Q. **Reference: Tab 2; Volume II: Rewind Unit 3 Stator - Holyrood**

Hydro states on page 2, lines 14-16:

> No problems were identified at that time but the OEM and Iris Power, an independent third-party, recommended a rewind of the stator in the near-future due to the overall age of the unit."

Please provide the above referenced reports from the OEM and Iris Power.

A. Please refer to PUB-NLH-019, Attachment 1 for a document[1] from Mitsubishi Hitachi Power Systems Limited (original equipment manufacturer) and PUB-NLH-019, Attachment 2 for a report from Iris Power.[2]

[1] "Estimation of Residual Lifetime of Stator Windings," Mitsubishi Hitachi Power Systems Ltd., January 31, 2019.

[2] "Holyrood Unit 3 Updated review of Inspection, Maintenance, Test, Rotor Rewind and Assessment Reports for CE Alstom and AMEC," Iris Power LP, February 2, 2017 (rev. 1).

Engineering Sheet	Doc. No.	GAE-2019-0063	Rev.	0
	Date: 2019-01-31			

Customer Newfoundland and Labrador Hydro (HFLH)	Department/Section Hitachi Power Systems Service Department Generator Global Service Engineering Group
Project Holyrood Thermal Generating Station Unit #3 Generator	Prepared *R.Umezu*
	Checked *D.Lunney*
Subject Estimation of residual lifetime of stator windings	Approved *S.Muramatsu*

PM
Relevant Section
Subcontractor

三菱日立パワーシステムズ株式会社
2019-1-31
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		Reply of date	

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MITSUBISHI HITACHI POWER SYSTEMS, LTD.
POWER SYSTEMS SERVICE HEADQUARTERS

Doc. No.	GAE-2019-0063

1. Background

Holyrood Unit # 3 generator has been operating for over 40 years without ever having the stator rewound. Stator winding insulation is made up of a combination of fragile mica particles reinforced by organic epoxy resins. Since the resins are organic, they breakdown and deteriorate with the application of thermal, mechanical and electrical stresses over time. Through the process of this deterioration, voids begin to form within the groundwall insulation. Over time, some of these voids become large, and electrical strength will be decreased gradually. Utilizing this known failure mechanisms, MHPS has developed two methods for statistically evaluating the remaining life of the insulation system.

The first method is known as D Map Method. D Map Method requires MHPS to perform a variety of high voltage diagnostics tests on the unit, using the same equipment utilized in our factory tests. By evaluating the diagnostics results against the D Map model, MHPS is able to estimate the remaining life of the insulation. Since MHPS has not performed D Map tests on Holyrood Unit # 3, we are unfortunately not able to apply this method at this time.

The second method is known as NY Map Method. NY Map Method is done by mapping the specific unit's operational history against MHPS's NY Map model to predict the remaining life of the stator bar insulation. In this document, we show the evaluation results for residual life of the existing Hollyrood Unit # 3 stator windings by the NY Map Method.

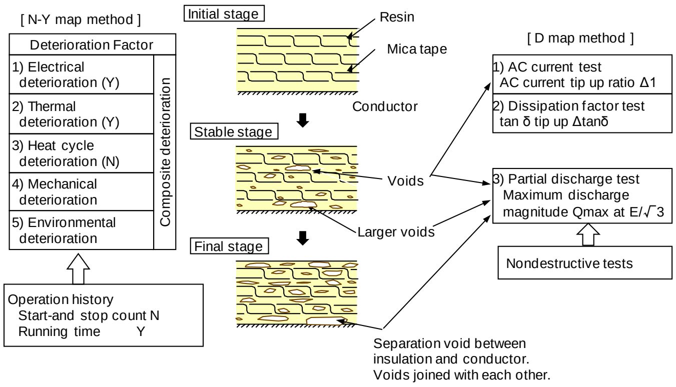

Figure 1: Mechanism and Inspecting Method of Insulation Deterioration

Utilizing the known history for Hollyrood Unit # 3, MHPS has evaluated the remaining breakdown voltage for 3 cases shown in Table 1.

