Cut and dry

Low frequency drying process in transformer production can cut energy costs in half

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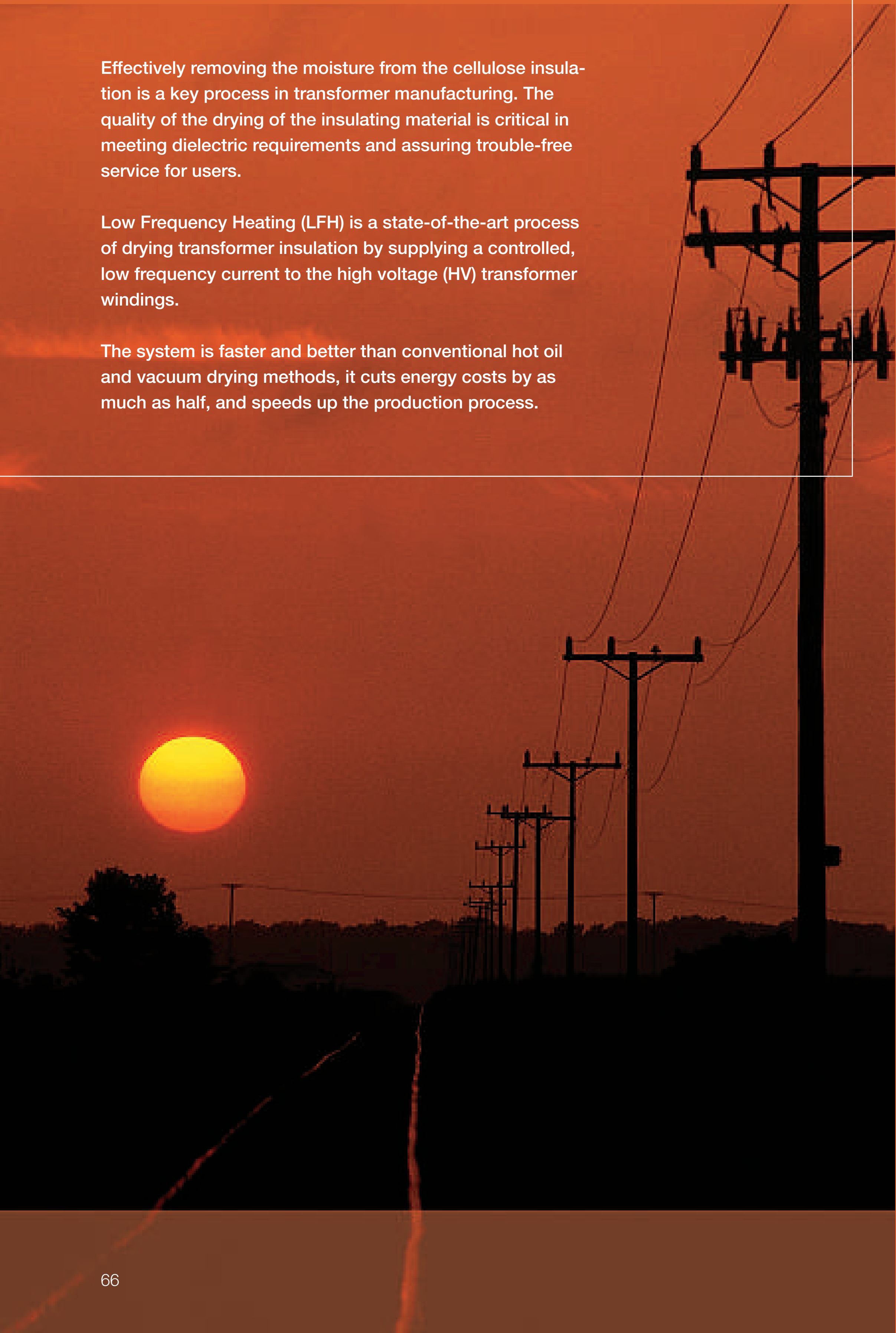


Effectively removing the moisture from the cellulose insulation is a key process in transformer manufacturing. The quality of the drying of the insulating material is critical in meeting dielectric requirements and assuring trouble-free service for users.

Low Frequency Heating (LFH) is a state-of-the-art process of drying transformer insulation by supplying a controlled, low frequency current to the high voltage (HV) transformer windings.

The system is faster and better than conventional hot oil and vacuum drying methods, it cuts energy costs by as much as half, and speeds up the production process.

After a distribution or power transformer has been made, but before it is filled with insulation oil, the solid insulation inside the transformer must be thoroughly dried.

This insulating material is mostly cellulose, consisting of a long chain of glucose rings. If it isn't dry, insulation performance deteriorates, reducing the electrical and mechanical strength of the transformer.

