CPRI High Voltage Laboratory

Bangalore India

For More Information Contact

Mrs. M.Kanyakumari
Joint Director, High Voltage Division
Central Power Research Institute
Bangalore-560080
Tel:+91-80-2360 1917
Fax:+91-80-23601917
Mob; 09620078473
E-mail: kanya@cpri.in
E-mail : hv@cpri.in, aradya@cpri.in

HIGH VOLTAGE DIVISION

The High Voltage Division comprises of the following laboratories providing services on dielectric testing and on surge arresters.

1. The EHV test laboratory (Main laboratory)
2. Impulse current test laboratory
3. Pollution laboratory

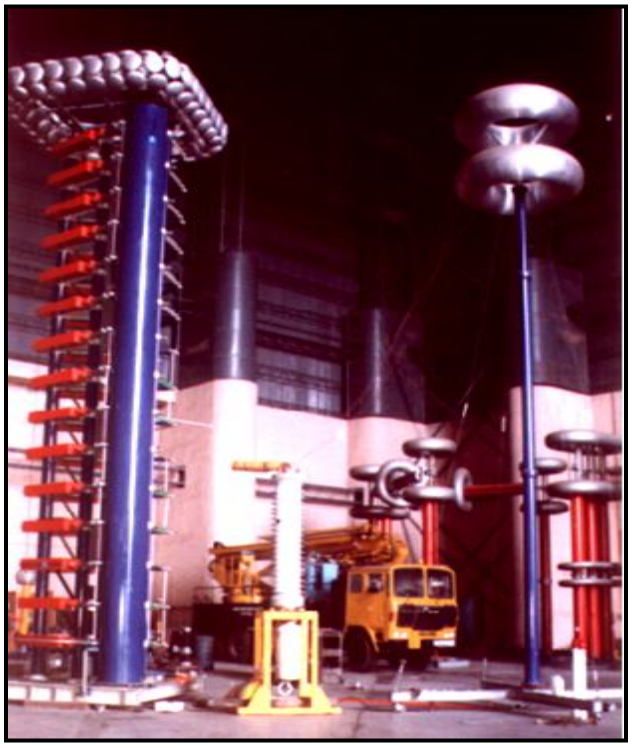
The division undertakes quality assurance tests as per national (IS) and International standards, like BS, IEC, ANSI, Canadian standards etc. All the test facilities are of the state of the art type and compare well with the facilities available at other international laboratories like KEMA-Holland, CESI, Italy, IREQ, Canada etc., provides consultancy on transmission line insulation related problems and develops indigenous high voltage test and measurement systems. The division has good R& D track record with its technical personnel publishing many papers in International and National journals, conferences and symposiums. The laboratory has NABL and ASTA accreditation and serves clients from within the country and abroad.

THE EHV TEST LABORATORY

The EHV test laboratory consists of an indoor laboratory and an outdoor laboratory test bay. Indoor laboratory is a high voltage test hall of dimensions 50mX40mX35m housing a 3MV, 150kJ impulse generator, a rain making equipment and power frequency testing transformers of ratings, a) 150kV, 300kVA. b) 100kV, 100mA and d) 600kV, 2000kVA.

The outdoor test bay consists of a 1800kV, 2000kVA cascade transformer comprising of three 600kV, 2000kVA transformer units. All these transformer units and the 600kV, 2000kVA transformer located in the indoor test hall are all similar for the convenience of inter changeability. The Ac test voltage up to 800kV from the outdoor bay can be taken into the high voltage test hall by means of a wall bushing.

Suitable arrangements are available to mount all types of 400kV class insulator strings on conductors for testing. Material handling facility includes a 24 ton (boom end max), 1 ton (with boom in telescopic mode) mobile crane & 3 ton fork lift.



