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Power Systems Division

Power system division carries out Power System Planning, operational studies, relay coordination studies, power system grounding and earth mat design. Power systems division with its state of the art facilities and latest software tools offers a wide range of power system simulation services, including real time performance analysis of various types of controllers such as FACTS, HVDC, SVC and protection relays. It has been conducting studies for the past two decades for its own needs and at the request of utilities, manufacturers and end users of electric power. To carry out such studies the division posses Real Time Digital Simulator, E-Megasim electric power system simulator and different off line power system analysis software packages like SIMPOW, NEPLAN, EMTDC, etc.

1.0 PREAMBLE

Power Systems Division initially was functioning merely as a service division catering to providing maintenance services for various other division of CPRI. Later in 1985 onwards the division started working in R&D projects concerning Load-flows, Stability, Reactive power management, Voltage stability, Power system grounding, Control aspects of FACTS devices, line parameter calculations, dynamic testing of protective relays using Electromagnetic Transients Program etc. As a result of these projects Power systems Division developed in house power systems analysis software loadflow, stability, short circuit, DISTPLAN (distribution planning), CAPCOMP (capacitor compensation), Power system operator training simulator, GMAT (ground mat design) software, load forecast and protection software for relay co-ordination are developed

During 1986–1988, the division was strengthened in Power systems physical simulation activities by augmenting it with the HVDC Simulator from ABB, Sweden and Transient Network Analyzer (TNA) from CESI, Italy. Also, to complement with the physical simulation studies, digital simulation of power system was supported through power system software ‘SIMPOW’ from ASEA housed in MICRO VAX–II computer system. Thus, the division has oriented its research activities towards physical simulation and digital simulation studies and also to be on par with the simulation techniques and developments, the division augmented with Real Time Digital Simulator (RTDS) from RTDS technologies, Canada in 2003. Thus, the division created physical simulator and digital simulation facilities to take up planning and operational studies for power utilities. The division is augmented with relay lab in 2008.

Apart from this, division had R&D collaboration with CESI, Italy, this facilitated to exchange of experts between CPRI and CESI. This division also executed TOKTEN programme under UNDP scheme.

PS division also conducted International and National conference for dissemination of knowledge on important areas for research and for implementation in Indian power Sector.

Brief description on the Physical simulators - HVDC Simulator, Transient Network Analyser, Real Time Digital Simulator is given in the following sections. Digital software packages available in the division, details on relay testing laboratory and power system grounding are also provided. Research Programs, important contributions of the division and Important trainings carried out by the division are given in section 6.0 to 9.0.

2.0 ANALOG AND DIGITAL SIMULATORS

2.1 HVDC Simulator (1986–2003)

The HVDC Simulator is a tool used for modeling of the HVDC system and its controls and also the associated power system AC network. Physical simulator Studies helps to decide comprehensive control mechanism and system protection parameters.

The HVDC simulator as shown in Figure 1 shows low power model and contains most of the elements necessary to represent both HVDC and AC system components. It is a powerful tool to carry out studies of performance of the converter control and protection systems.

The important studies that can be carried out using HVDC simulator are:

- Dynamic performance and factory system testing of control and protection systems for HVDC systems
- Dynamic performance of an integrated AC/DC power system
- Equipment stress in case where exact simulation of the commutation process is essential.

2.1.1 Studies carried out using *HVDC Simulator*

- Dynamic Performance Study of Control and Protection System for National HVDC Projects Stage I&II, for BHEL, EDN, Bangalore
- Factory System Testing of Control and Protection System, for National HVDC Project Stage I&II, BHEL, EDN, Bangalore
- Dynamic Performance Studies of Chandrapur - Ramagundam back-to-back HVDC scheme

Two Officers of Power Systems Division were trained in using of HVDC simulator at ABB, Sweden.

2.2 Transient Network Analyser (TNA - 1988–2002)

In 1988 the analog simulation facility for AC system Transient Network Analysis – Transient Network Analyser as shown in Figure 2, was added to further enhance the physical simulation capabilities.

