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Swedish Bushings Plant Sees Growth in RIP Designs

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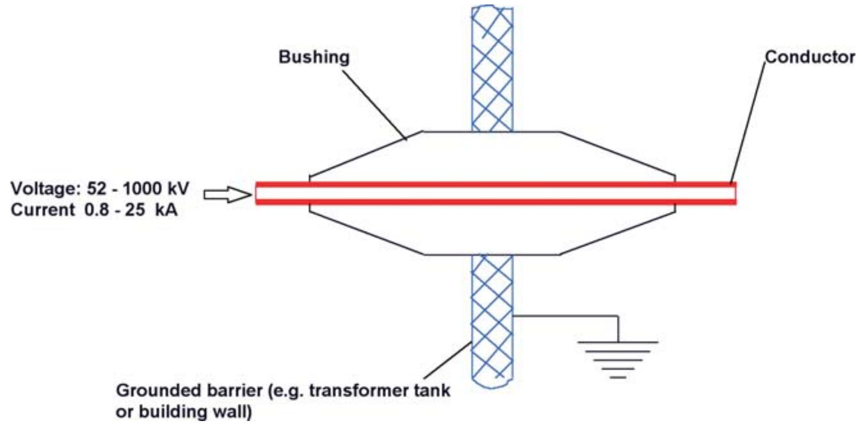
Like the insulator, the bushing is another of those critical components which comprise all electrical networks and whose failure can have very serious economic consequences.

Although many in the electric utility industry still regard it as nothing more than a hollow piece of porcelain with a conductor running through it, notwithstanding its simple appearance, the task performed by a bushing is actually quite extraordinary.



This is because, for apparatus operating at many thousands or even hundreds of thousands of volts, it is almost a Herculean task to adequately isolate the current carrier from the equipment's metallic housing. HV bushings accomplish this task by relying on sophisticated insulation systems able for example to keep a 550 kV conductor operating safely only some 20 cm from the grounded flange.

The basic design of most condenser bushings has not changed in decades and this is perhaps a tribute to how effective the current technology actually is. This design involves special paper wrapped around the conductor as well as metallic foils placed at strategic locations within this wrap. The precise location and the size of these floating metallic electrodes is very important since their capacitive effect controls the electric field along the unit's length and radius.

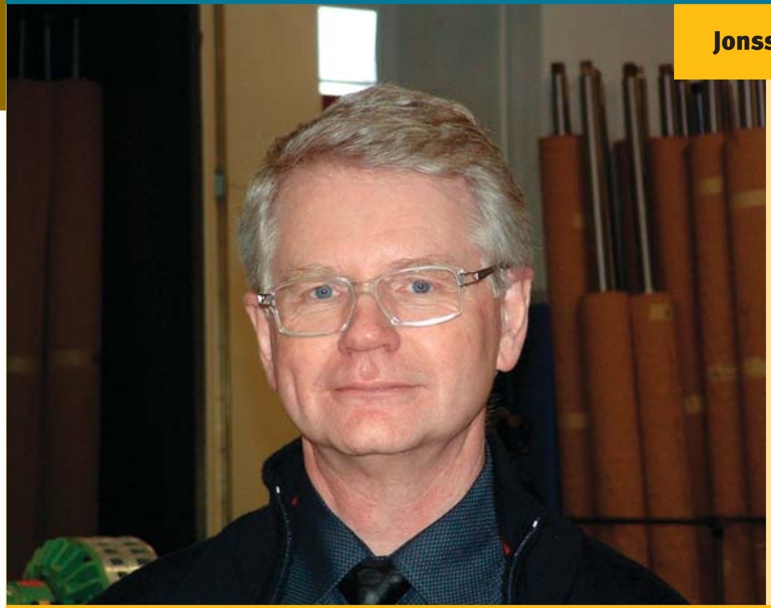
To achieve its required high dielectric strength, no air or gas bubbles can be trapped between the successive layers of paper. Therefore, the cylinder of wound paper and foil is thoroughly impregnated with either oil or a special resin material. Hence the two major technologies for HV condenser bushings: OIP (oil-impregnated paper and RIP (resin-impregnated paper).

