Power engineering research for the 21st century

The high power laboratory of ABB Switchgear AB in Ludvika, Sweden, has been upgraded and modernized to make it one of the most advanced and efficient of its kind anywhere in the world. With the new facilities the most severe conditions occurring in power networks can be simulated, providing more reliable testing of new systems and products. The short-circuit rating of the laboratory was increased to 75,000 MVA, and voltages of up to 1,600 kV and short-circuit currents as high as 80 kA rms can now be generated. The test laboratory is accredited in accordance with EN 45001.

Power engineering research and the development of switchgear and other power systems equipment rely heavily on the test capability provided by a company's high power laboratory. The recent upgrade and modernization of its high power test facility in Ludvika, Sweden, strengthens the position of ABB as a leader in this sector 1.

A test facility satisfying international requirements

The high power test laboratory in Ludvika meets all of the R&D demands made today in the electrical power systems sector. New, future-oriented products as well as complete power grids can be simulated and tested under a wide range of conditions. Advanced I&C equipment and state of the art data conditioning and processing systems allow the widest range of development and type tests to to be carried out 2. This is an important precondition for satisfying the requirements formulated by the electric power utilities and international organizations in their standards and regulations for substations.

The first high power test laboratory in Ludvika was built in 1933, and from the start enjoyed the reputation of having one of the world's highest short-circuit power ratings for a test facility. Tests carried out in this laboratory, for example, made a major contribution to the development of HVDC and 400-kV AC transmission. However, by 1958 the time had come for a new laboratory to be built, and it is this facility which has now been retrofitted. The modernized and upgraded laboratory has all the test capability necessary for future R&D in the electrical energy network sector.

The deregulation of national power markets which can be observed all over the world has led to sharpened competition. At the same time, high voltage networks are being expanded and upgraded to make them more efficient. Substations and switchgear obviously play an important role in this development.

Magnus Olofsson
ABB Switchgear

Capacity and power rating have been doubled

In the course of the latest upgrade and modernization, the capacity and power rating of the high power laboratory have been almost doubled. Also, twice as many test circuits are available today. Thanks to its improved capability, the test facility increasingly will be able to offer total solutions, allowing the overall functioning of complete systems and not only individual components to be tested.

Protection and switchgear are installed in power grids 3 for the purpose of being able to detect and isolate faults as quickly and reliably as possible. To confirm that the current interrupting components will always trip when required, it must therefore be possible to simulate every conceivable kind of fault, even the most unlikely. In addition, the type tests and development tests carried out on system components, such as circuit-breakers, disconnectors, surge arresters and instrument transformers, have to be carried out under the most realistic conditions possible. In this area, too, the Ludvika test facility is state of the art.

The short-circuit power rating was increased during the retrofit to 75,000 MVA. With this high short-circuit power, the tested products can be subjected to the most severe loads that can occur in a complex electrical energy network with a high transmission power rating.

The new capability of the upgraded facility may be understood better by considering that a short-circuit power rating of 75,000 MVA at a power factor of 1 is equivalent to the power required by two billion 40-W light bulbs or 10 million electrically heated homes. A short circuit in a network with such a rating causes a very high fault current to flow. In such an instance, the circuit-breaker has to isolate the faulted part of the network within fractions of a second. If this is not done, extensive damage can be caused. Until the fault has been isolated, disconnectors

Premises of the new, upgraded high power laboratory in Ludvika, Sweden **1**

and other equipment installed in the network have to be able to withstand the high fault current.

Advanced data collection

The quality of the test results depends on the measured values being correct. High power tests, however, produce disturbances in the form of HF currents and strong magnetic fields, often resulting in large potential differences at the earthing point. In extreme cases, the potential difference can reach values of several kilovolts.

To ensure efficient, trouble-free collection of the large numbers of test data, it was decided to install a data collection system that can be counted among the most advanced in the world **4**. It was developed by the staff of the high power lab, working together with a Dutch company that specializes in such systems. The precision and reliability of the installed system is so high that it can hardly be bettered.

