in any of the samples inspected.	Insulation voids is refuted.	Some minor delamination in ICP (2 lapped layers of conductive tape) was apparent which explains some of the hollow indications from tap testing. Condition is benign due to conductivity of ICP layer and not unusual for in service stator bars.

4.0	**Failure Process # 4 – Stator Bar Configuration** Description: The construction of the bar does not conform to design specifications. Loss of margin to a critical design characteristic resulted in premature failure.					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
4.4	Material Properties	Sample insulation adjacent to fault location for test 1. Tensile test 2. Glass transition temperature 3. Burnout test to measure % organics 4. Soxhlet extraction to separate solids from insulation	Tensile test requirement: 5,000psi minimum for new coils Glass transition temperature requirement: 70C minimum for new coils % Organics requirement: 18-28% for new coils Soxhlet extraction requirement: 2.5% maximum for new coils Above test results will also be compared to the non-faulted bar	Samples from bars B10 (control) and B17 were subjected to all material tests.[D38] All samples passed Tensile test with significant margin with mean peak stress of 21276.7 psi 113.7C Glass Transition temperature was measured for B17 insulation sample is within expected value. All burn-out test insulation samples passed requirements for organic content All soxhlet extraction samples tested less than 2% unpolymerized content	The cause is refuted. Satisfactory test of various insulation samples demonstrates acceptable insulation material properties.	

4.0	**Failure Process # 4 – Stator Bar Configuration** Description: The construction of the bar does not conform to design specifications. Loss of margin to a critical design characteristic resulted in premature failure.					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
4.5	Bar Shape / Construction	Verify Bar dimensions within expectations.	Consistent along length of bar and within Siemens specification	There were no pronounced indentations or high spots on the coils. 5 measurements were taken of the height and width in the slot portion of the bars. The results were all within the tolerance for these coils.[D38]	The shape and construction of the bar did not play a role in the failure and is refuted.	

5.0	Failure Process # 5 – Ground to Stator Slot Coupler					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
5.0	Ground to Stator slot Coupler	Inspect Stator Slot Coupler Wiring Perform insulation resistance test at slot coupler	No evidence of wear or damage to insulation along SSC wiring path in stator. Low voltage IR demonstrates Slot coupler is not grounded to shield	Fault is located on the end arm adjacent to location of SSC wiring. Inspection of the wiring and location provides no indication this was involved in the fault. Insulation under the SSC wire banding is intact. [O3,D38] Testing of the SSC removed from Slot 17 demonstrates that the device is intact with acceptable insulation resistance. [D38]	This cause is refuted. There is no evidence the SSC device or its wiring was involved in or could have contributed to the fault.	

6.0	**Failure Process # 6 – Crack in Insulation**					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
	Crack in Insulation	Determine if cracking is present in stator bar insulation. 1. Non Destructive CT exam of bar 2. Visual and Microscopic Exam of fault area surface 3. Section Bar and perform Microscopic Examination of insulation at fault	Insulation is free from crack indications	No evidence for cracking in the ground wall insulation has been observed from visual and microscopic examination. The CT exam did not reveal any cracking.	All failure processes for cracking damage are refuted. No other evidence supporting cracking has been noted. This failure mode is refuted.	
6.1	Cracking during Installation/ Rewind	Review installation history / Siemens PCMs (internal records) for anomalies	No significant non-conformance with accepted installation practices	The generator winding activities were documented. Review of minor damage to bars in slot #35 and #42 were noted. The assessment and repair was documented in the Siemens PCM process. No report of damage to B17 was noted [D23,D41]	This cause is refuted. No evidence of cracking during installation was noted.	Passed High Potential Tests during installation which general demonstrates no cracking in the insulation.

