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TRANSFORMER TECHNOLOGY MAG

Part 2

Bushings

Design, Maintenance and Monitoring

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Managing Bushings: **From Statistics to Singularities - Where to Focus?**

MV Transformer Bushings: **Global Technology and Market Trends**

The Dry Type RIF® Bushing: New Technology in HV Bushings

by **Robert Middleton**
and **Eric Euvrard**

WHEN DEALING WITH WHAT APPEARS TO BE PROPRIETARY OR PROTECTED INFORMATION RELATED TO NEWER TECHNOLOGIES, IT IS HARD TO SEPARATE THE COMPANY FROM THE TECHNOLOGY AND PROVIDE VALUABLE, LEADING EDGE INFORMATION. IN THIS ARTICLE, ROBERT AND ERIC HAVE BEEN ABLE TO WALK THAT FINE LINE BETWEEN PROMOTING THEIR UNIQUE BUSHING SOLUTION AND PROVIDING LEADING EDGE INFORMATION THAT EVERY TRANSFORMER PROFESSIONAL WILL VALUE. WELL DONE ROBERT AND ERIC.

Robert L. Middleton was born in Winnipeg, Canada. He received his degree in Electrical Engineering from the University of Manitoba in 1971. He is a registered professional engineer in the Province of British Columbia. He has an extensive background in generation and transmission engineering including quality assurance. He has served on several CSA, CIGRE and IEC working groups and co-authored numerous technical papers. He is presently Chief of Technology and Engineering for RHM International, a manufacturer of high voltage dry type current transformers, bushings and cable terminations. Prior to joining RHM International he worked over 40 years at two western Canadian provincial electrical utilities.

Eric Euvrard is President of RHM International, the specialist of high voltage dry type insulation technologies. With a background in material science engineering and business he held positions in research, manufacturing and marketing in different large traditional and high-tech industries in Europe and North America. In 2004 he founded RHM International which is based in Brookline, MA USA with operations in Hudson, NH USA and Beijing, China.

Photo: RHM International

A Short Bushing History

To better understand the latest developments in bushing technologies it would certainly be helpful to readers not fully familiar with this segment of the power industry to understand how we got there.

HV AC bushings appeared in the late 19th century with the first AC transformers. Those first bushings were bulk bushings, meaning the insulation relied on the thickness of a solid material placed around the high voltage conductor.

As voltages increased, the diameter of those bushings became quickly prohibitive.

About a century ago the capacitance graded insulation structure was introduced. It inserts a succession of capacitive layers within the core insulation, providing a more linear and controlled electric field distribution. A key benefit of this technology was the significant reduction of the bushing's diameter. It has been the core design concept for HV bushings ever since.

Still, from this same concept, differences between the successive bushing technologies are directly related to the type of materials and fillers used to create the capacitive structure.