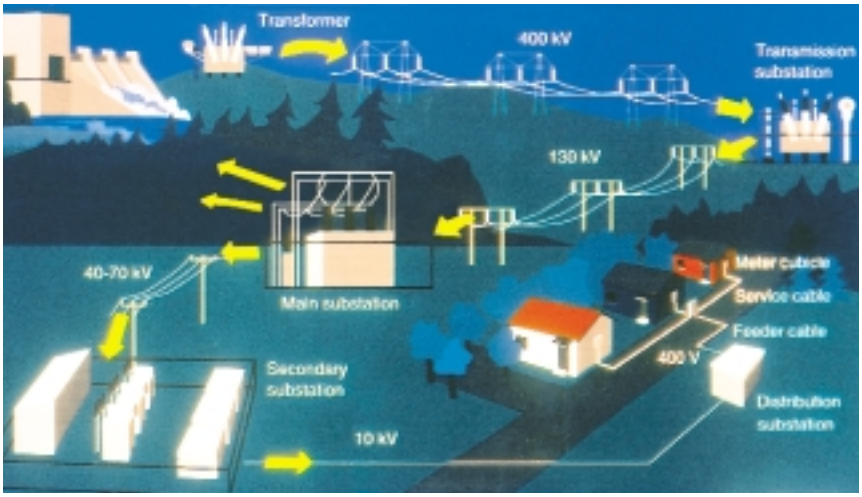
Short-circuit test being carried out in the high power laboratory in Ludvika **2**

Opto-electronics for trouble-free transmission of test data

The data signals are transmitted over opto-electronic links. Such links are excellent carriers of data as they not only allow trouble-free transmission but also

electrically isolate the data collection system from the test circuit, making it immune to any disturbances occurring in the latter.

Before being transmitted over the fiber optic links, the analogue output signals of the measuring sensors are changed into digital light pulses by special signal converters 5 . These converters are fitted as close as possible to the transmitters. They have their own power supply with battery back-up and are specially screened to protect their electronics from being influenced by the strong electromagnetic fields produced during testing.



Schematic of an electrical power network 3

Test data are stored on a CD-ROM for processing

A powerful computer system conditions the test signals and carries out a thorough analysis of the collected data. The chief test engineer is told just 10 to 20 seconds after the measurements have ended whether or not the test item has satisfied the specified criteria. This is a considerable improvement on the earlier procedure, which took much longer.

The customer also receives a CD-ROM with the data prior to conditioning stored on it. The results can therefore also be evaluated by the customer, who can use his own programs for the calculation and analysis. Besides adding value to the test data, this also helps to speed up the development of new products.

On completion of the measurements, a comprehensive and detailed test report is drawn up. For certain projects, this report may also double as certification of the tested product 6 .

One of the world's largest capacitor banks

With a discharge energy of 4 MJ, the capacitor banks in the Ludvika high power laboratory are among the highest rated anywhere in the world.

The capacitor banks 8 are used to store the energy for recovery voltages during short-circuit breaking tests and high-frequency currents during inrush current tests. Each bank consists of a 12-level stack of capacitors connected in series. The heavier of the two banks weighs approximately 40 t.

New voltage circuit

The building in which the voltage circuit stands has a floor area measuring 30 m by 60 m and a height of up to 30 m 7 . The walls, with a total surface area of about 3,000 m^2, are panelled with insulated sheet metal. The average load-

Computer used to record and analyze measurement data in the Ludvika high power laboratory 4

Analogue/digital converter for the collection of measurement data 5

bearing capacity of the concrete floor is 5 t/m².

During a typical short-circuit breaking test, fault currents of up to 80 kA rms and recovery voltages of up to 1,600 kV (peak) are possible.

Retrofitting of the short-circuit generators

All of the current and voltage needed for the tests can be supplied by the high power laboratory itself. The short-circuit generators 9 have been modified and now also allow 60-Hz tests to be carried out. As a result, products for electrical power grids operating at this frequency can now be tested in Ludvika.

1000 m² of floor space for assembly work

Since many customers of the Ludvika test facility are engaged in developing new products and systems, the laboratory has added a new assembly workshop with a total floor space of 1,000 m² for setting up the equipment and tests.