Common insulation drying methods used for drying insulation in large power transformers include: circulating hot air in a vacuum chamber; and vapor phase drying which is also carried out in a vacuum chamber. Special transformer designs, known as shell-type transformers, use a hot oil spray drying method.

The transformer is heated from the inside with a low frequency current supplied to the high voltage (HV) windings.

However, no matter which method is used, the drying process itself is expensive and energy intense. Process time and overall energy consumption are thus decisive factors when choosing a suitable drying procedure.

The National Industry of Norway built the first Low Frequency Heating (LFH) drying plants for distribution transformers between 1984 and 1987.

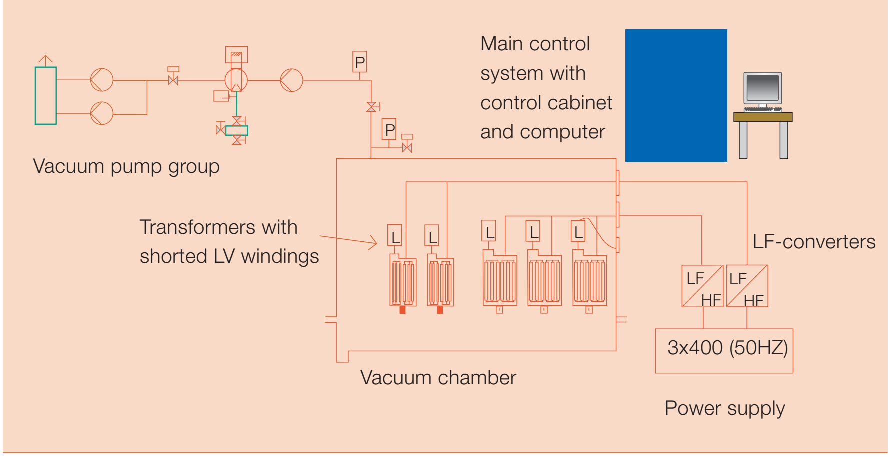
ABB Switzerland Ltd. Micafil further developed the LFH drying method for small power transformers in production, and large power transformers for on site drying.

Instead of using hot air or solvent vapor as the main heat transfer media, the transformer is heated from the inside with a low frequency current supplied to the high voltage (HV) windings.

For larger transformers, LFH is used in combination with hot air circulation.

The LFH concept at work
The temperature of the drying object and the vacuum level are the main factors affecting drying speed and quality.

1 Principle setup of LFH equipment.



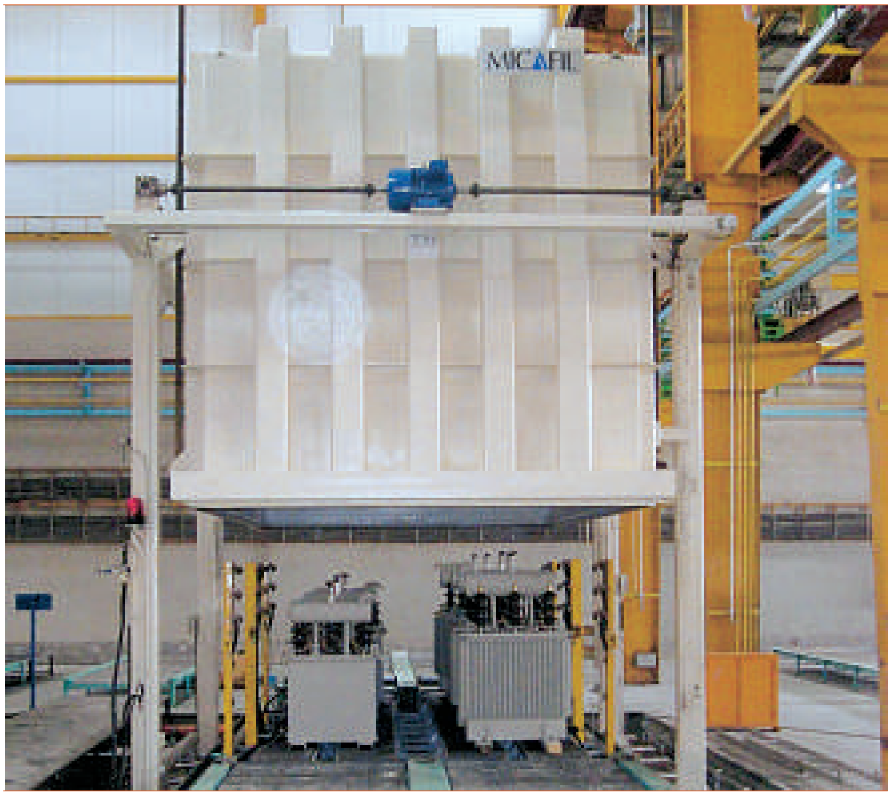
The ABB Micafil LFH process heats the transformer HV and low voltage (LV) windings uniformly from the inside by applying a low frequency current at low voltage levels through the HV windings, while the low voltage (LV) windings remain short circuited.

