Germany is currently in the process of reinforcing much of its power grid, upgrading lines from 220 kV to 380 kV. This has been made necessary by changing demands on transmission networks in recent years. The increased use of renewable energy sources and the growing international trade in electricity have increased the amount of energy flowing through the grid. This takes its toll on all of the components used in electricity supply, not least the cost-intensive units. It is already apparent that demand for power transformers will continue to rise. One direct consequence of this development can be seen in longer delivery times, with some orders of new transformers now taking up to three years.

There is increasing pressure to find alternative ways to meet the demand for 380 kV transformers. The challenge for manufacturers and operators alike is to find new sources of capital equipment to close the gap in supply, while still remaining cost-effective. Given the large number of 220 kV transformers currently in service, the prospect of upgrading them to handle a high voltage of 380 kV, re-using as many of the components as possible, is certainly attractive.

A new lease on life

An example can help demonstrate the advantages of re-manufacturing. A good choice for this purpose is a type KDRF 315 001 / 220E transformer. Before German reunification, the TRO transformer factory in the Schöneweide area of Berlin produced this type in large numbers for East Germany’s energy sector. These transformers are in use today and still going strong - although some are more than 30 years old.

The engineers from the ABB transformer diagnosis & service centre in Halle were given the task of finding a way to increase the high voltage of a 220 kV transformer to 380 kV, re-using as many components as possible in the process. This meant altering the rated power, ratio and the tapping range associated with it (see table).

Just like a new transformer, the retrofit had to be certified as fulfilling all the requirements of IEC 60076 at 100% of the standardized test voltage.

Focus on the core

The first analysis yielded mixed results. The turrets required for transformers with this voltage could not be fitted to the cover. This was because of the “bridge construction” of the tank and cover, a shape which allows the transformer to be transported by rail in Germany. As a result, it was impossible to re-use the tank and cover.

On the other hand, the core was found to be large enough to accommodate the new windings with the insulation clearances required for the maximum voltage. A commer-

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<th>Table: The main parameters of the type KDRF 315001/220E transformer</th>
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cial viability assessment was then carried out, with the following clear result: Even if the core is the only component that can be re-used, it makes economic sense to do so. (see figure 1)

Before a core can be re-used, it must be tested to ensure that it is in good condition. The first test assesses the overall suitability of the transformer core for re-use. Once the transformer had arrived at the factory in Halle, a 12-hour no-load test was carried out at 108% of the rated excitation. At the same time, the insulating oil was continuously monitored by gas chromatography. During the technical assessment, the decision was taken to reduce the rated induction by 2% in the course of the retrofit. The test therefore corresponded to 110% of the permanent no-load strain after modification. The gas chromatography during the test showed no increase in the concentration of any known fault gases, or only increases that were well below the standard values specified in IEC 60599.

Once removed from the tank, the iron core and its clamping elements were subjected to the usual thorough measurements and tests. This included checking the insulation between active and inactive parts, measuring the capacities and insulation of the shielding and testing the insulation on the laminations by measuring the electrical resistance between them. All of the results indicated that the core was in good condition, which is certainly impressive given that it was constructed in 1972.

Figure 1: 3D model of the transformer core

Putting the plan into action

All of the necessary technical and commercial requirements for putting the idea into action had been satisfied. Now it was time to start work on the electrical reconfiguration and reconstruction. While the windings were being laid out and the necessary electrical calculations performed, a three-dimensional model of the core was created in a CAD program. This provided a vital starting-point for all further tests and adaptations.

The design of the active part was accompanied by numerous specialized tests and observations. Generally speaking, it was possible to apply the standard solutions developed by ABB for transformers in this voltage range. However, there were many details that required special field computations. For example, particular attention had to be paid to the connections between the different windings and between winding outlets and bushings. This presented the team responsible for constructing with a particular challenge. Thanks to a combination of years of experience and the latest in computational techniques on the basis of CAD simulations, they achieved their goal.

Modeling shows the way

Different set-ups for the 400 kV outlets and its insulation were tried

Figure 2: 3D field computation of a outlet and clamping beam
out in the model until the results of the 3D field computation fell within the acceptable range. To achieve this, the shape of the clamping beam near to the outlets had to be changed. This, in turn, altered the mechanical strength of the structure, requiring a further 3D simulation to confirm that it was still acceptable. (see figure 2 and 3)

While the work on the core and simulations were in progress, the individual parts of the transformer were manufactured and assembled - more than 10,000 of them in total. Following the task specification, the next step was to carry out a complete type test in accordance with the latest version of DIN EN 60076, including temperature rise tests and voltage tests at test level of 100%. In addition, extensive special testing was carried out at the customer’s request. As well as ascertaining factors for the transfer of lightning impulses, the tests focused on noise measurements, all under predefined conditions designed to simulate a normal working environment. Thanks to the 2% reduction in core induction at rated voltage, the sound power level (Lw) was reduced from 96 dB(A) to 93 dB(A) during no-load and ONAN-operation. When the high and intermediate voltages were short-circuited at rated current, the sound level reached 85 dB(A). All of these values were within the range set out in the task specification. The same was true of the no-load and short-circuit losses as well as the short-circuit voltages, so all of the guaranteed values were reached and/or fell within the range of tolerance. (see figure 4)

The transformer left the ABB site in Halle on time and ready for service after its thorough check-up and overhaul. Complete with its “new attire”, the core has recently been reinstalled and put online.

Summing up

The demand for transformers is on the rise. So are the prices. The vast demand in world markets for raw materials like copper and steel, particularly on the part of India and China, is pushing costs up even further.

The engineering solution from the ABB transformer factory in Halle has proved that 220 kV transformers should not be destined for the scrap-heap. We need to get away from the idea that “old” automatically means “inferior”. The reward for this new thinking is a quality technological solution at a clear cost-efficiency. Upgrading 220kV transformers to 380kV opens up new options for network operators, providing an attractive add-on to buying new.

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