Dry Type (Non-Oil) Paperless Bushings (RIS and RIF®) For T&D Power Systems

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Introduction

The main purpose of a transformer bushing is to safely transfer power through the earthed transformer tank. OIP and RIP type bushings have been the industry standard for many years and in general have performed satisfactorily. However, as our transformer assets age, paper deterioration in the original supplied bushings can cause these bushings to fail; some even catastrophically.

Today we are seeing more movement towards silicone insulated, dry type (non-oil), paperless condenser bushings as they offer better safety, no oil leakage concerns, optional maintenance and a lighter installation weight. There are now several suppliers that can offer this bushing technology.

What is the Difference Between RIS and RIF®

RIS which stands for Resin Impregnated Synthetic is the industry's generic terminology for the dry type (non-oil), paperless bushing. RIF® which stands for Resin Impregnated Fiberglass is a registered trademark name for the dry type (non-oil), paperless insulation technology developed by RHM International. Even though the RIF® bushing falls within the RIS category of bushings it is a distinctive technology that offers many unique advantages over the other RIS bushings currently on the market. The RIF® bushing technology is the more mature bushing technology, introduced to the market in 2003 and having over 22,000 units installed worldwide. The RIS bushing is a relative newcomer which was introduced to the market in 2014.

A major difference between RIS and RIF® is how the condenser core is manufactured. The RIS bushing condenser cores are wound with synthetic fabric [6] (Figure 1) after which the wound condenser core is encapsulated under vacuum where it is impregnated with epoxy resin and cured [6] (Figure 2).

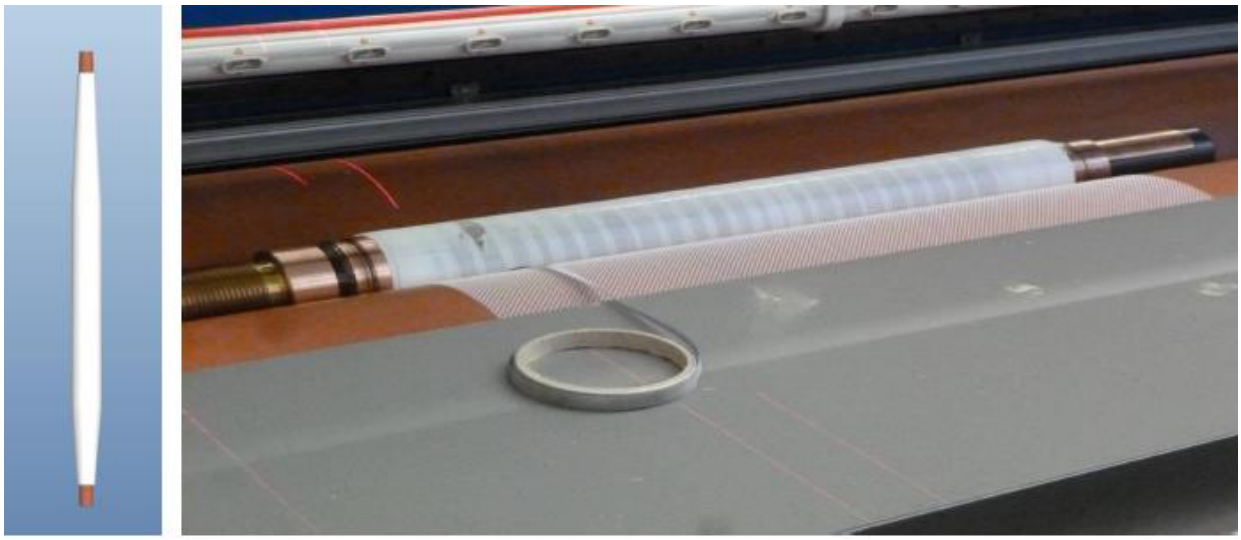


Figure 1: Synthetic Fabric Wrapping Process [6]

Figure 2: Vacuum Encapsulation - Resin Impregnation and Curing [6]

The RIF® bushing condenser core is made from a continuous wrapping of fiberglass threads that have been impregnated in an epoxy resin bath. There is no casting and full control of every inch being wrapped. The final wrapped condenser core is then heat cured after which it is machined into its final shape.

The RIF® bushing production process is shown in Figure 3.

