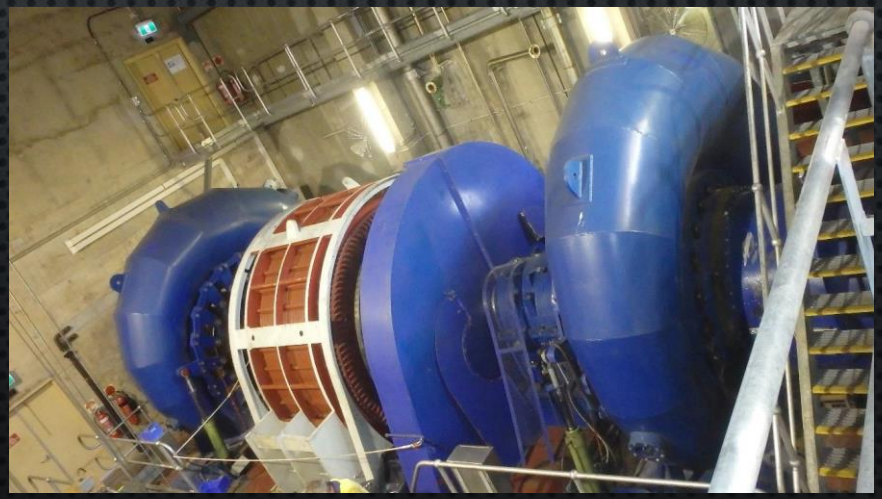
AUSTRALIANWINDERS

Ord River power station
Planned Outage case study

PPA Annual Conference, July/August 2018

PROJECT DETAILS

- ACEC (Belgium) generator
- Commissioned 1996
- 19.5 MVA, 11 KV
- Horizontal shaft Twin Francis turbines
- Planned 26 Day outage
- Refurbish generator to enable continuing reliable performance
- Historical insulation problems on stator windings
- Rotor was OK

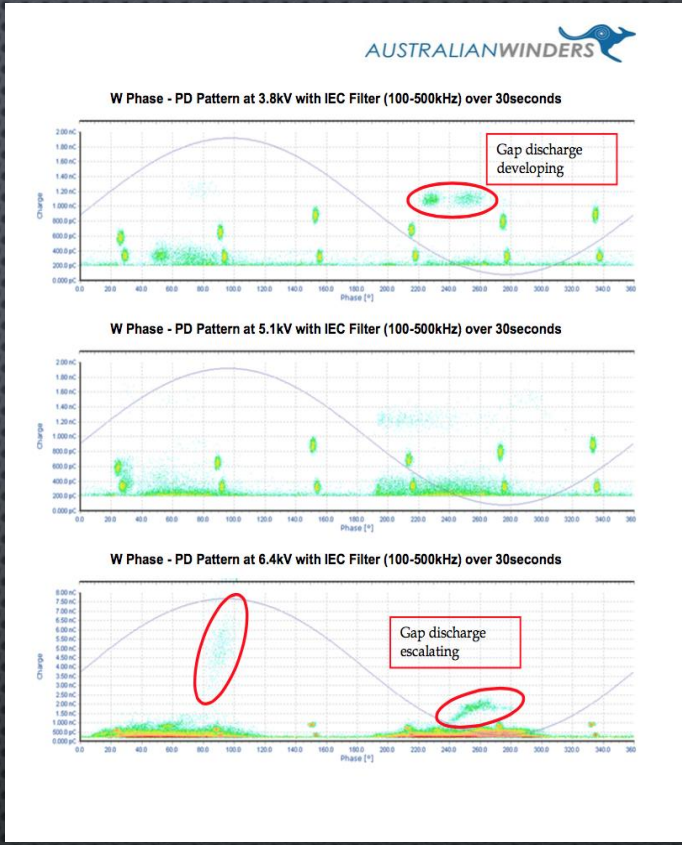


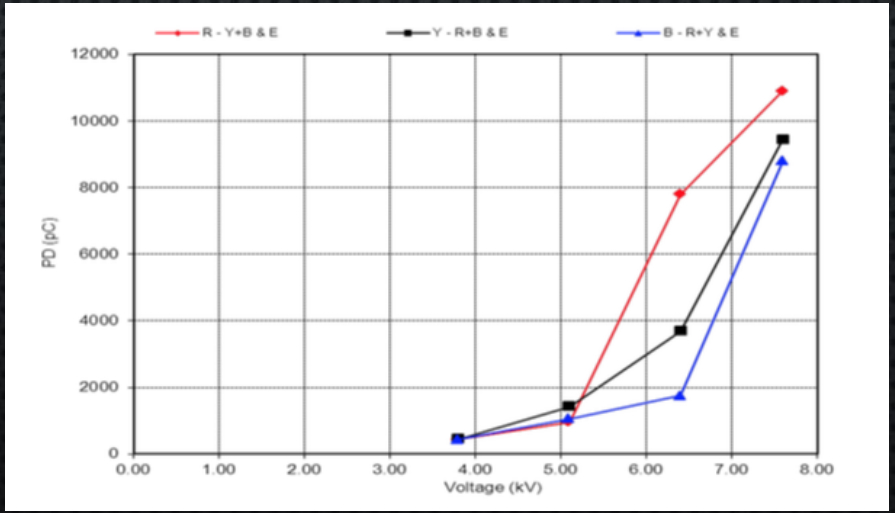
MAINTENANCE ISSUES

- VISUAL INSPECTIONS OF THE STATOR WINDINGS WERE PERFORMED BY AN EXPERIENCED WINDER, SHOWING LARGE AMOUNTS OF **PARTIAL DISCHARGE (PD)** IN THE BUNDLED CABLE CONNECTION RINGS AND COILS.
- PARTICULAR CONCERN WAS FOR INSULATION DAMAGE NEAR THE END OF THE SLOT
- ALSO, SLOT WEDGES WERE LOOSE AND FRETTING IN MANY PLACES
- IR READINGS WERE GOOD