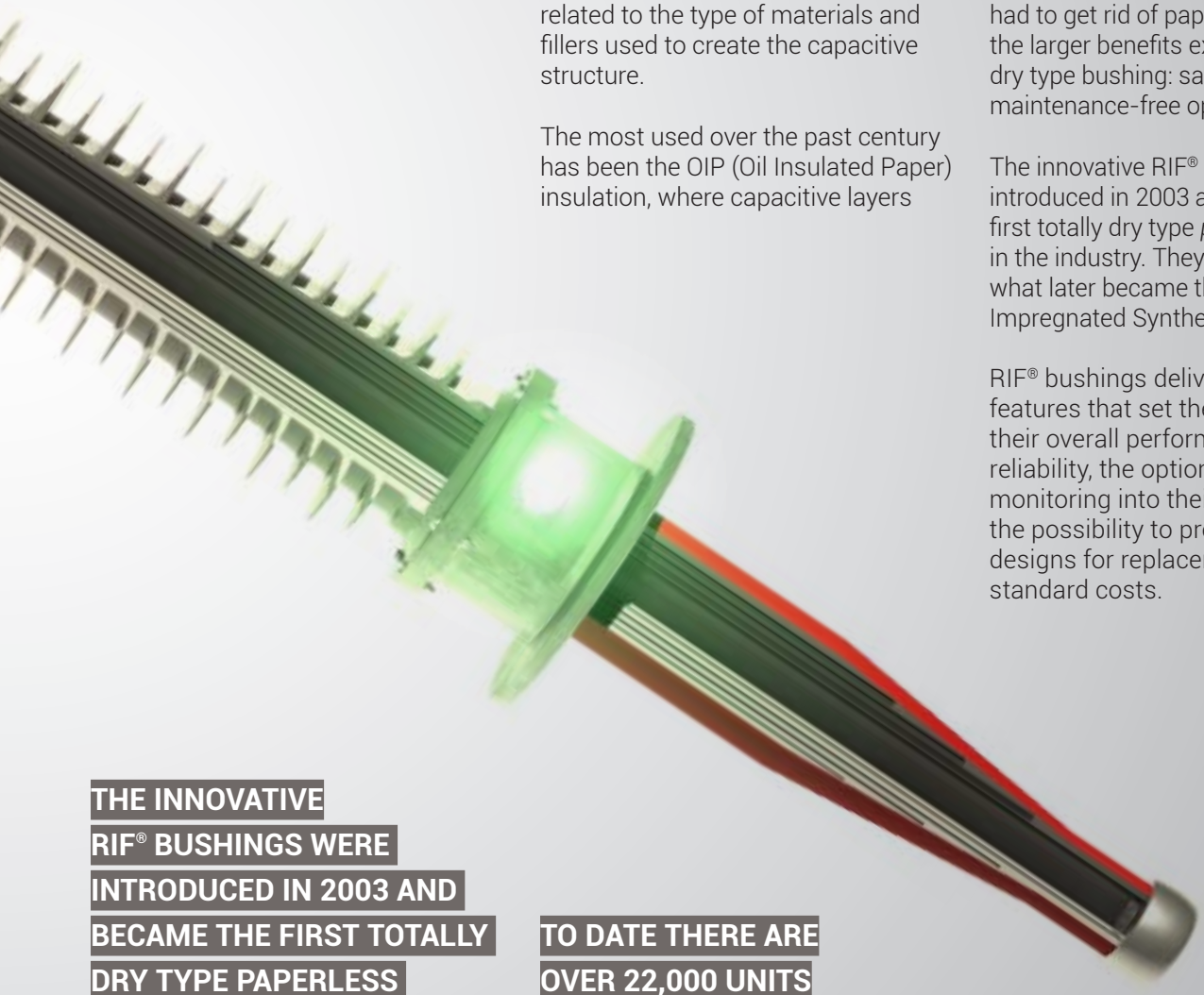
The most used over the past century has been the OIP (Oil Insulated Paper) insulation, where capacitive layers are separated by a special paper and immersed in insulating oil.

To try to mitigate the challenge of managing large volumes of oil, from leaks to potentially dramatic failures, the RIP (Resin Impregnated Paper) insulation was introduced in the mid-20th century. This technology substituted a resin for the insulating oil. Leaks were eliminated, but the presence of paper still presented a potential hazard if stored incorrectly or operating in high humidity conditions. But it was considered a "dry type" bushing.

The next generation of bushings then had to get rid of paper to fully deliver the larger benefits expected from a dry type bushing: safety, reliability and maintenance-free operation.

The innovative RIF® bushings were introduced in 2003 and became the first totally dry type *paperless* bushings in the industry. They pioneered what later became the RIS (Resin Impregnated Synthetics) category.

RIF® bushings deliver a unique set of features that set them apart; namely, their overall performance for high reliability, the option of integrating monitoring into their structure and the possibility to provide custom designs for replacement needs at standard costs.



THE INNOVATIVE RIF® BUSHINGS WERE INTRODUCED IN 2003 AND BECAME THE FIRST TOTALLY DRY TYPE PAPERLESS BUSHINGS IN THE INDUSTRY.