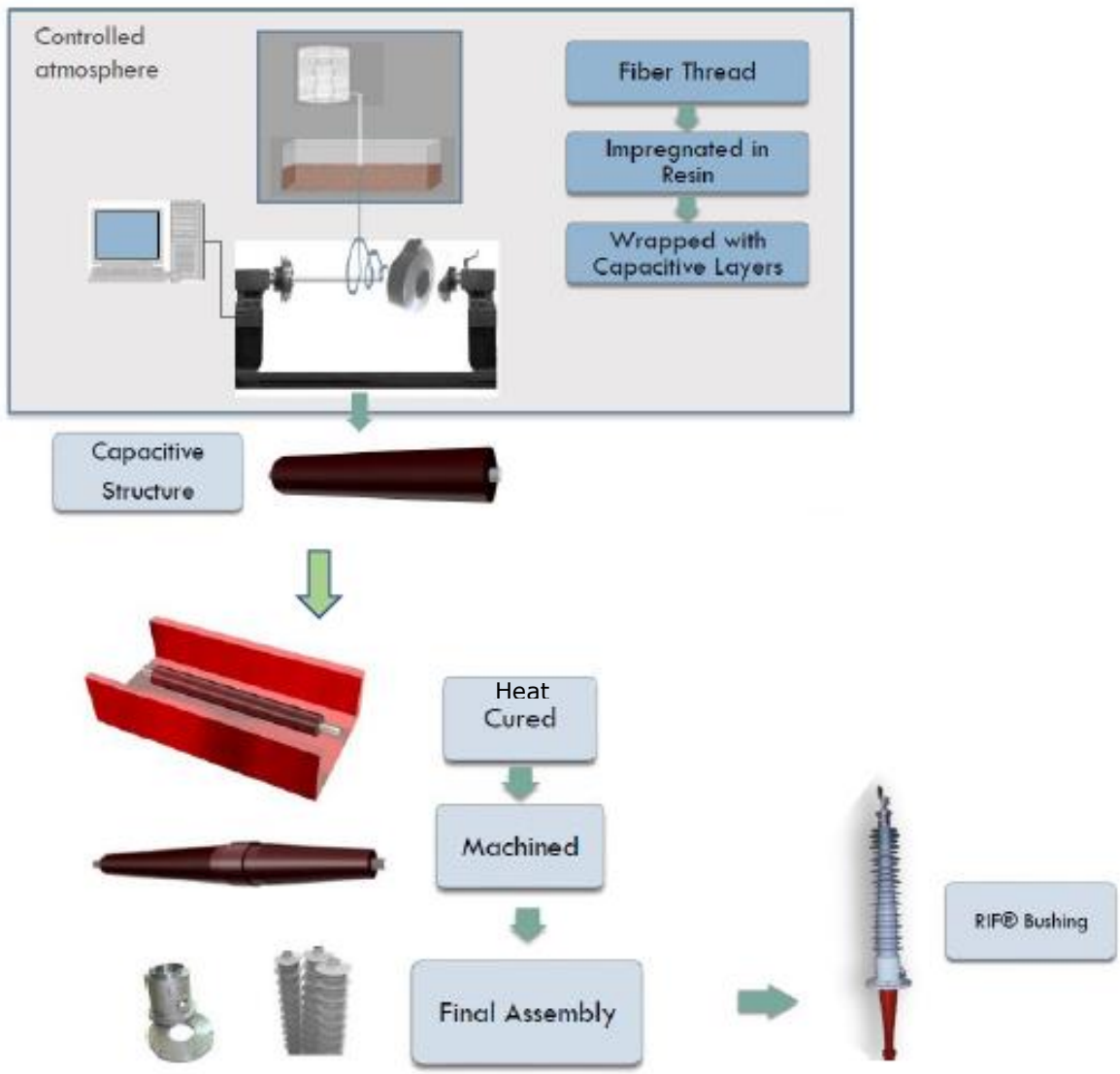


Figure 3: RIF® Bushing Production Process

Today there are several suppliers of dry type (non-oil), paperless condenser bushings; the main ones being:

Supplier	Insulation Type	Bushing Type Reference	Ratings
RHM International	RIF®	FGRBW	Up to 550 kV and 6000A
ABB	RIS	O Plus Dry	Up to 230 kV and 3000A
Siemens (HSP)	RIS	SESTFt	Up to 245 kV and 2000A
Moser-Glaser	RIS	DURESCA® RIS	Up to 170 kV and 2500A

Industry standards have only recently recognized this type of bushing. The following is a listing of the definitions used in the IEC and CSA bushing standards and proposed for the revised IEEE bushing standard.