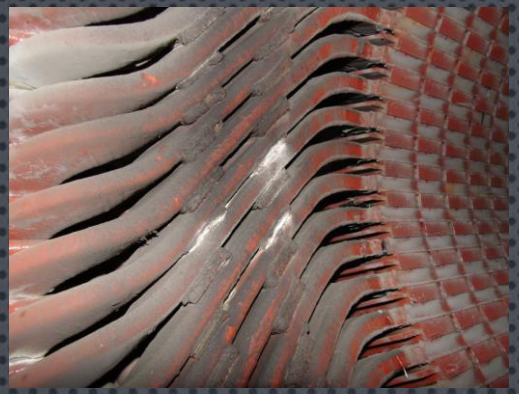
PD MEASUREMENT

- Offline PD testing showed the following trend
- The PD level at rated voltage is beginning to approach a deteriorated condition (IEC standard 10nC)
- The PD level at 7.6kV varied between 15.9nC and 24.2nC with two test runs.
- This QU plot shows this large increase in activity around the 7.6kV setting via a vertical line.
- This indicates the 7.6kV voltage is on the border of significantly increased PD activity.





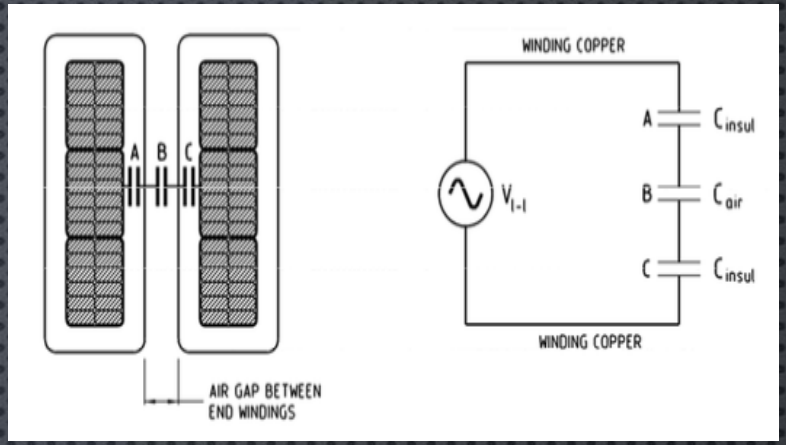
WHAT IS PARTIAL DISCHARGE?

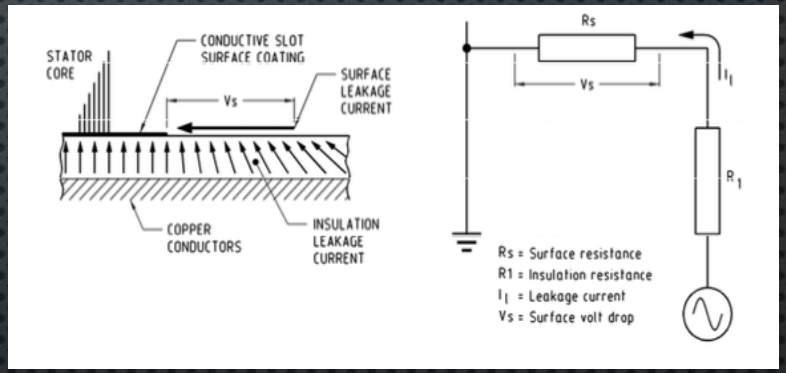


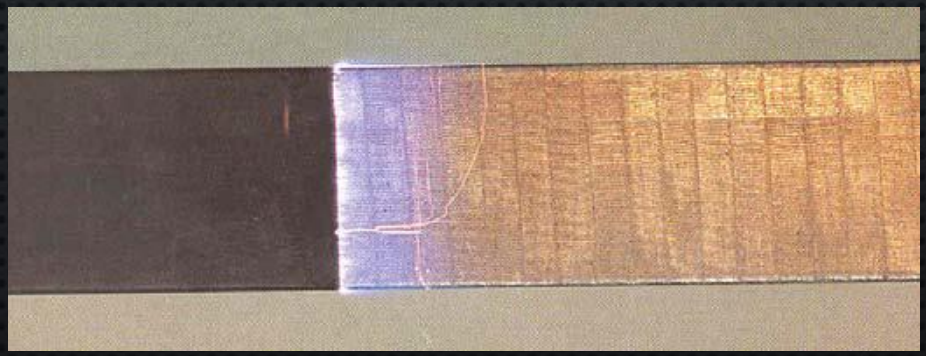
- In air cooled hydro generator windings partial discharges (corona) occur when dielectric breakdown of air is exceeded (approx 3 kV/mm).
- Heat generated by ionized air particles contribute to thermal degradation and erosion of insulation.
- A side effect of the process is the conversion of oxygen into ozone and the formation of nitrogen oxides in insulation voids.
- This phenomenon is termed "partial discharge" (PD), because it involves partial breakdown of an air space, rather than complete breakdown of insulation.

