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Partial Discharge Levels Before and After Partial Stator Winding Refurbishment in PSHPP Velebit

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PSHPP Velebit



INTRODUCTION

PSHPP Velebit is located on the bank of the river Zrmanja, upstream from the town of Obrovac, Croatia.

Water is delivered from the reservoir to the power plant through a 8191 m long pressure tunnel and 2108 m long penstock.

The hydraulic head is 517 m.

Two motor-generator units with a power of 155 MVA each and a rotation speed of 600 min^{-1} are installed in the power plant.

Units work in generator and pump operation and as compensators.

Pump operation is achieved in two ways: "back to back" and using a frequency starter.

MOTOR-GENERATOR'S MAIN DATA

Year of manufacture	1984.
Power	155 000 kVA
Voltage	15 750 V
Current	5 688 A
cos φ	0,89
Speed	600 min ⁻¹
Frequency	50 Hz
Excitation	209 V, 1 193 A
Stator winding	insulation class F, bars, two layers, two parallel circuits per phase
Rotor winding	insulation class F

HISTORY OF OPERATION

Motor-generator MG2 was commissioned in 1984., but during the war in Croatia it was not in operation from the beginning of 1991. until the end of 1995.

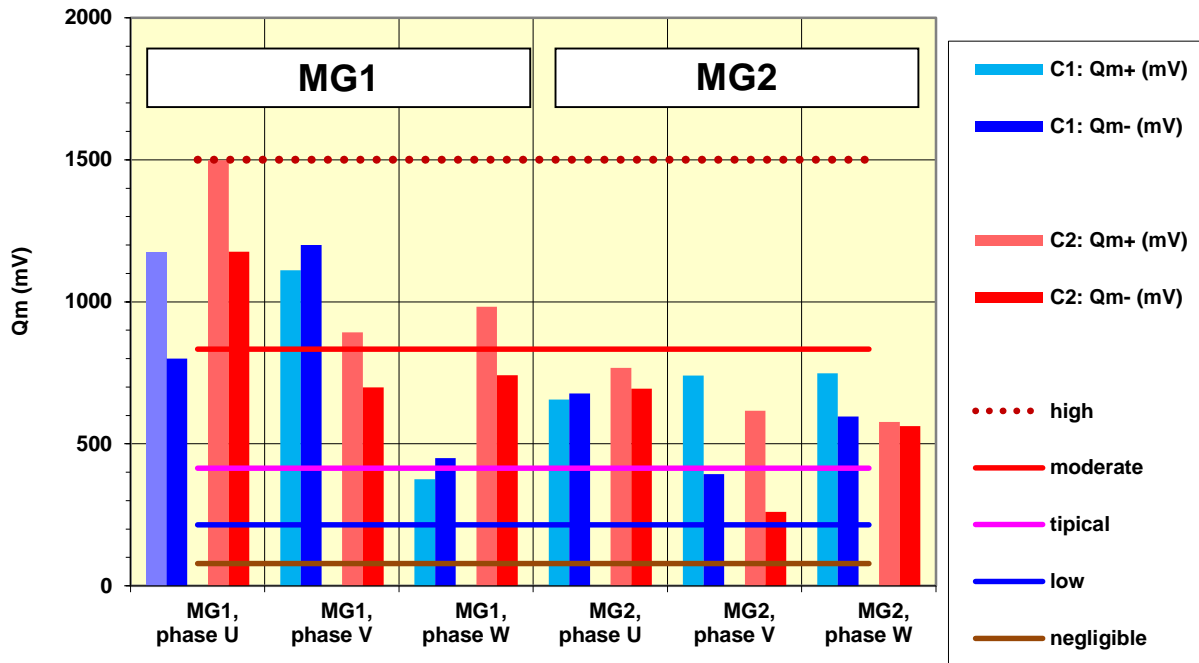
Condition of insulation system has been regularly checked by off-line and on-line measurements since commissioning of the motor-generator. There were several faults of insulation system, most recently in 2008. due to cooling system failure and flooding of the stator.

In 2002. IRIS couplers have been installed for on-line measurement of PD.

History of measurements indicate high level of partial discharges with slow and steady increase over the years.