IEC 60137 – 2017

3.11
resin-impregnated synthetics bushing
RIS
bushing in which the major insulation consists of a core wound from synthetics subsequently impregnated with a curable resin

Note 1 to entry: A resin-impregnated synthetics bushing can be provided with an insulating envelope, in which case the intervening space can be filled with an insulating liquid or another insulating medium.

Note 2 to entry: If not otherwise stated by the manufacturer, bushings in accordance with 3.11 shall be considered as RIP bushings according to 3.10.

CAN/CSA C88.1 – 2018

Resin-impregnated fibre or synthetic capacitance graded bushing – a bushing in which the major insulation consists of a resin impregnated non-hygroscopic fibre or synthetic fabric with capacitance grading layers.

Note: This type of bushing is generally provided with an insulating envelope at the outboard section having weather sheds.

IEEE C57.19.00 Proposed Revision (A PAR for the revision of this standard has been issued. PAR expiration is 2022)

Resin impregnated synthetic or fiber insulated bushing: A bushing in which the internal insulation uses no paper and consists of a graded condenser core composed of synthetic or fiber material impregnated in epoxy resin.

History of the RIF® Bushing

As described in [3] starting in the early 2000's RIF® wall bushings and transformer bushings were developed for voltage levels ranging from 35 kV to 220 kV and currents up to 6000 A. The main development milestones for the RIF® bushing technology are summarized below:

1) 35kV wall bushing successfully developed in December, 2002
2) First 40.5kV bushing sold and installed in January, 2003
3) 110kV wall bushing successfully developed in March, 2003
4) 110kV wall bushing passed special hot quench test performed in factory in May, 2005
5) 110kV transformer bushing passed type test in December 2005.
6) 220kV transformer bushing passed type test in July 2006.
7) 110kV transformer bushing passed hot quench test and water seal test in August 2006.
8) 110kV transformer bushing passed cold test in October 2006.
9) 110kV transformer bushing passed a 7-day mechanical strength test in December, 2006.

With the recent developments of the 420 kV and 550 kV ratings RIF® transformer bushings are available in voltage ratings from 15 kV to 550 kV and for currents up to 6000 A. As mentioned previously more than 22,000 units are in operation in power systems all over the world to date.

The Unique Advantages Offered by the RIF® Bushing Technology

The unique advantages of the RIF® bushing technology are extensively covered in [1] from which the following is partly extracted. The RIF® bushing utilizes a finely graded condenser design and a core insulation that is composed of fiberglass impregnated with epoxy resin wrapped between capacitive screens. The outer insulation for the RIF® bushing is silicone rubber sheds that are adhered directly to the condenser core. This ensures there is no gap or opening in the overall bushing structure and eliminates the need for filler fluid or material. The electrical field is controlled by a finely graded capacitive core which ensures a linear surface potential profile from the conductor to the grounded flange (100% to 0%) which greatly improves its' flashover resistance. In addition, the thermal insulation strength of the resin-impregnated fiberglass is IEC Class B (temperature limit rating of 130°C) which gives the RIF® bushing a larger thermal margin than other bushing types. The latest 2019 CIGRE report on Transformer Bushing Reliability from working group A2 [2] is listing RIS bushings as class E (120 °C)

Finally, the simpler manufacturing process which is primarily a wrapping and heat curing process introduces minimum internal stresses in the capacitive core that can affect the long-term operational life of the bushing.