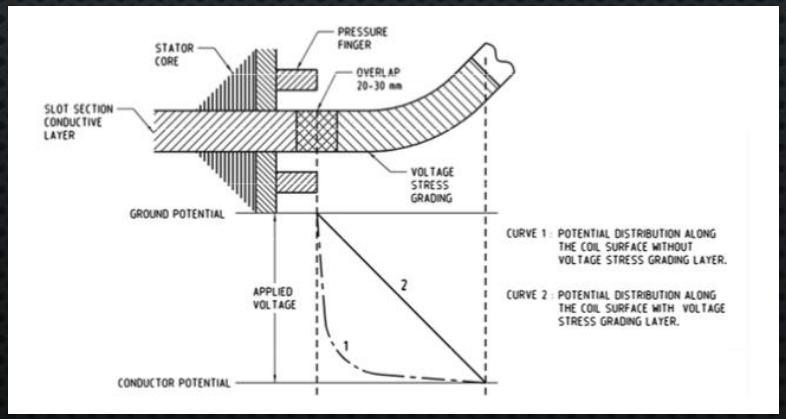
PD EXAMPLES

- PD can occur in the insulation voids or on the winding surfaces.
- Referring to the drawing here, two end windings and an air gap between them can be represented by an equivalent series circuit of three capacitances, capacitance of ground insulation of coil A, capacitance of air gap B, and capacitance of ground insulation of coil C.
- The typical "*ring of fire*" is formed at the end of the slot section conductive coating. To prevent these partial discharges the special *voltage grading Semi* conductive layer is fitted, overlapping the slot section conductive layer, and extending around the first coil slot section bend



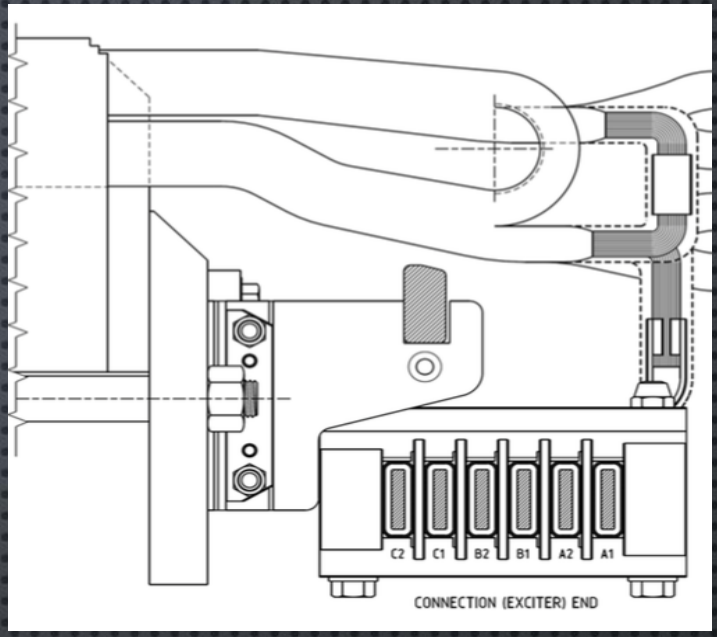






REPAIR OPTION-1 CIRCUIT RING REPLACEMENT

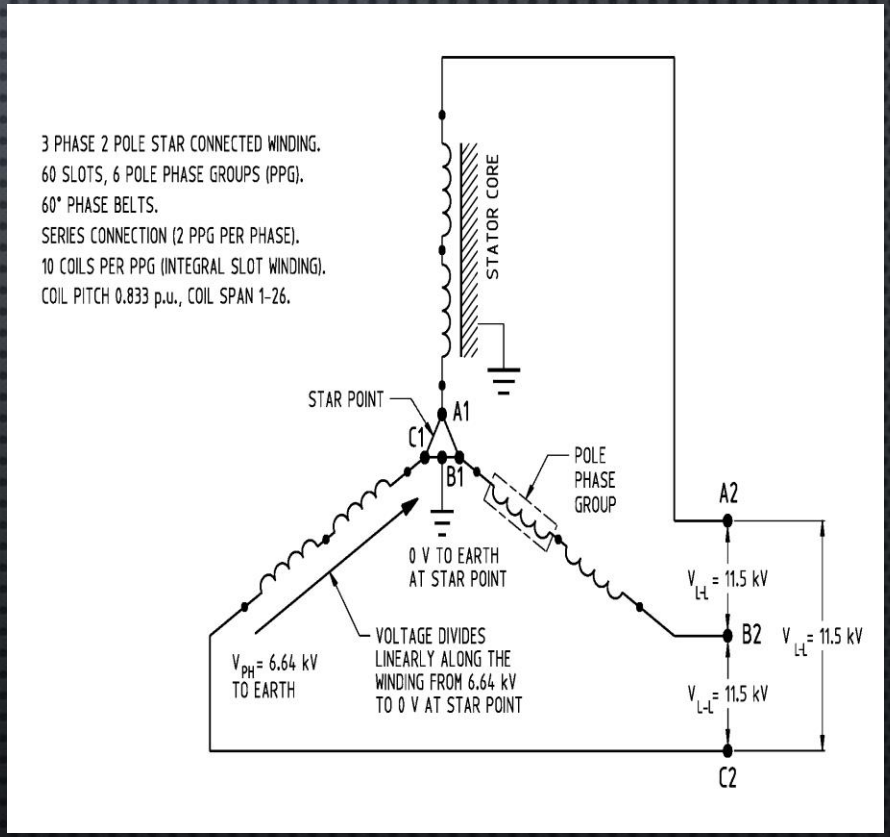
- THE HV END CABLES HAVING FULL LINE TO LINE VOLTAGES BETWEEN THEM ARE CLOSELY BUNCHED TOGETHER WITHOUT REQUIRED AIR GAP WHICH IS THE PRIMARY CAUSE OF PARTIAL DISCHARGES BETWEEN CABLES.
- COMPLETE REDESIGN OF STATOR BUS CONNECTIONS TO APPROPRIATELY SIZED, INSULATED AND SPACED SOLID COPPER CIRCUIT RINGS AS DEPICTED IN THE DRAWING ABOVE
- THIS OPTION IS THE PROPER ENGINEERING SOLUTION, AND WOULD POSITIVELY ELIMINATE ALL CURRENTLY EXPERIENCED PD PROBLEMS WITH STATOR CABLES.



