Case study

Major Fault Caused by Stator Winding Circuit Ring Failure

Joël Pedneault-Desroches, P. Eng.

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Presentation Outline

Introduction

Inspection report

Chronology of events

Repair

Conclusion

Introduction

August 13, 2017 : 202 MVA, 13.8 kV generator failed and forced the evacuation of a power house

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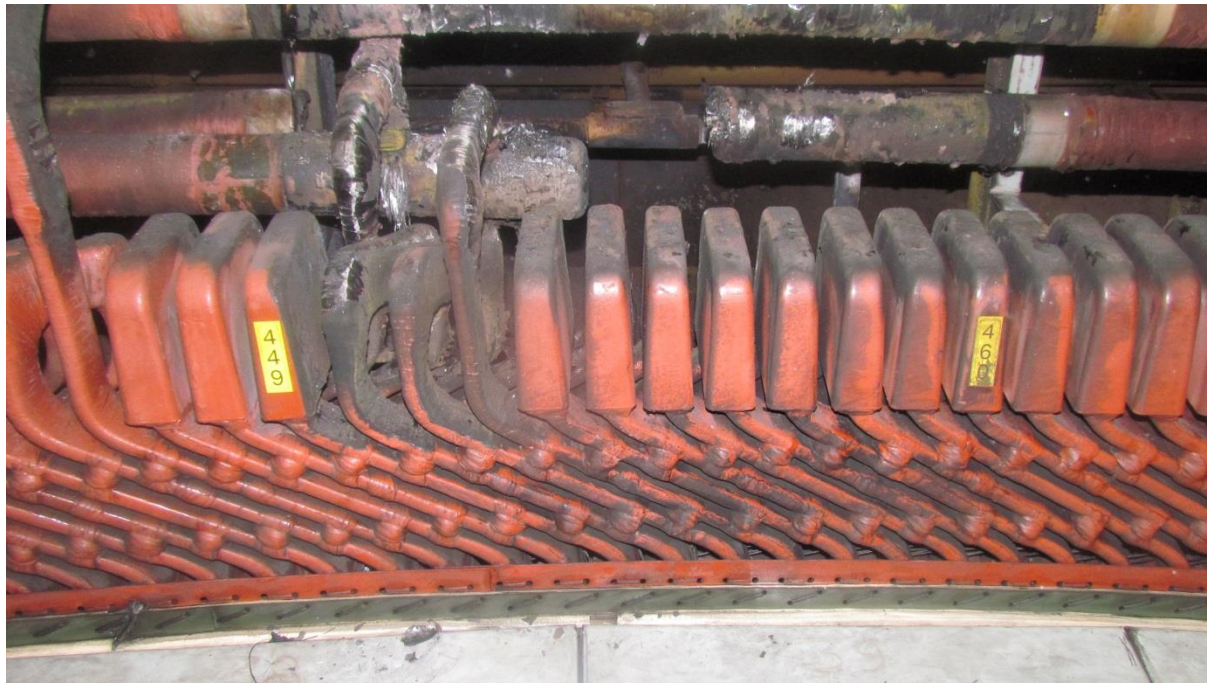
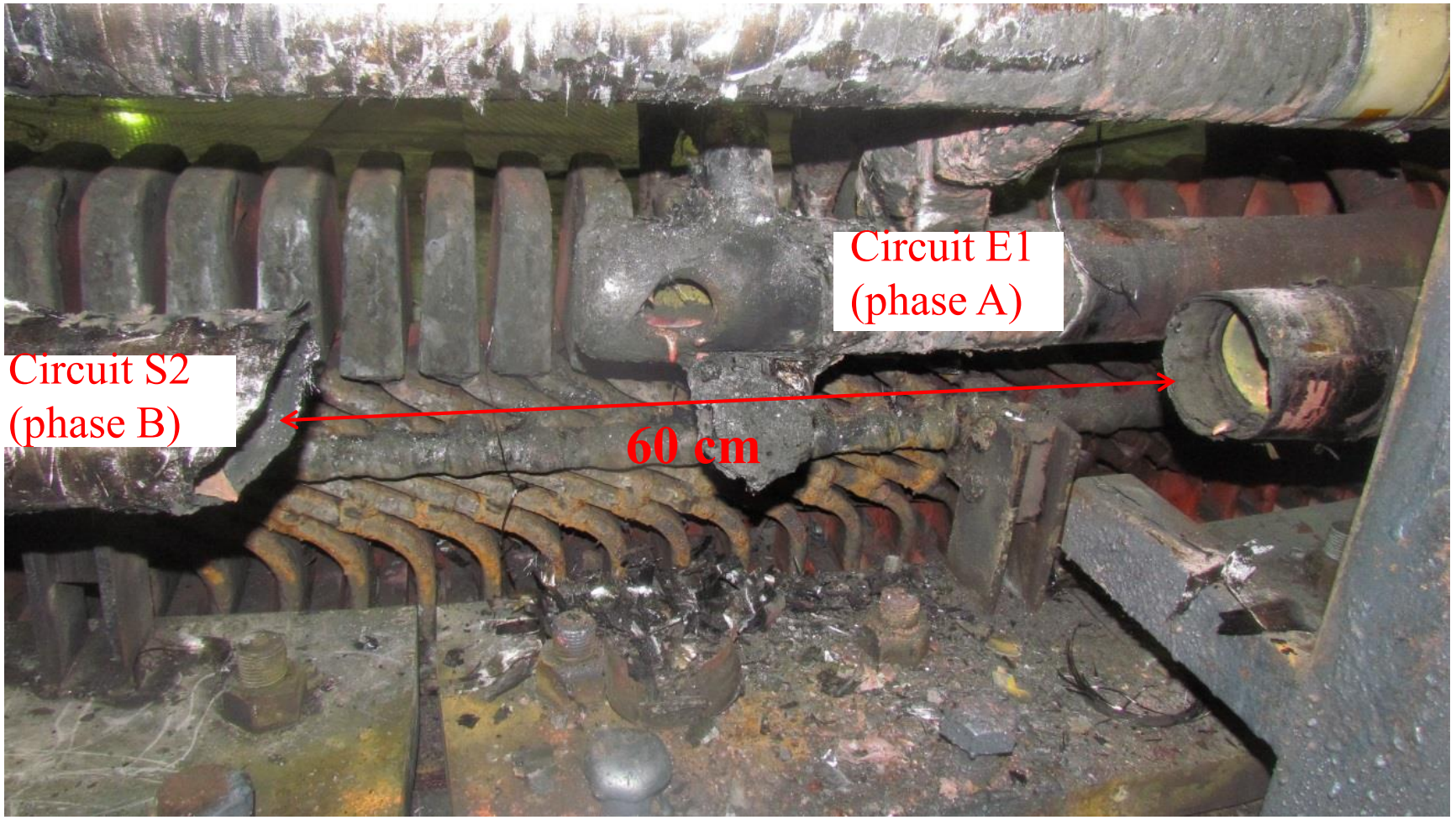
Inspection report