The RIF® bushing has low routine test values for dissipation factor (≤ 0.5%) and partial discharge (≤ 5 pC under operational voltage and ≤10 pC under the highest operational voltage) ensuring a distinctly longer operational life. In addition, special testing that has been performed simulating extreme environmental and operating conditions along with

its long, proven in-service record demonstrate the safety and reliability of the RIF® bushing technology. Some examples of the extreme testing that has been done include:

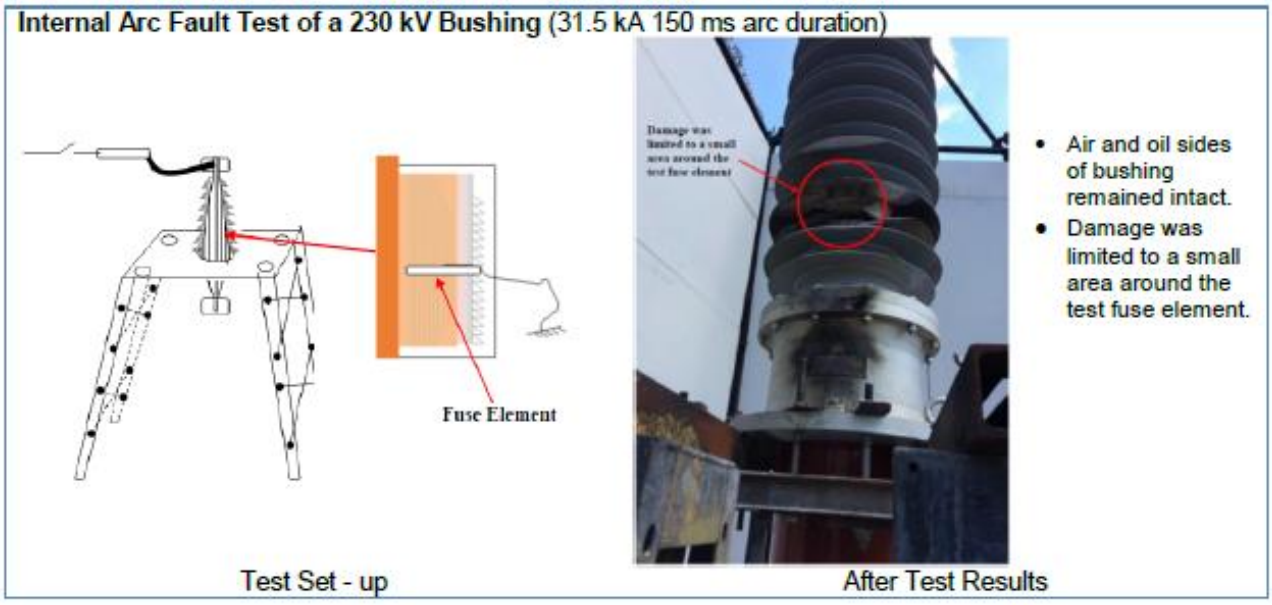


Figure 4: Internal Arcing Fault Test – Exceptional resistance

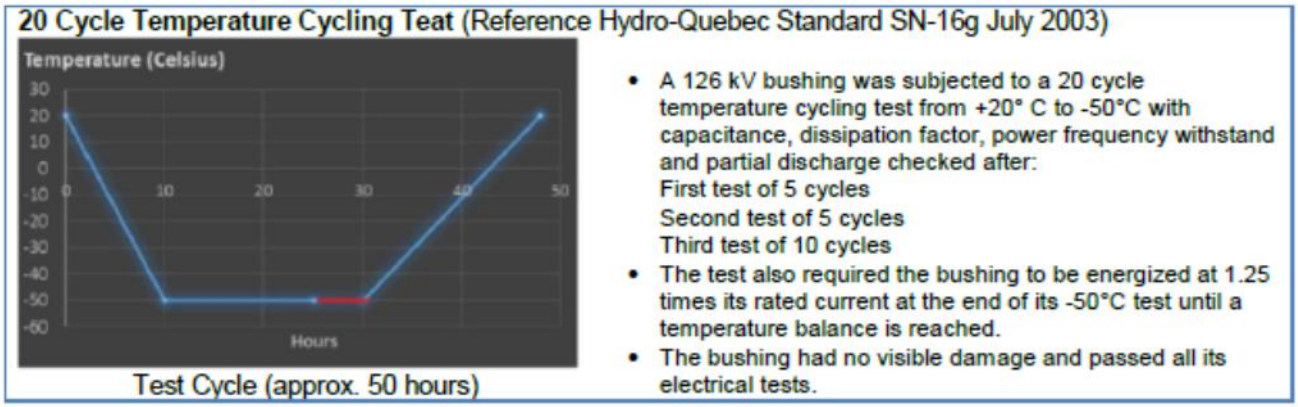


Figure 5: Low Temperature 20 Cycle Test - The performance was not affected

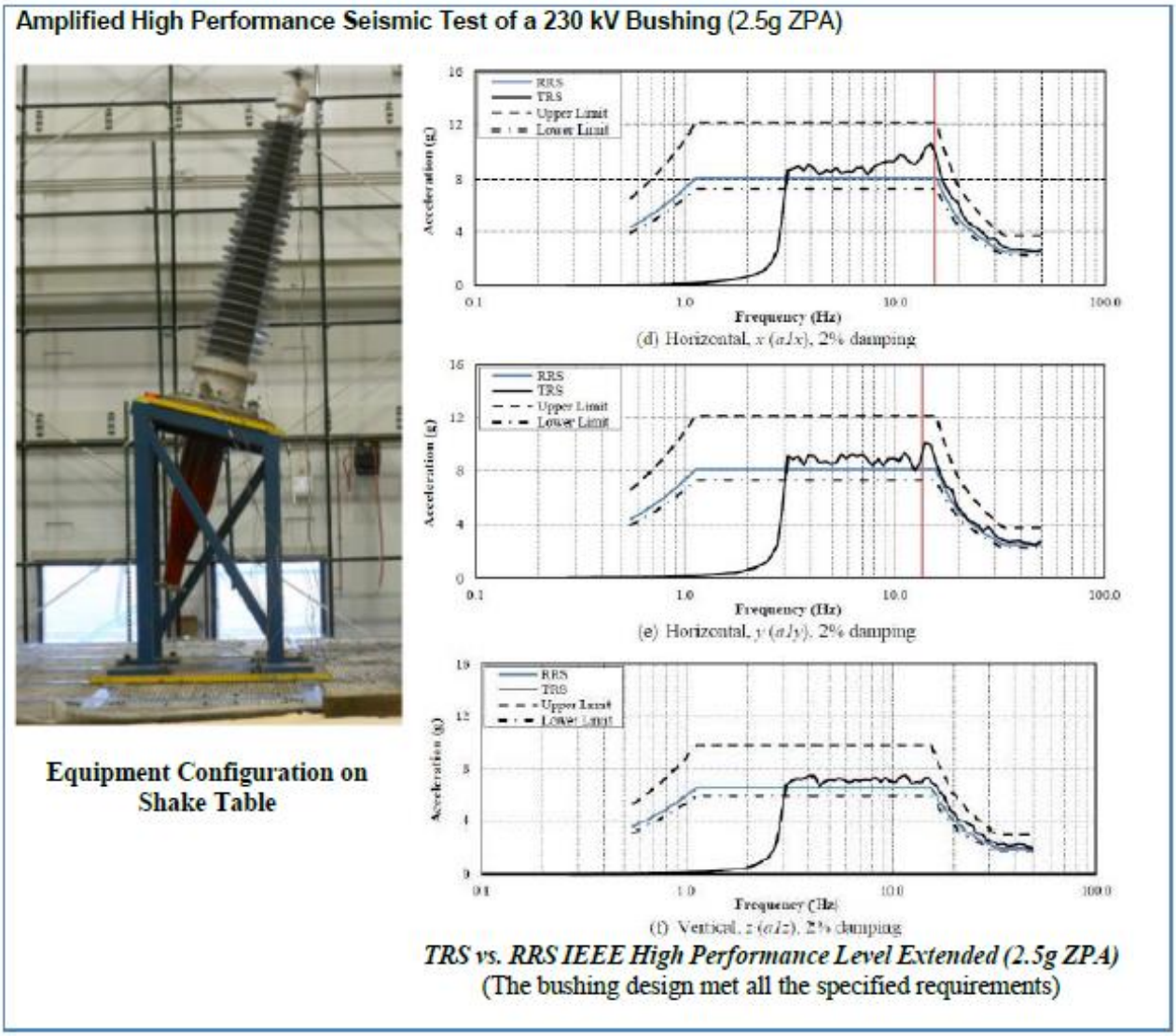


Figure 6: Amplified High Performance Seismic Test – Performed at the maximum capability of the shake table

