ABB Invests in Expanded Insulator Production Capabilities

Part 2 of 2

The steady move into UHV by important electricity markets, including China, India and South Africa, has created a sudden demand for bushings, breakers and other substation equipment rated as high as 1100 kV. At such voltages, composite insulators have demonstrated both performance and cost advantages that have helped make them the technology of choice for many if not most such applications.

Responding to this trend, one of the world's largest producers of composite hollow core insulators has recently upgraded its production capabilities to handle increasing volumes of very large pieces.

INMR travels to Piteå, Sweden, to visit ABB Composites – likely the world's northernmost production facility for HV components used in the power industry.

ABB's insulator plant in Piteå.

Recognizing a strategic opportunity in an emerging market, ABB made its initial foray into the field of composite hollow insulators during the late 1990s. At the time, manufacturing of the final products was sited within the company's expansive Swedish facilities in Ludvika, close to manufacturing of related 'downstream' apparatus such as bushings and switchgear. Here, FRP tubes produced by affiliate ABB Composites were primed and over-molded with silicone housings using a unique extrusion process. It was not long, however, before it was decided that there was more sense transferring the molding operation to Piteå in order to bring all production steps under one roof.

ABB Composites, in fact, had already long established itself as a producer of composite insulating materials that, apart from tubes, also included items such as fiberglass loops for cage-type arresters and insulating rods for breakers. All these diverse items had one common link, namely filament winding, which was regarded as the firm's core technology in terms of materials and processes.

"Growing interest in UHV projects during the past several years has created a demand for pieces so large that it was obvious changes would have to be made to move them through our workshop."

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General Manager, Markus Holmlund, reports that since insulator production was shifted to Piteå in 2000, ABB Composites has supplied over 100,000 composite hollow insulators from this facility. Moreover, annual output has been growing steadily to a volume of some 15,000 units, reflecting what he views as a clear trend toward greater use of such housings in place of porcelain – especially for applications in dead tank breakers, arresters and large HVDC bushings.

Holmlund also points out that growing interest in UHV projects during the past several years has created a demand for pieces so large that it was obvious changes would have to be made to move them through the workshop. For example, the filament winding department has been completely re-outfitted with new machinery, replacing all previous equipment. These new machines have been designed to accommodate tubes of 15 meters or more in length and one of their first such applications involved an order for 12 m long bushing insulators for a 1100 kV converter transformer. Says Holmlund, "while it's possible to glue pieces together to achieve such long tubes, we feel there could be reason for concern when it comes to electrical and mechanical properties."

Lars Jonsson, a specialist in bushings at ABB's Ludvika plant, agrees and claims that while a gluing solution has historically worked well for porcelain housings, the same may not hold true for FRP tubes. "With porcelain", he says, "high compressive forces serve to reinforce the epoxy joints. With composite insulators, however, there are no such forces, meaning that weakness might result if the insulators must operate in a very challenging service environment."

FRP tubes have long been ABB Composites' main product group but now there is growing demand for very long pieces.

"Since extrusion sees each shed molded on in a continuous cycle, a lot of effort has been devoted to make this step as efficient as possible to avoid production bottlenecks."

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Automated winding machine pulls fiberglass rovings through resin before winding them onto mandrel. (top) Winding final protective layer onto tube, to be removed later, is final step before curing.

According to R&D Manager, Anders Holmberg, one of the key requirements during winding is maintaining as low a porosity as possible to ensure no partial discharge activity within the tube. "With these new machines," claims Holmberg, "we have already succeeded to lower porosity to the point that it is not really feasible to get much better." Other key requirements during winding are protection of employees as well as control of possible contamination.

For example, employees approaching a certain distance to the machines must wear special breathing apparatus while all raw materials and tubes are checked to ensure no contaminants, such as flying insects, become trapped.

One of the recent areas of R&D at the Piteå plant has involved finding improved ways to extract the steel mandrel after the tube has been wound. Holmberg notes that this is an important yet difficult step for very long insulators since the tubes have that much more weight. Extracting a mandrel without damaging the tube can therefore be difficult and time-consuming.

After winding and curing, tubes are machined to accommodate assembly of flanges, which is accomplished in much the same way across the industry. At this point, the complete outer layer of each tube is routinely peeled off. "This procedure,"

says Holmberg, “guarantees no contamination will be present and also gives us more flexibility when handling the tubes. We know that, whatever happens while moving them through the plant, they will always have a clean surface layer just before start of the molding process.”