Main damages to the generator:

- Stator circuit ring (section of 6 feet)
- 18 Bottom bars seriously damaged
- Cable ducts and instruments



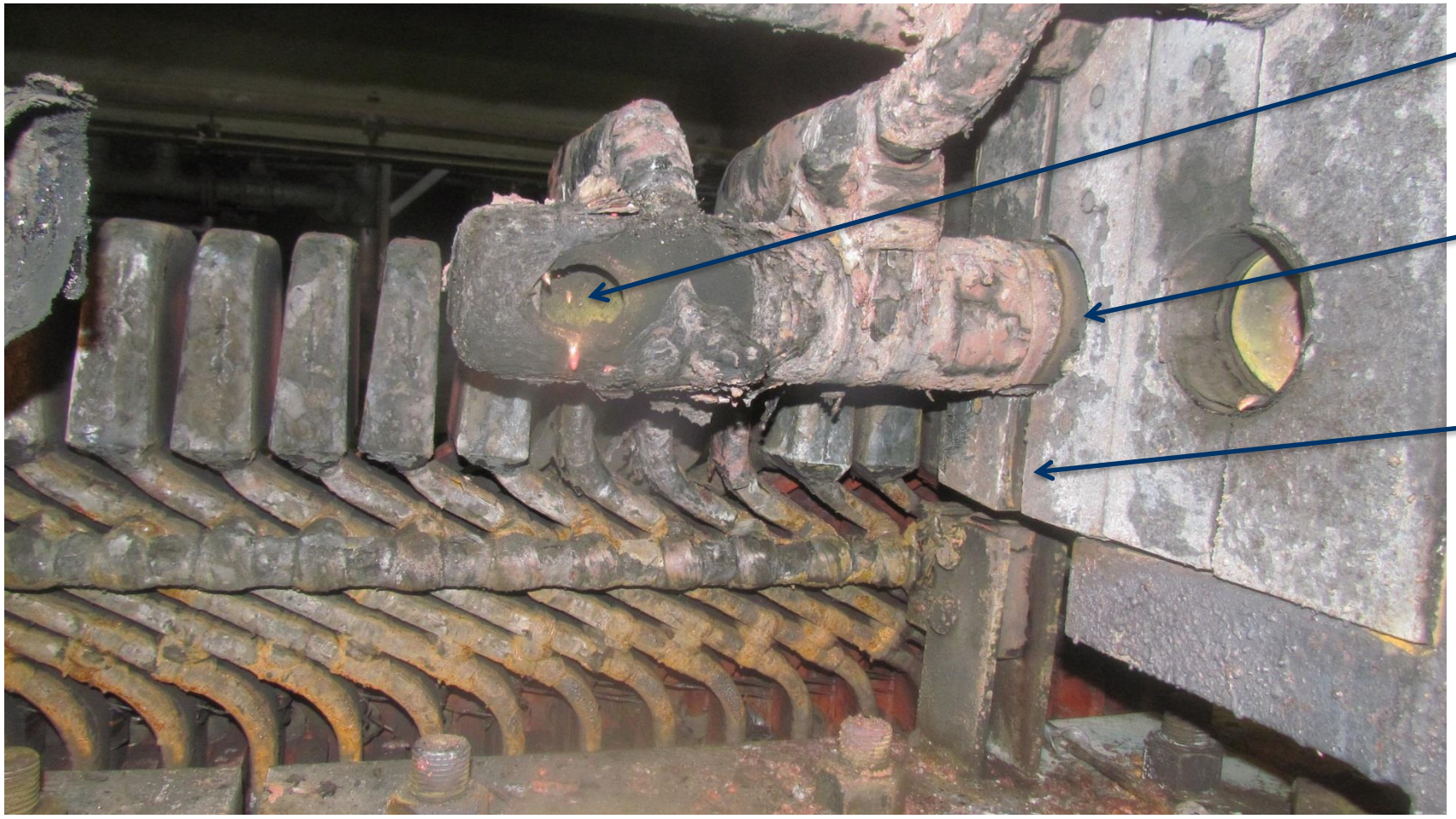
Inspection report: Stator circuit ring



Circuit ring insulation is burned and damaged around the fault

60 cm (3 feet) of S2 circuit ring is missing (copper pipe of 3 ½ inches and ¾ thickness)

Inspection report: Stator circuit ring (2)



Golf ball hole in circuit E1 (phase A)

