

# **Practical Partial Discharge Mitigation on Reyrolle LMT 11kV switchgear**

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## **Abstract**

Wellington Electricity has over recent years identified a number of Reyrolle LMT type switchboards with high levels of partial discharge. This was discovered during routine partial discharge surveys undertaken for the company. Whilst not trending upwards and indicating imminent failure, the level of discharge was higher than desirable.

When assessed using the internally developed Stage of Life assessment method (now superseded by the EEA Asset Health Indicators), the switchboards were identified as being in “mid-life” and these sites had no other concerns around condition, age, or utilisation. Replacement of the switchboard to address the high levels of partial discharge was not an economic proposition and other switchgear types in the fleet had higher need for replacement.

Wellington Electricity initially identified the cast resin type current transformers as being a problem area and undertook a trial to replace just these components with a separate primary bar and CT assembly. This was successful in around half of the trial sites, and those in which it was unsuccessful there were other components such as the cable box, synthetic resin-bonded-paper (SRBP) bushings, and other cast resin components which were found to have high levels of discharge. Testing of SRBP bushings found them to have high dielectric loss angles.

Wellington Electricity worked with the OEM, RPS Switchgear Limited to develop a retrofit kit which included all the necessary replacement components between the cable termination and the circuit breaker spouts to replace the original components. This modification has been undertaken at a number of sites and has brought the level of partial discharge at these sites to acceptable levels.

## **About Wellington Electricity**

Wellington Electricity purchased the Wellington distribution network from Vector in 2008 and took over local management from June 2009. Wellington Electricity supplies the areas of Wellington City, the Hutt Valley and Porirua basin. Around 166,000 connections are supplied by the network which serves around 400,000 people. Wellington Electricity is owned by Cheung Kong Infrastructure and Power Assets Holdings Limited. CKI and Power Assets own and operate electricity distribution networks in Australia, Hong Kong, New Zealand and the UK.

## **Background**

An external specialist, HV Diagnostics (NZ EA Technology agent), undertakes an annual partial discharge location service on all Wellington Electricity zone substation circuit breakers. This is to ensure that any partial discharge occurring in the insulation of the circuit breakers will be identified and monitored. The results from 2008 to 2012 had shown partial discharge occurring in Reyrolle type LMT circuit breakers at seven zone substations, consistently over a number of testing cycles.

The type LMT circuit breakers were installed from late 1960s onwards. They are the most common model of circuit breaker on the Wellington Electricity network, with over 900 units in service, of which 272 units are installed at zone substations.

An internally developed method of prioritising major asset replacement, known as “Stage of Life Analysis”, in place between 2009 and 2014, showed that apart from the partial discharge issues, the LMT circuit breakers are in good condition, reliable, well-supported by the manufacturer, and do not require replacement in the foreseeable future. The need therefore was to identify the source of the partial discharge, and develop a cost-effective means of mitigating it to ensure the switchgear would continue to give good service.

## **Risks Involved with High Partial Discharge Levels**

High partial discharge levels provide an indication that an asset’s insulation may be deteriorating in a way that could lead to failure. The process of deterioration can propagate and develop, indicated by a trend of increasing partial discharge, until the insulation is unable to withstand the electrical stress, leading to flashover.

The ultimate failure of circuit breakers can be sudden and catastrophic, posing a significant health and safety risk to personnel through arc flash, causing major equipment damage, and with considerable network outages. This is especially the case for circuit breakers located at zone substations, potentially placing the entire substation at risk.

## **Partial Discharge Locations**

Partial discharge testing on LMT switchgear indicated potential issues around the current transformer (CT) chambers on units with resin encapsulated CTs, with some sites generating levels as high as 50dB. While the magnitude of partial discharge was

not increasing over time, this steady high level of PD occurring on high priority assets was considered unacceptable and in need of further investigation.

As the project proceeded, further issues were identified with cast epoxy resin risers and synthetic resin bonded paper (SRBP) bushings between the CT compartment and cable box. There are also instances where partial discharge was occurring in heatshrink cable terminations where the cable boxes had been converted from a compound-filled box to an air box, without adequate clearances being maintained between the phases of the termination. In some instances the source of the partial discharge was the circuit breaker truck itself. Examples of these components are shown in Figure 1.



**Resin Encapsulated CTs**



**SRPB Bushings**



**Cast Epoxy Resin Monoblock Riser**



**Compound Box Converted to Air Box**



**Heatshrink Termination**



**Circuit Breaker Truck**

**Figure 1 - Example Components Identified with High Partial Discharges**

When the partial discharge was initially identified, a number of zone substation LMT circuit breakers had cleaning carried out on the affected components with unsuccessful results. The PD levels caused by dirt and surface electrical stresses may have been reduced but the solid

insulation PD element was still present. This indicated that component replacement was necessary.