REPAIR OPTION-2 STATOR WINDING

LEADS INVERSION

- The Highest Gradient Across the Stator Ground Wall Insulation (Line to Ground Voltage) is At The Main Output High Voltage (HV) Lead End. Thus the HV Winding Side Incurs the Highest In-Service PD Degradation (Internally and Externally)
- The Lowest Dielectric Gradient Across the Stator Ground Wall Insulation Occurs at the Neutral End of the Winding. The Neutral Winding End Is Unaffected by the PD Damage
- By Reversing/Inverting Stator Leads (Active Side and Neutral Side), the Neutral Side which is Not Affected by PD Erosion is Now Connected to the HV Output Side. The Bars that were Previously Connected to the HV Side are Now Exposed to Very Low Voltage Stresses and are not Expected to Incur Further PD Degradation
- By Stator Winding Leads Inversion it is Possible to Appreciably Extend the Winding Life by Shifting Weaker Degraded Coils Near the Neutral End Under Lower Dielectric Stress



REPAIR OPTION-3 REWEDGE

- DUE TO THE MAJORITY OF WEDGES BEING LOOSE OR HOLLOW, A REWEDGE WAS PERFORMED DURING THE SAME OUTAGE.
- THE WEDGE DESIGN SYSTEM USED WAS A FLAT WEDGE WITH TOP RIPPLE SPRING
- THE WEDGE KIT WAS MANUFACTURED AND SUPPLIED BY AUSTRALIAN WINDERS

Slot Wedge Survey												Assessment Criteria			
Slot No.	Slot Wedge Number											Criteria 1	Criteria 2	Criteria 3	Criteria 4
	1	2	3	4	5	6	7	8	9	10	11	All End Wedges Tight	2 Hollow with Tight Both Sides	1 Loose with Tight Both Sides	No More than 3 X Criteria 3/Slot
127												Fail	OK	OK	OK
128												Fail	Fail	Fail	OK
129												OK	OK	OK	OK
130												Fail	OK	OK	OK
131												Failed	Failed	OK	OK
132												OK	OK	OK	OK
133												OK	OK	OK	OK
134												OK	Fail	OK	OK
135												Fail	OK	OK	OK
136												Fail	Fail	Fail	Fail
137												Fail	Fail	Fail	Fail
138												Fail	Fail	OK	OK
139												Fail	OK	OK	OK
140												Fail	Fail	OK	OK
141												OK	OK	OK	OK
142												OK	Fail	OK	OK
143												OK	Fail	OK	OK
144												Fail	Fail	OK	OK
145												OK	OK	OK	OK
146												OK	OK	OK	OK
147												Fail	Fail	OK	OK
148												Fail	Fail	OK	OK
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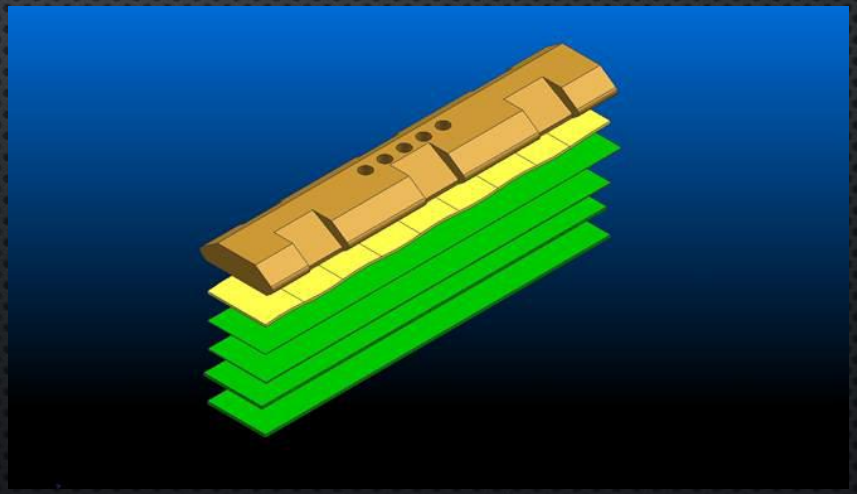
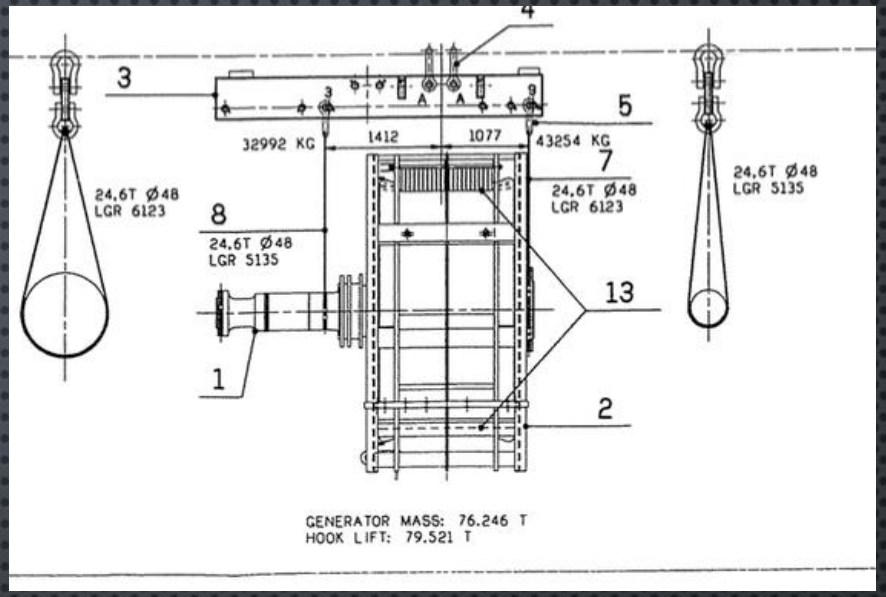
161												Fail	OK	OK	OK
162												Fail	Fail	OK	OK
163															
164												OK	OK	OK	OK
165												OK	OK	OK	OK
166												OK	OK	OK	OK
167												OK	OK	OK	OK
168												Fail	Fail	Fail	OK

