Extreme maintenance

No location too challenging for an on-site repair!

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When a transformer fails in a plant, it is usually shipped back to the factory for repairs as soon as possible. However, what do you do when the transformer weighs more than 180 tons and the nearest factory is 1200 km away? And additionally, the state of the roads makes transport slow, expensive and increases the risk of damage? This is exactly the situation that confronted ABB when called upon to repair a transformer at the Itaipu power plant on the border of Brazil and Paraguay.

Rather than move the transformer to the factory, a complete factory was taken to the transformer! A fully equipped workshop including clean room was constructed on site. The transformer was taken inside, dismantled, repaired, reassembled and tested locally. This flexible and innovative approach reduced down time,risk and cost for the customer.

Power transformers represent a considerable investment and customers expect to keep them running for as long as possible – optimally and trouble-free. However, the older a transformer gets, the higher the probability that a breakdown will occur. The service and support side of ABB Transformers is there to ensure their continuing performance. Guided by diagnosis and preventive maintenance as well as regular inspections, proper service work can be implemented by their customers, either utility or industrial, to ensure optimum availability of his transformers.

Refurbishment, service and repair as well as on-site work are growing in importance because the average age of power transformers around the globe is approaching the final phase of their lifecycle. A power transformer failure can, and usually does, have serious consequences through the loss of electricity supply. The financial issues related to such a shortfall are significant. Penalties for non-delivery are extremely high for the simple reason that a non-delivery situation directly affects the customers of the utility, who in the worst case have to shut down their own production facilities causing severe economic difficulties. This negative chain reaction also demonstrates the responsibility that power suppliers are faceing and explains why reliability and availability are such important key words within the industry.

Service portfolio and on-site repair solution for a longer life

ABB covers a wide range of service and support activities in order to guarantee that transformers stay on-line. Regular maintenance carried out professionally and proactively contributes towards optimum transformer performance.

The main areas of service and support are:

- On-site preventive maintenance
- Spare parts supply
- Condition assessment including advanced diagnosis and monitoring
- Engineering support
- Workshop repair
- On-site repair or retrofit.

ABB workshops and service centers worldwide provide a complete portfolio of solutions to care for transformers produced by all manufacturers in all phases of their life cycles. Of course, all the work carried out by ABB's experienced and professional staff follows accepted international standards.

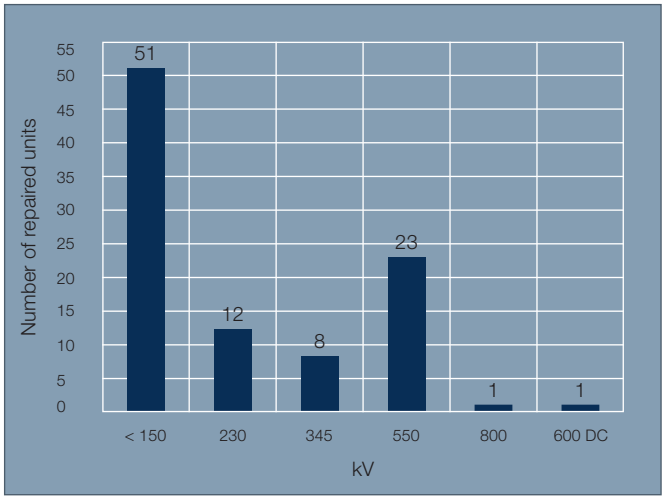
ABB makes efficient use of state of the art tools in its workshops around the world to design, produce and test the transformers repaired in its factories. However, ten years ago, several large utilities in different countries, but especially in Brazil and South America in general 1, asked for new solutions that would allow the repair of large units directly on site.

These requests were driven mainly by transport issues in remote regions or in areas with difficult transportation conditions. The challenges for the transformer owners were to find a way to:

- Reduce repair lead-time of failed units.
- Reduce transportation costs.
- Avoid risks linked to transporting aged units under tough conditions.
- Ensure the same high quality standard was available as for work done in repair shops.

1 Map of South America showing locations of on-site repairs of high voltage power transformers.

2 On-site complete repairs from 1992 to 2003.



Several manufacturers have offered site repairs for many years, but ABB's goal was to set up a professional process to provide a quality and cost effective solution.

An important component of the on-site repair process is the high voltage test capability. High voltage on-site tests for power transformers are one of ABB's important developments. This is of growing interest, either as part of transformer commissioning or as a diagnostic assessment tool after a failure or as a preventive check. This capabilty is also used as an acceptance test after transformer repair or refurbishment.

A detailed on-site repair project

Experience counts

ABB has a global presence, which demands the highest of standards in differing economic and environmental situations. ABB Power Technologies in Brazil has carried out more than 96 on-site repairs of transformers for electric power supply companies as well as industrial plants. Not all of these transformers were ABB transformers, hence the service teams were faced with different technologies.

