Correlation Between Online Partial Discharge Intensity (PDI) Using RTD Sensor And Voltage Breakdown Test At 30 Years Large Turbo Generator

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ABSTRACT

Inner Cooled Hydrogen Generator 474 MVA 23 kV Single Vapor Pre-Impregnated Insulation (VPI) has been operated from 1988 with average capacity factor more than 80% annually. In 2014, Partial Discharge Intensity (PDI) reached an alarming state on RTD no 8B slot 19 of 30 (phase B) and 12A slot 29 of 30 (phase A). The testing and justification from manufacturers showed that the activity of Partial Discharge (PD) is categorized to HIGH level. This paper proposed a correlation between indication of HIGH PDI and breakdown voltage value. Value of PDI from the 30 years operated bars has been compared with PDI value from the new bars. The result shows the PDI level of old bars lower than new bars, however, both of its breakdown voltage are similar. This result shows that HIGH PDI level has low correlation with voltage breakdown threshold. Hence, it is needed to redefine the level of PDI which contribute to voltage breakdown value

Index Terms

Large Generator, Stator Winding Insulation, Partial Discharge Intensity (PDI), Voltage Breakdown Test

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Introduction

Generators are one of the main equipment in the power generation system such that reliability is always maintained at a high level [1, 2]. If the winding generator stator is damaged, it will take a recovery period of 6-12 months, resulting in a substantial loss of production in the power generation business.

Insulation stator winding generator typically has a life cycle of 20-30 years [3, 4]. However, some companies that have generators that have been in operation for more than 20 years have not made full use of the design lifetime, and have to rewind their generator stators with consideration to duration of work time and expensive costs. Some companies use condition-based maintenance to monitor the condition of the stator winding generators, one of which uses partial discharge technology [3, 5].

Defects in the insulation system of the stator generator may occur during the manufacturing process [6]. It may also happen due to thermal, mechanical, electrical, or chemical damage caused by the long-term operation of the generator. With the degradation of insulation due to a combination of operating pressure, voids can be formed within the material insulation, and dielectric damage can gradually occur from partial discharge activity. A forced power outage of the generator during operation due to dielectric damage from the winding stator takes a long time to fix and thus results in a major operating loss. This highlights the importance of isolation diagnosis that evaluates the increase in noise generator stator winding insulator. The voltage breakdown test method is used to verify whether the power is dielectric by applying the voltage until the flash-over occurs and testing the insulation ability to hold the voltage until it fails.

The trend of deteriorating insulation conditions of the stator winding generators can be observed by conducting Partial Discharge Testing, both offline and online [3, 7]. There are several types of sensors that can be used to detect partial discharge activity, such as a coupling capacitor and Resistive Temperature Device (RTD) [8] stator winding. Related parameters include Partial Discharge Intensity (PDI) level, Qmax, and Pulse per Second (PPS). The type of damage that occurs insulating stator winding can be known based on a specific pattern and phase resolve.

The reminder of this paper is organized as following. In Section 2, materials and methods are presented. In Section 3, the results of the experiments are provided. Finally, discussions and conclusions are respectively presented in Section 4.

Materials & Methods

A. Generator General Specification

Testing was conducted on the Inner Cooled Hydrogen Generator which has technical specifications as detailed in Table 1. Location of RTD no 8B & 12A is shown in Fig. 1.

B. Online Continuous Partial Discharge

Online Continuous Partial Discharge is attached to the Inner Cooled Hydrogen Generator using 2 types of sensors, coupling capacitor, and Resistive Temperature Device (RTD), in stator windings where both sensors become partial discharge inputs online analyzer as shown in Fig. 2.

The output parameters produced by Online Continuous Partial Discharge are PDI level, Qmax (mV), Pulse per Second (PPS), Phase PD, or PD Pattern values.

