Mobilizing transformers

Fast deployable modular transformers for high-voltage transmission systems

MIGUEL OLIVA – The installations that deliver power to your home or factory are designed and maintained to provide the highest levels of reliability. However, despite good design and maintenance, failures can never be ruled out altogether. A severe incident can put a transformer out of service for months or even over a year while a replacement is procured or heavy repairs effected. To be able to serve customers in the interim, an alternative is needed. One solution is to deploy a mobile transformer. Such a transformer is sufficiently small and light to be able to be moved by road, either in one piece or in a way that permits rapid assembly and commencement of service. Until now, mobile transformers have been limited to 230 kV. Through innovative design, ABB has now been able to deliver a 400 kV mobile transformer.

The continuity and quality of the power supply are the two most important operational objectives of electrical utilities. Managing the increased demand for power requires new investments and even more effective utilization of existing equipment. In that context, utilities need to have strategies in place to minimize the operational and maintenance costs while reducing the number of forced outages and failure rates.

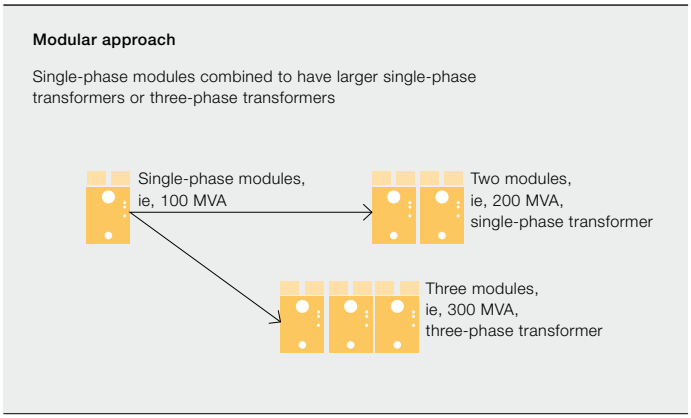
Power transformers represent a significant asset in the utility delivery chain. They are one of the most important and costly components and critical nodes in the high-voltage transmission networks. Large power transformers are a major concern to any electric utility when it comes to reliability. Transformers are critical to the operation of the delivery system and their replacement requires considerable time and expense. A transformer is a complex piece of equipment representing high cost, engineering expertise and manufacturing effort. Furthermore they have relatively long delivery times and require adequate maintenance to optimize operation and life expectancy.

Depending on the strategic importance of the unit, the unplanned unavailability of a transformer can imply a significant loss of production or income for the utility and have a major impact on the system. In the extreme case, a failure can lead to a blackout with the corresponding loss of public image, customer complaints and administration fines.

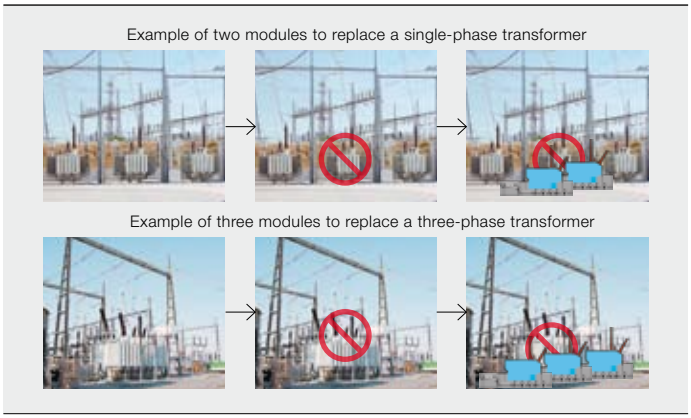
To avoid these problems, contingency planning is required to be able to react to the failure of transformers that would result in prolonged outages. There are different contingency planning strategies

> The time required to install a transformer in an emergency can be improved from several weeks or months to 10 to 15 days including mobilization and transportation.

1 The flexiformer: Smaller sized single-phase transformer modules are combined to build a larger unit



2 Modular concept: 400kV mobile transformer for contingencies



for incidents related to power transformers. These include:
- Meshed grid
- Redundant transformers
- Standardization of transformers
- Spare units
- Polytransformers
- Mobile transformers

The procurement of a new transformer with a required specification consumes from several months to more than a year. Installing an existing spare may take from weeks to months as it involves transportation, hauling, assembly and other activities if the replacement unit is not already at the site of the failure. Emergency recovery plans with quick response are essential. Mobile transformers can play an important role here.

Mobile transformers are not a new concept. They have, however, traditionally been limited to 230 kV applications. Typical mobile transformer characteristics range from 35 to 245 kV with power ranging from 5 MVA to 100 MVA three-phase units. High temperature insulation is normally used to minimize dimensions and weights. To permit fast deployment they are transported fully assembled and already filled with oil.

The project's main focus was to get the maximum rating within the existing shipping restrictions for road transportation.

Increased weight and dimensions are the major constraints for making mobile transformers for ratings above 230 kV. Hence the capability of mobile transformers has hitherto been limited to that voltage level. ABB has been working to address this challenge and provide solutions for quick-reaction contingency plans for transmission networks of higher voltage.

