Improving Efficiency and Safety in HV Circuit Breaker Testing: How Should India Embrace Best Developed Practice?

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Abstract

The Indian electrical power network is in a major phase of change with substantial growth and asset development planned over the next 30-40 years.

Electricity deregulation changes the business environment for utilities, switchgear owners and service companies. Deregulation has shown to lead directly to increased emphasis on efficiency of operations, maintenance and service levels – all of which impact network technical activities. International experience in the domain of substation circuit breaker diagnostic test has shown demands for shorter time periods for testing, whilst the switchgear is less and less available to be taken out of service.

Many of these drivers are not new to private network operators (e.g. in heavy industries) where overall plant operation is directly linked to reliable availability of critical power supplies.

In the Indian context, utilities and industries may not be facing the same problems of reducing availability of expert technical staff to undertake testing of critical switchgear assets. However, India's rapid economic growth and increasing visibility within the International community means that there will be greater pressure for reliable electricity supplies at the same time as efficient development of critical grid assets. Also, the Indian network operators need to maintain and develop the industry safety record.

Whilst concerns have been raised in the Industry on all of these business drivers, there are new technical solutions that will provide Indian network operators with better, faster and higher accuracy circuit breaker testing regimes. At the same time, such new techniques will allow test engineers to complete their work in a safer environment, significantly improve their management and presentation of test records, together with improved results traceability thereby providing additional value to network operators.

The authors will present a review of international best practices in the testing of HV circuit breakers and will explain why such new test techniques are very relevant to the forthcoming growth in investment and development of the Indian electricity grid.

Introduction

Network Operators in India, as elsewhere, are faced with the expectation of stakeholders (customers, regulator, government) that they will be able to continue to "do more, with less." Unlike many other network operators, India continues to expand its networks to reach those who have not previously been connected to the network and continues to reinforce its networks to provide sufficient capacity to meet the increasing industrial and commercial demands.

There will be significant emphasis upon investment into the core transmission and distribution (T&D) infrastructure in India for the foreseeable future. As a consequence, the testing and commissioning of high voltage circuit breakers will be a critical component in the overall growth plan. In parallel, India's plans to push forward with electricity network deregulation will increase emphasis upon efficiency and effectiveness of both Capital and Revenue expenditures.

India has a major opportunity to benefit from new techniques and technology developed and applied in other leading Industrial nations that have been proven to be adapted to the post-deregulation business environment. Further, they will allow India to take full advantage of the business benefits associated with increased safety for personnel involved in high voltage switchgear testing. In complement, the application of new techniques in substation data management will give India every opportunity to manage its network development in a safe and orderly fashion.

Network Development and Deregulation: Issues for Indian Utilities

Faced with huge increases in demand and improvements in quality and reliability of supply to support the nation's economic growth, network owners and operators are taking every opportunity to become more efficient and effective. International experience of electricity industry deregulation has been seen to lead to change in the business environment for utilities, switchgear owners and service companies. Deregulation has been shown to lead directly to increased emphasis on efficiency of operations, maintenance and service levels – all of which impact network technical activities. International experience in the domain of substation circuit breaker diagnostic test [4] reveals demands for shorter time periods for testing, particularly because higher utilisation factors will mean that the switchgear is less often available to be taken out of service.

In the Indian context, utilities and industries may not yet face the same problems of reducing availability of expert technical staff to undertake testing of critical switchgear assets as is seen in other leading industrial nations with the impending retirement of the Post War "Baby Boom" generation. However, India's rapid economic growth and increasing visibility within the International community means that there will be greater pressure for reliable electricity supplies, at the same time as efficient development of critical grid assets.

Internationalisation of business brings new challenges: substantial investments by global corporations will bring with them new requirements for increased emphasis on Health, Safety and Environmental compliance. It is therefore apparent that the Indian network operators, industrial companies and contractors alike will need to establish and develop industry safety programs and records more aligned to International best practice.