PD ON-LINE MONITORING

Installation 1999 on MG1, 2002 on MG2
 6 couplers,
 2 per parallel circuit per phase,
 differential installation



**Results of
measurements in
2002 on both
generators**



PD in end-winding (corona)



PD on semi-conducting and gradient coating connection (coating deterioration)



PD on interface semi-conducting and gradient coating (coating deterioration)



PD where bar exit's slot

MG2 – Analysis of first measurements in 2002

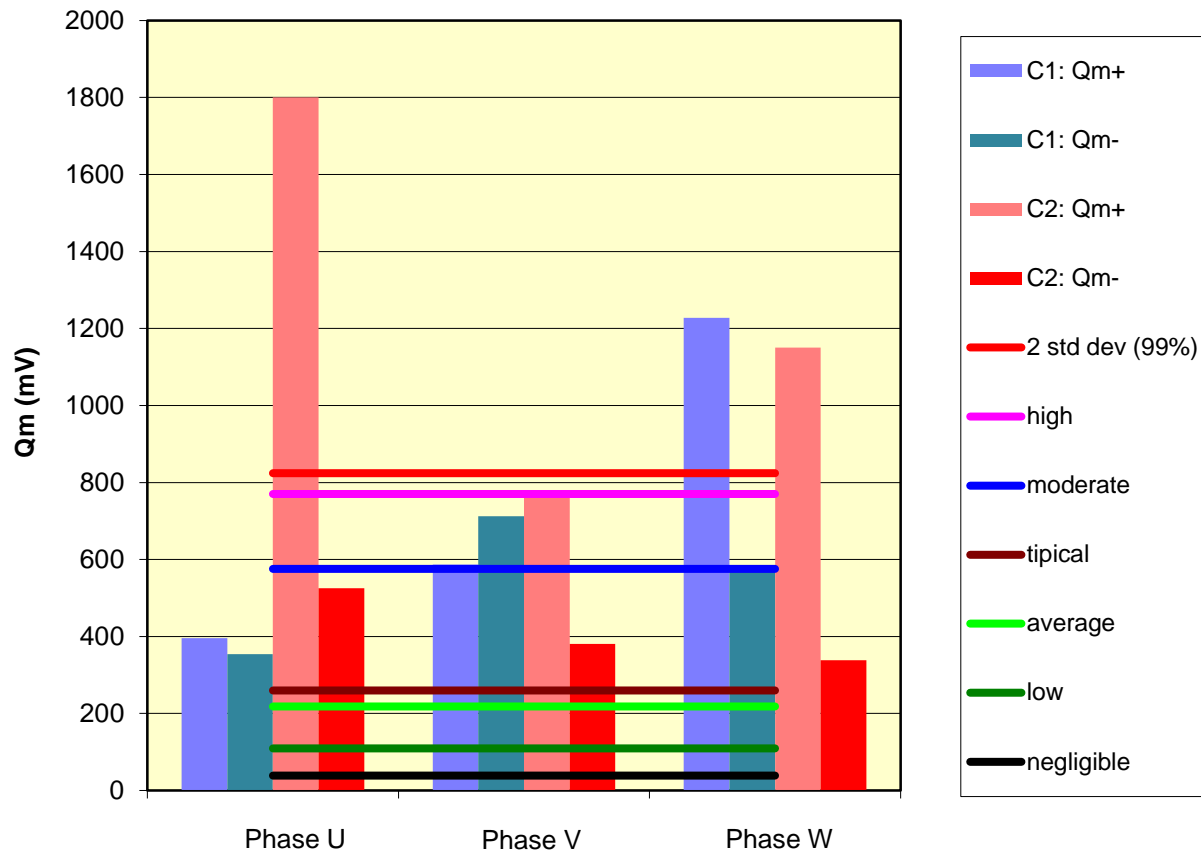
Classic PD pulses

- normal degradation of slot insulation due to age, including damage of semi-conduction coating in slot area