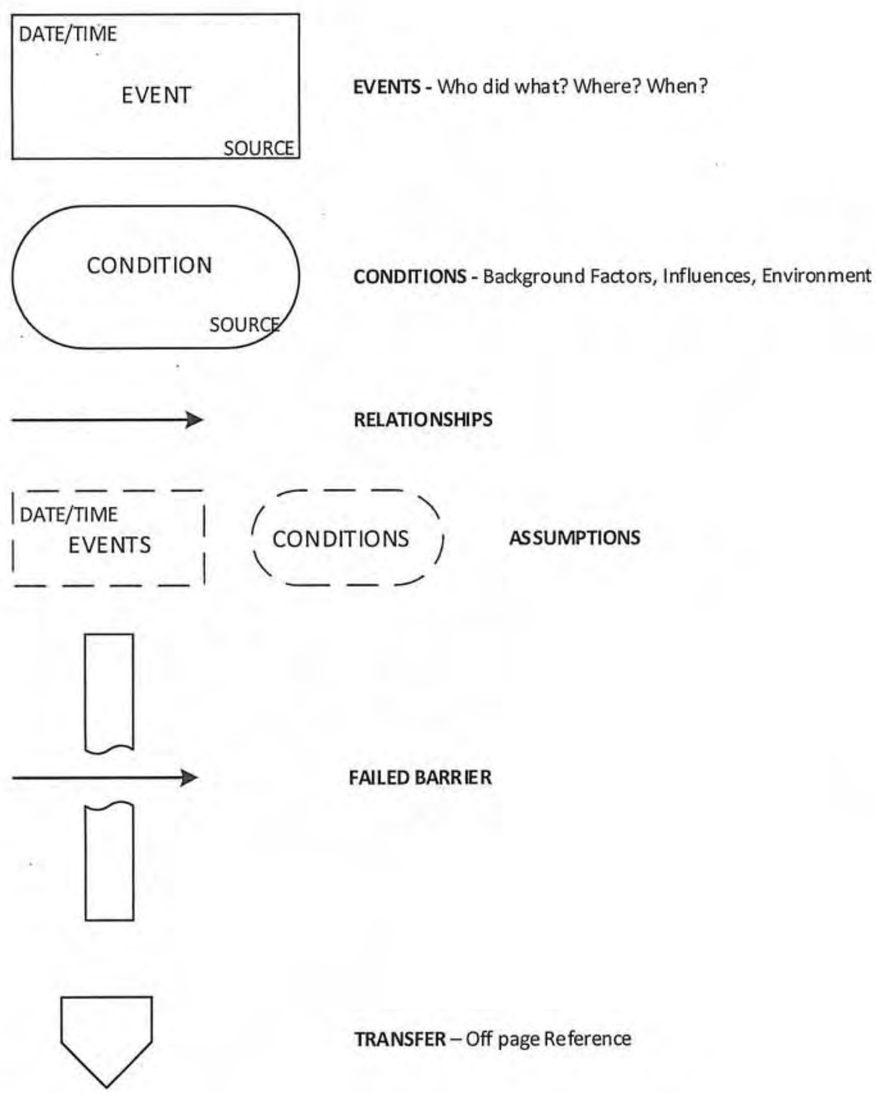
6.0	Failure Process # 6 – Crack in Insulation					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
6.2	Close in Short Circuit event or out of phase synchronization	Review generator operating history	No significant events identified since startup from SL1-24 after rewind	St Lucie Unit 1 did not have any valid generator relay or lockout trips during this period and notable grid disturbances were identified. Unit 1 did have an Inadvertent Energization lockout that occurred 8/21/2016, however the lockout was caused by a wiring issue and not a valid trip condition for the generator [D42]	Cracking due to a short circuit or out of phase event is refuted.	
6.3	Crack in operation due to thermal expansion	Evaluate insulation physical properties: exam and testing as described in 4.2.4 Compare properties of bottom 17 stator bar with other in service bars from generator as control samples	See 4.2.4	Samples from bars B10 (control) and B17 were subjected to all material tests. All testing results were satisfactory. Additionally, no cracking of the bar at the location of the fault has been observed from visual and microscopic examination of the surface and sections of B17. [D38]	Cracking due to thermal expansion is refuted.	