In addition, there is a workshop for support work, such as the manufacture of clamping devices and prototypes.

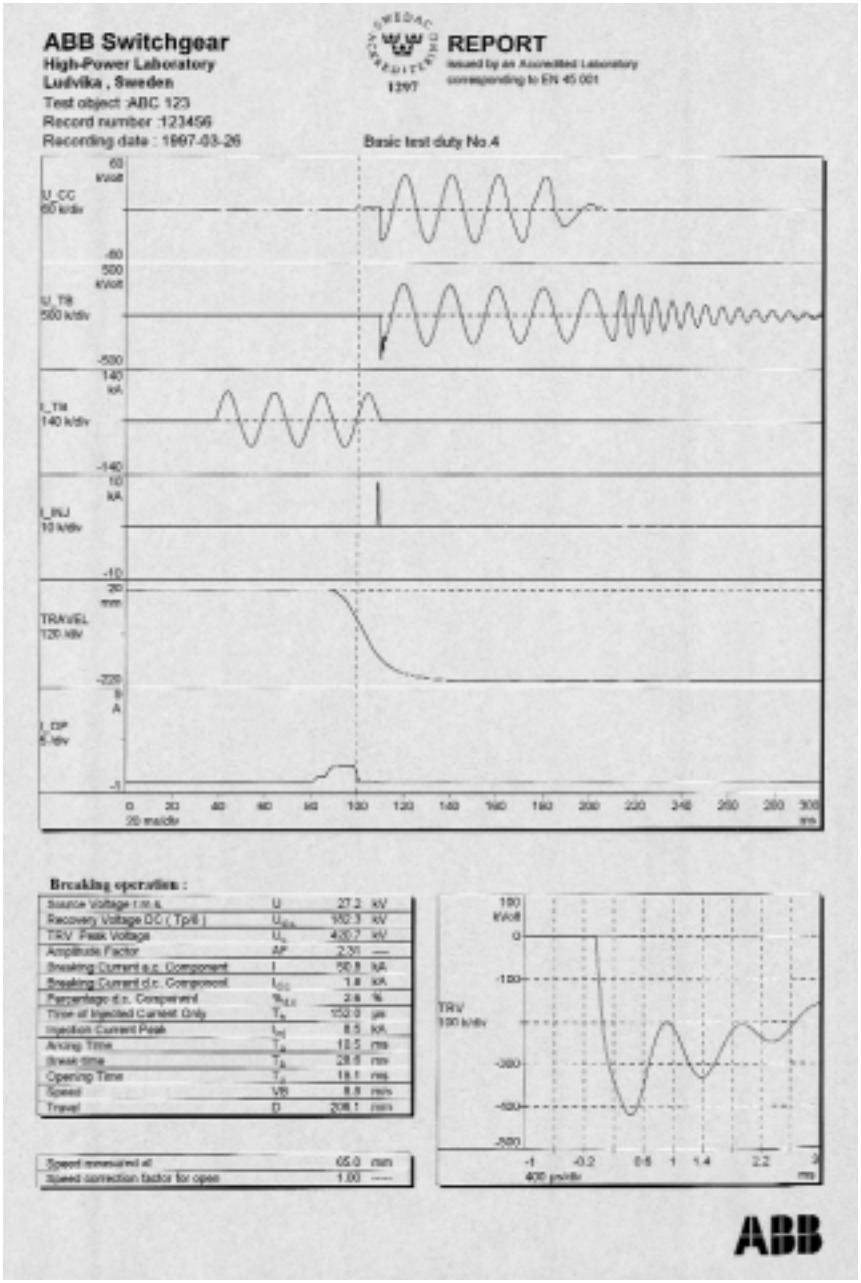
Tests on behalf of non-ABB customers

The Ludvika test laboratory also carries out certification tests, etc, for companies not belonging to the ABB Group. To ensure that secrecy is observed, the test facility is operated as an independent unit within ABB Switchgear.