Circuit E1 moved by a inch

Support bloc opened by the force of the fault

Inspection report: Bottom bars

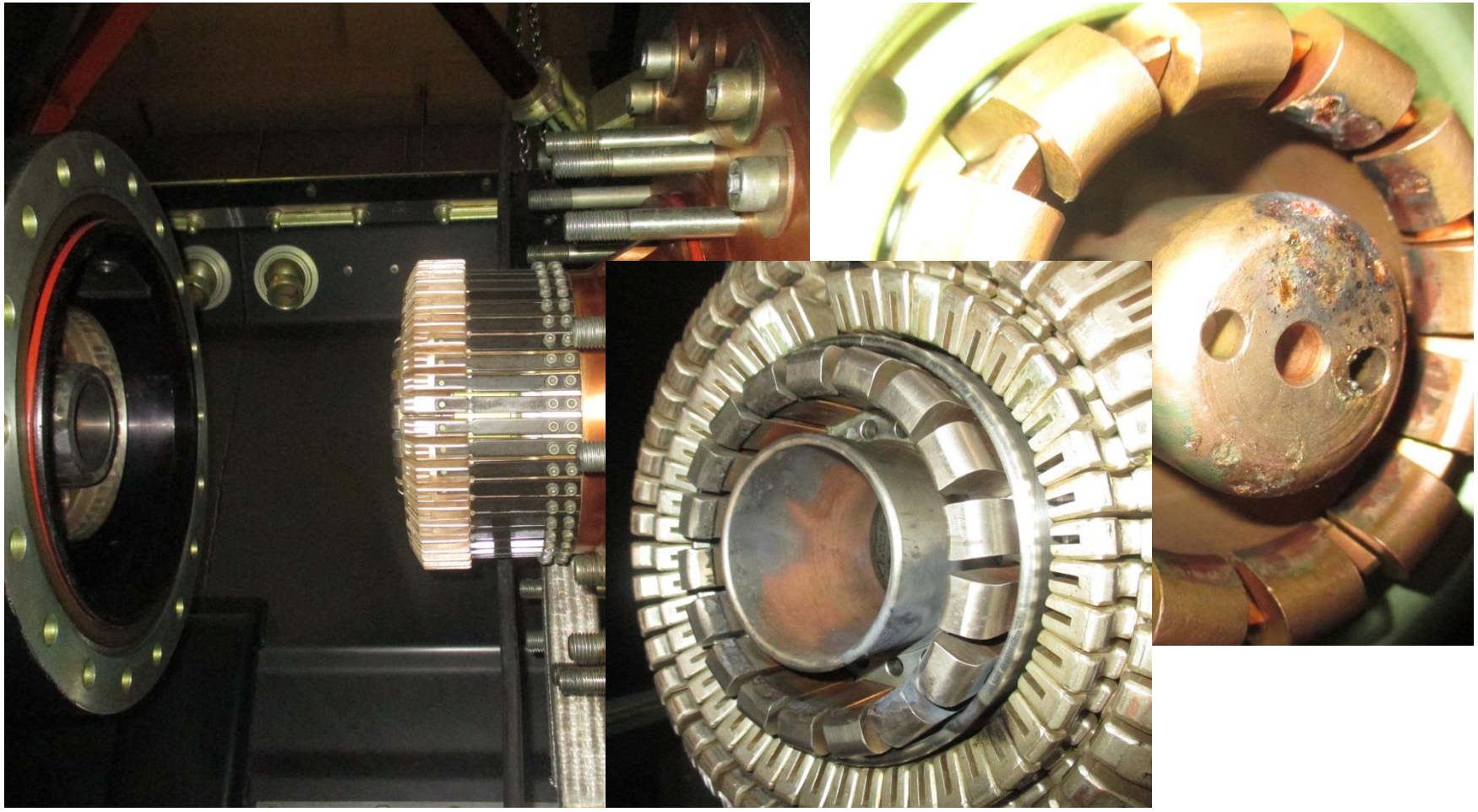
Insulation of 18 bottom bars was seriously burned and covered by copper

Inspection report: Instrumentation

Many cable ducts and instruments were burned

Neutral cable, neutral CTs cables, RTDs cables…

Inspection report: Generator circuit breaker



Burned spots in the mobiles contacts

Current fault:
$\sim 100\ \mathrm{kA\ rms}$
$(\sim 12\ pu)$

Presentation Outline

Introduction

Inspection report

Chronology of events

Repair

Conclusion

Chronology of events: Protection

08:57:03: After being stopped for a part of the night, the group is started

1 min

08:58:03: The generator circuit breaker is closed

2 min 43 sec

09:00:46: Abnormal voltage of third harmonic at the neutral of the generator detected

1 sec

09:00:47: Smoke detected in the generator

19 sec

09:01:06: Current in reverse sequence detected

15 sec

09:01:21: Current in reverse sequence alarm

3 sec

09:01:24: First overvoltage in the neutral of the generator

3 sec

09:01:27: Tripping with complete stop by differential protection, fire protection activated

Chronology of events: Protection

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19 sec

09:01:06: Current in reverse sequence detected

15 sec

09:01:21: Current in reverse sequence alarm (400 ms)

3 sec

09:01:24: First overvoltage in the neutral of the generator (15-25 ms)

3 sec

09:01:27: Tripping with complete stop by differential protection, fire protection activated

Alarm

Tripping alarm

Duration of the fault ≈ 41 seconds

Chronology of events: Summary of the event

Fault started with a resistive contact that made circuit S2 (phase B; neutral end) rise in temperature and start an arc that caused :

- Smoke detection inside the generator;
- Intermittent ground fault not constant enough to shut down the unit by the operation of protections (lower voltage side);
- Damage the insulation of the circuit E1 (phase A; high voltage end).