Table 1 Condition of Operating Hour and Start / Stop Times

CASE		Total Operation hour	Start / Stop times
1	Actual operating data	210,000 hr	720 times
2	In case operate until 2020	220,000 hr	756 times
3	In case operate until 2025	245,000 hr	846 times

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2. Generator Specification

Unit No.3 generator specification is as follows.

(1) Generator Capacity	185,000 kVA
(2) Power Factor	0.85
(3) Terminal Voltage	16 kV
(4) Stator Current	6,676 A
(5) H2 Pressure	0.31 MPa
(6) Rotating Speed	3,600 rpm
(7) Frequency	60 Hz
(8) Insulation Class	130 (B)
(9) Temperature Rise	130 (B)
(10) Standards	ANSI C50.13 (1965)
(11) Cooling Method	
Rotor	Direct Hydrogen Gas Cooled
Stator	Indirect Hydrogen Gas Cooled
(12) Manufacturing Number	162861-1
(14) Commercial Operation Year	1978

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3. Definition of Lifetime

One important point for the residual life estimation is to define a criteria for insulation end of life. The international standard, IEC Publication 60216-2, defines the end point to be the when the insulation only has 50% voltage of the initial breakdown voltage. The reason why 50% is defined as the end point is that, as the bathtub curve in the Figure 2 shows, the insulation deterioration speed accelerates at the final stage of life.

Further to this definition, MHPS also have our own definition based on our experience. We define the end point to be the 40% voltage of the initial breakdown voltage remaining. Although there is some difference in the definition of end of life, it is generally recommended to plan for the stator rewinding when the estimated remaining breakdown voltage become close to 40～50% of initial break down voltage.

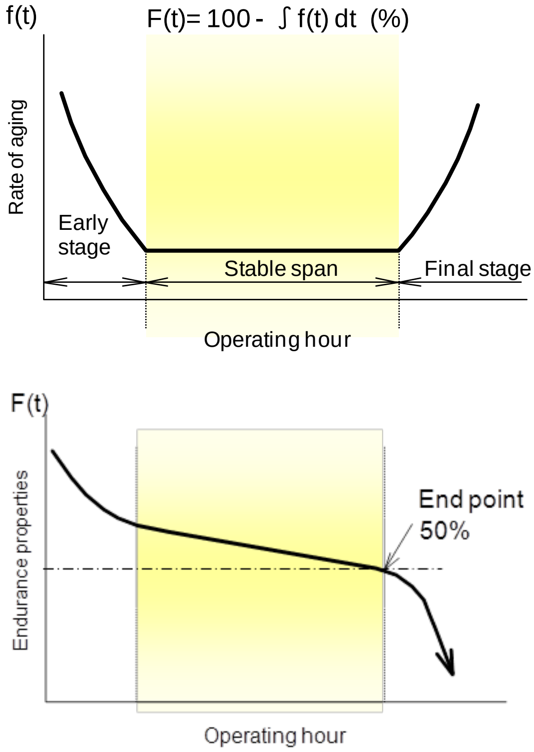

Figure 2: Bathtub Curve of Insulation Reliability

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4. Insulation Diagnosis (NY map method)

4.1 NY map method

Deterioration of insulation is caused by multiple factors, such as heat deterioration, heat cycle deterioration and electrical deterioration. These factors have relationship with start-and–stop times (heat cycle deterioration) and operation period (heat deterioration, electrical deterioration). Therefore, we can estimate residual breakdown voltage using a formula as follows.

Vr / V0(N, Y) = VH / V0(N) x VT / V0 (Y) x VE / V0 (Y)

V0 : Initial Breakdown Voltage
Vr : Residual Breakdown Voltage
VH: Residual Breakdown Voltage by Heat
VT : Residual Breakdown Voltage by Heat Cycle
VE: Residual Breakdown Voltage by Voltage

Using insulation deterioration test data of each deterioration factor, we developed the NY Map shown in Figure 3. The graph is based on average value of each deterioration test data, and Figure 3 shows “Average Residual Breakdown Voltage”. A generator is composed of many coils and ***residual life is determined by the weakest coil***. We, therefore, should estimate the weakest bars residual breakdown voltage.