3 MV, 150 kJ Impulse Generator

1800kV, 2000kVA Testing Transformer

600kV, 2000kVA Testing Transformer

150kV, 300kVA Testing Transformer

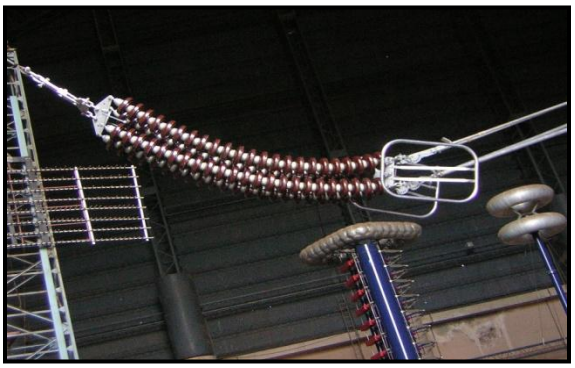
Rain making Equipment

Major test, measurement and calibration equipment available are:

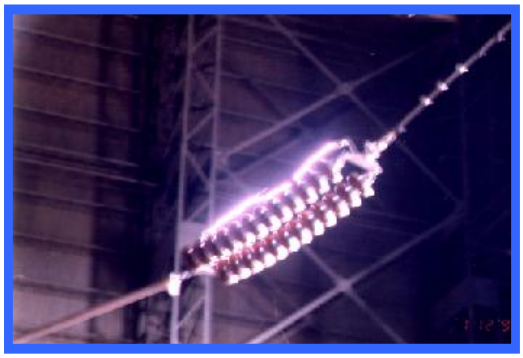
- Impulse voltage generator of 3 million volts. 150 kJ
- Power frequency Cascade Transformers setup of 1800kV(ie. 3 nos. of 600 kV each)
- Power frequency Transformers one each of 50 kV & 100 kV, 10 kVA
- 600 kV Partial discharge free coupling capacitor
- 400kV, 2400pF RIV free coupling capacitor
- Digital impulse measuring system of 120 Msamples/sec.
- 1GHz Steep front impulse measuring system.
- One meter sphere gap capable of measuring of 1MV (Impulse & Power frequency voltages) as per standards.
- Artificial rain equipment (small & big)
- 50 tonne Universal Testing Machine with digital recording
- Hot & Cold bath for temperature cycle test
- Reference voltage divider 180 kV, AC/DC, 500 kV LI/SI
- Recurrent surge generator.
- Unit Step generator.
- Reference Impulse calibrator.

With the equipment installed at present, it is possible to undertake following tests on electrical equipment like high MVA power transformers, current transformers, potential transformers, reactors & line traps, air break switches, isolators, cables, bushings, insulators etc up to and including 400 kV system.

Types of Tests:



400 kV Quadruple String under test



220 kV string under Lightning impulse test

This Laboratory can undertake the following tests as per National & International Standards:

- Lightning impulse voltage tests up to 2,800 kV (Peak) level.
- Switching Impulse Voltage Dry & Wet Tests up to 1.2 MV peak level.
- Steep front impulse test on ceramic insulators and on polymer insulators of length up to 500mm.
- Steep front Impulse puncture test for insulators up to & including 33 kV insulators.
- Corona Inception and Extinction Test and RIV measurements up to & including 400 kV system
- Power frequency voltage Dry & Wet withstand tests up to 1,000 kV (rms) level
- Porosity test on porcelain insulator fragments.
- Electro-Mechanical test up to 40 tonnes on porcelain insulators.
- Mechanical performance/mechanical test up to 40 tonnes on polymeric insulators.
- 24 hour mechanical test up to 40 tonnes
- Under oil puncture test for porcelain insulators up to and inclusive of 33kV rating.
- Temperature cycle test on insulators up to & including 110kV rating.
- Ferro Resonance tests on CVT at rated voltage up to 220 kV.
- Surge withstand test.
- Voltage distribution tests on insulator strings
- DC withstand & flashover tests under dry &wet conditions.
- Performance tests on high voltage dividers as per IEC 60060-2.
- Calibration of digitizers used for impulse measurements as per IEC 1083-1.