It ends by a phase-to-phase fault with E1 and S2 causing the unit to trip by differential protection.

Presentation Outline

Introduction

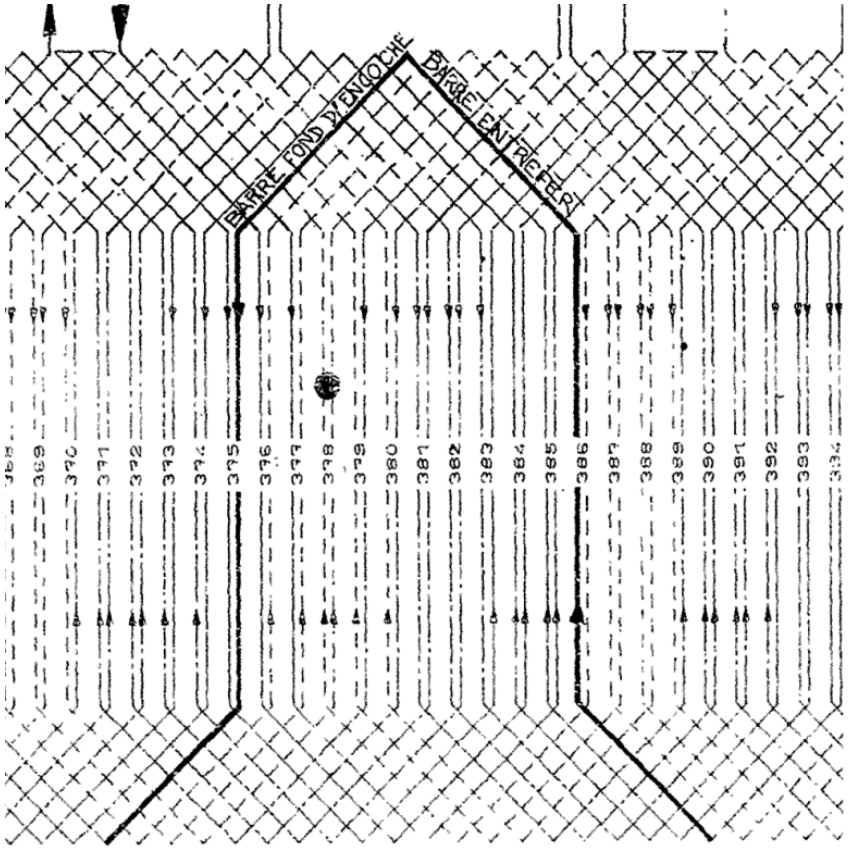
Inspection report

Chronology of events

Repair

Conclusion

Repair: Stator bars



Wave winding

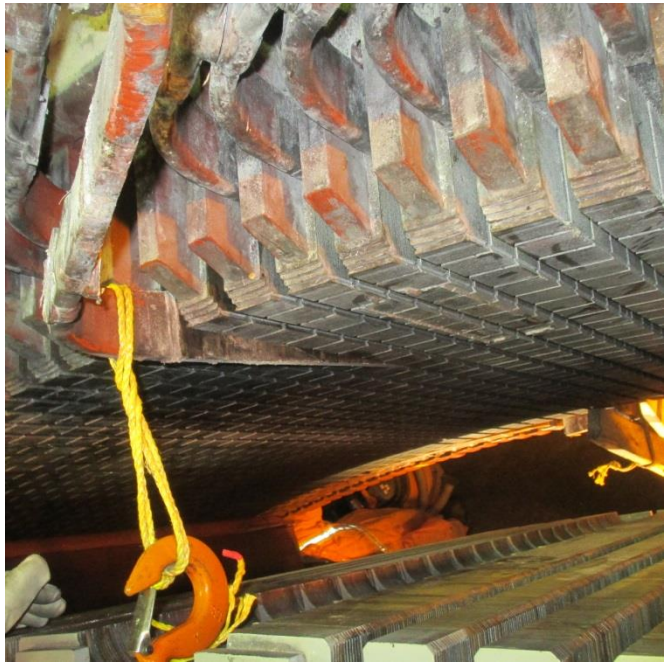
First bottom bar cost 20 top bars

Bars replaced: 18 bottom and 37 top (55 total)