Non-Classic PD pulses

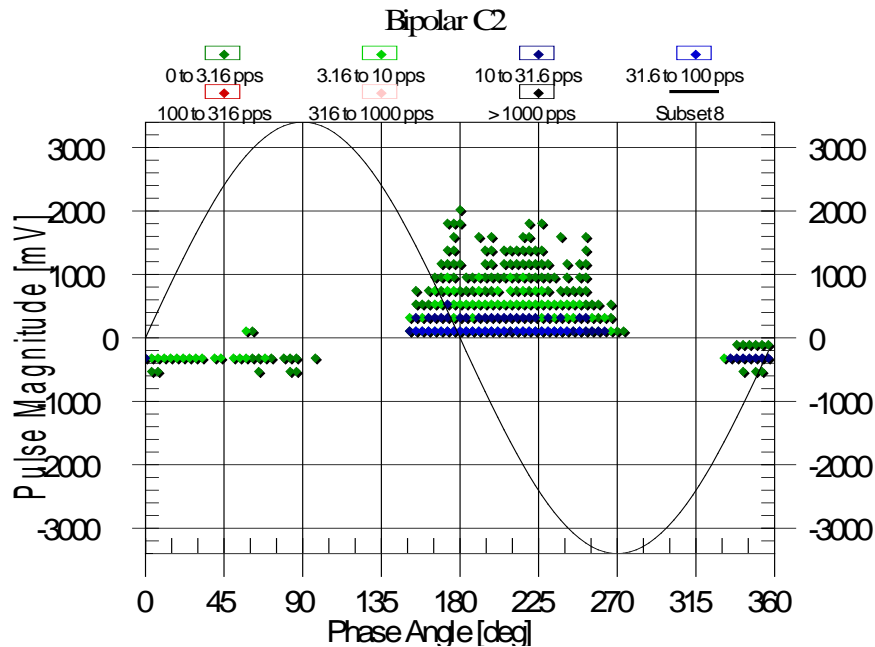
- multiple source of PD, problem distinguishing in some measurement since PD appear along the entire AC cycle:
 - PD in end-winding caused by dust, dirt, inadequate spacing, vibrations or bad connection between gradient and semi-conductive layer
 - Cross-coupled PD do not necessary show problems in insulation, they can be result of winding geometry
 - PD at the ac cross over (0° and 180°) show mechanical vibrations

MG2 – Measurements in 2015

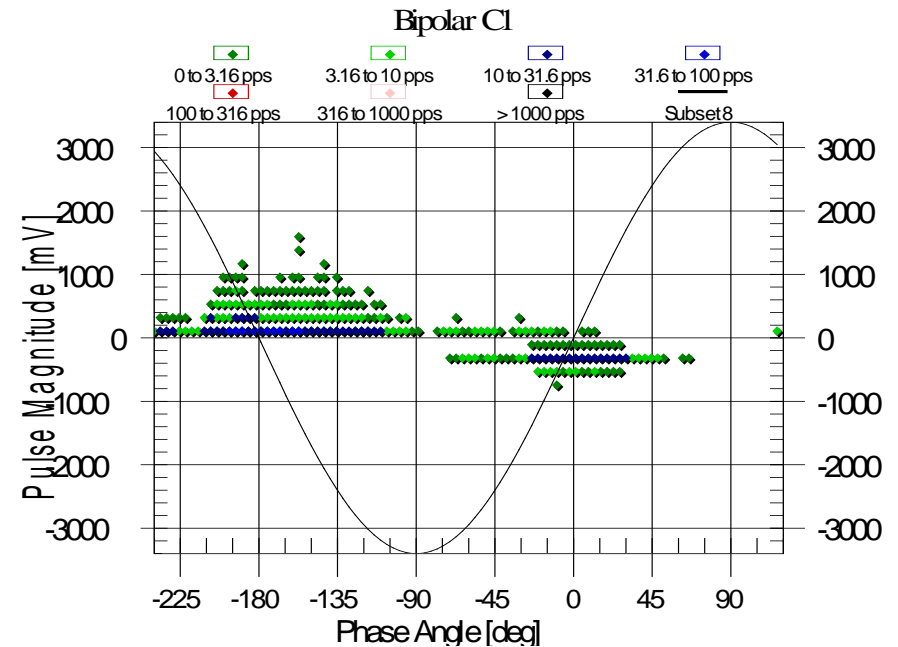


MG2 – Measurements in 2015

(two highest results are shown)