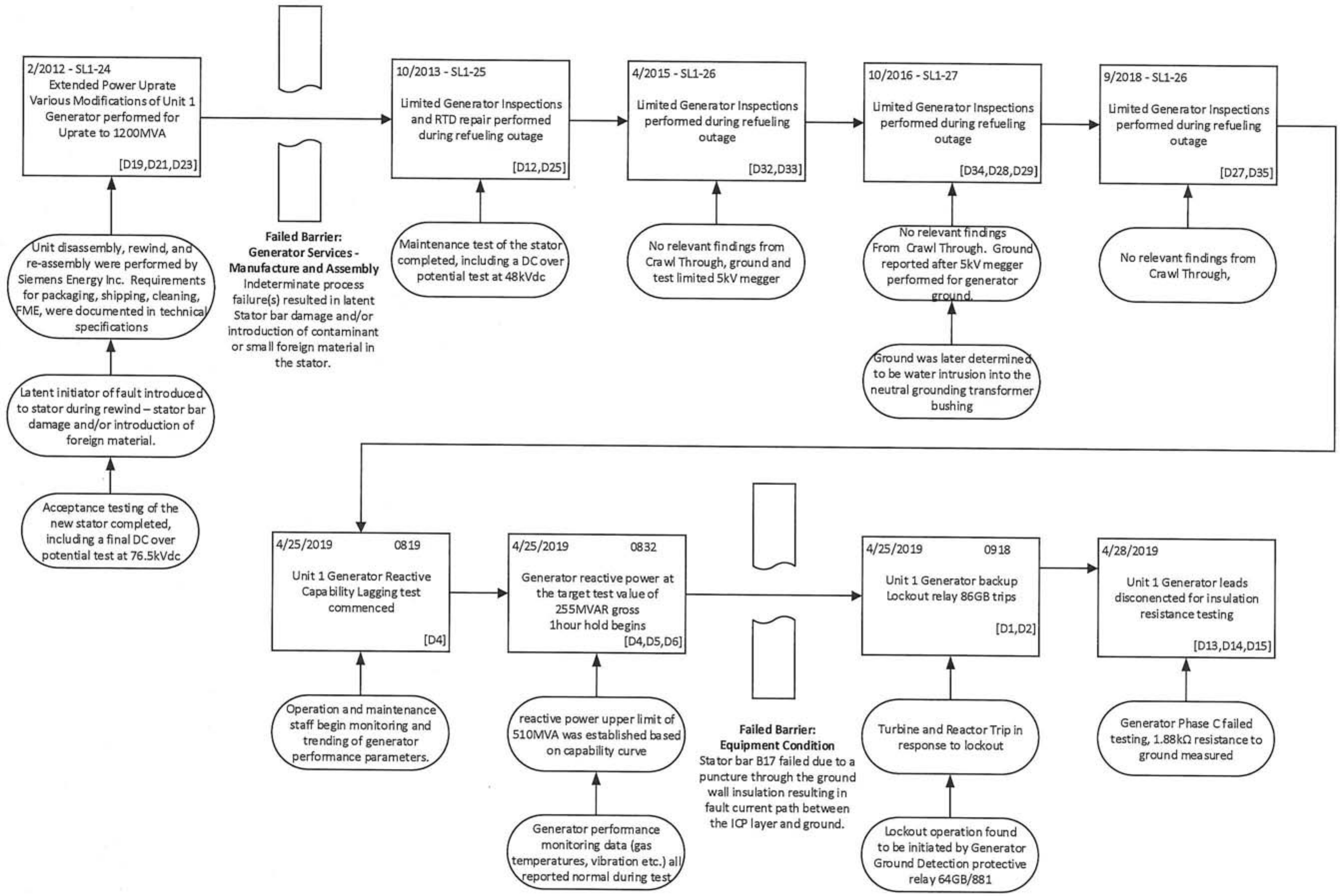
6.0	Failure Process # 6 – Crack in Insulation					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
6.4	Delamination / Transverse cracking between layers	Perform visual examination of bar for delamination of insulation Inspect sectioned bar: exam and testing as described in 4.3 and 4.4	See 4.3 and 4.4	There are no signs of delamination in the insulation either from inspection of the surface surrounding the fault location or from inspection of sections from the bar. Testing results from all insulation samples are satisfactory.	Delamination between insulation layers is refuted.	

7.0	**Failure Process # 7 – Electrical Damage to Stator Bar Insulation** Description: Excessive electrical stress results in current flow on, or in, the ground wall insulation that thermally damages and carbonizes the organic constituents of the insulation. The resulting carbon track forms a conductive path along or through the insulation between the stator conductor and a ground.					
	CAUSE	**VERIFICATION**	**EXPECTED / NORMAL**	**ACTUAL**	**CONCLUSION**	**NOTES**
7.1	Partial Discharge / Corona	Determine estimated maximum void size for partial discharge based on voltage stress applied to insulation of B17 in service Inspect fault location for evidence of partial discharges.	Voltage across any voids or spaces in bar construction is insufficient to ionize H2 cooling gas resulting in PD activity. No evidence of carbonized voids and tracking indicating PD in insulation at fault location.	Fault is located on the turbine end arm of B17. Voltage stress on the ground wall insulation at this location is less than 3000Vac. PD is precluded as this is below the ionization voltage for the H2 cooling gas [D20,D38] The fault location does indicate some carbonization which follows the path of the fault current through the OCP along the bar to ground. This is attributed to the fault current after the insulation was breached. There is no internal tracking or any evidence of the fault following a path along the half lapped layers in the insulation as would be expected [D38]	This cause is refuted. PD at voltage below 3000Vac is unlikely in any machine. Pressurization in the St Lucie machine increases H2 ionization voltage such that PD could not occur at this location.	