Once the outer layer has been removed to yield a fresh surface with no cut fibers, each tube is transferred to an adjoining climate-controlled chamber where a primer is applied to ensure optimal bonding with the silicone housing along its entire length.

Unique Molding Technology

After winding, the second critical process during manufacture of composite hollow insulators involves molding the silicone housing onto the primed tube. In the case of ABB, this is accomplished using a patented helical extrusion technology that sees the rubber material molded directly onto the tube surface, shed-by-shed, using a special tool. This process differs substantially from the technique used by most other insulator suppliers, which relies instead on injecting the silicone material into cavities of a long mold, thereby allowing many sheds to be molded on simultaneously. Insulators up to 220 kV and sometimes higher can be molded this way in a single cycle while at higher voltages two or more injection ‘shots’ are typically needed.

(Top) Cured tube ready for machining prior to attachment of flanges. (right) Tube with outer layer peeled off ready to move to climate-controlled chambers (background). Final cleaning of tube surface before application of primer.

Since extrusion sees each shed molded on in a continuous cycle, Product Sales Manager, Roger Sundqvist, explains that a lot of effort had to be devoted to make this step run as efficiently as possible in order to avoid production bottlenecks. Additional extruder capacity was therefore added in 2011.

“It may appear simple at first glance,” remarks Sundqvist, “but a lot of investment was actually needed to customize both the parts and the process. Once we have the tool, which is unique to the specific profile desired, we can use it for any diameter or shape of tube. Basically, that gives us a fairly complete set of possible insulator geometries.”

Indeed, Sundqvist claims that among the major advantages of this process versus classical injection molding is that it is highly flexible with no need to order expensive molds to achieve different insulator geometries. “Another advantage”, he explains, “is that tooling does not have to be changed to accommodate conically shaped insulators, which are growing in popularity due to savings from reduced volume of internal insulation. This also gives us more freedom in design, such as being able to supply customers with unusual items such as tapered station posts.”

Another benefit of the extrusion molding process, adds Holmlund, is the fact that there is no ‘parting line’ caused when the mold inside an injection machine opens to allow removal of the object. “This”, he says, “means a seamless housing across the insulator’s entire length. Basically, we like to tell customers that our process results in an insulator where there is a one-piece tube and a one-piece housing. There are no joints either in the internal structure or in the silicone.”

Jonsson, from ABB’s bushings unit, provides a user perspective and explains that a seamless housing design is particularly advantageous when thinking over a lifetime of many years service since there is no risk of moisture ingress through seams and joints as the unit ages. But he also emphasizes that perhaps the ultimate benefit of this molding technology lies in being able to easily

Polished steel mandrels having lengths up to 12 or more meters can prove difficult to extract efficiently once tube has been wound.

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produce housings with smooth sheds tips having a relatively large radius so that water drips off them instead of creeping underneath. “This ‘drip edge’,” claims Jonsson, “ensures water rolls-off and also increases tear strength. But the main benefit is minimizing electric field and the risk of flashover.” He also remarks that while such a shed design is also possible with conventional injection molding, it is costly to achieve and therefore not usually seen in practice.

Now that equipment at the plant has been upgraded to allow for the largest dimensions of insulators, current production objectives in Piteå are focused on automating the process. ‘We are not quite there yet,” admits Holmlund, “but getting close. The goal will be to load the product into a machine and basically press a ‘start’ button, leaving the machine to do everything else.”

Another target is leaner production in order to further reduce lead times. Says Holmlund, “while we can already produce even difficult

Continuous extrusion of silicone sheds directly onto tube.

“One of the advantages of extrusion versus injection molding is that there is no need to order expensive molds for each possible insulator geometry.”

items such as 800 kV DC insulators in less than two days, we are looking to eliminate stocks of semi-finished tubes. That means filament winding could one day be done only to order, allowing us to benefit fully from the flexibility offered by our extrusion process.”

HTV Silicone Housing Material

One of the important features influencing the long-term performance of any composite insulator is the formulation of its housing, with some compositions of silicone claimed to offer superior long-term hydrophobicity versus others. In fact, one of the ongoing debates in the

Holmlund (left) and Holmberg examine tapered 800 kV DC station posts, selected as a maintenance-free solution. With traditional injection molding, such designs would normally require different molds and much time to change them.

Large radius shed tips minimize electric field and also ensure water drips off instead of creeping under sheds.

Ends of helical silicone sheds are machined by robots at time of manufacture to ensure same smooth finish at top and bottom of insulators.

industry and among customers is how high consistency (HTV) silicone rubber compares in this regard with liquid silicone rubber (LSR).