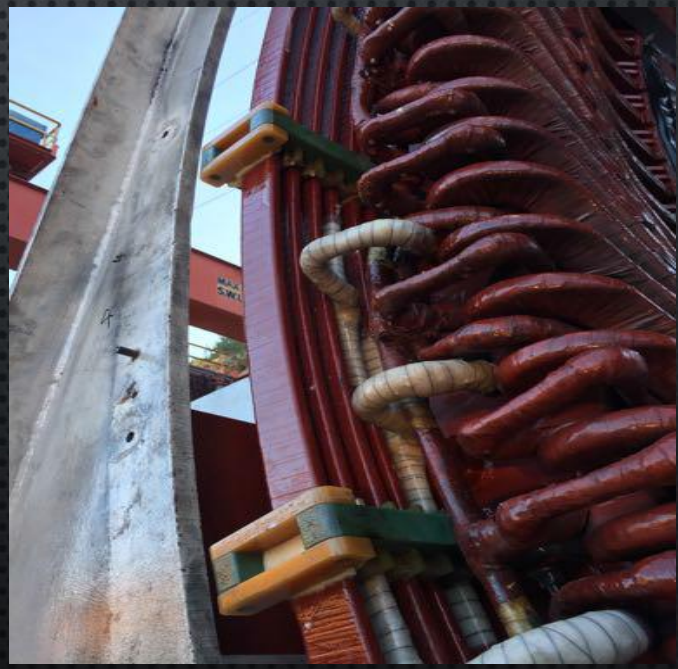


MAKING ROOM!


4
3
5
32992 KG
1412
1077
43254 KG
7
24,6T Ø48
LGR 6123
24,6T Ø48
LGR 6123
24,6T Ø48
LGR 5135
8
24,6T Ø48
LGR 5135
13
1
2
GENERATOR MASS: 76.246 T
HOOK LIFT: 79.521 T