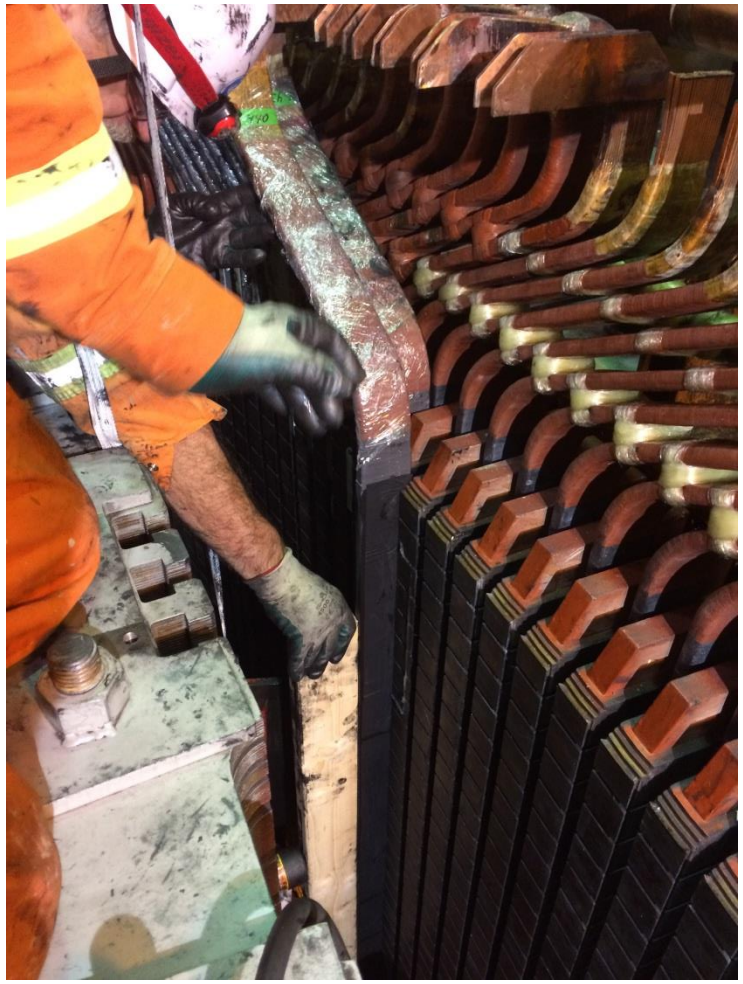
Challenge: Work to be done with the rotor in place

Repair: Stator bars (2)

1 – Removing the bars after debrazing and removing the wedges



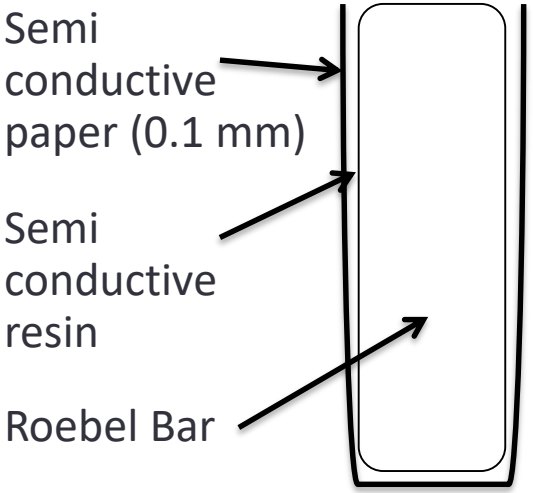
Repair: Stator bars (3)



2 – Replacing the bars after cleaning and painting the slots with semi-conductive paint

(Hipot tests on spare bars before installation: 34 kVac, after insertion of the bottom bars: 32 kVac, after insertion of the top bars: 30 kVac)

"U" packing with semi-conductive resin:

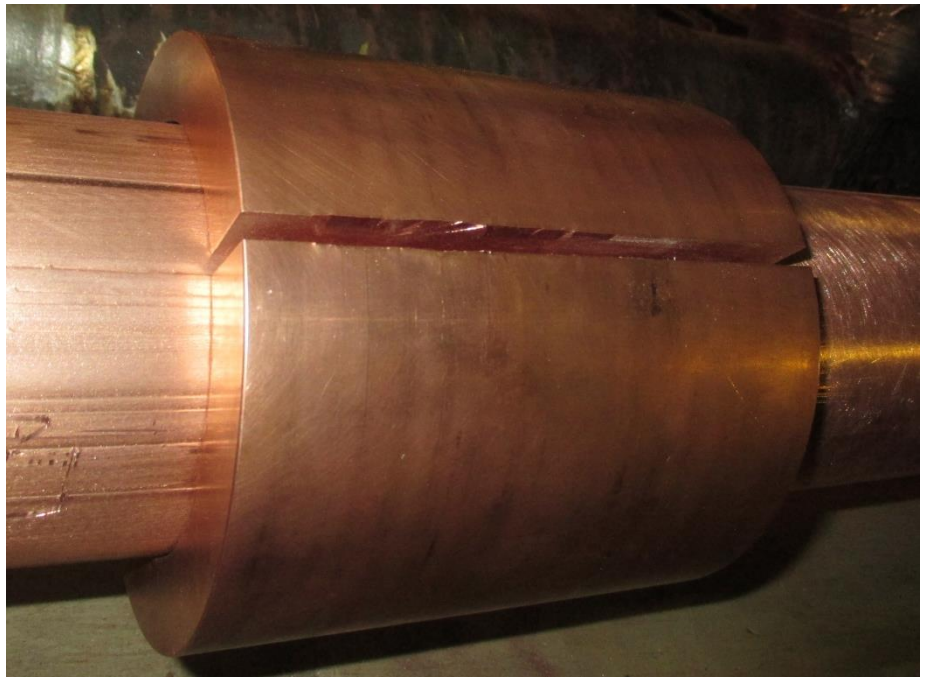


Repair: Stator bars (4)

3 – Final tests after the radial wedging with original wedges (ripple springs), brazing and attaching the bars

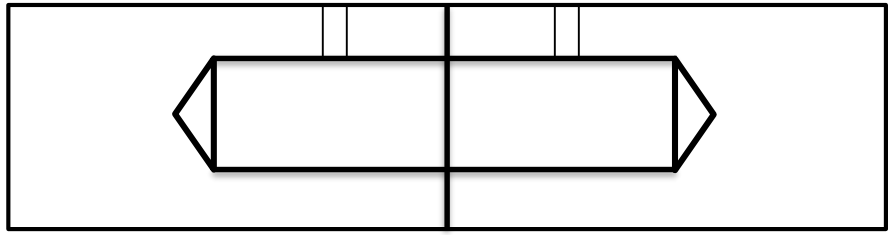
- Final Hipot: 13.8 kVac
- Winding resistance