In order to estimate the weakest bars residual breakdown voltage, MHPS utilizes the relationship between the average residual breakdown voltage and standard deviation (Figure 4). Figure 4 is based on sampling coils test result which have been accumulated over extensive years of testing. In the Figure 4, we first determine average line σ1, and determine 90% confidence range σ2. Then, we estimate minimum residual breakdown voltage by 3σ method.

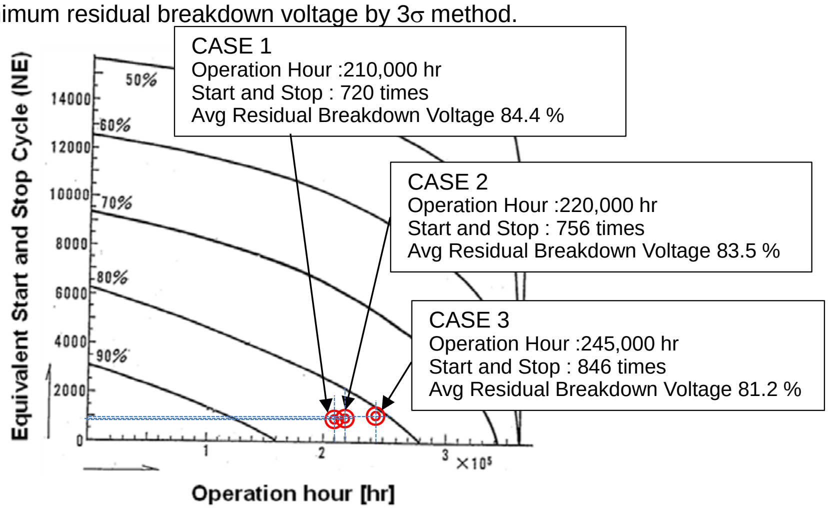

Figure 3: NY map of Epoxy Resin Insulation System

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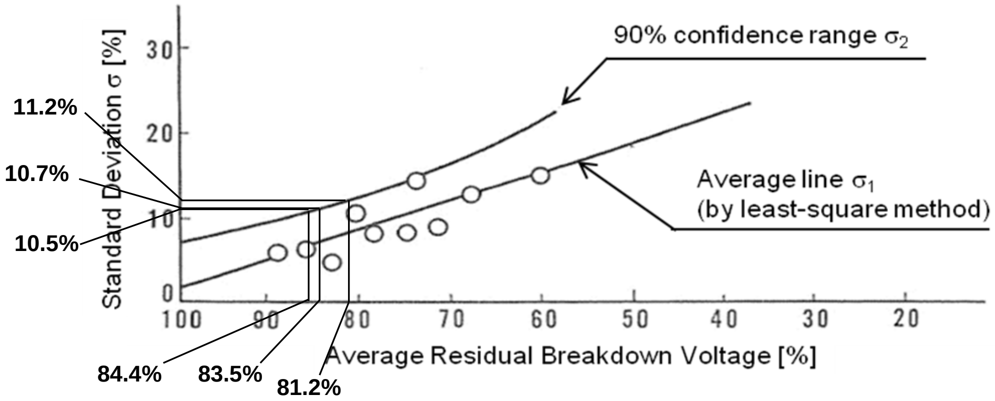

Figure 4: Relation between Average BDV and Standard Deviation

4.2 Estimated Residual Breakdown Voltage

According to the NY Map method, the residual insulation breakdown voltage is shown in Table 2.

Average value (design value) of residual breakdown voltage of all three cases is higher than 50% (IEC criteria). However, in actual case, the source of error with this method of evaluation becomes larger with longer operation period. According to our NY Map, the remaining insulation breakdown voltage of weakest bar (3σ) of CASE 3 is 47.6%, which is less than 50% (IEC criteria). On the other hand, BDV of weakest bar (3σ) of CASE 1 and CASE 2 is still higher than 50 % (IEC criteria).