### **First Trial of Component Replacement**

Reyrolle LMT switchgear used a one-piece cast resin CT and primary bar assembly on most equipment from the late 1960s to the 1990s, when they changed to a screened primary bar with slip on CTs. Voids created during the resin moulding process are thought to be the main cause of the discharge on these components.

Five sets of resin encapsulated CTs were replaced in 2012 with mixed results. In several cases the PD was reduced to normal levels, but in others the reduction in PD in the CT compartment revealed PD occurring elsewhere in the cabinet.

Discussion with the switchgear manufacturer and field investigations led Wellington Electricity to suspect that the cast epoxy resin riser and SRBP bushings between the CT chamber and the cable box were also exhibiting PD. Similarly, PD levels were also high on compound cable boxes that had been converted to an air-box using heatshrink terminations.

### **Second Trial of Component Replacement**

In the later part of 2012 a LMT circuit breaker at Waitangirua zone substation with abnormally high PD values coming from the CT chamber was targeted for additional component replacement. Tan-delta testing confirmed that the insulation around the encapsulated CTs and SRBP bushings was in poor condition.

The project involved replacement of the resin encapsulated CTs, SRBP bushings, and pitch-filled cable termination with retrofit components specifically developed for Wellington Electricity by the switchgear manufacturer. This significantly improved the partial discharge and tan-delta results, given in Figure 2, and confirmed that the retrofit was effective in addressing the risk.

<b>Location</b>	<b>Tan-Delta Before Replacement</b>	<b>Tan-Delta After Replacement</b>
Blue Phase – CT and cable bushing	13.017%	0.612%
Yellow Phase – CT and cable bushing	10.077%	1.034%
Red Phase – CT and cable bushing	13.336%	0.496%

**Figure 2 – Waitangirua CB3 Tan-Delta Results Before and After Component Replacement**

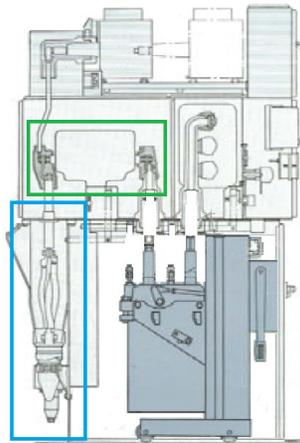
From replaced CTs, visible signs of surface tracking were observed on the monoblock riser, as shown in Figure 3. This indicated that, while the magnitude of partial discharge was not increasing, the potential for failure still existed and the replacement of components was justified.



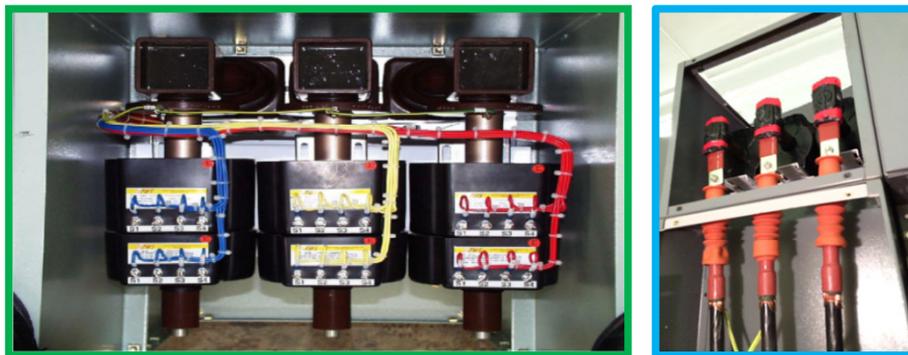
**Figure 3 –Damage on Monoblock Riser due to PD at Waitangirua CB3**

### **Retrofit Kits**

This work has led to two retrofit kits being developed for LMT switchgear by RPS Switchgear Limited, each targeting a different compartment. One kit replaces components when PD is present in the CT compartment, shown in green in Figure 4, and replaces the resin CTs and monoblock riser. The second kit targets the cable box, shown in blue in Figure 3, and includes a larger cable box to facilitate the use of heatshrink terminations, and replaces the SRBP bushings by providing dropper extension bars with insulated standoffs. Where PD is present on the circuit breaker truck, this is replaced with a standard retrofit vacuum truck.