TNA has physical models of AC systems like Transmission lines, Synchronous machines, Shunt Reactors, Lightning Arrestor, Loads, Static VAr Compensators, Transformer with Saturation etc. It has its own data acquisition system with PDP-II digital computer systems housing software's for statistical analysis and risk analysis of switching surges.

FIG. 1 HVDC SIMULATOR

FIG. 2 TRANSIENT NETWORK ANALYSER (TNA)

Some of the CPRI engineers were trained at CESI, Italy in the usage of this facility.

2.2.1 Studies carried out using *TNA*

- Insulation Co-ordination Studies for 800 kV system of Vindhyachal - Bina for NTPC
- Study of Switching Overvoltage in electrical system of underground coal mines located in Western Australia
- Lightning Arrester failure studies for 220 kV system of UP
- Overvoltage studies for 765 kV Anpara – Unnao line
- Switching overvoltages studies for 400 kV Tehri Gas Insulated Sub-station (GIS)
- Switching overvoltages for Koradi – Bhusawal 400 kV line
- Performance evaluation of Digital SVC Controller

2.3 Real Time Digital Simulator (RTDS - 2003–Till Date)

Power System division's Physical simulation facility was augmented with the 'Real Time Digital Simulator (RTDS)', as shown in Figure 3, from RTDS Technologies, Canada, during 10th plan.

The RTDS Simulator is a fully digital electro-magnetic transient power system simulator, utilizing advanced custom hardware and software technologies, and created specifically for real time power system simulation. This simulator finds application for study of (a) control systems for HVDC, SVC, synchronous machines, FACTS devices and custom power devices, (b) integrated protection and control systems, and (c) interaction of AC and DC systems.

RTDS with its Real Time Simulation capability is the most flexible and efficient means for testing control equipment. The flexible and abundant signal input and output structure available on the RTDS Simulator facilitates the high volume of signal transfer required when testing complex controllers.

FIG. 3 REAL TIME DIGITAL SIMULATOR

RTDS provides for a realistic testing environment for testing the protective device on the system in which it is installed and also the interaction between the system and device through 'Closed-Loop Testing'. Using a RTDS Simulator for closed-loop testing enables a large number of contingency tests to be run either with or without user interaction, many of which cannot be performed by any other means or would not be permitted on the real system.

The Software is the main interface with the RTDS Simulator hardware and is designed to allow the user to perform all the steps necessary to prepare and run the simulation, and also analyze its output. The RTDS hardware comprises of a five rack system dimensioned for 18, 3-phase nodes/buses per rack and upto 56 single phase switches. The RTDS Software RSCAD – supports modeling accurately all power system component models required to represent most of the complex elements present in physical power systems. The control system library allows customized control system to be created to interact with the modeled power system and/or outside world.

External Voltage and Current Amplifiers are connected in the test loop between RTDS and equipment under test for providing secondary level voltages and currents.

Four Officers from the division have undergone a fifteen days training programme at RTDS technologies, Canada in the usage of RTDS.

2.3.1 Studies carried out using RTDS are as follows

- Testing of TCSC controller for 400 kV Kanpur Ballabgarh line for M/s BHEL
- Testing of Distance and Transformer Differential Relays for M/s Siemens
- Protection System studies for series compensated Gorakhpur- Muzafarpur – Purnea 400 kV double circuit line for M/s Siemens
- Testing of SVC controller for Electric Arc Furnace Application - M/s BHEL
- Testing of Composite Intelligent Load Management System (CILMS) controller for BALCO Plant for M/s ABB
- Testing of controller for series capacitor protection of Allahabad – Mainpuri 400 kV line for M/s BHEL
- System Studies to evaluate the behavior of HVDC Controllers for ±800 kV HVDC system associated with Lower Subhansiri HEP for M/s PGCIL
- Testing of Composite Intelligent Load Management System controller (CILMS) designed by M/s ABB for M/s Hindustan Zinc Ltd, for M/s BALCO, M/s Jharsuguda
- Testing of CILMS controller designed by M/s Siemens for Jindal plant
- Testing of Distance relays for M/s General Electric
- Testing of Distance, Transformer Differential Relays, Bus Bar Protection Relays, Line differential Relays for M/s Areva
- Testing of 2.5 MVAr STATCOM controller developed by M/s BHEL for Bhilai Steel Plant