Therefore, if the generator experience CASE3 operation (245,000hr with 846 times Start / Stop per year), average stator bars will still be in good condition, but the weakest stator bar would likely be approaching its end of life.

Table 2 Residual Breakdown Voltage

CASE		Operation hour	Start / Stop times	Residual BDV	
				Average	Weakest 3σ (99.7%)
1	Actual operating data	210,000 hr	720 times	84.4 %	52.8 %
2	In case operate until 2020	220,000 hr	756 times	83.5 %	51.4 %
3	In case operate until 2025	245,000 hr	846 times	81.2 %	47.6 %

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5. Conclusion

As mentioned above, if we require 99.7% reliability, weakest bar may deteriorate below IEC criteria (50%) after CASE 3 operation. If unit # 3 continues to operate in the same manner, with the same frequency of start stops and operating hours per year, then we strongly recommend performing stator rewinding before 2025. On the other hand, if the operational regimen is likely to change, with more stops and starts, then we strongly recommend performing a stator rewind sooner for Unit # 3.

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Revisions				Doc. No.	GAE-2019-0063
Rev.	Description	Revised	Checked	Approved	Date

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March 6, 2017

Newfoundland & Labrador Hydro
Thermal Generating Station
Holyrood Warehouse
Duffs Road P.O. Box 29 - Holyrood
CONCEPTION BAY, NL A0A 2R0
Canada
Attention Jonathan Whelan

Newfoundland&Labrador Hydro
Holyrood Unit 3
Updated Review of Inspection, Test, Rotor Rewind and Assessment Reports from GE Alstom and AMEC

Attached please find a copy of our Updated Review of GE Alstom and AMECAssessment Reports for the work carried out at Newfoundland&Labrador Hydro on the generator Unit 3, at Holyrood. The report concludes that the condition assessment and recommended maintenance strategies are reasonable, based on off-line generator tests & inspections with rotor in place and rotor rewind in 2016.

The Rotating Machine Technical Service Group at Iris Power LP is committed to providing you with superior service. We value your business and any input you have that can enhance our service to customers. If you require further information or have any questions, please do not hesitate to contact us.

Yours Sincerely,

Mladen Sasic
Manager RMTS

Type of Service

Newfoundland&Labrador Hydro

Holyrood Unit 3
Updated Review of Inspection, Maintenance, Test, Rotor Rewind and Assessment Reports from GE Alstom and AMEC

Client Purchase Order No:	24629-000 OB
IRIS RMTS Reference No:	50255480-0
Issue No:	1
Revision No:	1
Date:	February 2, 2017

Prepared by: **Signature**

Joe Kapler **Date** **February 2, 2017**

Reviewed by: **Signature**

Greg Stone: **Date** **March 2, 2017**

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Table of Contents

1.0 Introduction

Newfoundland and Labrador Hydro, Holyrood Generating Station, requested Iris Power LP to carry out a condition assessment of the Generators Unit 3 stator and rotor winding, based on:

1) Alstom Field Service Reports FSRG019866 and FSRG020035 of visual inspections and bump test on Unit 3 generator in June 2013 and July 2013, respectively,

2) Alstom Recommendations Report UTGE672108, June 2014

3) Alstom Generator Unit 3 Condition Assessment Summary Report, September 4, 2013,

4) Generator Diagnostics Rotor Electrical Test Report S481/14/038, April 2014,

5) AMEC Report AM160-09, August 2014,

6) Holyrood 3 Generator Rotor Rewind, CFRG033854, July 2016,

7) Generator Rotor Final Acceptance Test at Site, CFRG034173, August 2016,

8) GE Canada FSR#203512250 May 2007

The Assessment was carried out under Iris Power task references 50255480-0.