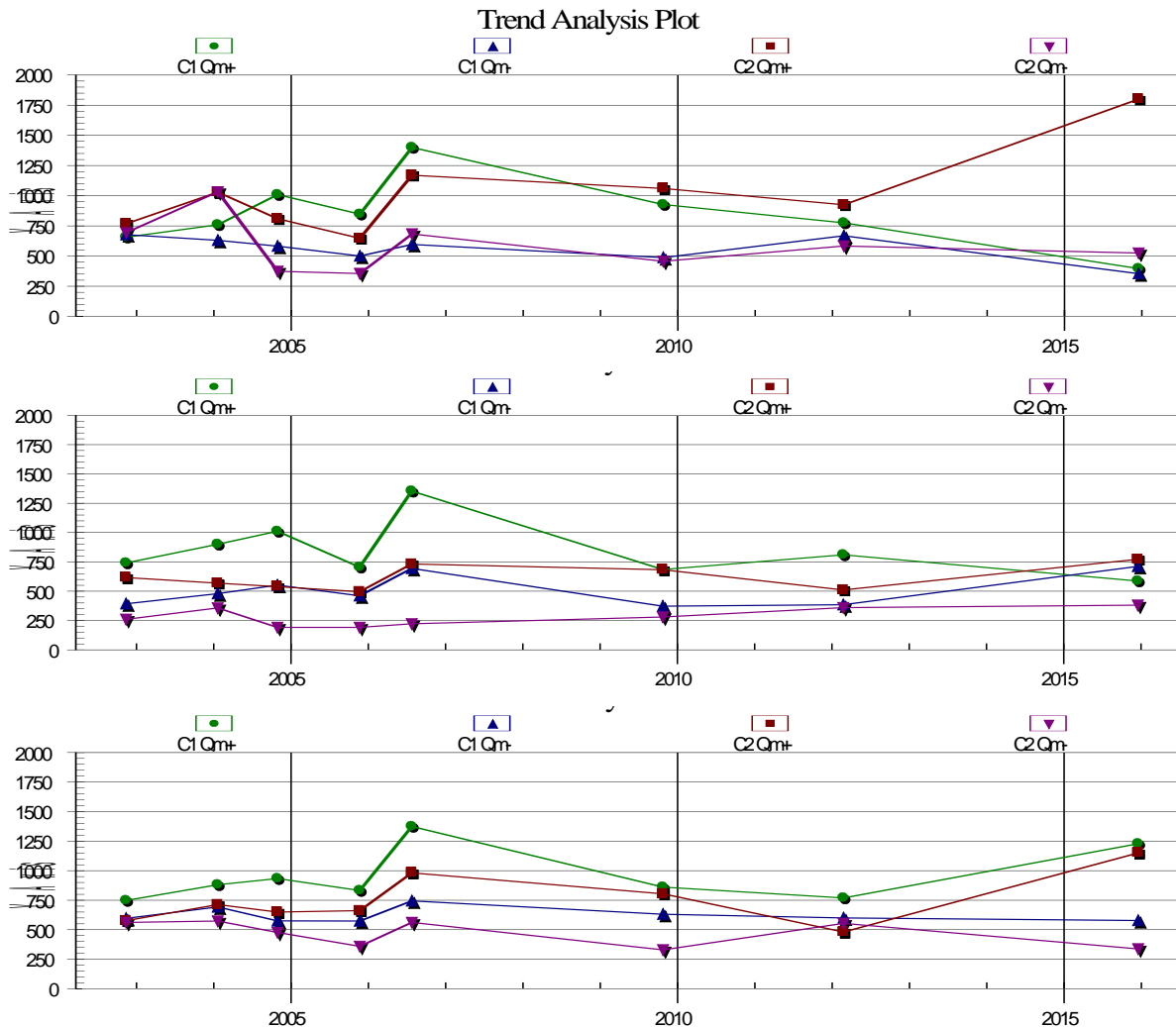


Phase U, coupler C2



Phase W, coupler C1

MG2 – Trend per phase up to 2015



Trend variable due to outage activities (cleaning, re-painting and recovery of corona damage)

MG2 – Motivation for refurbishment

Due to high PD levels, continuous operation on upper voltage range and visual inspection of winding where at least one third of stator bars showed degradation due to partial discharges, it has been decided to refurbish the stator winding.