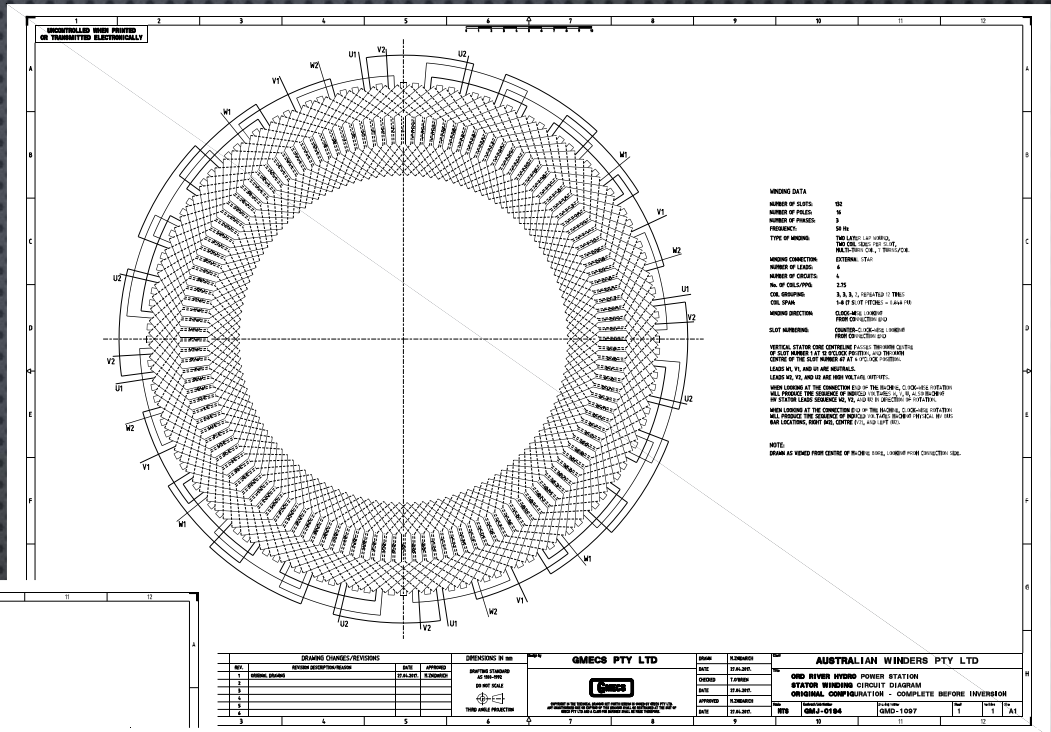
1- CIRCUIT RING REPLACEMENT

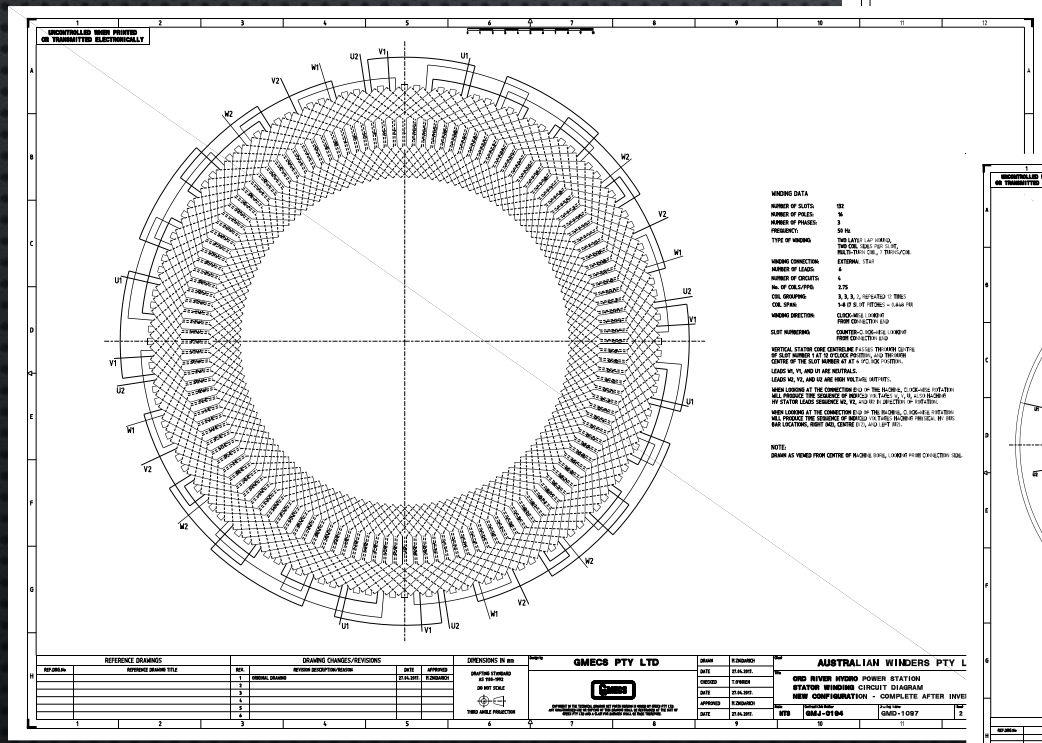
- CIRCUIT RING DESIGN WAS DONE BY DR. MICHAEL ZNIDARICH, PHD, FIEAUST, CPENG
- THE SEMI CIRCLE RINGS WERE WATER JET CUT AND INSULATED IN PERTH WORKSHOP AND TRANSPORTED TO SITE IN QUARTERS
- ALL NEW SUPPORTING BRACKETS AND SIMPLE LOCKING SYSTEMS
- RINGS WERE CONNECTED TO THE WINDINGS AND THEMSELVES IN SITU AND INSULATED TO SPECIFICATIONS.