The concept

Power transformers above 100 MVA are relatively heavy and large. Their transportation requires dedicated vehicles, thorough evaluations and planning as well, and require administrative permits which can take a long time ➔ 4.

ABB thus set out to meet the challenges of MVA rating and transportability for mobile transformers. The requirement was to manufacture a transformer of large rating in reduced dimensions, permitting it to overcome shipping limitations so that it could be moved by road and using simplified administrative procedures.

ABB adopted a modular approach. Smaller sized single-phase transformer modules are combined to build a larger unit ➔ 1. For example, two single-phase modules for a larger single-phase unit and three modules for a three-phase unit ➔ 2. To provide optimization in terms of size, shell transformers are used. Some advantages of shell transformers are:
- Compactness of the design with magnetic core enclosing the windings

3 Mobile transformers at a glance

Main features of the high-voltage mobile transformer:
- Modular concept for 345 kV, 400 kV and 525 kV applications
- Fast deployability
- Quick and simple transportation
- Possible polytransformer units to cover additional number of voltages

Advantages and applications of mobile transformer of higher rating:
- Contingency plans with quick response and flexibility to recover service in critical substations in case of transformer failures with a reduce time target
- Temporary installations for important events and for allowing temporary increased capacity in critical areas in case of peak load seasons or for specific events
- Reduction of insurance premiums
- Reducing Homeland Security concerns
- Reduction of risks of blackouts, avoid administration fines for loss of service and reduce claims and complaints from customers
- The return of the investment is immediate once it is needed and the cost of opportunity is very high

4 Transportation by road of a standard large transformer requiring special permits and vehicles

5 The mobile transformer is ready for transportation

to match the transportation and hauling restrictions.
– Horizontal lay-down operation that allows better transportability and better optimization of the transformer design.

The transformer is assembled onto a platform vehicle to allow quicker transportation by road, with a minimum of administrative permissions. Traditional cellulose insulation was selected because high-temperature insulation had hitherto not been used for applications beyond 230 kV. Research work is currently ongoing to use high temperature insulation for increased ratings within the same dimensions or to reduce weights while maintaining the rating.

An important aspect is the fast deployability of these transformers. If transportation limitations governing weight and dimensions are exceeded, the transformers must be shipped partially disassembled and without the insulating oil.

The transformer design is customized to the application and aims to minimize any disassembly work. The transformer can also be engineered to be transported and assembled with coolers located on the vehicle. Depending of the type of external connections, the high-voltage bushings need to be removed for transportation, although plug-in terminations may be used.

The final assembly works had to be carefully planned to take into account all the practical aspects: oil filling, commissioning and testing while minimizing the time needed to put the unit into service. The installation time can be reduced if the unit is stored so as to be well-prepared for shipment and personnel are well trained for their task and the processes are defined.

With this concept, the time of reaction can be improved from several weeks or months to 10 to 15 days including mobilization and transportation. This provides greater advantages for the utilities to quickly restore failed transformers in the transmission network ➔ 3.

A practical case

The fast deployable mobile transformer concept was developed to support strategic contingency plans for the Spanish transmission system operator and owner of the 400 kV system (REE: Red Electrica). This is the world's first reference of a 400 kV mobile transformer.

A collaborative approach was used to take advantage of synergies between ABB and the utility. The rating of the single-phase modules, 117 MVA, and other

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characteristics such as the impedance were selected to be able to substitute the utility's standardized system transformer (200 MVA single-phase units) and provide a high rating as a three phase unit (350 MVA) while fitting within the dimensional restrictions for road transportation.

A polytransformer was built with 400 kV on the high-voltage side and a selectable 230 kV or 138 kV on the low voltage side, with three different voltage levels on the tertiary side (33 kV, 26.4 kV and 24 kV). This facility provided additional usability and extended field of application of these transformers permitting them to substitute a wide number of units of the utility's existing fleet (either single or three phase).

The possibility of using of an on-load tap changer was rejected in order not to add additional weight and volume. However a de-energized tap changer was included to add some extra functionality and some off-line regulation capacity.

The project's main focus was to get the maximum rating within the existing shipping restrictions for road transportation. A horizontal lay-down shell transformer was used. The final product represented less than 60 tons for transportation, and less than 3.4 m height and 2.7 m width.

The transformer was prepared for mobile transportation being assembled onto a road vehicle, without oil → 5. It was agreed with the utility to ship it with the bushings and coolers disassembled. A thorough assembly plan was prepared together with the utility in order to minimize the assembly time on-site and have service personnel adequately trained. The utility also developed all the arrangements needed for interconnection to the system, arresters and insulators for the line connections, cable connections, controls, etc. Safety and the environmental aspects were also addressed through a portable oil receptacle in case of oil leaks.

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Three 400 kV units have been built. To be prepared for an emergency situation, the utility performed a trial installation which permitted it to verify the performance, the reaction time and the training of their personnel in a single exercise. The utility was satisfied with the test result, which in a real situation would have represented a quick recovery of service.

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