Impulse Current Lab

The Impulse Current Laboratory has been established in 1996 as a comprehensive test facility for testing of Zinc Oxide elements and ZnO arrester pro-rated sections up to 11 kV rating as per IEC 60099-4 considering the importance of ZnO arresters which are being increasingly used by several Utilities. Its superiority lies in the fact that, it has a unique Computer-controlled Impulse Current Generator of rating 100 kA, 150 kJ incorporating all conceivable features in a single consolidated design and is perhaps the only one of its kind in this part of the world at the time of its commissioning. The generator has the capacity to generate 8/20 µS lightning impulse current of 40kA magnitude, 4/10 µS high current impulse of 120kA magnitude, 1/20 µS steep impulse current of 40kA magnitude, 36/80 µS switching impulse current of 2kA magnitude with a 36/90 µS and long duration rectangular impulse current with a maximum duration of 4000 µS and a maximum magnitude of 1kA. The generator has accessories like separate current shunts for measuring each of the current types mentioned above, wave shaping resistors and inductors. It has a total of 12 stages with a 2.5 µF capacitor in each stage. An advanced Dr. Strauss make impulse recording system (TRAS 100-12, 4 channel, 100 MS/s, 12 bit) with advanced software for recording and analyzing impulse current and voltage and impulse current superimposed with AC voltage at varying time base, which is a unique feature required for recording voltages and currents in Operating Duty tests on arrester nonlinear elements is a part of the Impulse Current laboratory. With this generator set up all type tests on ZnO arrester blocks up to 6 kV voltage rating as per National (IS 3070) and International Standards (IEC 60099-4) can be carried out.

Impulse Current Generator 100 kV, 150 kJ

Accelerated ageing test set up for ZnO blocks.

Types of Tests:

- All type tests on Zno arrester blocks up to 6 kV As per National and International Standards.
- Residual voltage, Reference Voltage, Power loss, leakage current measurements on complete assembled arrester.

1. Type Tests on ZnO blocks

* Residual Voltage Tests:

- Steep Current Impulse 1/<20 micro second.
  Front time : 1 micro second ± 0.1 micro second.
  Time to half value : <20 micro second.
  Max. Current : 20 kA
  Residual Voltage : Upto 40 kV

- Lightning Current Impulse 8/20 micro second.
  Front time : 8 micro second ± 1.0 micro second.
  Time to half value : 20 micro second ±2.0 micro second.
  Max. Current : 50 kA
  Residual Voltage : Upto 50 kV

- Switching Current Impulse 36/90 micro second.
  Front time : > 30 micro second.
  Time to half value : approx 2.5 T1.
  Max. Current : 2 kA
  Residual Voltage : Upto 30 kV

* Long duration current impulse withstand test upto class V Blocks can be carried out .
* High current and Switching Surge Operating Duty Tests upto class V prorated sections.
* Power frequency voltage V/S Time curve :
* Reference Voltage, Power loss and Leakage current measurements on ZnO Blocks
* Accelerated Ageing test on ZnO Blocks:

2. The Laboratory undertakes the following measurements on complete arresters to be used in Systems up to 400kV rated voltage.

   - Lightning and switching impulse Residual Voltage tests on full arrester upto a maximum of 10 kA.
   - Reference Voltage test on complete arrester
   - Power loss and Leakage current measurement.

3. In addition to the tests on gapless arresters and arrester blocks, the laboratory also undertakes the following works.

   - Consultancy works on design of grading rings for lightning arresters and insulators based on electric field computations using Finite Element techniques.

- Optimization of minimum clearance requirements for transmission lines with different types of towers based on computations of electric field, Corona loss, Radio noise, and audible noise levels.

Pollution Laboratory

The gravity and importance of the problem of insulator pollution is directly related to the possible effects on the electric power system due to the flashover of insulators caused by surface pollution. For high degrees of pollution, the reduction in the withstand characteristics may be high enough as to cause failure of insulation, even at rated operating voltage. A whole series of faults may occur and in some cases, even result in a real breakdown of important sections of the transmission and distribution system. The importance of a correct design for outdoor insulation in polluted areas becomes evident when a successive re-closing of the system after a failure caused by pollution flashover fails.

Although, these problems are old (began at the time of the first electric installation), their importance have grown steadily in nearly all countries in recent years, tending to be far more acute than in the past. The principal reasons for this are shown in the following:

- Increase in level of industrial pollution and geographical area affected by pollution due to industries.
- Increased establishment of EHV lines near sea coast.
- Increased adoption of higher transmission system voltage of the level of 765kV and higher, as the pollution flashover is more critical as the system voltage increases.
- Increased adoption of HVDC transmission, the pollution flashover is more pronounced under DC voltage.

Hence, evaluation of pollution performance of insulators of all types in a test laboratory is essential.