A project group comprising non-ABB customers and ABB staff can be assigned to work confidentially on the contract, with additional services bought in as necessary during development.

As soon as the product is ready for type-testing, the customer can ask for an accredited test to be performed. To ensure impartial testing, the personnel who carry

Page of a test report with diagrams 6



View inside the building with the voltage circuit. The bay is 30 m wide, 60 m long and 30 m high. **7**

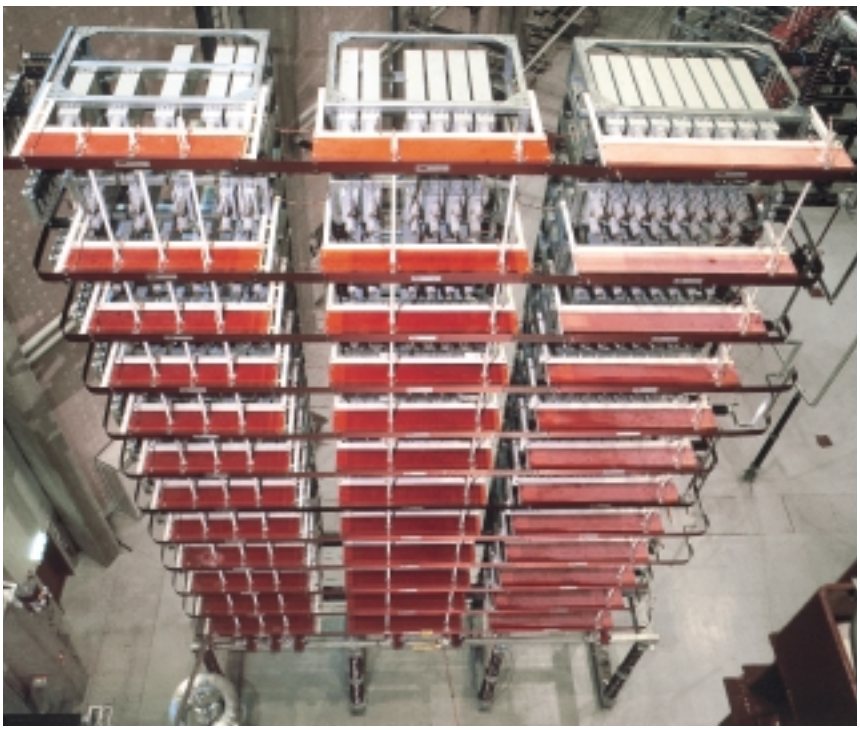
out the tests are not the same as the staff who worked on the project. Also, the rooms in which the tests are performed are sealed off to prevent outsiders from gaining access. All the measured data and test results remain the property of the customer.