Repair: Circuit ring

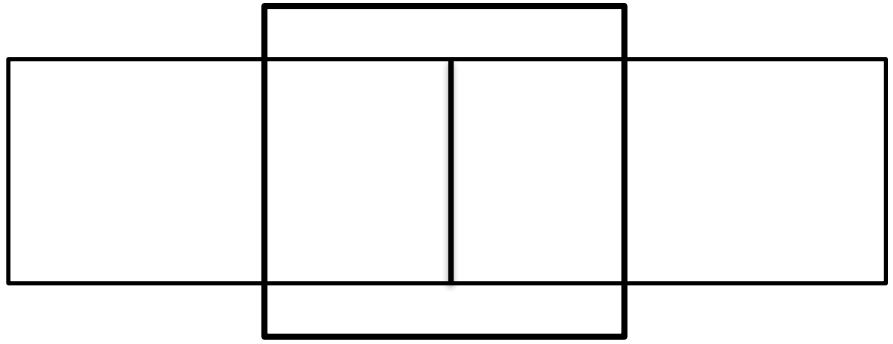


Preparing and brazing the junction

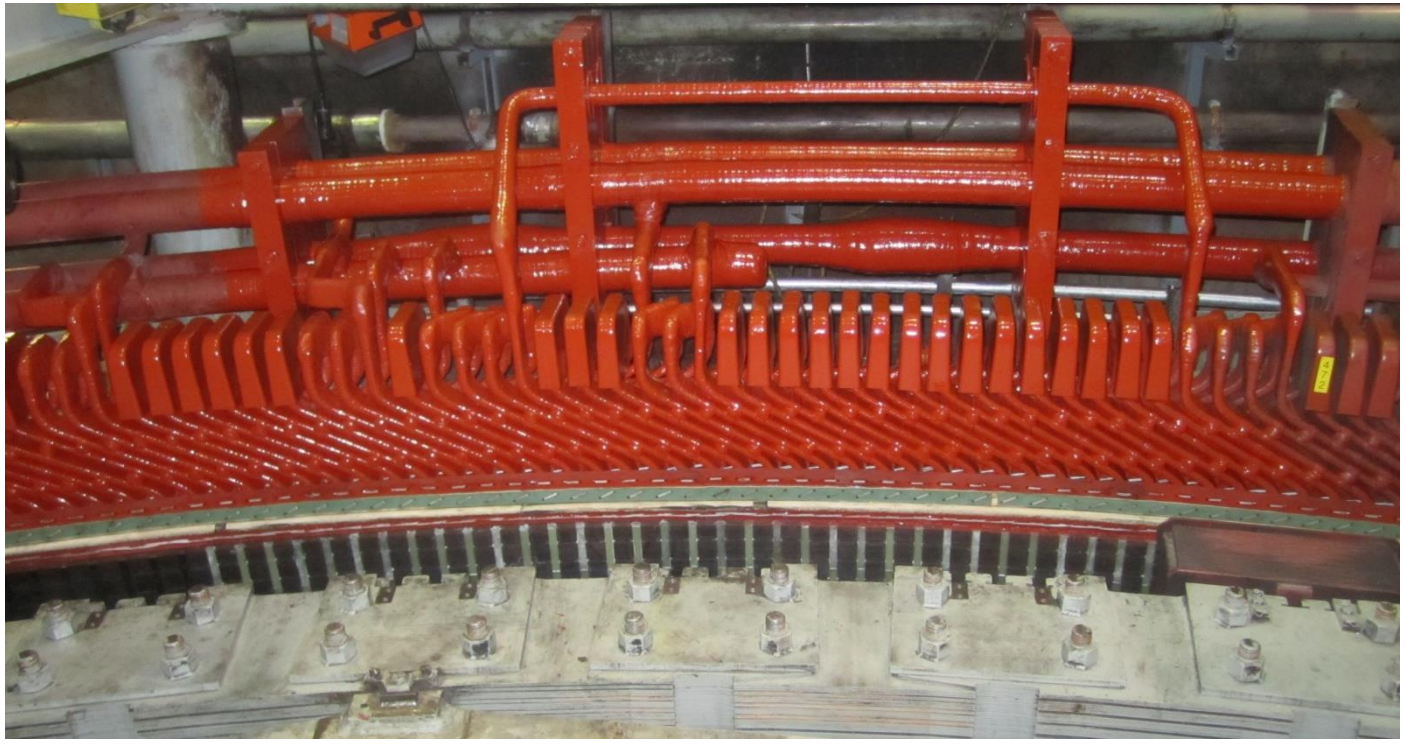
Original junction :



New junction:



Repair: Final look



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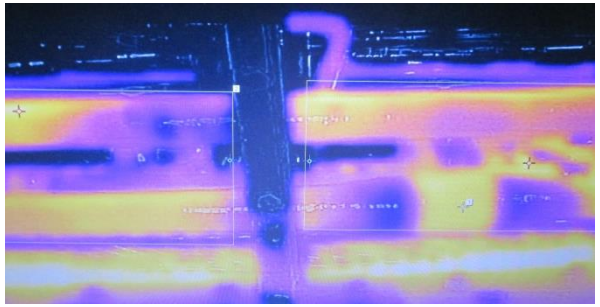
- Bad junction in the circuit ring can be difficult to detect with conventional protection setting and can cause serious damages to the generator.
- Protection logic has to be revised to reduce the damages in case of failure (protection sensitivity, combining smoke detection with ground fault for tripping…).
- Other monitoring solutions such as permanent thermal imaging should be considered to enable early detection of such faults.



- The fault caused a down time of 3 months; repair was a success.

Questions ?

Hydro Québec