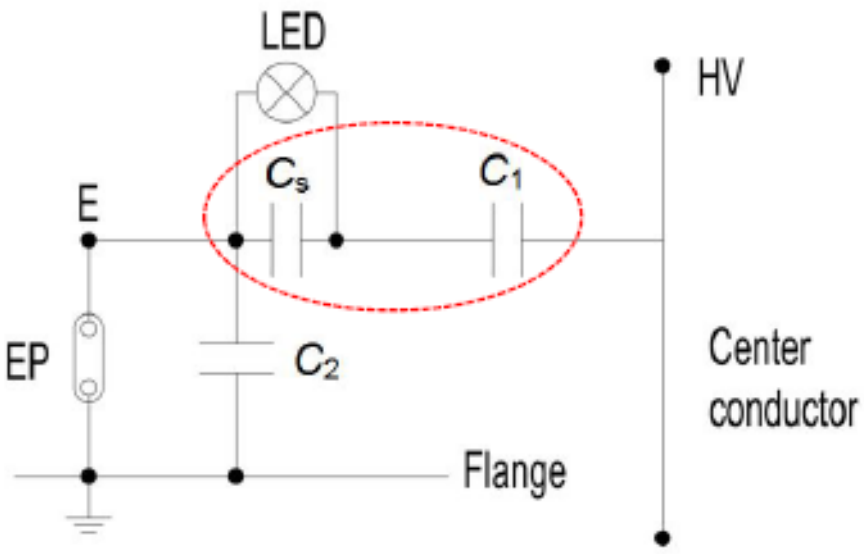
RIF® Custom Designs Are Easier To Design And Produce

Another important advantage offered by the RIF® bushing technology is that custom designs can be produced with very little impact on the price and lead time due to the simplicity of the manufacturing processes. OIP and RIP type bushings have been the industry standard for transformers for many years and in general have performed satisfactorily. However, as our transformer assets age paper deterioration in these bushings can eventually cause these bushings to fail, some even catastrophically. Deteriorating test results (power factor) and leaking sealing systems are a good indicator that it may be time to replace an OIP bushing. When considering a replacement program, it is important to remember the age of the operating transformer

inventory and the obsolete standards that the originally supplied bushings were built to. Because of the age of many transformers the biggest challenge for the program is to be able to get custom-engineered “like for like” replacement bushings at reasonable prices and lead times. As lead times for RIF® bushings are typically quoted as 12 weeks ex-works transformer outages can be scheduled without the worry of insecure supply and long delivery times.

RIF® Bushing Can Come With Built-In Monitoring

RIF® bushings are considered to be maintenance-free. During operation neither oil level measurement nor chromatographic analysis is needed. Detection of moisture ingress is not necessary either. To eliminate the need for off-line testing of the bushing insulation the RIF® bushing can be supplied with an optional built-in insulation condition monitoring system, [4] [5] that detects changes in capacitance current due to failing capacitive screens (Figures 7). An LED sensor mounted on the test tap (Figure 8) which is normally lit GREEN indicating normal status will turn to RED indicating a possible deteriorating condition inside the bushing. RED is a pre-alarm and does not have to be acted upon immediately as tests have shown that the propagation of a fault inside the RIF® bushing is a very slow process.



HV – HV terminal connected to grid, C_1 – main core insulation capacitance, C_s – signaling capacitance (C_s>>C_1), C_2 – test tap to bushing flange insulation capacitance, E – earth terminal, EP – equipotential plate