3.0 Digital Software Packages

Systems and Software Capabilities for Digital Simulation

Systems:

- DEC Alpha workstation
- SUN workstation
- Pentium IV Servers / PCs
- Printers, Plotters and Digitizer

Softwares:

SIMPOW (Windows NT Version 10.2.105)

- Package for static and dynamic simulation of power system
- Models of all network components involving transmission elements, HVDC converter stations, static VAr components, series capacitors, prime movers and rotating machines with their controls, protection equipment, and loads
- Supports Dynamic Simulation Language a built-in high level programming language, allows user-defined modeling of any power system component such as regulators and primary components, e.g. drive systems, FACTS devices and special machines
- Optimal power flow analysis
- Stability analysis
- Transient stability
- Small signal stability of generators and automatic control systems
- Small disturbance angle stability e.g. controller interaction, Tuning of Power System Stabilizers (PSS), Sub synchronous resonance
- Short circuit studies
- Eigen value analysis

3.1 Hiwave

- Design of filters - Examine and reduce harmonic disturbances in power systems
- Includes a user customized library for modeling of almost all harmonic sources

3.2 Mipower

- Over current and Earth fault relay coordination
- Distance relay coordination

3.3 GMAT - Grounding System Software

- In-house developed software for Ground mat design for grounding system for HV/ EHV substations/power stations
- Incorporates design methods that are based on latest developments and techniques in power system grounding practices including the Indian codes of practice in Earthing.
- Software is written based on the method described in the latest version of ANSI/ IEEE Standard 80/2000 - Guide for safety in AC substations.
- Other features are incorporated based on the recommendations of CBI & P, India, and IS 3043/1987 - code of practice for earthing in India.
- Non-uniform soil model is a 2-layer soil model proposed by J. Endrenyi, consisting of a top layer soil of resistivity p1 to a depth 'h' from the surface of soil and a bottom layer of resistivity p2 extending up to infinite depth.
- The effect of spreading gravel on the surface of substations can be studied using this software.
- Effective placing vertical ground rods can be studied.

4.0 RELAY TESTING LABORATORY

The Relay testing laboratory of Power Systems Division is mainly concerned with:

- Type testing and Field testing of Protective relays
- Dynamic testing of Protective relays
- Relay setting calculation and Relay co ordination
- Protection audit

Relay testing Lab is equipped with type testing facilities for protective relays as per IS and IEC standards. The laboratory is accredited according to the 17025 certification. The main facilities available are four numbers of PC based relay test kits, 2 numbers of Omicron test kits, one doble make and one Programma make test kit. The lab also takes up Field testing of Protective relays and third party inspection of control and Relay panels. Figure 4 shows DOBLE-F-6150 for Relay testing and Figure 5 shows CMC 256 Plus Relay Test Set.