In this article, INMR Contributing Editor Dr. Claude de Tourreil tours the Swedish plant of ABB - by far the world's largest supplier of bushings. Although the Ludvika facility still devotes most of its production capacity to the OIP style, developments over the past decade are apparently now fueling sales growth of RIP designs.

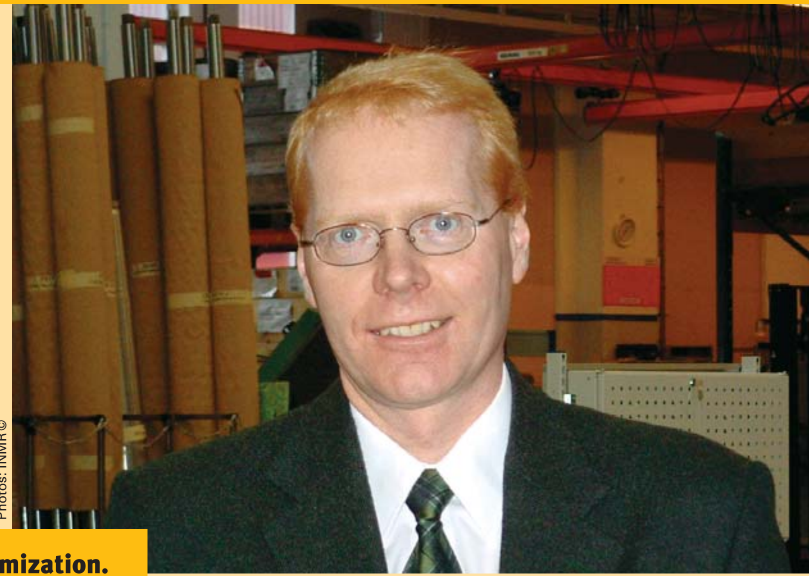
Photo: Courtesy of ABB Comp

145 kV RIP bushings.

Although the majority of the bushings made in Ludvika are still based on OIP technology, the number of RIP units produced annually is apparently increasing steadily.



Johansson. Continued efforts to be placed in process optimization.



Jonsson. RIP manufacturing technology more demanding than for OIP.

Photos: INMR ©

The nearly 100 year history of bushings production at ABB and especially at its flagship Ludvika plant has provided management with an interesting perspective on how the changing requirements of electrical networks has pushed the advancement of this technology. Bushings Vice President Rutger Johansson and Senior Specialist Lars Jonsson look back at some of the major steps in the evolution of the bushing since the earliest days of this plant's operations.

The very first ABB bushing designs were based on an insulation system involving Bakelite material. This type of insulation system, while effective at lower transmission voltages, apparently could not accommodate the move toward higher voltages without an unacceptable increase in the level of internal partial discharge activity.

Therefore, as the Swedish power network developed and moved to 350 kV during the 1940s, the old Bakelite technology had to be abandoned and replaced with OIP dielectric systems, which at the time were regarded as quite novel. Says Jonsson, "with the OIP design, we found that we could now handle even the highest voltage class. For example, by the early 1960s, ABB was able to supply the first 750 kV bushings for the new EHV system of Hydro Québec in Canada."

Computer-controlled machine winds condensers for large RIP bushings.

Winding machine for OIP bushing condensers up to 550 kV.

Photos: Courtesy of ABB Comp

Winding machine for RIP bushing condenser up to 170 kV.

Photos: Courtesy of ABB Comp

Machine winds condensers up to 12 m in length for use in UHV OIP bushings.

After the merger between Asea and Brown Boveri in the mid 1980s, the Ludvika plant and Swiss-based Micafil joined forces in continued development of dry bushing technology. Ludvika also became a major producer of the RIP bushing designs which had first been developed and which today are still mainly manufactured at the Micafil facility.

By the 1990s, notes Jonsson, the demand for the comparatively new dry RIP technology had grown substantially, triggered by increasing requirements for availability and events such as major fires occurring at HVDC converter stations. RIP bushings, being made with a basically dry insulation system and with silicone rubber insulators, have therefore become the preferred choice for these types of applications.