A review of current practice with recommendations for changes

Test preparation

Preparation for high voltage circuit breaker (HV CB) testing involves the safe isolation of previously energised high voltage equipment. Earths are then applied to the isolated equipment, although present practice sometimes requires the omission of one earth to enable correct operation of the test equipment. See Figure 1, below.

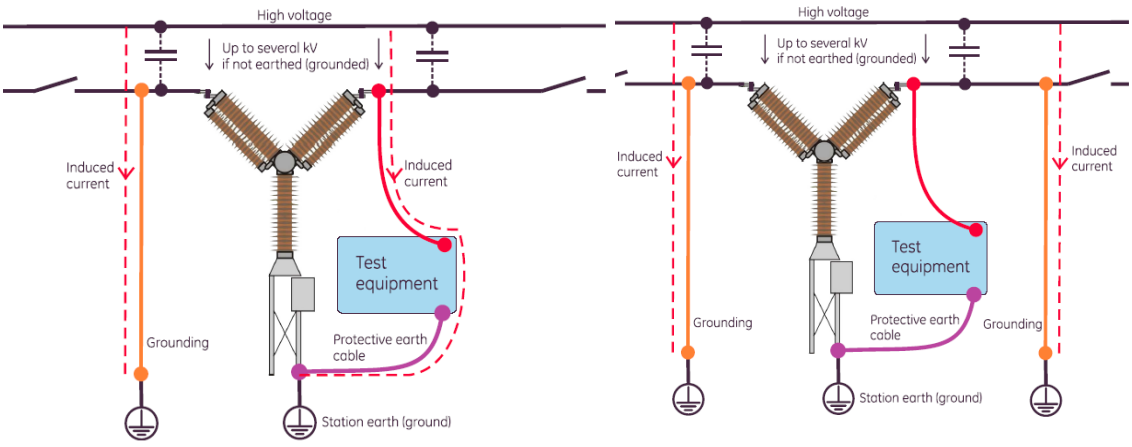

Figure 1. There is a capacitive connection between live lines close by the test object. A constant current generator is formed with current strengths of double-digit mA. This is a threat to people and is causing interference in the test system if not handled with care. Earthing both sides of the test object will lead the induced current to earth and provide a safer and more secure area for the test engineer.

Electrocution accidents in substation are mainly due to flashover from fault currents, lightning strikes on power line connected to the substation and capacitive coupling within the substation. Such incidents are often fatal. In conventional high voltage circuit breaker testing, this risk appears because testing is performed after the removal of safety earthing.

Visibility of a good safety record within the International community, as well as among local customers, is becoming a crucial asset in attracting investors and customers. Figure 1 illustrates why it is important to create a safe area by earthing both sides of the test object and keep it earthed throughout the test.

International regulations and country specific laws require all test objects to be earthed on both sides before any maintenance work is performed on the object. Exceptions for this safety prerequisite are common, but not supported, since conventional circuit breaker technology is not functional with both sides earthed.

The most important test for circuit breaker diagnosis is main contact timing. Conventional instrumentation technology requires the safety earthing to be removed during the test and is, therefore, strictly not in compliance with substation safety procedures produced by eminent International bodies, including the IEEE and IEC. National Safety agencies, including the UK's HSE and USA's OSHA, and their counterparts in other countries, have issued guidelines prescribing that circuit breakers need to be earthed at both ends during any maintenance work [1], [2].

Conventional timing with one side earthed requires special safety procedures. In many leading industrial nations, a “Senior Authorised Person” (SAP) will be required during the test, see Figure 2. This means that testing will take longer, with the test equipment, test engineer and, most importantly, the circuit breaker out of service for a longer time. Out of a typical working day, the safety administration commonly requires up to four hours of additional standby/out-of-service time. Typically, there is also an increase in the training/education level required for SAP over Authorised Person status.