Application of modern insulation systems was expected to alleviate the PD problem.

Since stator core was in good condition, it has been retained.

Refurbishment was carried out in Q4 2020.

MG2 – Scope of refurbishment

It was decided to remove all the bars and test them individually. Those which wouldn't pass the high voltage test would be completely refurbished (reinsulated).

All bars would have the semiconductive (slot part) and gradient (slot exit) layers of insulation replaced.

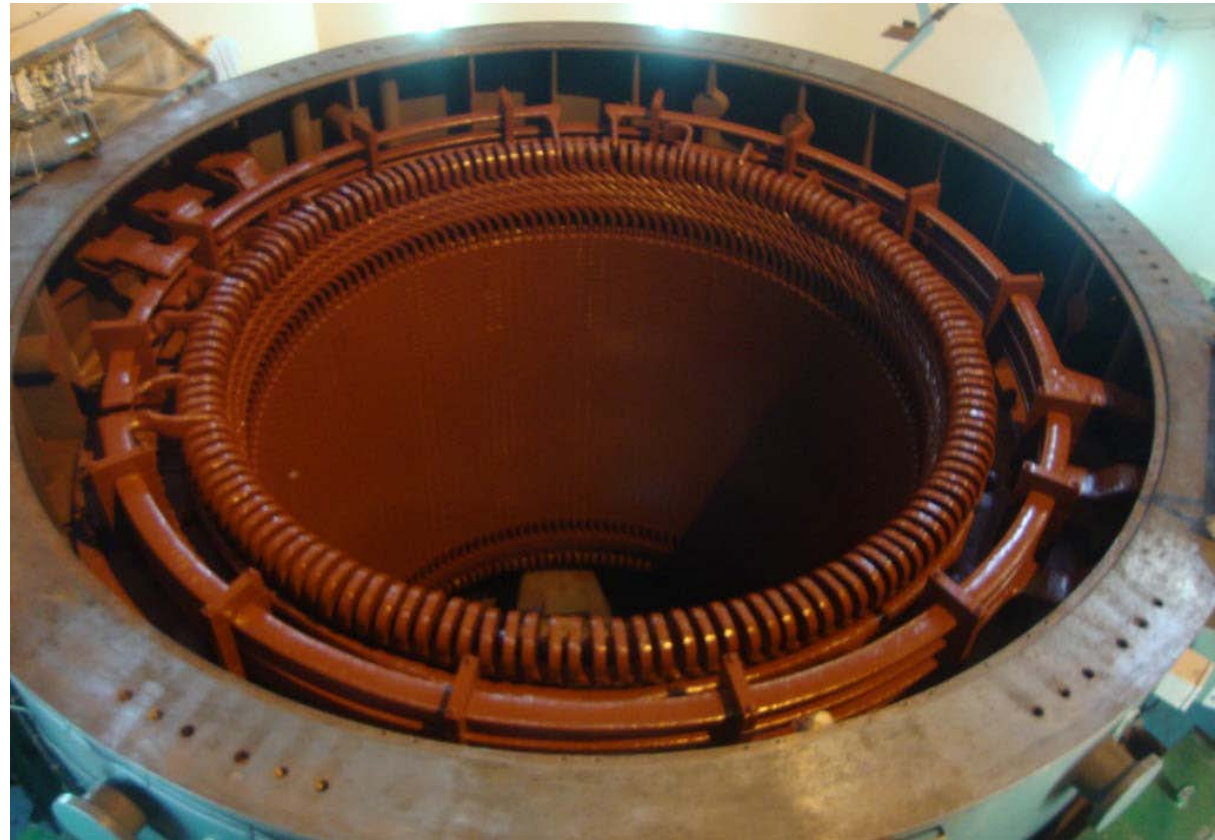
Semiconductive layer is varnish and gradient layer is tape.

Modern approach to wedging and slot filling, as well as end-winding binding was expected to affect the vibration of the stator winding.