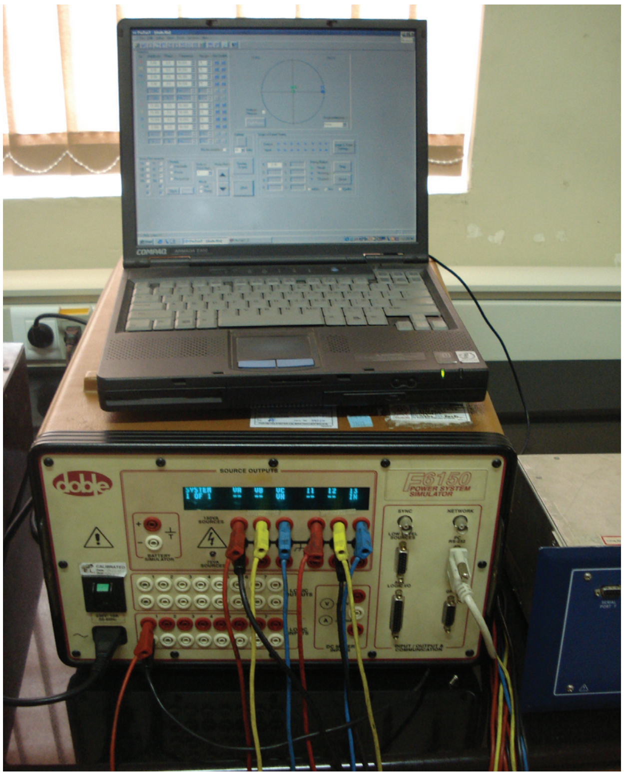

FIG. 4 DOBLE-F-6150 FOR RELAY TESTING

FIG. 5 CMC 256 PLUS RELAY TEST SET

Under the Type testing of relays the relays will be tested for accuracy of operating value and operating time using steady state signals. But relays are meant to operate under fault conditions; hence it is also required to test the relay performance under transient/fault conditions. Dynamic testing of relays can be carried out in accordance with CIGRE 34 guidelines. The Power system is simulated on RTDS and various faults are simulated, the fault waveforms fed to relay and its performance is evaluated. Suitability of a relay for specific application can also be studied by simulating the given network on RTDS and testing the relay for different types of faults.

Dynamic tests are being carried out for relays of various manufacturers. Studies have been carried out check the suitability of relays for series compensated lines. Relay coordination Studies i.e. relay setting calculations for relays used for protection of individual equipment is carried out using Relay coordination software.

The Division takes up protection audit studies covering the following activities

- Review of Protections used for various electrical equipment and Relay settings and suitable recommendations are suggested to meet the National and International guidelines.
- Relay coordination
- Checking the healthiness of DC system at the substations/Generating stations
- Checking the healthiness of communication channels like PLCC/optical fibers used for protection
- Checking the healthiness of Event recorders/ Disturbance reorders
- Review of the test procedures of various types of relays and suitable recommendations for improvement
- Sample relay field testing including end to end testing of Distance relays using GPS synchronized Relay test kits at both ends.
- Review of Circuit breakers test reports suitable recommendations for improvements

The operation of a protective relay will also depend on its associated systems like DC system from where the supply is given to the relay, the input signals from CT's and PT's the communication channels used by the protection schemes, and also the healthiness of the circuit breakers and its associated circuits. Hence it is required to check the healthiness of these associated systems.

Relays may mal-operate or fail to operate due to problems in the relays, its settings or due to problems in any one of its associated systems. A regular checking of the relays and its associated system will help in improving their performance and hence reliability.

It is important and essential that the utilities carry out protection audit for the substations and generating stations. It is advisable to carry out such studies and audit whenever there is change in the system configurations. It will bring out the deficiencies and help in improving the protection system.

The division has carried out 'Protection Audit' for Delhi Transco, during 2011.

5.0 POWER SYSTEM GROUNDING

Another very important activity of Power Systems division is the Power System Grounding measurement and studies:

The purpose of a grounding system is to limit the potential gradient within and immediately outside, say a substation area to a value that is considered safe for the personnel. This requirement must be met under normal and abnormal operating conditions of the power system. A grounding system is used for

(i) Providing a uniform electric potential in all non-current carrying parts of the structure and apparatus, as well as ensuring that the operators and attendants are always working at the same electric potential.

(ii) Achieving a low uniform potential gradient throughout the grounding system. This will reduce the chances of large potential differences between reasonable stride and reach distances. Failure to do this could result in electric shock or injury to attendants when short circuit or other abnormal occurrences take place.

(iii) Grounding for lightning and surge protection.

Adequate grounding is required to prevent dangerous conditions, which may arise at station or line installations. Structures and equipment may become alive from a power circuit by means of failure of insulation, breakage or displacement of a conductor, arcing from the power circuit, induction.