If the safety earthing were not removed, the dangerous voltage would be kept at a safe distance from all personnel throughout the circuit breaker timing test. A safe area around the circuit breaker is created and can be clearly marked with security fencing in accordance with recommendations. The risk of accidents with arc flash and electrocution can hence be avoided in this way. The need for risk management is therefore modified and reduced. Also, the time consuming administrative process to obtain a work permit is reduced.
There are also several positive complementary “side effects” including social perception of the Network operator and corporations involved to have higher social integrity, the resulting improved safety record and a potential reduction in the skill levels required. In the long term, this improvement may add value to the corporation’s stock price and makes recruiting and keeping highly skilled employees easier.

If the method of working can be simplified, the situation with less skilled, or less experienced, test engineers in the field can be turned into a cost advantage. Expensive time can be saved and substation equipment need not be taken out of service as often. The resulting streamlined testing process can lead to more efficient scheduling of the workforce and associated test equipment. Expert technical staff can be focused on the most important work with confidence.

A review of recent, relevant cases includes one example [3] where a substation contractor was ”injured when he touched live equipment” resulting in a fine of £30,000 on the network operator, plus exposure to further civil action by the contractor. In justifying the fine, the oft-repeated remark is that the responsible manager has failed to do what is *reasonably practicable* to reduce risks. *“Before allowing work to start, those in control should identify the hazards present, the risks posed by the hazards, and the control measures needed to reduce the risks so far as is reasonably practicable.”*

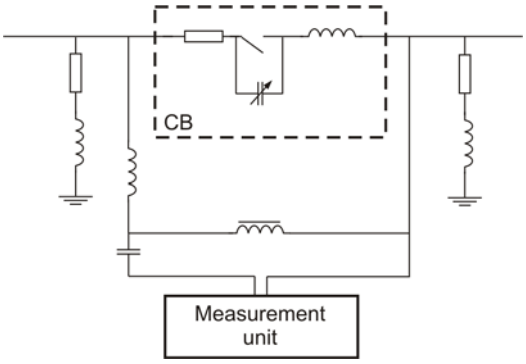

Figure 3. The resonant circuit model formed by the circuit breaker (dashed box), the connection cables from the measurement unit and grounding on both sides.

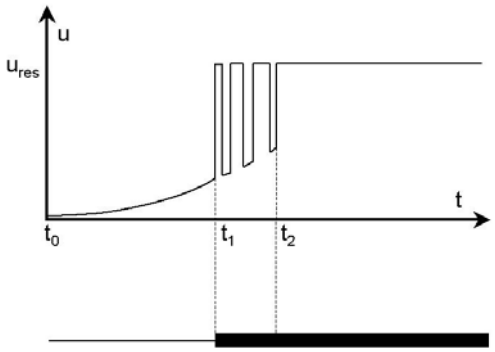

Figure 4. The response measured when applying the high frequency AC test signal over a close operation with three bounces before stable contact. Below is the traditional thin or thick line indication circuit breaker status.

In summary, the conventional way of testing with one side unearthed is a high-risk activity involving more qualified/experienced staff and with the circuit breaker out of service for longer. It is also a potential violation of rules from standardization and National Safety bodies.

Circuit Breaker Main Contact Timing

A new technology enabling both sided earthed timing is described below. For more in depth description the CMD conference proceeding is recommended [4].

The fundamental basis of the new timing technique is that a capacitance is formed when two areas of conductor are separated by an insulation medium. In a circuit breaker, the contacts are the conductors and the insulation media is usually oil, air, vacuum or SF_6. Any circuit breaker, therefore, holds capacitance. When the contacts move, i.e. during a close or open operation, the capacitance varies.

The capacitance in the circuit breaker is used as a part of a resonant circuit where the other components are a part of the test equipment. See Figure 3 for a model. The resonant frequency is dependent on the value of the circuit breaker capacitor and the resonant frequency will vary with movement of the main contacts.
The recorded response to a high frequency signal will be proportional to the capacitance of the circuit breaker. Figure 4 shows a theoretical diagram for a close operation. The method for diagnostic test is covered in two patents held by GE Energy.