Although the majority of the bushings made in Ludvika are still based on OIP technology, the number of RIP units produced annually is apparently increasing steadily. This, says Jonsson, is due to some significant advantages RIP technology has over the more established OIP design - especially from the point of view of the end user.

Photo: Courtesy of ABB Comp

RIP bushings prepared for vacuum processing and injection molding.

Photo: INMR©

Hedlund. Performance increasingly more decisive a factor in purchasing than cost.

While the technology to manufacture RIP bushings is more demanding than that for the OIP type, this is offset by the fact that RIP technology offers several important advantages to users.

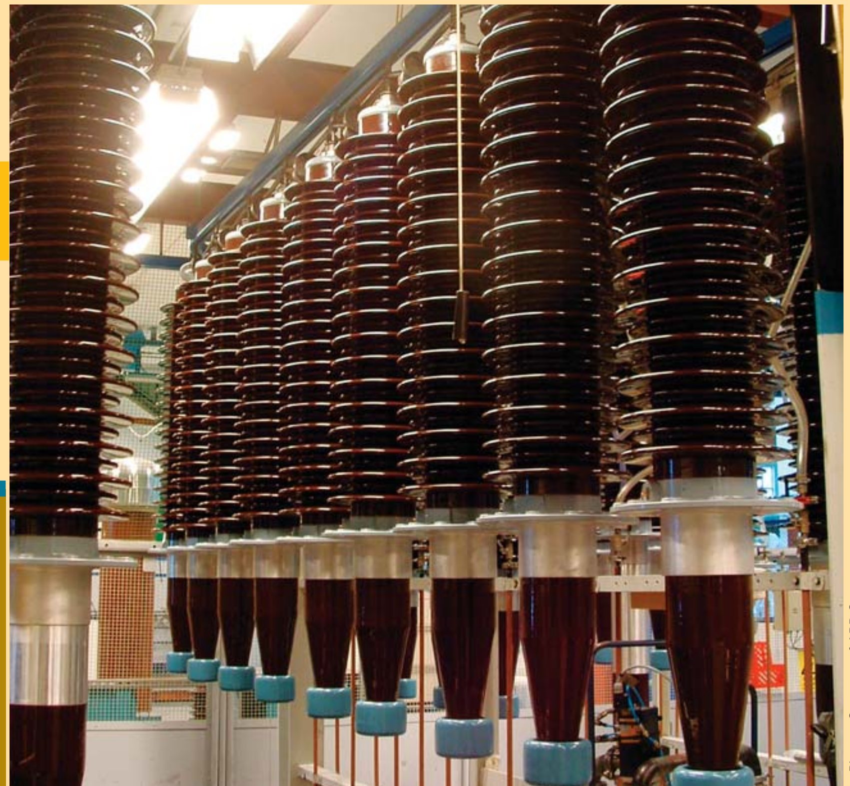
"Given the advantages, the difference between the cost of a porcelain insulator and that of a composite insulator with silicone sheds should not really be the decisive factor in the selection of one bushing type over the other."

Resin impregnation vessels for RIP bushings up to 550 kV.