TO DATE THERE ARE OVER 22,000 UNITS IN-SERVICE WORLDWIDE.

Figure 1.
Smart measurement terminal and LED sensor for core insulation condition monitoring

RIF® BUSHINGS DELIVER A UNIQUE SET OF FEATURES THAT SET THEM APART: THEIR OVERALL PERFORMANCE FOR HIGH RELIABILITY, THE OPTION OF INTEGRATING MONITORING INTO THEIR STRUCTURE AND THE POSSIBILITY TO PROVIDE CUSTOM DESIGNS FOR REPLACEMENT NEEDS AT STANDARD COSTS.

RIF® BUSHING TECHNOLOGY HAS INTRODUCED THE NEXT LEVEL OF RELIABILITY AND SAFETY THAT OPERATORS NEED FOR THEIR TRANSFORMER ASSETS.

RIF® Bushing Technology

RIF® transformer bushings were introduced to the market in 2003 and to date there are over 22,000 units in-service worldwide. These bushings have proven to be ultra-reliable under all types of operating and environmental conditions.

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. Additionally, 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 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. Finally, RIF® bushings require no special storage conditions, thereby reducing the handling costs.

In summary, the RIF® bushing technology has introduced the next level of reliability and safety that operators need for their transformer assets.

The Smart RIF® Bushing

RIF® bushings can be provided with built-in smart measuring circuitry that continuously monitors the bushing's core insulation condition. Sealed within the primary core is a built-in signaling capacitance to collect and measure stray capacitive current generated by a damaged condenser screen layer.

A self-powered LED sensor collects and processes the signal which is compared to a benchmark voltage. The sensor is factory-calibrated to provide a GREEN LED indication for a normal insulation condition and RED LED pre-alarm indication for a deteriorating insulation condition.

The RIF® bushing's built-in sensing circuitry can also be used to capture high frequency signals generated from partial discharge activity inside the power transformer by installing a PD sensor in the smart measurement terminal. This monitoring can be continuous without any need to shut down the transformer.

Photo: RHM International

Figure 3.
RIF® bushing with smart terminal and PD sensor

THE USE OF THE RIF® BUSHING AS A PARTIAL DISCHARGE SENSING DEVICE DRAMATICALLY SIMPLIFIES TRANSFORMER MONITORING WHILE PROVIDING HIGH PD MONITORING RELIABILITY AND ACCURACY WITH ITS DIRECT COUPLING AND SHIELDING DESIGN. THIS CAN PROVIDE SIGNIFICANT ADDED VALUE FOR CRITICAL SYSTEM TRANSFORMERS.

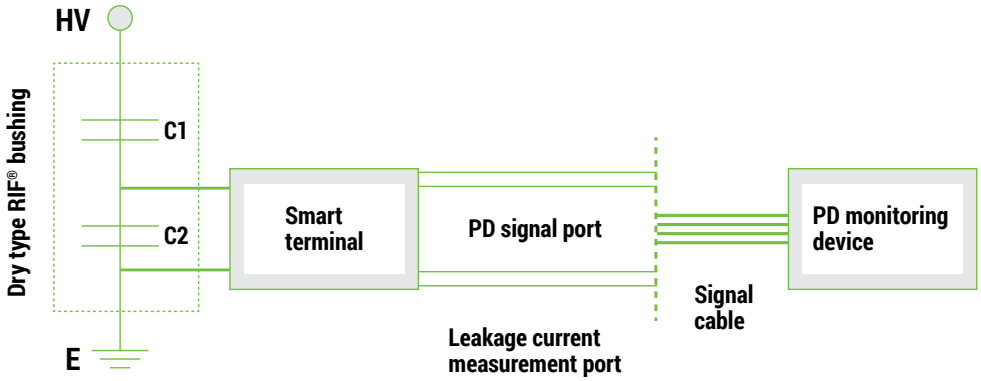


Figure 2.
Signal coupling

If the transformer is equipped with all smart RIF® bushings, the location of the PD within the transformer can be accurately determined. The use of the RIF® bushing as a PD sensing device dramatically simplifies transformer monitoring while providing high PD monitoring reliability and accuracy with its direct coupling and shielding design (Figures 2 and 3). This can provide significant added value for critical system transformers.