The benefits of such a technique over conventional circuit breaker timing techniques include:

- Safer, and hence more efficient, circuit breaker testing
- Less opportunities for accidents to occur in the substation during high voltage testing of the circuit breaker
- Test method in harmony with eminent International bodies, including IEEE, IEC and National Safety bodies.
- Faster and simpler work procedures with fewer persons involved

Record and Store Test Results

As mentioned above, maintenance and testing has been performed, typically with one equipment per test, providing one report per test. The test report is conventionally a print out in the field on thermographic paper. This has proven to be less than ideal since the report is not “archive safe.” The text fades within a few years and, therefore, needs to be transferred to a more resilient medium, e.g. by Xerox photocopying. Further, experience of major users has shown that reports from micro Ohm measurement are not associated with timing measurement on the same circuit breaker. This imposes a significant amount of additional administrative work in keeping legacy test data in order. The traditional method of test data recording and storage has often failed to provide the necessary knowledge base, especially for cases where different substation providers or subcontractors have been hired over the years.

New data recording and management techniques are now available and are being applied by leading international utilities and service companies. These companies are using an SQL database application with an asset management system tailor made for the electrical industry that is integrated with test equipment software. The database system is able to include test results covering all major plant and objects in all substations. Data is collected with a common test plan/format ensuring full compatibility with legacy data and is automatically archived, independent of the source software, through bespoke software integration. This solution provides secure, robust and full, enterprise-wide, access to a library of authenticated test records, both at a

detailed level for field personnel, as well as executive summary reports for business administration. Other documents that are associated with the test object, including user manuals, service instructions, commissioning reports, and drawings are also readily available via the same system. Finally, launch of associated software for results and settings analysis is made from one common user interface.

The benefits of a single, integrated approach to test data management include:

- Better data management: all records in the same format;
- Better, simpler management reporting providing accurate, concise primary plant status reports;
- More complete analysis and review of test data settings and comparison with historic settings: giving more complete verification of setting amendments prior to primary plant re-energisation;
- Improved repeatability of testing: all test staff being able to use a common test plan, irrespective of the test equipment being used.

Summary and Conclusions

The substantial growth and asset development planned over the next 30-40 years in the Indian electrical power network provides a significant opportunity for network operators to benefit from new testing and recording technology:

1. Reliable power in the transmission and distribution infrastructure is fundamental for the expansive Indian industry and to continue to encourage International direct investment.
2. New technology offers a more cost efficient circuit breaker test procedure with both sides grounded. Reduced time for test, fewer involved persons and decreased administration is combined with easier operation.
3. Both sides earthed techniques also assure safety for key employees in accordance with national law, international standardization and Corporate Social Responsibility. Through the application of such systems, the Indian safety record and practice, visible within the International community, has the potential to catch up and supersede International levels.
4. An asset management database system can provide optimization of field maintenance work and planning through intelligent software integration. Test records on detailed level are available for field personnel, as well as executive summary reports for administration.

Quite simply: India needs its rapidly developing transmission and distribution network to grow with its strengthening demand for power. By embracing new techniques, Indian utilities and major power users can minimise some of the consequential risks that may arise from delayed circuit testing or loss of key test data through the application of innovative best- developed practices.

References

[1] HSE. The Health and Safety Commission is responsible for health and safety regulation in Great Britain. The Health and Safety Executive and local government are the enforcing authorities that work in support of the Commission. http://www.hse.gov.uk/electricity/

[2] OSHA, The Authority On Occupational Safety, Health And Loss Prevention. http://www.occupationalhazards.com/.

[3] HSE report, Electrician was injured touching live equipment. http://www.hse.gov.uk/electricity/maintenance/touch.htm

[4] L. Claesson, Z. Stanisic, H. Wernli, K. Pettersson, “Safe Circuit Breaker Timing with New Technology” CMD2006, Korea, April 4, 2006.