7.0	**Failure Process # 7 – Electrical Damage to Stator Bar Insulation** Description: Excessive electrical stress results in current flow on, or in, the ground wall insulation that thermally damages and carbonizes the organic constituents of the insulation. The resulting carbon track forms a conductive path along or through the insulation between the stator conductor and a ground.					
7.2	Surface Tracking	Perform visual examination of bar surface insulation for evidence of tracking. Insulation Resistance test of cone pad sample [Turkey Point OE]	No evidence of carbon deposits, treeing formations or other indications of electrical tracking between the bar ends and the ECP/OCP layers or any adjacent surfaces to ground. Cone Pad material sample exceeds 1000 MΩ/in2 to refute condition similar to Turkey Point	No evidence of tracking was identified on B17. The fault was located at a location in the end arm in the OCP layer region, which contradicts any surface tracking due to this layer being conductive. Cone pad material was tested and found acceptable. The insulation resistance was 23.8GΩ at 5000Vdc	Surface Tracking is refuted.	Turkey Point OE on conductive cone pad material that resulted in failed high potential testing. St Lucie passed initial high potential testing after rewind

SYMBOL KEY


DATE/TIME
EVENT
SOURCE
EVENTS - Who did what? Where? When?
CONDITION
SOURCE
CONDITIONS - Background Factors, Influences, Environment
RELATIONSHIPS
DATE/TIME
EVENTS
CONDITIONS
ASSUMPTIONS
FAILED BARRIER
TRANSFER – Off page Reference


2/2012 - SL1-24
Extended Power Uprate
Various Modifications of Unit 1 Generator performed for Uprate to 1200MVA
[D19,D21,D23]
Unit disassembly, rewind, and re-assembly were performed by Siemens Energy Inc. Requirements for packaging, shipping, cleaning, FME, were documented in technical specifications
Latent initiator of fault introduced to stator during rewind – stator bar damage and/or introduction of foreign material.
Acceptance testing of the new stator completed, including a final DC over potential test at 76.5kVdc
Failed Barrier:
Generator Services - Manufacture and Assembly
Indeterminate process failure(s) resulted in latent Stator bar damage and/or introduction of contaminant or small foreign material in the stator.
10/2013 - SL1-25
Limited Generator Inspections and RTD repair performed during refueling outage
[D12,D25]
Maintenance test of the stator completed, including a DC over potential test at 48kVdc
4/2015 - SL1-26
Limited Generator Inspections performed during refueling outage
[D32,D33]
No relevant findings from Crawl Through, ground and test limited 5kV megger
10/2016 - SL1-27
Limited Generator Inspections performed during refueling outage
[D34,D28,D29]
No relevant findings From Crawl Through. Ground reported after 5kV megger performed for generator ground.
Ground was later determined to be water intrusion into the neutral grounding transformer bushing
9/2018 - SL1-26
Limited Generator Inspections performed during refueling outage
[D27,D35]
No relevant findings from Crawl Through,
4/25/2019 0819
Unit 1 Generator Reactive Capability Lagging test commenced
[D4]
Operation and maintenance staff begin monitoring and trending of generator performance parameters.
4/25/2019 0832
Generator reactive power at the target test value of 255MVAR gross
1hour hold begins
[D4,D5,D6]
reactive power upper limit of 510MVA was established based on capability curve
Generator performance monitoring data (gas temperatures, vibration etc.) all reported normal during test
Failed Barrier:
Equipment Condition
Stator bar B17 failed due to a puncture through the ground wall insulation resulting in fault current path between the ICP layer and ground.
4/25/2019 0918
Unit 1 Generator backup Lockout relay 86GB trips
[D1,D2]
Turbine and Reactor Trip in response to lockout
Lockout operation found to be initiated by Generator Ground Detection protective relay 64GB/881
4/28/2019
Unit 1 Generator leads disconencted for insulation resistance testing
[D13,D14,D15]
Generator Phase C failed testing, 1.88kΩ resistance to ground measured