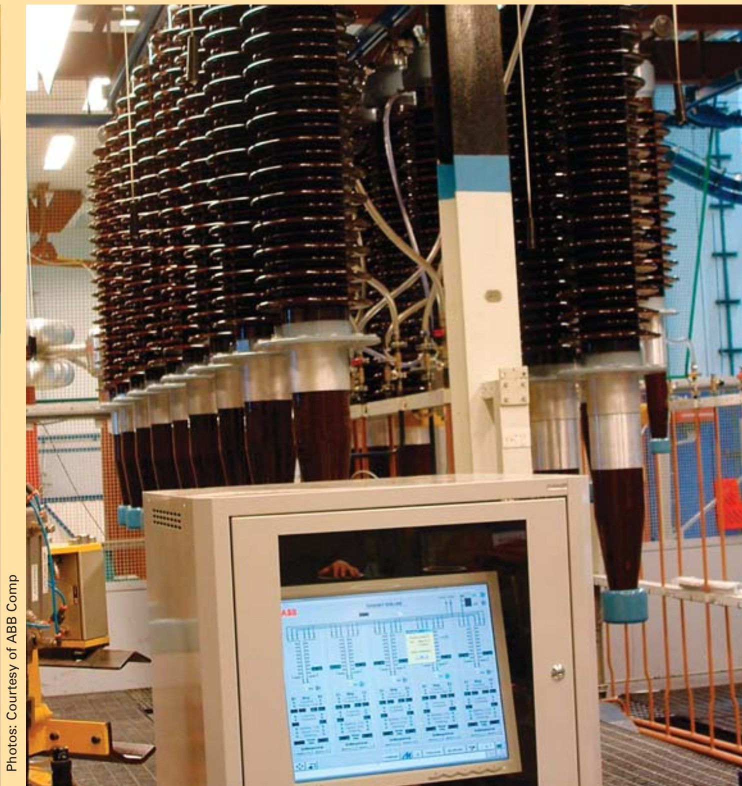
Photos: Courtesy of ABB Comp

RIP condenser fitted with mounting flange.

According to Jonsson, the technology to manufacture RIP bushings is more demanding than that for the OIP type. However, this he notes is offset by the fact that RIP technology offers several distinct benefits such as lower weight, with such designs being up to 50 per cent less heavy than equivalent OIP designs. This makes such bushings easier to transport and store.



145 kV OIP bushings being impregnated with oil.



Photos: Courtesy of ABB Comp

Station for vacuum processing and oil impregnation of OIP bushings.

OIP oil-to-air transformer bushings near test bay. Two 420 units standing vertically in front of four 550 kV units.

Photo: Courtesy of ABB Comp

In addition, RIP bushings have low dielectric losses and, like OIP designs, are partial discharge free. Moreover, they can be installed at any angle and can be energized immediately after installation. Finally, having no oil, they require less maintenance.

Apart from the increase in market interest in RIP bushing technology due to these advantages, there has been another design element change which is now increasingly impacting the bushings industry. This involves the substitution of traditional porcelain housings with hollow core composite insulators.

Bushings, especially of the RIP type, when equipped with composite insulators having silicone sheds are increasingly regarded as an excellent choice when safety and pollution performance are key decision criteria.

For example, in case of explosion or vandalism, there is no risk of fire and the silicone sheds ensure superior performance under polluted service conditions. Yet another consideration promoting increased market interest, say Jonsson and Johansson, is the superior performance of these bushings under seismic conditions.

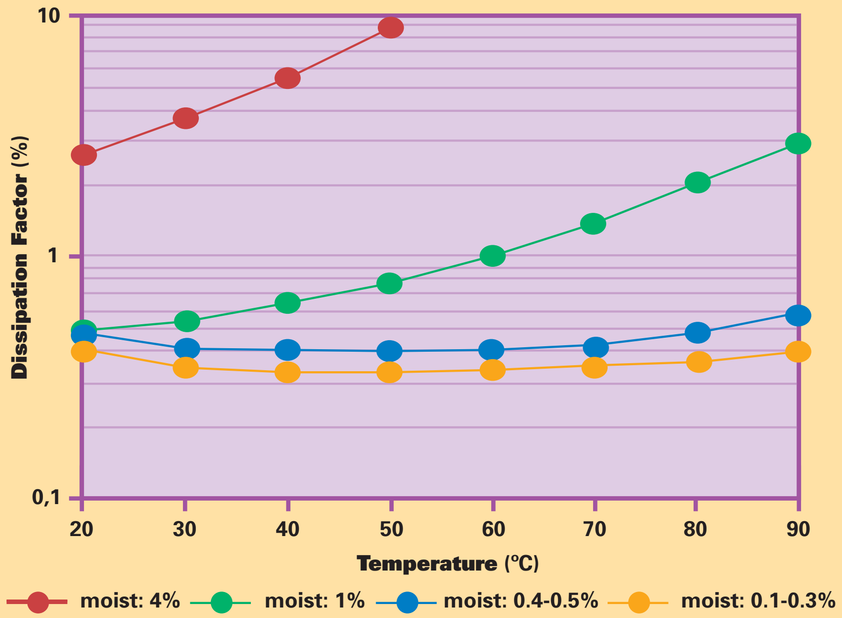
"Given these many advantages," remarks Project Manager, Roger Hedlund, "the difference between the cost of a porcelain insulator and that of a composite insulator with silicone sheds should not really be the decisive factor in the selection of one type over the other."