2 shows the repaired transformers in their various power classes. Since 1992 more than 520 transformers have improved their performance and reliability after on-site repair work was carried out.

Background Situation

This on-site repair study is centered on the Itaipu Power Plant 3. This is the largest hydro power plant in the world and is situated on the Parana River, bordering both Brazil and Paraguay. It has a generation capacity of 12600 MW with an additional 1400 MW coming on-line during year 2004. The power plant is connected via two main transmission links to the heavy industrial load centers of Sao Paulo and Rio de Janeiro. The distance from the power plant to the main centers is more than 900 km. The HVDC transmission system is located near Foz do Iguaçu and has been in operation since 1984.

Repairs of high voltage power transformers

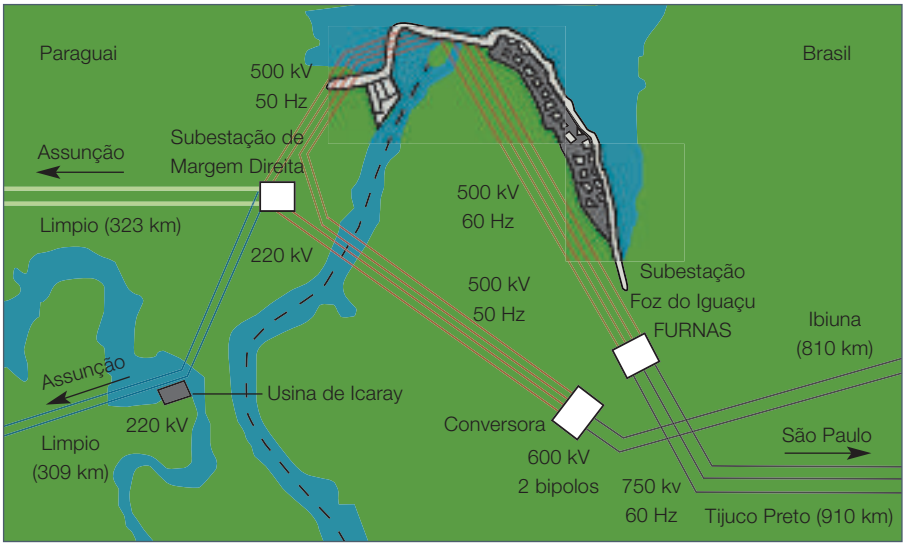
For many parts of the world a large distance between generation and consumption centers is typical. Such geographical difficulties are challenges the ABB service teams often have to face. The importance of the stabilizing effect the Itaipu power system has on the whole Brazilian network and the associated economy must not be underestimated.

Scenario

The story begins in 2002 when an electric failure damaged one of the converter transformers installed at Foz do Iguaçu. The required repair work entailed a complete replacement of the winding blocks.

The larger transformer factories are centered around Sao Paulo. This means that the distance that would have to be covered by large and heavy custom

3 The substation at Foz do Iguaçu and its importance in the transmission system.



trucks is approximately 1200 km (one way). In this particular case the time involved would have been about 60 days as a result of the geographical and infrastructure conditions. The total cost for such a site-factory-site solution would be more than $1 million. In addition the risks of damage as a result of the complex transportation route should not be underestimated.

The decision was made to carry out the operation on-site. This was to become the first on-site repair of such a large HVDC converter transformer in Brazil.

The on-site repair process

An experienced team of transformer specialists are required to perform on-site repair of high voltage transformers. This is where the quality and standards of the experienced ABB service team has its chance to show its competence. First, the site repair facility must be erected and the transformers hauled there. The draining of oil and disassembly of the active part follows. The necessary core repairs are carried out and new parts are installed. Now re-assembly of the active part begins followed by on-site drying. Finally, the on-site routine of high voltage testing takes place to ensure that all is well.

4 The metal house erected for on-site repair at Foz do Iguaçu.

Erection of the site repair facility

In order to carry out such an on-site repair it is necessary to erect a repair facility with a solid foundation. In this case the metallic housing had an area of 500 m² and was 20 m high 4. It was erected on a spare transformer base. Environmental circumstances had to be taken into account: The repair facility was built to be able to withstand winds of 150 km/h and to remain watertight under heavy rainfall. Within the metal exterior, there was an internal extra-clean room. This provided a controlled environment for assembling the active part. The weight of the transformer's active part was approximately 180 tons and the lifting equipment used had a capacity of 400 tons 5.

Additionally, dry air generation stations (air dew point of < –30°C and air outflow above 400 m/h) were installed to guarantee that the transformer's active part as well as the extra-clean room was under a continuous and controlled dry airflow with a positive pressure. A mobile station with vacuum, drying and oil treatment equipment was brought on-site. The necessary mobile lifting devices (mobile cranes) and the lifting devices needed for the assembly and pressing of the active part were also erected.