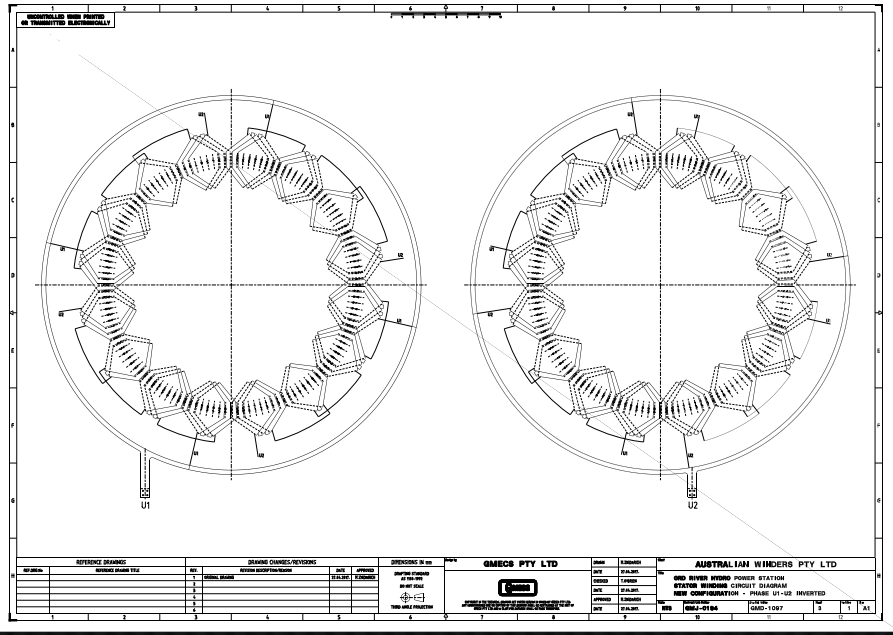


2- LEAD INVERSION

- A TECHNICAL BUT EASY FIX, WHEN PERFORMING A CIRCUIT RING EXCHANGE

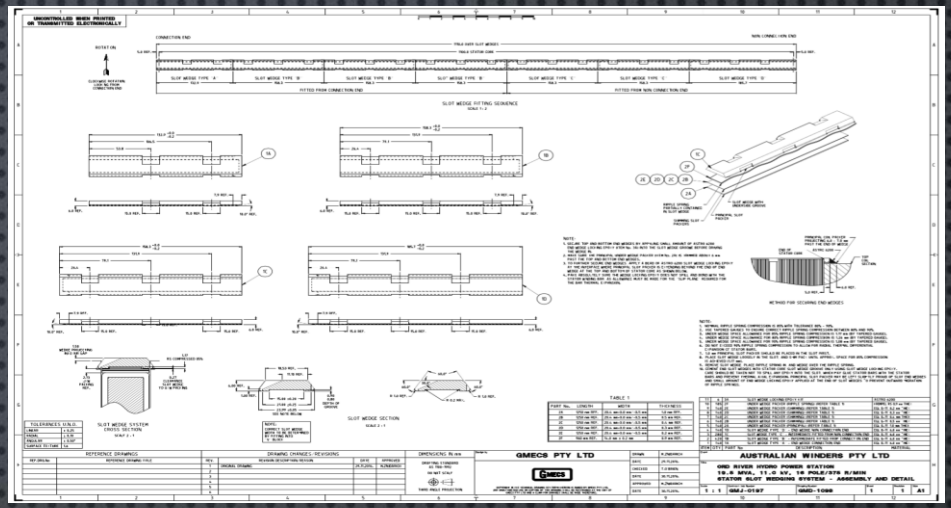


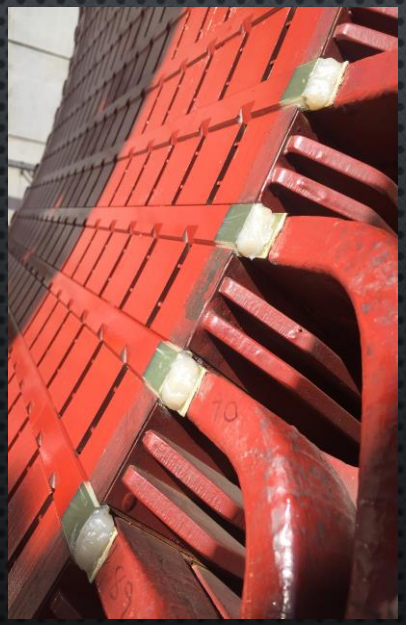


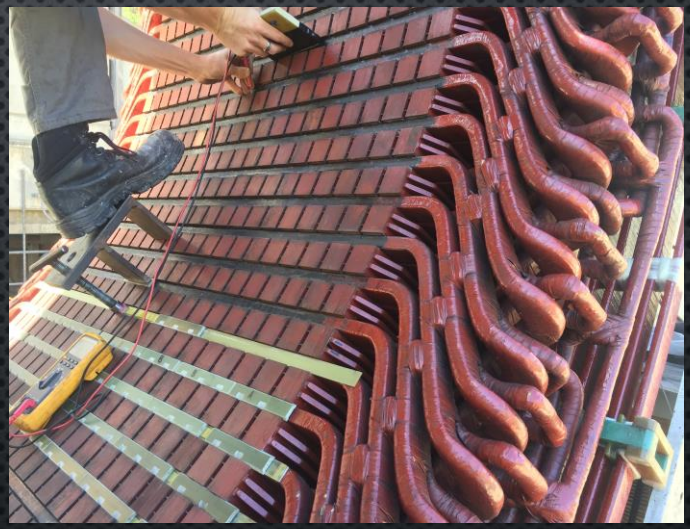


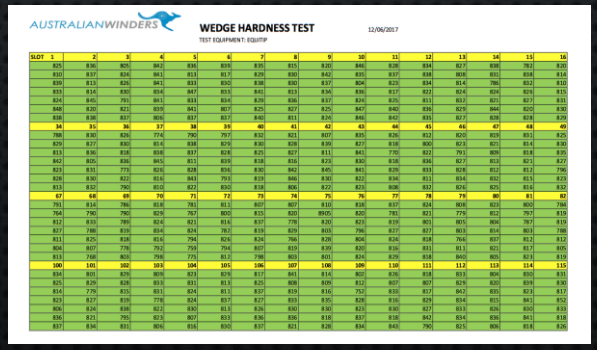
3-REWEDGE

- Our wedge system with ripple spring tensioning method was designed by Dr Znidarich. He took into account the radial slot bar forces applied against the wedging system from the electro magnetic force present during operation.
- These slot bar forces can be in excess of 200MPa and act at double frequency (8.64 million cycles/day)
- After wedge removal, contact resistance checks were made between coil and iron core and any damage to coil corona protection systems were repaired.