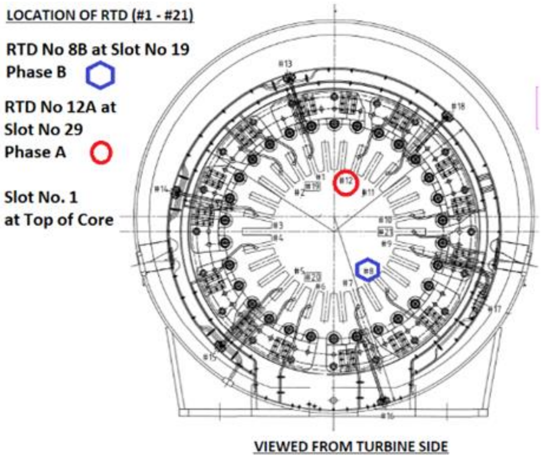

Figure 1. Location of RTD no 8B & 12A.

Table 1. Inner cooled hydrogen generator technical specifications.

Power	:	474 MVA
Nominal Power Output	:	400 MW
Voltage	:	23 kV
Cooling System	:	Inner Cooled Hydrogen
Hydrogen Pressure	:	3 kg/cm2
Insulation Class	:	F
Insulation System	:	Epoxy-Mica Paper
Insulation Type	:	Single VPI
Nominal Speed	:	3000 rpm
Commercial Operation	:	since 1988
Total No. of Slots	:	30 Slots
Total No. of Bars	:	60 Pcs

C. Offline Partial Discharge Test

Offline Partial Discharge is performed on new replacement bad and Bar no. 12A after the bar has been removed from the stator slot. The test could not be conducted on Bar no. 8B due to damage that occurred during shipping from the site to the testing laboratory. The testing was conducted by the generator owner, manufacturer, and independent surveyor in the generator manufacturing laboratory. This test is based on the IEEE Standard No. 1434–2000 [9]. The parameters measured are the discharge values (pC) between 20 to 500 PPS. The test was carried out on the 20th April 2017 for the old bar at room temperature (24°C), 38% humidity, and sunny weather conditions. While for the new bar, it was conducted on the 21st June 2016, at room temperature (22°C) and 64% humidity.

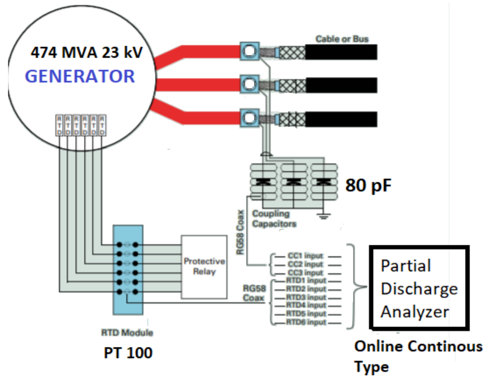

Figure 2. Wiring Diagram Online Continuous Partial Discharge.

D. Voltage Breakdown Test

Online Continuous Partial Discharge is attached to the Inner Cooled Hydrogen Generator using 2 types of sensors, coupling capacitor, and Resistive Temperature Device (RTD), in stator windings where both sensors become partial discharge inputs online analyzer as shown in Fig. 2.

Results

A. Online Continuous Partial Discharge (PDI) Monitoring

The monitoring condition of the generator's Partial Discharge Intensity (PDI) from January 2014 to March 2017 can be observed in Fig. 3.

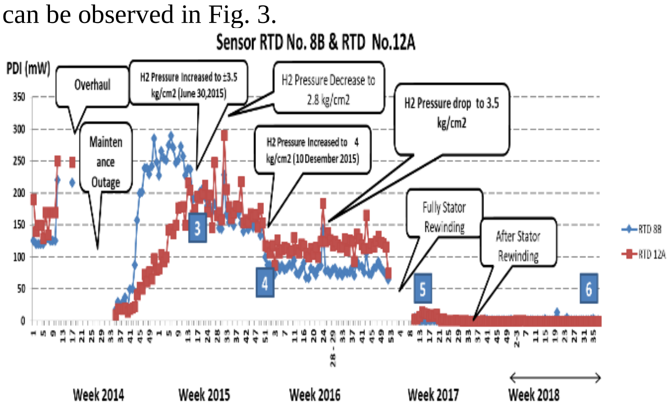

Figure 3. Activities Trending of Partial Discharge by sensor RTD 8B dan 12A.

Hydrogen pressure raising activities are carried out to verify the partial discharge activity. After rewinding, there was a significant decrease in Partial Discharge in RTD 8B and 12A as shown in Fig. 3. Phase resolve chart before rewinding is displayed in Fig. 4.