Custom-designed "Like for Like" Replacement Bushings: The Strength of the RIF® Bushing Technology

OIP and RIP type bushings have been the industry standard for transformers for many years and in general have performed satisfactorily. However, as transformer assets age, paper deterioration in these bushings can eventually cause the bushings to fail, some even catastrophically. If you are seeing deteriorating test results (power factor) and sealing systems, it may be time to consider a bushing replacement program. When considering a replacement program, it is important to remember the age of your operating transformer inventory and the standards that the originally supplied bushings were built to, which may be obsolete today. 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. Also, to alleviate safety and environmental concerns dry type bushings should be specified for your replacement program.

THE VERY SIMPLE MANUFACTURING PROCESSES INVOLVED IN THE PRODUCTION OF RIF® BUSHINGS ALLOWS FOR COST EFFECTIVE CUSTOM-ENGINEERED DESIGNS WITH MINIMAL EFFECT ON LEAD TIMES. TRANSFORMER OUTAGES CAN THEREFORE BE SCHEDULED WITHOUT THE WORRY OF INSECURE SUPPLY AND LONG DELIVERY TIMES.

The value-added benefits of RIF® bushings over other bushing technologies

Feature	RIF®	RIP	OIP
	Dry type, paperless. (Resin Impregnated Fibreglass)	Dry type, paper. (Resin Impregnated Paper)	Oil filled, paper. (Oil impregnated paper)
Maintenance	Maintenance-free.	Tan δ and C1 need to be checked regularly.	Tan δ and C1 need to be checked regularly. DGA testing older bushings. Leak mitigation.
Explosion resistant	Yes (31.5 kA, 150 ms internal arcing fault test performed on a 230 kV bushing).	No	No
Thermal temperature rating of insulation	130°C A higher thermal margin.	120°C	105°C
Optional built-in insulation condition monitoring	The test tap can also be supplied with an LED sensor that provides visual indication of a real-time change to the C1 capacitance.	Not provided.	Not provided.
Cost to produce custom design "like for like" replacement bushings	Low No re-tooling required for custom designs.	High Expensive re-tooling required for custom designs. Cost and lead time significantly impacted.	High Expensive re-tooling required for custom designs. Cost and lead time significantly impacted.
Cost of ownership	Low Lower production costs than RIP. Maintenance-free. High reliability. Explosion resistant.	Medium High production costs. Regular offline testing required. Expensive long-term storage requirements.	Higher Lower production costs than RIP and RIF®. Regular offline testing required. DGA testing of bushing oil recommended for older bushings. Leak mitigation. Can fail catastrophically.
Long term storage	No special requirements. Can be stored horizontally in their shipping crate.	This technology uses creped insulating paper. Therefore, RIP is sensitive to humidity ingress. Long term storage requires the oil end to be fitted with specially designed metallic covers filled with dry transformer oil.	Must be stored in an upright position to avoid creating air bubbles.

In summary, the RIF® bushing technology provides the safety and environmental benefits that customers want to see in transformer bushings. This technology offers the customer an explosion-resistant design, a proven record for reliability under all types of extreme operating conditions and a maintenance-free bushing.

It is particularly noteworthy that long term operating experience has shown that the dissipation factor and partial discharge level remain stable over its lifetime.

Further to those performance gains, the optional built-in monitoring features increase significantly the value that RIF® bushings can bring to grid operators at a reduced cost when compared to existing solutions.

Last, RIF® bushings are available in custom sizes that allow economical replacement of older difficult-to-procure bushings while improving the transformer's safety and reducing maintenance costs.

Photo: RHM International