ABB Composites uses only viscous HTV silicone material in its extrusion molding and Holmberg points out that it is important for users to understand that it is not material alone but also shed design that will determine how well an insulator performs. Still, he states that in 2007 ABB's HTV composition was directly evaluated against LSR, with two identical insulators, but with different housings, tested at the same time in a 1000-hour salt fog chamber. The first was an LSR-housed unit having a typical design with sharp shed tips and a relatively low angle of shed inclination while the second was an HTV silicone insulator with ABB's greater inclination of sheds and larger shed tips.

According to Holmberg, a chart of findings revealed much less erosion on the helical HTV unit. "LSR has relatively more low molecular weight (LMW) cyclosiloxanes," he notes looking at the result, "while HTV has relatively more filler. But the key issue is not the overall content of the LMW species but rather ensuring that this content must be sufficient to always allow their migration from the bulk material to the surface. Our research has even suggested that this transfer mechanism may be enhanced by the presence of fillers."

Holmberg goes on to state that additional research was carried out with the goal of verifying the long-term stability of these LMW siloxanes in the sheds of ABB insulators. He claims that results confirmed that these key molecular groups regenerate through an equilibrium process in the bulk rubber such that a concentration of about 2% is always maintained. These groups then transfer to the surfaces of sheds at a rate governed by surface conditions and in the amounts needed to maintain hydrophobicity under polluted conditions. According to Holmberg, measurements performed on insulators after 10 years in service showed the same amount of LMW siloxanes in the bulk material as when new, suggesting

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that hydrophobic properties do not degrade over time. "We do not add silicone oil to our formulation," he says, "since we feel it is no more than a temporary measure to achieve good hydrophobicity. Rather, what we have aimed for in our housing material is an equilibrium level that remains constant over time and is sufficient."

Holmberg also answers one of the questions routinely asked by construction and maintenance personnel who handle such insulators in the field, namely what to do if there are minor nicks or tears to a shed caused by handling. He explains that in most cases these do not present a threat to an insulator's safe operation unless they happen to be in the highly stressed region near the live end. In any case, he suggests using an RTV silicone to fit torn pieces together on site or, in extreme cases, constructing a new shed to fit over the original and curing it with a hot air gun.

Says Holmberg, "we have seen problems when maintenance personnel handle porcelain and silicone insulators in the same way in the field. This can lead to permanent deformation of sheds

"It is important for users to understand that it is not material alone but also shed design that determines how well an insulator performs."

or damage to the surface. These people need to be made aware that they should always follow the manufacturer's instructions on how to handle apparatus equipped with composite insulators."

As for cleaning, Holmberg advises that this is necessary only in very severe conditions, in which case manual wiping using a cloth with either water or isopropyl alcohol is usually sufficient. High-pressure water cleaning of composite hollow insulators is neither needed nor recommended since it can cause lasting mechanical damage.

Looking to the future, General Manager Holmlund sees several challenges ahead, even now that the recent upgrading in capabilities and capacity has been completed. One of these is the fact porcelain producers have managed to lower their costs and now offer very competitive pricing in the marketplace, especially at 145 or 220 kV. This strategy, he says, has slowed the rate of transition from porcelain to composite hollow insulators from what took place between 2000 and 2009. For example, equivalence in cost between porcelain and composite insulators now generally occurs at about 550 kV while above this voltage composites are almost always less costly.

He sees the best response should be to continue to re-examine the production process, not only aiming for leaner production but also to optimize use of costly materials, especially the silicone rubber housing. For example, an 800 kV DC insulator can consist of between 200 and 300 kg of silicone rubber, which he feels is more than actually needed.

Holmberg presents results of comparative salt fog testing of LSR and HTV silicone housed insulators.

Another area where Holmlund sees potential for cost reduction is by increasing material utilization factors for tubes. “Filament winding is a complex process,” he remarks, “and contamination or defects during winding can result in loss of the entire tube. Still, with our extrusion process, we have already succeeded to lower costs compared to the alternative of injection molding, which we know well from manufacturing experience in other markets. And we feel we get a better product as well.” ⊠

At the same time, he recognizes that achieving such a reduction may mean extruding thinner sheds and this in turn will depend on improved control over the machine. “We are looking at a goal of reducing the silicone content,” he says, “and we already have a good idea how to accomplish this by adapting our formulation as well as process parameters. The ultimate goal, of course, is to decrease costs.”

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Applications of ABB insulators in Sweden, South Africa and China.