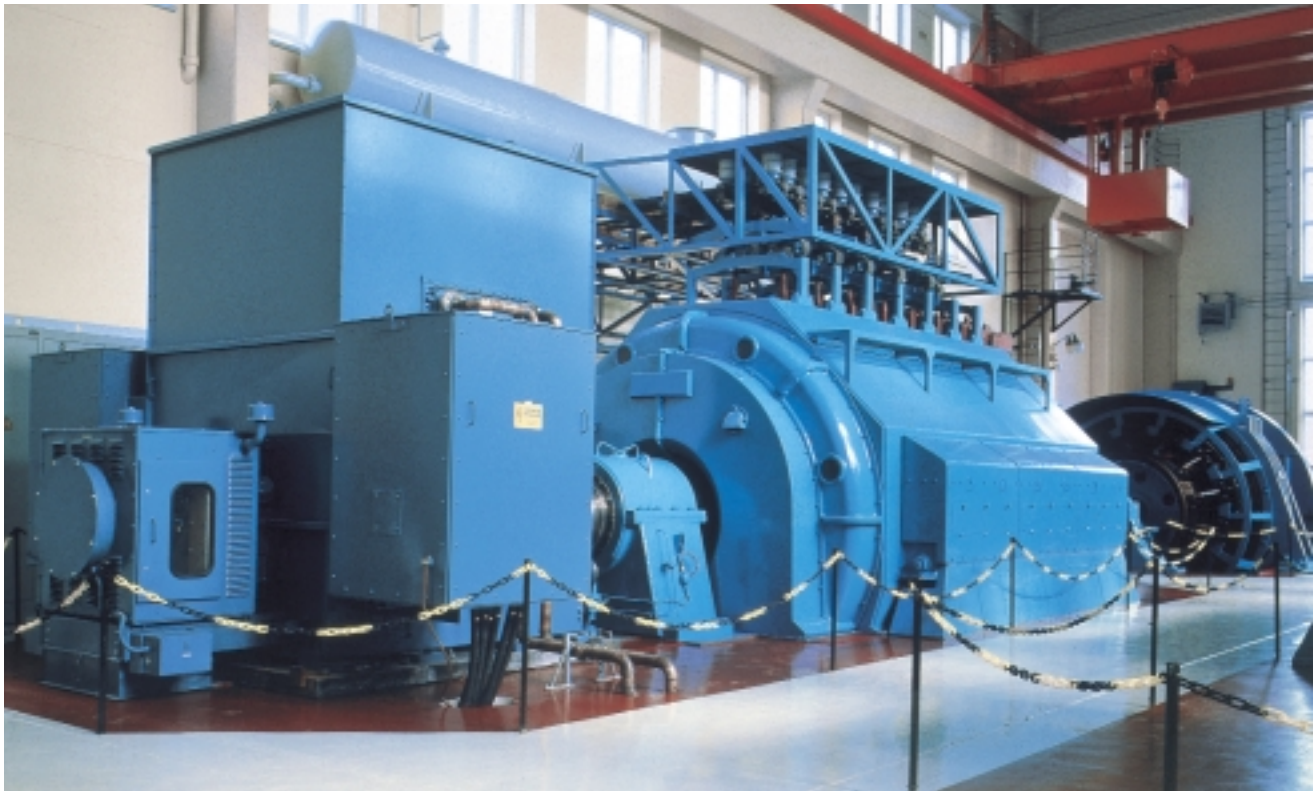
The customer can also request the support of experienced ABB personnel in analyzing and interpreting the measured data. Test reports and logs are prepared to confirm that the type-test has been passed.

International accreditation for type-tests

The laboratory was accredited in 1994 by the *Swedish Board for Technical Accreditation* (SWEDAC) and is a member of the *Scandinavian Association for Testing of Electrical Power Equipment* (SATS) as well

One of the laboratory's two capacitor banks for the short-circuit breaking tests **8**





The laboratory's two short-circuit generators for a total short-circuit rating of 4,000 MVA and frequencies of 16 to 60 Hz 9

as the *European Organization for Testing and Certification* (EOTC). In accordance with the requirements of these institutions, type-tests carried out on HV products have to satisfy the European standard EN 45001.

Membership of SATS also means that personnel from this organization may join the tests to ensure their impartiality. This ensures that customers receive internationally accepted test certification.

Tests carried out in the high power laboratory consequently enjoy the highest reputation, and the results are fully accepted in other countries with which Sweden has signed corresponding agreements. These are mainly the countries of the European Union, but the USA and Australia have also taken steps which are bringing them closer to the accreditation system.

The organization and facilities at the Ludvika high power laboratory have been evaluated by an independent committee, and ISO 9001 approval has been granted.

Center of excellence

Ludvika is home to the ABB Group's 'center of excellence' for the transmission of electrical power, which is represented by nine ABB companies whose business activities are mainly concentrated here.

When testing extremely complex electric power networks, the Ludvika laboratory also works together with ABB Transformers' high voltage test bay, which adjoins to the laboratory, and the *Swedish Transmission Research Institute* (STRI), which is operated jointly by ABB, the *Swedish State Power Board* and the *Swedish Grid Company*. STRI develops and tests systems and technologies for the transmission and distribution of electrical energy.

This concentration of capability has made the Ludvika high power laboratory one of the most modern and powerful test facilities for electrical power engineering anywhere, and plays a major role both in in-house strategic R&D as well as the customer-related activities of the entire ABB Group.

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