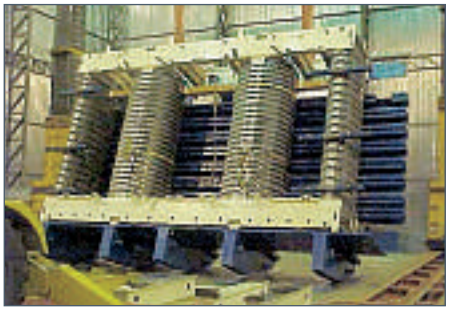
The project step-by-step

After the draining of oil from the active part, the upper core frame was opened and the upper core yoke disassembled. The opening of all internal lead connections and the disassembly of the HV winding connections and the pressboard lead structure followed. The next step was the disassembly of the windings, main insulation and core-winding insulation. Special lifting devices driven by the mobile auxiliary crane were used to remove the windings from the core limbs.

The repair was carried out including the replacement of the complete pressboard core insulation by fiberglass material. In order to retighten the core it had to be placed in a horizontal position. For this purpose a mobile core stack table capable of supporting 180 tons was constructed 6.

5 Lifting equipment inside the metal house.

6 Repairing the core. Assembled mass: 173 tons.



All parts delivered from the factory, such as windings and main insulation, had already undergone intensive in-factory tests. Measurements such as winding ohmic resistance, voltage ratio (with auxiliary test core), measurements of leakage magnetic flux and applied voltage between parallel conductors had been recorded.

The next step in the process was the on-site assembly of the active part and its tank, final pressing and the external assembly.

The on-site drying process is carried out after the assembly and tanking of the transformer's active part. It is made up of a series of successive cycles of vacuum and hot oil circulation. After each drying cycle, the control parameters are checked. These are vacuum time, vacuum pressure, core temperature and insulation and oil temperature. The quality of the on-site repair process, with its drying, low final moisture and high quality insulation of the transformer, is comparable to an advanced in-factory drying process.

Quality control is, of course, a very important aspect. Every phase of the process is recorded according to internal procedures certified in compliance with ISO 9001 and ISO 14001.

After re-assembly the final electric tests were carried out.

On-site electric tests

A complete set of mobile testing equipment was shipped to the repair facility. This included the following components:

- Variable frequency 60–240 Hz motor-generator group. There are three motor-generator groups available: 300 kVA, 850 kVA and 2MVA. The proper group is selected according to power and voltage rating of the transformer.
- Step-up and regulating transformers.
- Reactive power compensating capacitors and reactors.
- No-load and load measuring system.
- Partial discharge measuring and monitoring system as per IEC60076-3 and IEC60270.

7 depicts a general single-line connection diagram of the test setup normally used for HV power transformer on-site testing.

The following on-site tests were carried out:

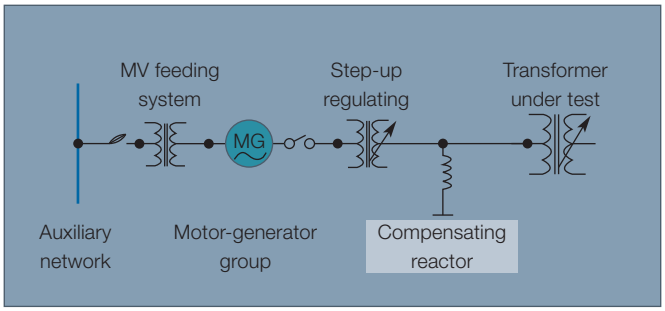
- Routine tests: Insulation resistance (core and structure-core); polarity, phase angle displacement and phase sequence; voltage ratio; measurements of winding ohmic resistance; insulation resistance measurements (Megger), insulation power factor measurements (Doble) and insulation capacitances of windings and condensing bushings; verification of accessories, functional tests and thermometer calibration.
- Loss measurements: no-load losses and excitation current at 90%, 100% and 110% of rated voltage; load losses with reduced current and short-circuit impedances.
- Dielectric tests: applied voltage, long-term induced voltage (1 hour) with monitoring of partial discharges and voltage level up to 150 percent of rated voltage; no-load energization with rated voltage during 24 hours with monitoring of partial discharges.
- Special tests: frequency response (FRA), in some cases.

Project conclusion

The successful conclusion of the project demonstrates the value of on-site repair work as a solution in areas that present geographical and infrastructural challenges with regard to transportation.

The whole project was a cost effective and reliable solution, which reduced the mean time to repair, increased transformer availability and avoided transportation risks. ABB's dedication to service has provided the operators with a reliable and long-lasting solution providing benefits at all stages.

7 Test setup: single-line-diagram.



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