MG2 – Refurbishment

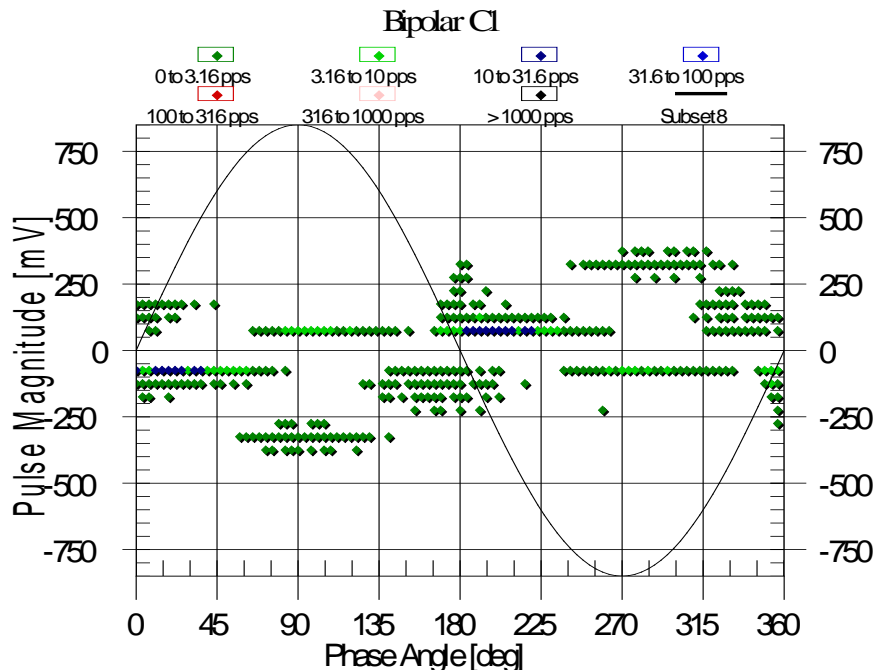
Stator core was cleaned and tested.

Refurbished bars
were installed and
connected to phases.

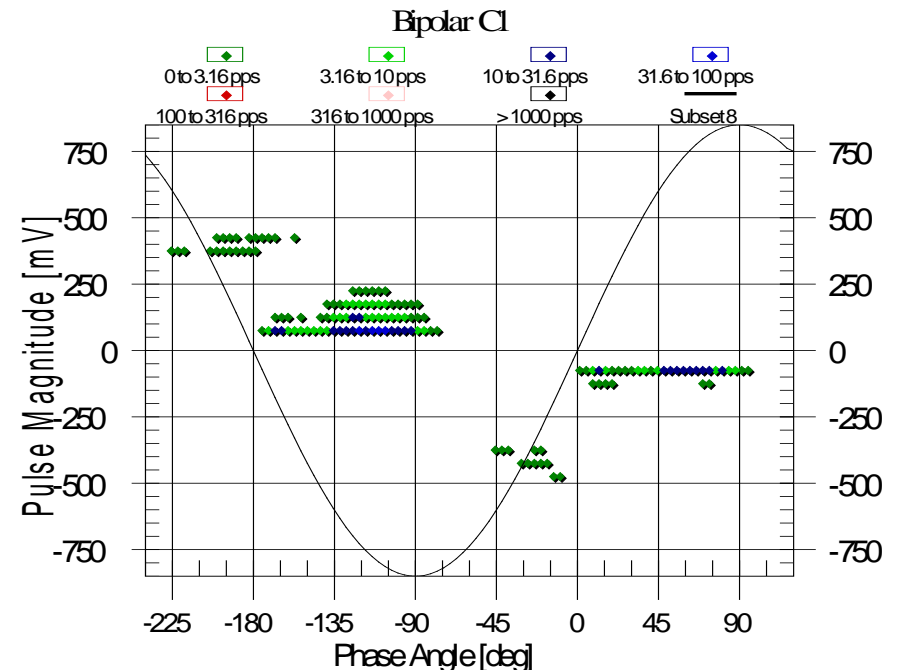


MG2 – Measurements after refurbishment

- two highest results are shown
- notice change in measuring range (sensitivity): from 200-3200 mV to 50-850 mV