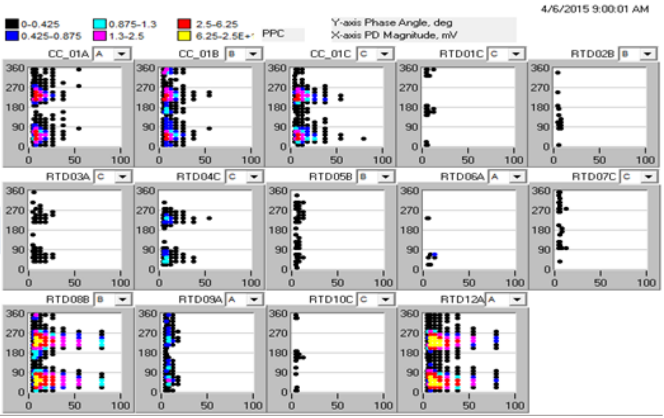

Figure 4. Phase Resolve Chart before Rewinding.

"HIGH & ELEVATED" partial discharge status of RTD 8B and 12A was observed. The possible cause is thermal deterioration for RTD 8B, and slot discharge activity for RTD 12A. On the other hand, "MODERATE: partial discharge status was captured by the coupling [12]. After total stator rewinding, partial discharge activity in all bars is reduced greatly significantly as per Fig. 5.

B. Offline Partial Discharge Test

Test results for the offline partial discharge of the old bar RTD 12A (Bar Slot No 29) are presented in Table 2. The test voltage 13.3, 16.6 and 23.0 are considered for different partial discharge intensity at pulse.

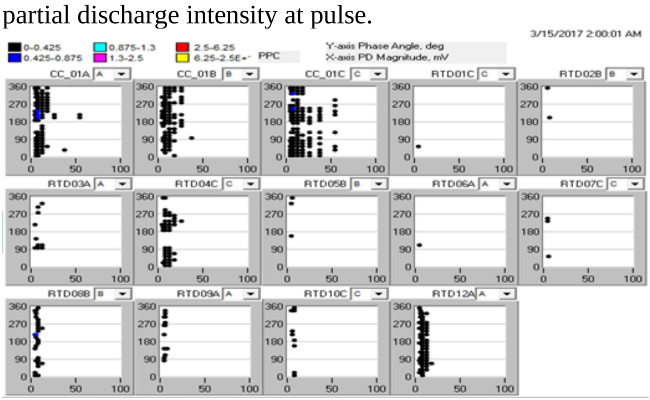

Figure 5. Phase Resolve Chart after Rewinding.

Table 2. Partial Discharge Test Results For Old Bar.

Bar No.	**Test Voltage (KV)**	**Partial Discharge (pC)** *Partial Discharge Intensity at Pulse (PPS)*				
		20	***50***	***100***	***200***	***500***
Old Bar B29 (RTD No. 12A)	13.3	25200	21100	19300	14000	11100
	16.6	34200	28100	23900	19600	14900
	23.0	46800	42100	35400	21300	273000

From the results, it can be concluded that the partial discharge values can be classified in the "CRITICAL" criteria, based on the reference by the generator manufacturer. However, as seen in Table 3, the Offline Partial Discharge test result for the new replacement bar is better than the old bar.

Table 3. Partial Discharge Test Results For Old Bar.

Bar No.	**Test Voltage (KV)**	**Partial Discharge (pC)** *Partial Discharge Intensity at Pulse (PPS)*				
		20	***50***	***100***	***200***	***500***
New BAR	13.3	2800	2600	2500	1500	800
	16.6	3200	3000	2800	2500	1900
	23.0	4500	4000	3500	9200	2400

C. Voltage Breakdown Test

From Table 4, the average value of the breakdown test result between the old bar and the new bar is relatively the same. Average breakdown voltage for old bar (B29) is 151 kV and for new bar is 139 kV.