The Pollution Laboratory of High voltage division is a chamber with dimensions of
12m x 12m x 12m. An array of nozzles confirming to IEC 60507 specifications combined with a salt water pumping and air compressor provide the required salt fog. The power supply to the chamber is from the first 600kV unit of the 1800kV cascade transformer. This unit has all the requirements of the test voltage source required by the standard IEC.60507. Probably this is one of the two test voltage source in the country strictly meeting such stringent requirement.

Test arrangement for pollution test

400 kV Quadra pole insulator string under pollution test

Equipment available in Pollution Laboratory:

- 600 kV, 2000kVA AC voltage source
- 100 kV, 600kVA AC voltage source
- 150kV, 1Ampere DC voltage source
- Leakage current analyster for ZnO arresters.
- Fibre optic based ZnO arrester element column temperature measurement unit.

With these equipment/facilities the Pollution Laboratory can carry out tests on insulators, insulator assemblies, cable terminations and ZnO surge arresters for systems up to and including 400 kV.

List of Types of Tests:

- Pollution test on insulators by salt fog/solid layer method upto 400 kV AC & 150 kV DC
- SF6 Puncture withstand test facility for DC insulators
- Thermal runaway tests on insulators
- Ageing performance of composite insulators
- Mechanical load test on polymeric insulators
- Brittle fracture resistance test on composite insulators
- Salt fog test on cable terminations
- Pollution tests on ZnO arreters

This Laboratory can undertake these tests as per National & International Standards.

Many research activities have been carried out in the Pollution laboratory and the following are some important ones:

1. Effect of pollution flashover with respect to diameter of the porcelain shell
2. Pollution performance of composite insulators
3. Ageing studies on insulator of ceramic & non-ceramic material
4. Pollution tests on ZnO surge arrester

5. Brittle fracture resistance test on composite insulators
6. Hydrophobicity recovery and mechanical load time tests for composite insulators.
7. Development of HV DC insulator profile for maximum pollution withstand capability
8. Mathematical model of dynamic arc under pollution condition to predict safe withstand voltage for a given degree of pollution.
9. Pollution mapping along the proposed Chandrapur Phadge ±500kV DC transmission line to choose suitable line insulators.

DEVELOPMENT OF HIGH VOLTAGE TEST AND MEASUREMENT EQUIPMENT

In addition to the testing, R & D and consultancy, High voltage division has developed may essential test and measurement equipment indigenously for its own use and for use of industry. Some of them are as follows:

- High Voltage Impulse Measuring Systems
- Spherical Electrode AC Electric Field Meter
- DC Electric Field Meter

- DC Ionic Current Meter
- Combination wave generator
- I.U. Sequencer
- Unbalance recorder

1 GHz Steep impulse Measuring System:

During lightning stroke on the transmission tower there may be a high potential rise at the earth end of the insulator. This Potential may sometime reach to create a flashover on the disc insulators. These type of flashover sometime create puncture in the insulators. This puncture is due to high steepness of the wave. This wave form will be of the order of 2500kV/µs and magnitude will be approximately 2.3 times the Lightning flashover of the insulator. So, approximately the waveform will have 80 to 100ns rise time. To record this as per the standard the digitizer should be having digitizing speed of at least 500Msamples/sec. Keeping this in view, High voltage division of CPRI has developed a steep impulse measuring system to record these steep front waves. The measuring system has been calibrated as per the standard. This has facility to save data and also graph in auto and manual mode. The evaluation on software has been developed in house.

In addition to the above, the same system has two independent 100Msamples/sec digitizes to record wave form during normal testing and also transformer testing. This is also having auto calibration facility as per the standard.

Measuring system developed For Kirloskar:

During transformer testing it is required to compare the frequency spectrum of two waves. For this purpose it is very important that digitizer should have better speed and have at least 10 bit resolution (2^{10}). For the first time High voltage division of CPRI developed a dual channel 100Msaples/sec. 12 bit system to carry out transformer testing for a outside party.

Kirloskar electric Co. is using this system regularly. This system has two independent 100Msamples/sec 12 bit digitizer to record the signal. So, it is possible to operate the digitizer independently. This also fetched revenue of 10lakhs to the division.

Measuring system developed for STDS BPL, CPRI:

With the experience gained in developing a system for Kirloskar Electric Co., a system was developed for STDS CPRI, Bhopal for carrying out transformer testing. Little improvements were made to simplify the operation of the system and the system was kept in operation for nearly 6 month at CPRI, Bangalore. During this period, this was used as a substitute to the HIAS Measuring system supplied by Hafely, Swizerland. Here also there two 100Msamples/sec 12 bit digitizer used for the measurement. This equipment has saved foreign exchange to the country as it is indigenously developed.