The resistance to earth of the complete grounding connection is never quite zero, and large currents passing through this resistance may cause between the grounded apparatus and earth, a potential difference (IR) which creates a hazard. With a given rod in soil of uniform resistivity, the greatest potential gradient exists in the region immediately adjacent to the rod.

Measurements show that 90% of the total potential difference may exist within the reach or stride of a man. A low resistance between the grounding connection and earth is therefore necessary to keep potentials to a minimum.

Because lightning arrestor currents have high frequency components, the inductance of the grounding conductor may introduce a high impedance component to the lightning current. As a result, the potential drop per foot in the grounding conductor may be high and may cause a "side stroke" to nearby grounded objects.

An induced voltage may also occur in parallel conductors adjacent to the grounding conductor. Therefore, lightning arrestor grounding conductors should be short and direct for both safety of personnel and effectiveness of the lightning arrestor.

For safety of personnel, a grounding system must ensure that the accessible non-current carrying metal parts are maintained at the same potential and that the difference between this potential and that of the surrounding earth is not dangerously high. By non-current carrying metal parts, we mean those parts that are not required to carry any current during normal operating conditions of the power system but they are called upon to carry in high value of current at times of faults and other abnormalities.

An adequate grounding system is essential to protect by dissipating into the earth, the energy released by lightning discharges, system fault currents and other system disturbances. Otherwise, these disturbances may cause extensive damage in equipment, and apparatus including non-associated equipment, such as communication cables; etc. Such damage might include insulation breakdown, electrically ignited explosions and fires.

An adequate grounding system is also essential for the proper operation of the system. The grounding system must, at times, carry heavy power and fault currents without being damaged and without causing dangerously high potential gradients. Protective devices, system voltage conditions and the effectiveness of overhead ground cable, etc. are dependent on adequate grounding system.

Grounding is an important feature of sub-station design. Special attention should be given to the grounding system because the substation is:

(i) The scene of frequent activity by operating and maintenance personnel.

(ii) A switching centre upon which continuity of service may be dependent.

(iii) A place of energy concentration.

In distribution systems, particularly at transformer locations, grounding connections are necessary to maintain the potential of the low voltage circuit at the correct value with reference to the earth, and to ensure the correct functioning of lightning arrestors. In order to ensure that the potential of motor frames and associated equipment is maintained at a low value with reference to the earth, Grounding connections on utilization equipment are necessary. The grounds on such equipment carry current only in the event of break-down of insulation or during the operation of lightning arrestors.

Power System Grounding Studies carried out are as follows:

- Measurement of ground mat resistance for 4×100 MW Koteshwar HE Project for M/s Thdcil.
- Measurement of ground mat resistance for 500 MWe Bhavini project at Kalpakkam.
- Soil resistivity measurement for electrode site at 2500 MW Ballia – Bhiwadi HVDC project. This measurement was carried out using High current DC source
- Design of Grounding system for Tintibi 132 kV sub station, Bhutan for L&T Chennai
- Grounding Grid Resistance measurement at all oil tanks and structures in refinery for M/s MRPL, Mangalore.
- Measurement of Grounding grid resistance at RAPP 5 and 6 for M/s HCC, Kota.
- Measurement of Grounding grid resistance at Kudankulam Nuclear Power Project for NPCIL, Kudankulam. This measurement was carried out using High current DC source.
- Measurement of Grounding grid resistance at NAPS, Narora. This measurement was carried out using High current DC source.
- Measurement of ground resistance and soil resistivity for Nuclear Power Corporation, Kaiga, Karnataka.
- Grounding system design and Measurements for the 1000 MW Tehri hydropower project in UP. The main features are design of underground power house ground mats, 400 kV, GIS grounding system and those in all the access tunnels (Adits).
- Design of Grounding System for Rampur Hydro Electric Project (6×68.67 MW) for M/s SJVNL, Shimla.
- Design of Grounding System for 4×33 MW Teesta Low Dam Hydro Electric Project for M/s GEA Ltd., Chennai.
- Design of Earth mat for Power house and Switchyard of 2×30 MW Tuirial Hydro Electric Project, Mizoram for M/s BHEL, Bangalore.
- Design of Grounding system for Power houses and switchyards of Bridavan HE scheme, Bhadra power project, Khadra Dam power house and Kodasalli Dam Power house of Karnataka Power Corporation Ltd. (KPCL).
- Soil Resistivity measurement for HVDC ground electrode stations at Ballia and Bhiwadi for M/s Siemens.
- Soil Resistivity investigations for Ground Electrode stations and terminal stations at Talcher (Orissa) and Kolar for 2000 MW Talcher, Kolar, HVDC Project for M/s Siemens.
- Vetting of grounding system for Power houses and switchyards of Raichur Thermal Power Station of Karnataka Power Corporation Ltd. (KPCL).
- Special grounding systems (using Bentonite and locally available clay) for 110 kV substations in Kozhikode and Taliparamba of Kerala State Electricity Board.