At low frequency (0.4 – 2 Hz) and low impedance, high voltage problems are avoided and the magnetic coupling ensures a controllable current in the LV winding. HV and LV windings can heat up to typical drying temperatures of 110 – 120 °C, as in a vapor phase plant.

Special controls must be used to closely monitor the drying process, in particular the winding temperature so that hot spots do not form and damage to the insulation is avoided. ABB Micafil uses a state-of-the-art process control and monitoring system to continuously observe currents, voltages and resistances as well as vacuum levels.

Vacuum levels must be controlled because of lower breakthrough voltages in a vacuum, and the temperatures of the high and low voltage windings are

2 Bell type autoclave with a low frequency heating system for processing distribution transformers.



continuously monitored to ensure an optimized process.

The system conducts extremely accurate temperature readings of both the HV and the LV windings, and allows the HV windings to heat separately, if the temperature is below that of the LV windings.

Why do it this way? Because the quality of transformer insulation is vastly improved by using low frequency heat as a drying method compared to the more conventional hot air vacuum system.

That's because the heat is generated in the windings, the perfect location to diffuse moisture out of the insulation. In addition, temperature in the windings can be precisely controlled.

That means process times are considerably shorter compared to conventional drying techniques using hot air and vacuum, and that in turn results in energy savings of up to 50 percent – as much as 2,000 kWh saved in drying a single, small power transformer.

As in any conventional drying system, an LFH heating system is part of a drying installation consisting of a vacuum autoclave or a transformer tank under vacuum, a vacuum pumping system 1, etc.

LFH plants for different applications

Drying distribution transformers in the 25 to 2,500 KVA1) range

LFH resistance heating of distribution transformers results in a simplified plant structure, consisting of a bell type autoclave 2, a vacuum pump stand, LFH converters to heat the transformers internally, and a control system.

Immediately after drying, the control system automatically fills transformer tanks with insulation oil. In this application, only the transformer windings are heated with the low frequency current – the bell autoclave itself is not heated.

> A conventional hot air drying system would require at least twice as long to complete the drying process.

This drying method for distribution transformers therefore consumes the least amount of energy, and offers additional advantages like short drying times, high throughput, easy handling and automatic oil filling after drying.

Drying power transformers in the 500 KVA to 30 MVA range

Drying is carried out in the transformer tank 3. Low frequency current is applied to the HV bushings with shorted LV bushings, and hot air is circulated through the transformer by way of flexible connections.

If the transformer does not need to be retightened after drying (depending on the design), it can be filled with insulation oil immediately following the vacuum phase.

The advantage of this is the transformer is never exposed to the atmosphere after it has dried. After the transformer is filled with insulation oil, nitrogen can be used to pressurize the tank.

A conventional hot air drying system would require at least twice as long to complete the drying process. If a small drying oven circulating hot air consumes 50 kilowatts in 80 hours of use, the total energy needed to dry a small power transformer is 4,000 kWh.

If you reduce drying time by 50 percent, the resulting energy savings from drying a single transformer with LFH is at least 2,000 KWh.

LFH equipment for drying active transformer parts in a vacuum autoclave, for power transformers up to 100 MVA

Upgrading an existing or new hot air vacuum autoclave with LFH equipment can significantly reduce drying time and improve drying results.

Hot air vacuum systems are widely used to dry small transformers, and there is huge potential for upgrading these systems with LFH.

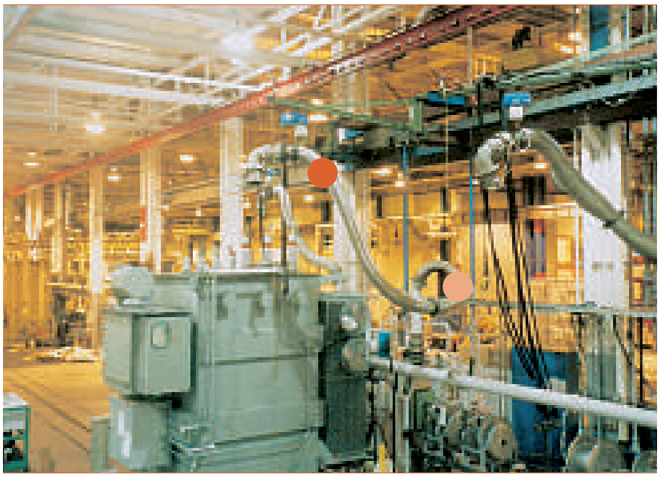
LFH equipment for on site drying of power transformers

Traditionally, the main methods of drying power transformers in the field have been hot oil circulation and vacuum, or in some cases hot oil spray and vacuum. Another method of drying the insulation is by drying the oil.