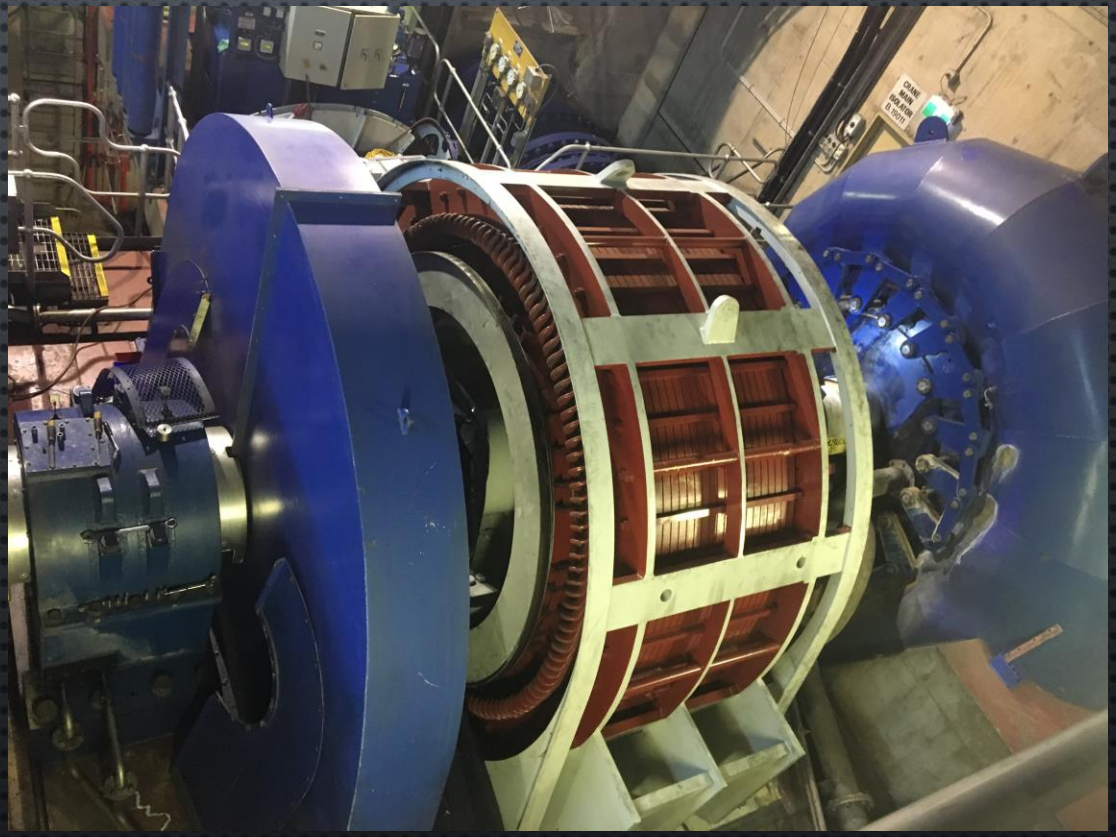






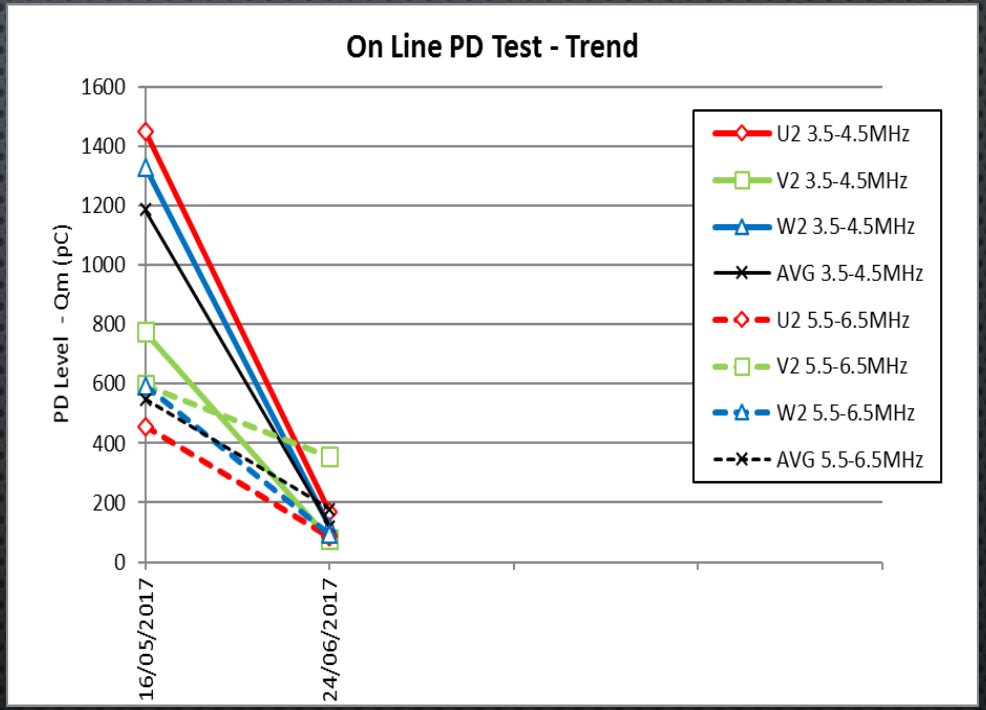
COMPLETION

- To safe guard the rotor of any moisture ingress, it was overhauled in the small space available downstairs.
- Offline static testing complete.
- Once the stator was complete, the rotor was lifted out to the upper deck and reinserted into the stator.
- The big lift again to position the generator and couple to the turbine.
- Commissioning and hot run complete with good results



DRAMATIC PD REDUCTION

- THERE WAS A DRAMATIC REDUCTION OF PARTIAL DISCHARGE AT THE CONCLUSION OF THE REPAIR WORKS
- THE REPORT AS WRITTEN BY THE TESTING ENGINEER: *THE ON-LINE PD TESTS FOLLOWING RE-COMMISSIONING INDICATED DRAMATIC REDUCTION IN PD ACTIVITY, BOTH DUE TO TOTAL ELIMINATION OF PD DISCHARGES IN CABLE BUNDLE AND DUE TO INVERSION OF THE STATOR LEADS, THEREFORE THE PROJECT HAS ACHIEVED ITS MAIN GOAL OF SIGNIFICANTLY REDUCING ON-LINE OPERATIONAL PD ACTIVITY AND EXTENSION OF THE WINDING OPERATIONAL LIFE .*



CONCLUSIONS

- A large project to attempt to extend the operating life of some highly affected generator windings, was an outstanding success.
- Completion was 2 days ahead of schedule
- No LTI's.
- The customer was very happy with the outcome!