The task was to evaluate the reliability of the stator and rotor windings for service in synchronous condenser operation mode from 2021 to year 2041.

Machine Type	*Turbine-Generator*	RPM	*3600*
Voltage/PF	*16.0 kV/0.85*	Manufacturer	*Hitachi*
KVA	*177235*	Date Manufactured	*1980*
Insulation /Class	*Epoxy mica, F*	Serial Number	*TFLQQ*
Cooling	*Hydrogen*	Stator Slots/ Winding Circuits	*60/2*

The stator winding is indirectly hydrogen cooled, the rotor winding and stator core are directly hydrogen cooled.

2.0 Assessment

2.1 Operational Period for Unit 3 generator is designated for full generating service until 2021 and then will be converted for only synchronous condenser operation to 2041. The generator has an accumulated service in the order of 153 000 hours in generating and about 48 000 hours in condenser modes.

2.2 Alstom Field Service Reports FSRG019866 and FSRG020035, Unit 3, June 20, 2013

The reports cover a visual inspection of the stator core and winding with rotor in the bore, DIRIS air gap robot inspection, DIRIS low flux test of the core, stator winding frequency response test & modal analysis, and electrical tests on the stator and rotor windings.

The visual inspection does not report any significant degradation in the stator windings insulation or mechanical damage. Only minor surface contamination and a small surface corona mark at one location in the end winding area were reported. The picture of this location indicates a low clearance between two bars of different phases which may be the reason for discharges.

A limited rotor visual inspection with borescope under retaining rings detected a detached piece of insulation at the drive end of the rotor and light dust contamination.

The off-line RSO test for shorted turn detection in rotor windings indicated one shorted turn at standstill. Further RSO tests in April 2014 in stages from zero speed to full speed confirmed the shorted turn at a single location.

The insulation resistance (IR) tests of the stator winding phases at 5000 VDC gave values in the Giga Ohm range; the polarization index (PI) was calculated between 2.8 and 3.2, although in our opinion PI does not have much meaning at such high IR. The insulation surface appears to be in good condition, with no indications of significant contamination. There is no indication of any maintenance high potential (Hipot) tests being performed. We assume none had been done.

The DIRIS bore inspection does not show any dusting or greasing along the stator winding wedges indicating that the winding in slot section of the core is mechanically stable; thus there is low probability of bar vibration and insulation abrasion, even though this is one of the more likely deterioration processes in this type of stator.

The DIRIS low flux test of the stator core (Alstom variant of El-Cid) indicates the results are within Alstom's acceptable range, although we do not know of any independent validation of this acceptance criteria. However Alstom has no commercial reason to say the core is good, if there would be indication that it is bad.

The frequency response test (bump test) and modal analyses at both end windings (EW) do not indicate any natural frequencies in the ranges that would result in resonances at the 60 and 120 Hz excitation forces. The tangential vibration magnitudes on some end caps and phase connections were identified as high, but visual inspections have indicated that this has not caused any apparent damage in 30 year-plus service.

The limited rotor visual inspection was done without retaining rings removal and thus assessment of the rotor condition remains less certain.

The rotor winding insulation resistance at a voltage of 500V DC was measured in Giga Ohm range with PI of 1.3, indicating acceptable ground insulation condition with essentially no contamination.

The recommended maintenance activities on the stator and rotor components during the 2013 outage were limited to the clean-up of stator end winding, rotor surfaces and slip rings, removal of loose strip of insulation from rotor end winding and clean-up of oil in the end section of the casing. We understand that the recommended maintenance was completed.

Report S481 14 038, April 20, 2014 confirms the finding of rotor shorted turn at several speeds up to the rated speed.

Report UTG 672108, **October 2014**, describes summary of GE/Alstom recommendations for long term maintenance of Unit 3 generator. The summary outlines reasonable maintenance alternatives. They are well presented and logical.