6.0 RESEARCH AND DEVELOPMENT PROGRAMS

To strengthen the research activity in power area, CPRI entered into R&D collaboration: with CESI, Italy on *Technical Cooperation Programme in the field of research, testing, power system studies, transfer of know-how etc.* Under this mutual cooperation program CPRI officers were deputed to CESI and CESI engineers visited CPRI, to work on identified research areas. Important projects undertaken under this collaboration program were, (i) *Generals about EHV-UHV AC systems*. During the period the reports prepared on specific topics were: (a) Generals about EHV-UHV AC system (b) Medium and Long Term Load Forecasting (c) Load Flow analysis (d) Particular problems due to shunt and series compensation (e) Evaluation of static reliability of the Transmission alternatives (f) Analysis of the transient stability (g) Reactive power optimization (h) Economical comparison between elaborate alternative network schemes. (ii) Development of real time long term dynamic simulator.

6.1 R&D Through TOKTEN Program

The TOKTEN program of Ministry was initiated during 1990 under UNDP program. This program facilitates experts of Indian origin from abroad to visit for a period of 2–3 months and initiate research in advanced areas. Under this TOKTEN program experts like Prof. M A Pai, university of Illinois, Prof Anjan Bose from Arizona university and Prof. O P Malik from Calgary University, Canada visited Power Systems Division during which research in the areas of small signal stability, Design of Power System Stabilisers using advanced control techniques, and Development of Real Time Power System simulator was pursued.

6.2 Sponsored R&D Project

The division has successfully completed sponsored R&D project on 'Full Spectrum Simulator'. To have a indigenously developed Power System and Power Electronics simulator that provides both off-line and real-time simulation capability at affordable cost, a team comprising of IISc, Bangalore; IIT, Bombay; IIT, Kanpur; IIT, Kharagpur; Bengal Engineering and Science University and CPRI was formed to develop a Full-Spectrum Simulator (FSS) under the Under the NaMPET (National Mission on Power Electronics Technology) instituted by Department of Information Technology, Ministry of communications and Information Technology, Govt. of India.

CPRI's role was to develop the bench marking programmes for testing on Real time digital simulator. As a benchmark system provides a good common base for testing of new simulators and digital programs, simulation of eight number bench mark systems on commercial grade RTDS was carried out by CPRI. These benchmark systems and results were used to validate the results obtained from the full spectrum simulator.

7.0 IMPORTANT CONTRIBUTIONS OF THE DIVISION TO POWER UTILITIES

The division has carried out the following important assignments to various power transmission and distribution utilities:

- Power Swing phenomena in Western Region System and suggestion for remedial measures to avoid cascade tripping of 400 kV transmission lines on power swing for WREB, Mumbai.
- Power Swing Blocking Study in Northern Region System for NREB, New Delhi
- Power Evacuation Studies for MPEB System, Jabalpur.
- Insulation Coordination Studies for Gas Insulated System for Tehri Hydro Development Corporation, Rishikesh
- Switching and Dynamic overvoltages for URI Power station, NHPC.
- Estimation of Technical losses in the Transmission system of Andhra Pradesh Power System for Andhra Pradesh Electricity Regulatory Commission.
- Failure Analysis of Generator Transformer at Salal, NHPC.
- Studies for SVC Sizing for M/S Sharq Steel Rolling Mills LLC, Sultanate of Oman.
- System Studies to assess the State Level Additional Transmission Requirements for 10th and 11th Plan Period in Southern, Northern, Eastern and North-Eastern Region for M/s Power Finance corporation.