**Figure 4 –Retrofit Kit Compartment Locations for LMT Switchboard**



**Figure 5 –Examples of Installed Retrofit Components**

## Corrective Refurbishment Programme

Specific switchgear panels at seven zone substations, as shown in Figure 6, consistently having high PD levels were identified for PD mitigation using the retrofit kits.

Priority Ranking	Zone Substation	CT Compartment	Cable Box
1	Waitangirua	CB2, CB3	CB2, CB3
2	Nairn Street	CB1, CB2, CB11, CB12, CB13, CB14	CB1, CB2, CB11, CB12, CB13, CB14
3	Titahi Bay	CB9	CB9
4	Tawa	CB13	CB13
5	Porirua	CB1	CB1
6	Moore Street	CB8, CB12	CB8, CB12
7	Ngauranga	CB2	CB2

**Figure 6 – Zone Substation CBs Identified with High Partial Discharge Levels**

To measure the effectiveness of the mitigation measures, transient earth voltage (TEV) and tan-delta measurements were taken before the modifications, and again once the work was complete.

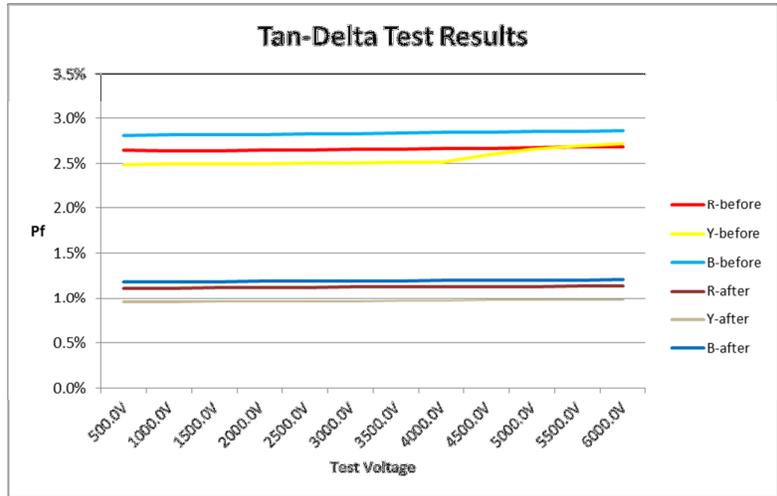
The partial discharge mitigation work is very cost-effective against a replacement of the panels. All circuit breakers in a substation could have retrofit kits installed for approximately 10% of the cost of replacing the switchboard.

### Results after Corrective Refurbishment

From 2013 to 2014, partial discharge mitigation using the retrofit kits was completed at the seven substations identified. Example partial discharge and tan-delta test results on Moore St CB12 are shown in Figures 7 and 8, demonstrating the effectiveness of the corrective measures.

Compartment	TEV Before Mitigation	TEV After Mitigation
CT Chamber	15 dB	5 dB
SRBP Bushing Area	39 dB	4 dB
11kV Cable Box	36 dB	4 dB

**Figure 7 – Results of TEV Testing of Moore St CB12, Before and After Mitigation**



**Figure 8 – Results of Tan-Delta Testing of Moore St CB12, Before and After Mitigation**

The success of component replacement was also confirmed in 2014 when the annual partial discharge and ultrasonic testing was undertaken at these substations, showing the PD levels on the identified circuit breaker panels had reduced to normal levels.

### Implementation and challenges

Challenges have been encountered, particularly as there are minor variations between cable boxes, bushings and monoblock CTs on different LMT models. The presence of RPS Switchgear personnel during some of the replacement activities has resulted into changes in the design of retrofits, simplifying the process and making the components in universal for all models of LMT.

### Next Step: Extension to Distribution Substations

Partial discharge mitigation at zone substation circuit breakers will continue to take priority, due to the criticality of these sites. However, over 600 panels of LMT switchgear are also located in Wellington Electricity’s distribution substations. Partial discharge is present on a number of these panels, and is being monitored for trends that may indicate a need for component replacement. After the completion of the zone substation PD mitigation, a programme will commence to implement the improvement measures on LMT switchgear at distribution substations, with priority determined by severity of partial discharge, frequency of personnel access for switching, the number of customers potentially affected.

### Summary

Wellington Electricity has identified issues with high partial discharge levels being generated on LMT switchboards at a number of its zone substations. The sources of the partial discharge have been identified and retrofit components developed by the OEM that have allowed the problem to be addressed through component replacement instead of switchboard or panel replacements. Experience has demonstrated that this is an economical and effective option for partial discharge mitigation on this switchgear, and the project will be extended beyond zone substations to include high priority distribution circuit breakers.