At the Ludvika bushings plant, both OIP and RIP bushings are manufactured in the same large hall but on separate production lines.

According to Production Manager, Fredrik Petrici, the characteristics of all incoming materials are routinely verified to ensure that they meet very tight specifications. This is apparently especially important since the insulation systems being produced are subjected to very high electrical stresses yet have to deliver problem-free service for several decades. Cleanliness is also stressed, so much so that certain vital production processes are performed only in enclosed areas.

Specialized computer-controlled winding machines of different sizes wrap the grade of paper, which varies by specific type of condenser, as well as the metallic foils onto a central tube or solid mandrel rod. A comparatively small unit is used for RIP bushings up to 170 kV, while a very large winding machine can produce 12 meter long condensers for OIP bushings having this length.

Figure 1: Dissipation Factor Versus Temperature & Moisture Content



With the downsizing of engineering staff at electric utilities, technical support offered by bushing manufacturers has become more important than ever before.

The wrapped condenser paper is then dried to ensure it is completely free of moisture before being impregnated with oil or resin. Impregnation, notes Petrici, is quite a delicate operation and this is much more the case for resin than for oil.

For higher voltage RIP bushings up to a maximum of 550 kV, resin impregnation is performed in vessels of varying size. It is critical that no air bubbles remain in the bulk of the insulation after curing because these could become the site of internal partial discharges which would eventually lead to production rejects.

After impregnation, the mounting flange and the insulator housing are fitted onto the resin-impregnated condenser. In the case of condenser systems for RIP bushings up to 170 kV, the external silicone housing is generally molded directly on to the entire unit.

For OIP bushings, which ABB offers up to 800 kV as part of its standard product range, impregnation with oil is carried out in a special computer-controlled installation after the condenser has been placed inside the insulator and flange assembly.

Each bushing is first put under vacuum during which time a leak test is performed. Subsequently, oil is introduced into the bushing to completely impregnate the internal condenser. Together, these two operations take approximately 24 hours.

Both RIP and OIP bushings then pass through a series of routine tests before being cleared for shipment. Capacitance and dielectric losses are measured up to the power frequency withstand voltage which is maintained for a duration of one minute.

The magnitude of any dielectric losses is directly related to the moisture content of the oil-impregnated paper dielectric system (see Figure 1). Detection of partial discharges is carried out during this entire test. Some of this testing requires fairly sophisticated set-ups because part or all of the bushing has to be submerged in oil and because there are very tight acceptance criteria on partial discharges.

RIP bushings prepared for shipment.

Photo: Courtesy of ABB Comp

Preparation for shipment is then the last step of the manufacturing process. Shipping bushings in the lower voltage range does not usually require any special precautions in the way of packaging. However, large bushings, especially of the OIP type, require sturdy crates which can sometimes measure more than 10 meters in length.

Petrici and Jonsson indicate that, in order to remain a market leader, ABB has invested much in the Ludvika production facility in order to bring it to a level which they regard as state-of-the-art. At the same time, they have tried to optimize all processes for both OIP and RIP designs. Indeed, Johansson sees that future efforts will likely continue to be placed on process optimization rather than on developing radically new designs.

Another area which Jonsson says has received much attention in recent years is technical support. With the optimization (read downsizing) of engineering staff at many electric utilities, which represent the end market for HV bushings, he states that technical support offered by manufacturers has become more important than ever before.

Johansson indicates that ABB owns bushing manufacturing units located all around the world, including Russia, Brazil, South Africa, India and China. The main production centers, however are in Sweden, Switzerland and the United States and this is where engineering specialists are employed to further develop and improve the technology.

As for the impact of growing competition, especially coming from low cost suppliers based in Asia, Johansson feels that this does not represent a serious threat. The labor cost component in the manufacture of HV bushings, he claims, is just not a large part of the total cost of the product and what really counts, he says, are modern facilities and well-trained personnel. ☒

Photo: INMR©

Petrici. Recent large investments made in Ludvika plant.