2.3 AMEC Generator Assessment, Units 3, August 22, 2014

The report was completed by Mr. G. Klempner, a respected generator specialist well known to us. His condition assessment conclusions from the test results and recommended long term options generally agree with Alstom strategy options for the operating life of Unit 3 generator as synchronous condenser to year 2041. The table of maintenance options and their risk assessment appears reasonable.

The recommended lists of generator tests prior to shutdown of the unit for major inspection in 2016 and inspection program are comprehensive and complete. The references to water cooled stator windings do not apply to the indirect hydrogen cooled Unit 3 generator at Holyrood. We strongly agree with the recommendation of obtaining all possible operational readings from the available generator monitoring sensors prior to unit shutdown in 2016, possibly at full and half of unit rated load. Such results may provide substantial support to subsequent condition assessment from visual inspection and off-line tests.

There is no follow up on this report at this time.

2.4 Partial Discharge (PD) Data Analyses

We reviewed the on-line stator winding PD test results from 2011 to 2013. The test results were recorded at about half load and an overvoltage from approximately 2 to 5%. The recorded stator winding temperatures and hydrogen gas pressures on the test sheets appear much lower than the design values. The maximum Qm magnitude from these tests was 5mV which ranks as Typical when compared to other stator windings in the Iris database with similar operating voltages and hydrogen pressures. This together with no discernible rising trend over the almost 3 years between the tests [3] indicates the stator winding insulation to be in relatively good and stable condition. So, reliable stator winding insulation life is probable. The on-line testing frequency of once or twice a year should continue in order to detect any unexpected and rapid rise in PD magnitudes indicating insulation degradation. Normally there are several years between the onset of high PD and high risk of stator winding failure.

There is no follow up on PD data at this time. This test should be completed and reviewed from time to time to detect possible indications of any gradual aging or failure modes developing in the stator winding.

2.5 Risk assessment of major generator components from typical major failure mechanisms

The following risk assessments of severe degradation or failure of Unit 3 generator from major failure mechanisms in the planned operation as synchronous condenser to 2041 were considered [4], [5]:

a) *Design and manufacturing deficiencies*

No major design or manufacturing problems, neither generic nor specific to this generator, have been identified from the latest inspection and test reports. The gradual relaxation of the stator winding in core slots and in end winding is a recognized and expected aging mechanism. No signs of insulation wear, neither in the slot section nor in the end winding of the stator winding, have been identified by visual inspection or tests.

In 2007 some relaxation in the stator wedge pressures was identified. The stator was re-wedged and no further pressure relaxation has been reported.

One shorted turn has been confirmed in the rotor winding. It is not clear if the short had been introduced during the original assembly, but had not been noted before the 2013 tests.

b) *Stator thermal aging of insulation*

Insulation overheating and thermal damage can occur due to extended operation at high current (e.g. overload, system voltage unbalance above 3%) or due to loss or reduction of cooling (locally or globally). Extended operation at winding temperatures near or above the insulation temperature class the thermal aging rapidly increases and shortens the life of insulation. Neither the visual inspections nor the on-line PD test detected stator winding thermal aging. It seems the stator winding had been operating well below its thermal class, making the thermal aging unlikely.

One location of electrical discharges has been identified, possibly at a reduced clearance between two adjacent bars in different phases. The photograph of that location appears to indicate a lack of clearance between the two bars.

c) *Loose Winding in the Stator Slots*

Excessive loss of stator winding wedging pressures leads to relative bar motions and insulation abrasion on core slot walls. In addition to a loss of the bar voltage suppression coatings and slot discharges, the thinning of ground wall can lead to insulation ground failures.