Combination wave Generator:

Surge immunity tests are being carried out on energy meter as per national and international standards. Generators are generally available as combination wave generator which means at open circuit the wave form will be 1.2/50μs and at short circuit through an impedance of 2Ω the current wave form will be 8/20μs. These two wave forms are standard wave form of voltage and current respectively as per IEC standard. Generators of this kind are generally available at 6kV and 3kA. Recent standard calls for more than 6kV and 3kA and an attempt is made to design and fabricate a combination wave generator of 12kV and 6kA rating. This generator is being used at STDS, CPRI, Bhopal for Energy meter testing regularly. This has the facility to adjust number of shots and its epetition. Voltage and current will be displayed through a Analog meters.

Measuring system for assorted waves like 1.2/50µS, 8/20 µS current wave , Ring Wave:

After the successful completion of the combination wave generator an attempt is made towards the recording of these waves. The recording of waveform like 1.2/50µs, 8/20 µs and ring wave and calculation of front time, tail time, first peak, second peak and frequency in case of ring wave were computed using validated software's developed in house. The hardware and software has been checked as per IEC standard. One single 100Mega samples per second, 12bit which has twin channels of 50Mega samples/ second were used for the measurement of these wave shapes which is sufficient as per standard. This equipment in working satisfactorily at CPRI Bangalore.

Spherical Electrode AC Electric field meter:

Power is transmitted from generating station to load centre by high voltage transmission network. As the system voltage increases, the height of the conductor from ground also increases. The height of the conductor is decided depending upon the electric field under the transmission line and the right of way also will be decided depending upon the field. To evaluate the electric field the field may to be measured under and at right off way point one meter above the ground. To measure the maximum field the field line should be perpendicular to the electrodes. First this division has come out with a parallel plate field meter and the technology was successful. The main disadvantage with this meter was to orient the plates parallel to the field and as it was analog meter reading at a distance was also difficult. To improve upon this division has a special electrode electric field meter which overcomes the orientation problem. This instrument was fitted with a LCD display which reads the reading from 1kV to 99.9kV/m. This instrument is floating body type and works on change oscillation principle. This was applied for patient and awarded. This instrument requires very low power as the display is LCD and the electronic circuitry used takes very low power.

Precision HV DC Source:

A 7kV, 50mA precision source was designed and developed by this division for the purpose of D.C. Voltage where fine application is required. This type of requirement was mainly required to evaluate the reference voltage of lightning arrester block. Here the reference voltage is based on reference current and the reference current is resistive current. If the same evaluation is carried out using AC voltage capacitive current has to be compensated to get pure resistive current. This source is having two displays with 1µA resolution for current measurement. It is also possible to precisely set and measure 1µA DC current. The current measurement is on High voltage DC side, which senses current from the return path.

Unit step generator:

High voltage impulses are required for testing purposes to simulate over voltage that occur in power system due to lightning and switching operations. For this purpose, apart from the generation of high voltages in the laboratories, accurate measurements of impulses are very important. The voltage dividers used for this purpose are to be calibrated periodically for amplitude and dynamic behavior. The dynamic behavior (evaluation of response measurement) is one of the requirements as per IEC and IEEE publications.

Step wave generators having a rise time in the range of a few nano seconds required for this measurement are not manufactured in this country and therefore they have to be imported at high cost. CPRI has designed and fabricated a step wave generator (SWG-200) that meets the requirements of IEC and IEEE publications. The step wave generator designed and fabricated by CPRI has following specification.

Step voltage output: 200V, 150V and 100V (selectable)
Rise time : <3ns
Switchable frequency: 25Hz
Remote control facility

AC Peak voltmeter:

The dielectric breakdown of any material is a measure of Peak/√2 and the rms value of the voltage. The equipment's used for this should work on high voltage environment and during flashover the meter should be on a position to hold the flashover value. CPRI has developed meter to suit such a requirement with $3\,^1/_2$ digit display to read directly the voltage. It has in built calibration to check the meter at regular interval. The meter is powered from 230V AC and consumption of power is very less. It has a changeover switch to read peak and Peak/√2.