Figure 7: Schematic of Insulation Condition Monitoring System

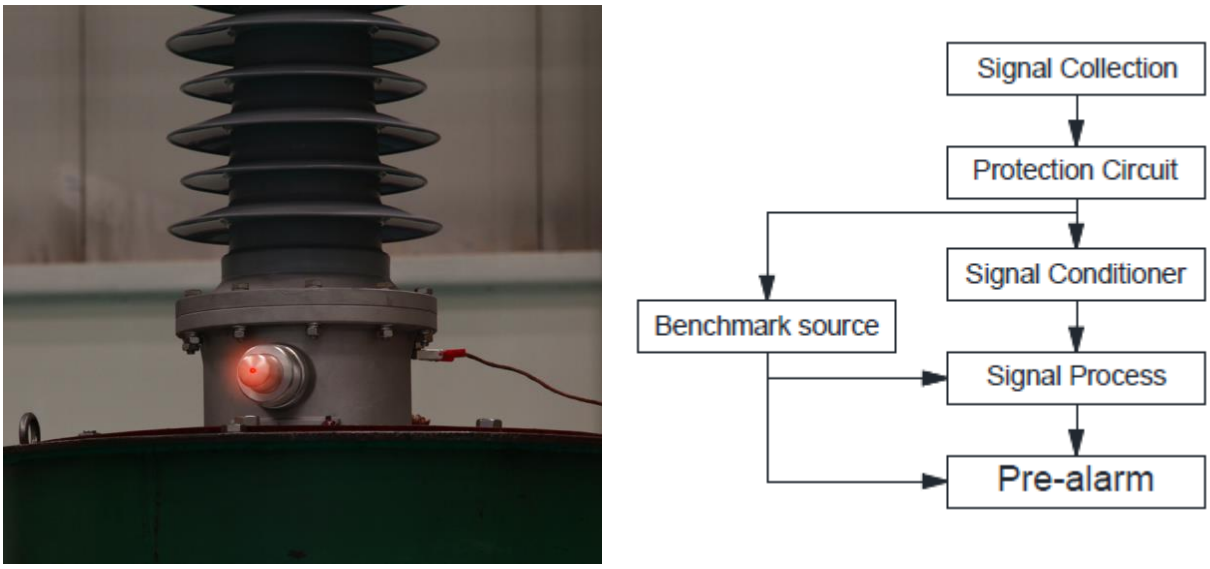


Figure 8: LED Sensor

In addition to the real time tracking of the bushing's insulation condition the capability to record the partial discharge activity inside an operating transformer can be added to the RIF® built-in monitoring by equipping the smart measurement terminal of each RIF® bushing with a special PD sensor. This provides a full monitoring platform for the transformer that is much simpler and more cost-effective than existing add-on monitoring systems.

Simplest Long-Term Storage

Finally, no special long-term storage conditions are required for RIF® bushings. They are shipped horizontally and can be stored outdoors in their shipping crates in the horizontal position.

RIF® as an Insulation Platform for Other Dry Type Products

Because of its intrinsically strong mechanical strength and proven performance under severe operating conditions the RIF® insulation platform is also used for other dry type products offered by the company.

The new RIF® cable termination provides a dry type, self-supporting cable termination for MV and HV levels (i.e. 35 kV to 110 kV with future designs up to 230 kV coming). The dry type RIF® cable termination offers a number of advantages including increased safety due to its explosion-resistant design, less environmental risk and a faster, easier installation process.

The new RIF® electronic combined voltage and current transformer (eVCT) was developed for the IEC 61850 market with designs currently available up to 245 kV. The measurement functions of the eVCT are based on measurement of the voltage using a

capacitor voltage divider and current using a Rogowski Coil. An acquisition unit converts the recorded data into a digital serial protocol and transmits them via optical fiber to the Merging Unit (MU) located in the control room. The eVCT design also offers ground level access to its acquisition unit and power supply for easier maintenance.

Conclusion

Dry type (non-oil), paperless condenser bushings are known in the industry as RIS bushings. To get away from the risks associated with oil and paper in their bushings, users are starting to specify RIS bushings for their power transformers. Today there are several manufacturers that offer RIS bushings, including one known by its' trademark name RIF®.

When selecting an RIS bushing for your new transformer requirements and/or OIP bushing replacement program it is important to consider the performance record and design flexibility of the technology. The RIF® bushing technology was the first dry type (non-oil), paperless condenser bushing introduced to the market in 2003 and to date there are over 22,000 units in-service worldwide. It is a mature technology that has been extensively tested for extreme operating conditions. Its' straightforward manufacturing processes also allows for custom designs to be produced with minimal impact on its price and lead times (important for "like for like" replacement of older vintage style OIP bushings).

References

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[3] Tianbi Tu, Eric Euvrard, Ruzhang Wang, *Development and Application of Resin Impregnated Fiberglass Transformer Bushing*, INMR World Congress, Seoul, Korea, April 2011

[4] Robert Middleton, Eric Euvrard, Jingshui Zhuo, *A Novel Built-In Insulation Condition Monitoring System Enabled by Dry Type by Dry Type Technologies*, CIGRE Canada Conference, Vancouver, BC, Canada, October 2016

[5] Tianbi Tu, Eric Euvrard, Z. Liu, *Combining Dry Type Resin Impregnated Fiberglass Paperless Transformer Bushings with Built-In Novel Insulation Monitoring Function*, IEEE PES Conference, Chicago, USA, 2014

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