No signs of insulation abrasion or greasing along the slot wedges have been reported in DIRIS report, indicating stable winding condition. The on-line PD tests also indicated no sign of damage to the insulation from loose windings.

d) Stator Winding Contamination, End Winding Tracking

In hydrogen cooled machines severe winding contamination is not normally expected. On Unit 3 generator only light surface dusting has been reported. Therefore the winding surface tracking to core and insulation erosion at phase-phase inter-phase blocking is unlikely. In any case, such surface discharges can be identified by PD monitoring and the winding cleaned as necessary, since the deterioration process is normally very slow.

e) Stator End Winding Vibration

End winding vibration is a recognized generic problem on a number of newer two-pole generators. The main reason has been identified as a lighter end winding support structure and unstable ties binding the winding bars to the support rings. The relaxation in service causes a shift of the natural vibration frequencies of the end winding basket to drift closer to the electromagnetic forcing frequency at 120 Hz (100 Hz in 50 Hz systems). The increased vibrations result in rubbing and abrasion of the bar insulation at support interfaces.

The Unit 3 inspection report does not indicate any dusting of insulation from vibration induced motion in the end winding. The bump testing also indicated no dangerous natural frequencies. One cannot predict if further relaxation may occur, causing winding damage. End winding vibration monitoring can be effective for detection of changes in vibration levels and indicate the need for corrective maintenance.

f) Stator Core Insulation Degradation, Loss of Core Pressure

The visual inspection and DIRIS test of Unit 3 core reports a core in good condition after more than 30 year service. In normal service, severe core degradation is not expected in the service period to 2021 and beyond.

g) Rotor Winding Insulation

The rotor was rewound in the spring of 2016. **Report CFRG033854** outlines the re-insulation of the winding with original conductors, replacement of the sliprings damaged in an earlier event, refurbishment of radial studs and refurbishing of bore leads. During the initial winding inspection there were no indications of insulation abrasion, migration, excessive contamination or signs of overheating. The rewind and balancing runs were completed by GE Alstom. The project was completed to comprehensive repair and test plan.

Generator Rotor Final Acceptance Test at Site, **CFRG034173, August 2016**, confirms that the rotor has been successfully returned to service.

The location of the earlier reported shorted turn had not been identified. It was possibly a singular defect rather than an indication of insulation aging or general insulation degradation.

h) Rotor Retaining Ring and Forging

The rotor incoming inspection to rewind facility indicated a number of mechanical issued with bore plugs, dents, wedge migration and fan blades minor damage. The forging did not indicate any signs of surface overheating of forging or crack initiations on wedge lands. The wedge migration did cause some shallow retaining ring depressions. The modification included application of insulation material pads to prevent similar damage in the future. The retaining rings were inspected, cleaned and liquid penetrant tested.

The inspections of the retaining rings and forging surface inspection on Unit 3 did not reveal any evidence of overheating or electrical sparking on the rings or at wedge to ring interfaces. Such indications would be expected, if the rotor was subjected to excessive negative sequence currents (I_2). The retaining rings and rotor forging appear sound and suitable for future service.

3.0 Recommendations

1. For added assurance that the stator windings are suitable for operation after each overhaul, high voltage potential tests should be considered at the conclusion of overhauls on each generator. Although the AC high potential test (Hipot) is generally more effective to find insulation weakness and is preferred, the DC Hipot or DC ramp tests are easier to perform. The tests should be conducted according to IEEE 95 (DC) or IEEE 56 (AC). The risk with the Hipot tests is a possibility of the winding insulation failure, which requires immediate winding repair. Such risk is reduced in the DC ramp test where the DC voltage and current are automatically displayed. If a disproportional current rise is detected the test can be terminated before the insulation fault occurs. Based on the visual inspections and test results, the risk of failure in a maintenance level Hipot is low.

2. Partial discharge on-line tests should be done about every 6 months to detect any rapid changes in the stator winding conditions. Similarly, any increase in the bearing vibration at 60 Hz may indicate rotor winding shorted turns. PD testing should continue during the whole period of synchronous condenser mode of operation to 2041.

3. A major maintenance outage, inspection and tests are recommended before releasing the generator to synchronous condenser duty in 2021. The final assessment of the stator winding condition and its suitability for service as synchronous condenser to 2041 should be completed.