The hot oil circulation system consists of an oil treatment plant with a heating system, vacuum pumps and accessories. The power requirement for this equipment can easily reach 100 kilowatts. Because the hot oil has temper-

3 LFH installation for drying a small power transformer in its own tank.

● Vacuum connection ● Power panel

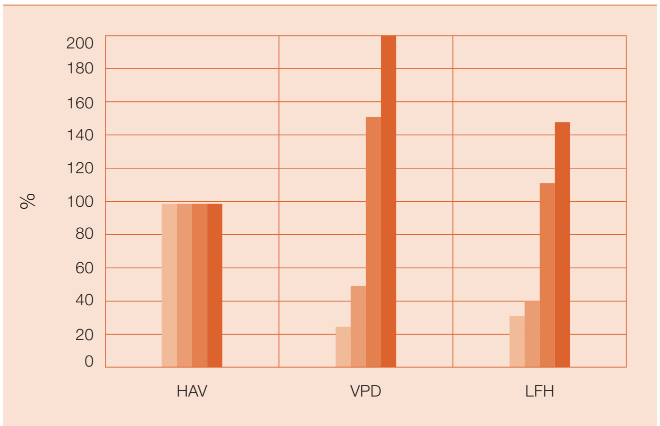


4 Mobile LFH unit for on-site transformer drying.

5 Energy and investment considerations and thermal and electrical energy requirements.

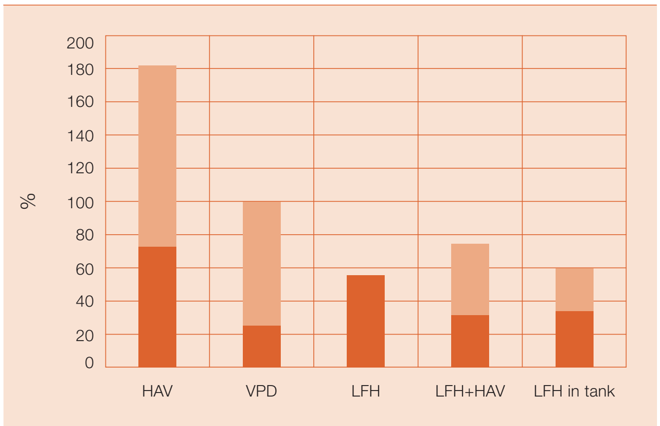
Different drying methods are compared in terms of process time, investment, maintenance costs and energy needed.

Process Time
Energy requirement
Maintenance
Investment



In terms of energy efficiency, the LFH drying systems requires 50 percent less energy than the hot air vacuum system.

Thermal E.
El. Energy



ature limits and there is no heat carrier in the vacuum, drying time is extremely slow – up to several weeks, at considerable energy cost.

The LFH heating system offers a mobile alternative.

An LFH converter with control system and accessories can be driven to a site in a container or on a truck 4. Heating and drying the transformer can be done either in combination with conventional hot oil circulation, or with hot oil spray.

The combination of hot oil spray and LFH heating allows much higher winding temperatures, and drying times compared to conventional hot oil circulation can be reduced significantly, while achieving moisture values below 1 percent.

The dryness level is near the original values of transformers in production. More than 40 power transformers ranging up to 400 MVA have been successfully dried on site using this method.

Measurements on large transformers have shown that the average water extraction rate per day is about 2.5 liters for the conventional hot oil circulation and vacuum method, compared to 20 liters for the LFH and hot oil spray method.

Given a moisture level in the insulation of between 3 and 1.5 percent, LFH offers a drying speed that is eight times faster than conventional methods, resulting in huge savings in energy, personnel and equipment 5.

FAQ related to LFH heating

Q. Are there hot spots during LF heating?
A. Maximum current and heat rise per minute is monitored by the control system. A stabilization time with intermittent heating is included after each heating step is reached, to allow temperatures to equalize throughout the windings. High voltage and low voltage winding temperatures are controlled separately.

Q. Is there moisture condensation on cold steel parts?
A. Moisture condensation has not been observed with equipment functioning normally. Process control and special features within the equipment prevent moisture condensation.

Q. Do insulation parts shrink?
A. On new transformers, shrinkage depends on the transformer design and manufacturing process of the windings. Retightening is required after the LFH drying process as in other drying processes, although some manufacturers of distribution and small power transformers have designed their transformers so that retightening is not required, deriving maximum benefit from the system since the transformers can be filled with insulation oil immediately after the drying process without re-exposing the transformer to atmospheric pressure.

Q. How is moisture removed from thick cellulose insulation?
A. For larger distribution and small power transformers, the LFH process is supported by hot air circulation. Whenever possible, thinner insulation parts should be used. Also, pre-drying thick sections with subsequent oil impregnation should be considered.

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Footnote
1) Larger distribution transformers have an additional input of hot air.