Ionic current meter:

In India a few number of HVDC lines are existing and number of lines are coming up. It is very much required to measure DC electric field under the transmission line and also at right of way. In addition to the electric field DC lines will also produce ionic current under the transmission line. Ionic current meters are not readily available in India or aboard. Keeping this in view CPRI developed a Ionic current meter consisting of ion collecting plates and meter to measure quantum of ionic current. It consists of a LCD display to measure directly the current (nano ampere) and can select the different plate. The meter works on a 9volt battery as the power consumption is very low. This has fetched few lakhs of revenue to the organization.

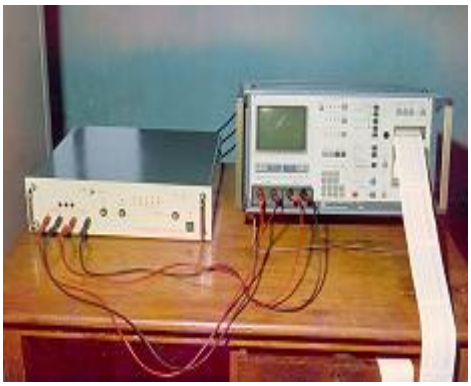
I-U sequences for single phase harmonic analyzer

Fast growing demand for electric power emphasized EHV/UHV AC and HVDC transmission over long distances with the advancement of semiconductor technology, more and more power electronics devices such as static power converters, static VAR compensate cyclo converters and so on are used in power systems networks. Most of these devices are non-linear in nature and produce harmonic current resulting in voltage and current distortion in the system. Harmonic distortion if exceeds certain limit, becomes a series problem for the power system. For the purpose of carrying out such measurements CPRI has a power line harmonic analyzer (Make: Wandel and Goltermann, West Germany) which can measure single phase ac voltage and ac current input. To have a study in three phase network with the same single input

device and 24 hours monitoring to record harmonic variation time required will be enormous.

To reduce such unproductive man hours spent on data collection CPRI has taken up a project to fabricate I. U sequence controller which requires only 24 hours to capture three phase voltage and current data. Thus reduce the man hours spent to collect data to the one sixth of its time.

All the three phase current and voltage inputs are given to the rear panel; of the I.U sequencer and the output available at the front panel of I.U sequences is connected to the voltage and current channel respectively in the Harmonic analyzer. Selectable time of recording and printing can be set by pressing the push button given in the front panel. RCA socket are available in I.U sequencer which has to be used to select voltage and current harmonic print out recorder of the harmonic analyzer and giving print command. The provision is also made to monitor single phase current and voltage harmonics and 3phase harmonic measurement. I.U sequencer has fetched few tend of lakhs to the revenue of CPRI.



Unbalance recorder

The voltage and current unbalance in a three phase electric power supply network in a well known phenomena. Its adverse effect are also known. Voltage or current unbalance is quantized by unbalance factor which is the ratio of negative sequence voltage/ current and positive sequence voltage / current expressed as percentage. In certain load the fluctuation is very frequent. In such cases measurement of the unbalance factor based on an integrated value over fairly long duration's short term data recorded using these type of recorder may not allow the devices like static var compensator not effecting the compensation. So an average value obtained by long time monitoring appears to be reasonable for correction.

Keeping this in view CPRI developed a unbalance recording system which can average the power frequency voltage from 1 cycle to 25000 cycles. The unbalance in calculated by using the formula

$$V_{a1}=1/3[V_a+\alpha^2 V_b+\alpha V_c]$$

$$Va_2=1/3[Va+\alpha V_b+\alpha^2 V_c]$$

$$\text{Unbalance factor}= V_{a2}/ V_{a1} *100$$

The software for the analysis was out sourced as per requirement of CPRI.

Development of Application software

The following are some of the software developed in the High Voltage Division:

- Software for 3-Ph and Multi Phase Transmission line design parameters like Electric & Magnetic field, Radio & Audible noise, Corona loss etc.,
- Software for Computing DC Transmission line parameters like Corona loss, Space charge distribution, Ionic current density, Electric field etc.,
- Software for evaluation of HV divider performance like Partial response time, Settling time, Overshoot &Virtual origin
- Software to evaluate the risk of failure of insulators under polluted conditions