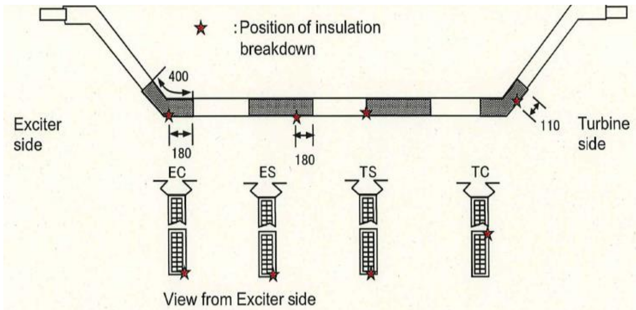

Figure 6. Insulation Breakdown Location of Old Bar No 29.

Table 4. Partial Discharge Test Results For Old Bar

Bar No		**EC**	**ES**	**TS**	**TC**	**Ambient Temp (°C)**	**Humidity (%)**	**Weather**
B29 (RTD no 12A)	Insulation Break-down Voltage (kV)	140	150	155	160	23	32	Sunny
	Average (kV)	151						
New Bar	Insulation Break-down Voltage (kV)	125	150	155	125	22	64	Rainy
	Average (kV)	139						

Location along with photo where breakdown insulation is tested in 4 parts on bars namely straight portion and knee portion shown in Fig. 6 and 7 for old bar as well as Fig. 8 and 9 for new bar.

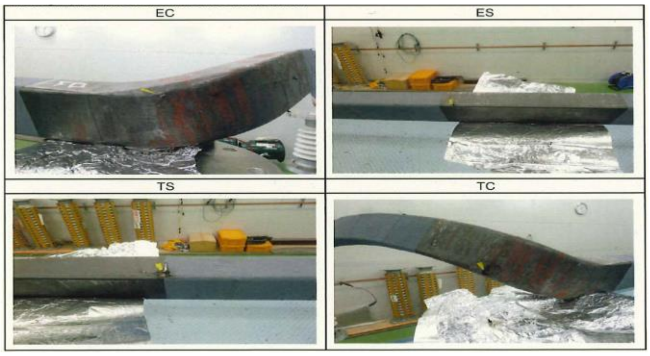

Figure 7. Photograph Insulation Breakdown Portion of Old Bar B29.

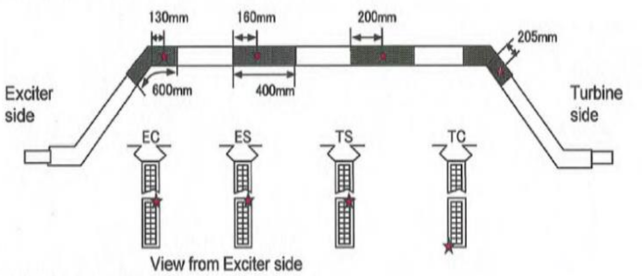

Figure 8. Insulation Breakdown Location of New Bar.

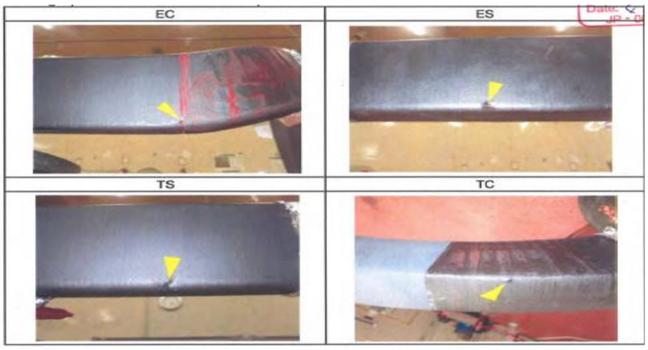

Figure 9. Insulation Breakdown Location of New Bar.

Discussion & Conclusions

Voltage Breakdown test result for the old bar is still in a good range and still far from the Limit of Safety Margin for Operation, which is 49 kV as per Generator Surge Arrester Cut Off Voltage. Even the average value is still better the new bar. The Stator Bar Winding should then be than able to operate much longer.

After rewinding, the Partial Discharge Intensity (PDI) decreased in both RTD and coupling capacitor sensors, suggesting that the activity of the new partial discharge winding is lower and better than the old winding. The result shows the PDI level of old bars lower than new bars, however both of its breakdown voltage are similar. This shows that HIGH PDI level has low correlation with voltage breakdown threshold. Hence, it is needed to redefine the level of PDI which contribute to voltage breakdown value

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