4.0 Conclusions:

The above assessments are based exclusively on the submitted test reports and inspections on Unit 3 by GE Alstom and AMEC. Additional information used to assess the stator windings insulation condition was the on-line PD test results obtained between 2011 and 2013. The generator condition assessments in both reports are sound, based on off-line tests and inspection in June 2013 and April 2014. They provide a risk assessments and maintenance options for operation of Unit 3 generator in the synchronous condenser operation to year 2041.

In addition to the reviewed reports we offer the following comments for your consideration:

1. A rapid global deterioration of the stator winding insulation is not indicated from the recent inspection and test report on Unit 3 generator. Although any future degradation cannot be reliably assessed and the end of winding life cannot be predicted, we conclude that a stator rewind should not be required at this time for service to the end of 2021. It is assumed that any gradual winding deterioration in normal service will be detected by condition monitoring and condition restored by preventive and corrective maintenance, if required.

2. We estimate that the Unit 3 generator projected VAR capability in service as synchronous condenser will be at about 140 MVAR rated output, assuming the rated short circuit ratio (SCR) of the generator at about 0.5. Currently the future projected VAR requirements from the Unit 3 generator/condenser have been reported to be well below this capability. This will result in more than 20% reduction in the stator winding current and temperature rise, and more than 40% reduction in the stator winding mechanical forces from current magnetic interaction. The risks of the winding insulation thermal aging and abrasion from bar vibration in slots and in the end winding will thus become significantly lower. This could extend the life of the stator winding to the end of the expected service life to 2041. We note that the epoxy mica winding insulation operating below 120 C and free of wear does not have a defined end of life. Monitoring for winding temperatures, periodic maintenance, on-line PD monitoring and inspections for signs of end winding vibration during maintenance outages should provide a timely warning of an unusual accelerated winding aging. We conclude that a stator winding replacement in the 2021/22 period may not be required from the technical assessment of the current winding condition.

3. GE Alstom did recommend a stator rewind in their report. The recommendation was based on the winding age rather than on an observed insulation condition and aging evidence. Such recommendations from OEMs are frequent and in some cases prudent. We do not consider that the winding condition in Unit 3 justifies such recommendation.

4. Generally the value of VAR generation is well below the generation of real power. Should a rewind of the stator be needed at any point in the projected operating period, a cost benefit evaluation may be required to justify the cost of a rewind. From the projected future VAR generation requirements it is not clear if such expenditure would be cost effective.

5. The decision for stator winding replacement can be delayed to 2021 and possibly beyond. The results of complete winding inspection and maintenance in 2021 should provide for additional information in regard to the stator winding insulation aging and a need for replacement at some future date.

6. A purchase of a set of spare bars sufficient to wind any three consecutive slots would provide a backup for unforeseen winding ground fault. We would consider such expenditure prudent, but not necessarily required. A set of such bars may be expensive even in the aftermarket and their purchase may not be cost effective.

7. The rotor duty in the condenser mode operation at rated MVAR output is the same as at the rated output in the generating mode. However, it is estimated that only 1% of the operating time would be close to the rated output and 5% of the time at 80% of the output would be required, and the remaining operating time at lower outputs. This is considered as a light operating duty. The rotor was successfully rewound in 2016. The continuous on-line monitoring for shorted turns has been implemented. It is considered that the life expectancy of the rotor winding to 2041 should be assured without any major future remedial costs.

It should be noted that this assessment is valid for normal expected unit service. The consequences of abnormal operation or unpredictable system stress events cannot be predicted.

5.0 References

1. *IEEE 43 – 2013 Recommended Practice for Testing Insulation Resistance of Electric Machinery*

2. *IEEE 56 –1977 Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery (10 000kVA and Larger)*

3. *V. Warren, "How Much PD is Too Much PD", Iris Machine Conference, Las Vegas, June 20122*

4. *G. C. Stone, et all, "Electrical Insulation for Rotating Machines", Second Edition, Wiley – IEEE Press, 2014*

5. *Geoff Klempner, Isidor Kerszenbaum, Operation and Maintenance of Large Turbo-generators, IEEE Press, A John Wiley & Sons Publishers, 2008*