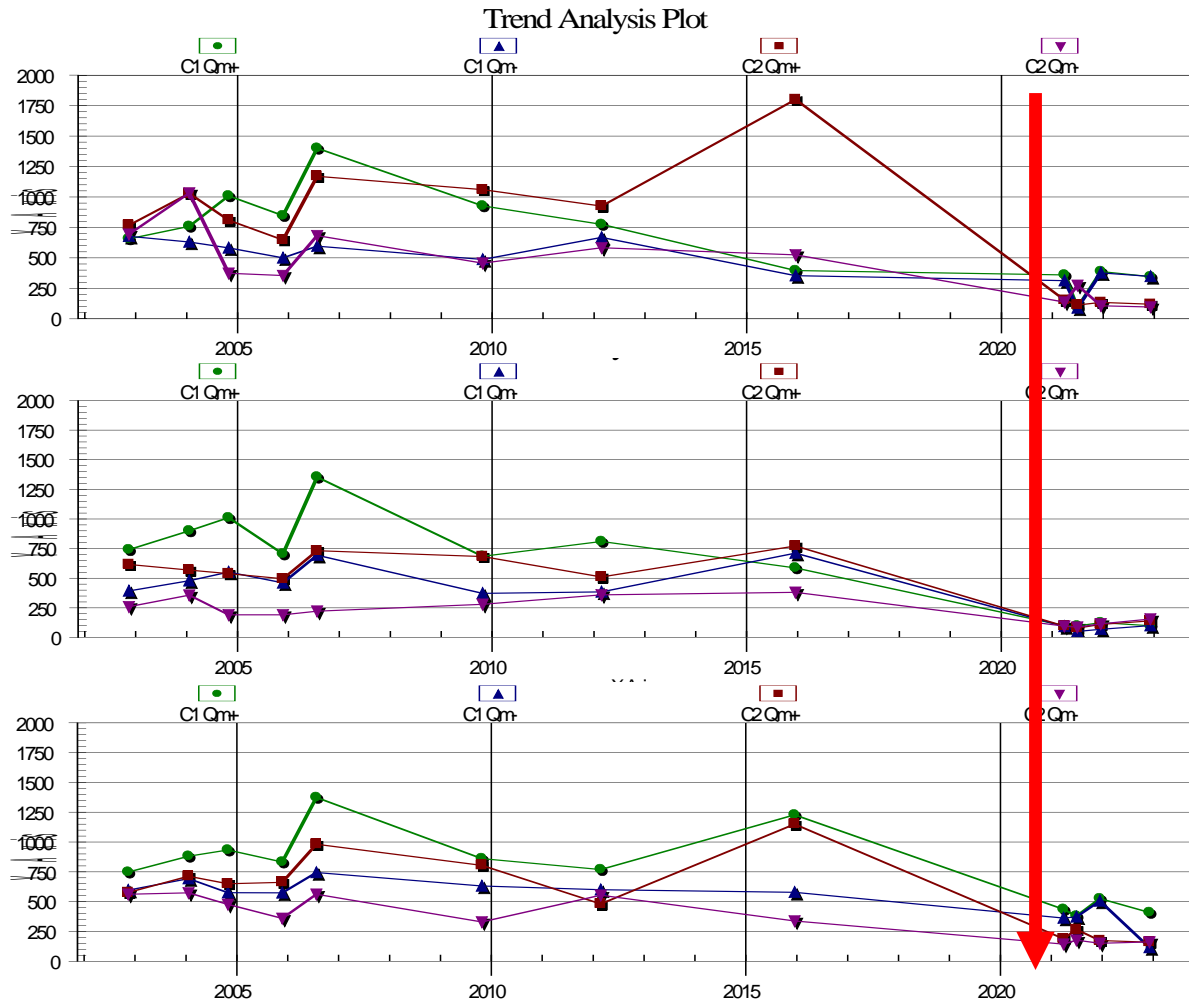


Phase U, coupler C1



Phase W, coupler C1

MG2 – Trend after Refurbishment



Conclusion

Refurbishment of MG2 stator winding has resulted in decreased PD levels.

After the refurbishment, the PD will be measured more often to determine the new trends.

Motor-generator 1 had PD couplers removed during the previous generator fault. It is under consideration to repair the PD measurement system in order to carry out on-line measurements on that unit as well.