- Power Evacuation Study For North Delhi Power Limited (NDPL) Network.
- System studies for Raichur Thermal Power Plant (RTPS) for M/s KPCL.
- System studies for Delhi Transco system for M/s Delhi Transco.
- SSR studies for series compensation on Lucknow Bhalia 400 kV transmission line for M/s Siemens.
- SSR studies for series compensation on Ghorakpur – Lucknow , Bareilley – Unnao , Bareilley – Mandaula 400 kV double Circuit line.
- Dynamic compensation studies for 1400 MW wind farms in Gujarat for M/s Suzlon.
- System studies and energy audit for Reliance network, Hazira.
- SSR studies for 765 kV Tehri- Meerut Line for M/s Siemens.
- Analysis of Technical Losses of Distribution System of major Towns viz. (i) Davangere, (ii) Hubli, and (iii) Dharwar of Karnataka.
- Estimation of Technical losses in the sub-transmission system of Andhra Pradesh Power System for Andhra Pradesh Electricity Regulatory Commission.
- Estimation of Technical losses in the distribution system of AP for Southern Power Distribution Company Ltd.
- Estimation of Technical losses in the distribution system of Kerala State for Kerala Electricity Regulatory Commission.
- Load flow study of transmission and subtransmission network in Maharashtra for the year 2005–2006 and 2006–2007 for Maharashtra Electricity Regulatory Commission.
- Relay coordination studies for the FACTS development project of Kanpur-Ballabgarh 400 kV line for PGCIL.

8.0 IMPORTANT TRAINING PROGRAMMES AND CONFERENCES

Power Systems Division has to its credit of having arranged various international conferences like IFAC in 1987 and National Power Systems Conference in 1988. Few of the other important training programmes and conferences conducted recently by PS Division are given below:

(a) Training Programme for Senior Officers from CEA

An Orientation programme on Real Time Digital Simulator was organized by PS Division during 16th to 20th February 2004 for CEA officers at the level of Member secretaries and in 2005 for CEA engineers at the level of Superintendent Engineers. This was conducted with a view to familiarize the utility engineers with the type of studies that can be undertaken on RTDS and to give them hands-on-training on the usage of the facility. Various Lectures on topics such as (1) Power System Modeling and Analysis, (2) Electromagnetic transients in Power systems, (3) Role of Reactive Power in Power Systems and Power System Stability, (4) Introduction to RTDS, (5) HVDC Controls, (6) Generals about Power System Operation, and (7) Introduction to EMTP. etc. were delivered during the course of the programme by staff of PS Division. Demonstrations on RTDS such as (i) Simulation of reduced NREB Network – Case studies, (ii) Dynamic testing of Distance relays using RTDS, and (iii) Simulation of Sub Synchronous Resonance – IEEE Bench mark case also formed a part of the programme.

(b) Training Programme for Power System Engineers from Sudan:

Power Systems Division conducted a one month training program on Power Flow and System Studies to Engineers from National Electric Corporation, Sudan during 27th January to 25th February 2005.

The course covered topics such as Power System Planning and operation Power flow

Analysis, Transient Stability Studies, Reactive Power Compensation which included in-depth modeling aspects of synchronous machine with its capability curves, Turbine, speed governor, Excitation System, PSS and transmission network. Aspects on Power system stability and methods to improve stability & Small Signal Stability, Voltage Stability, Reactive Power Control and Management, Harmonics and Filters were covered. Distribution System load flow (3-phase balanced and unbalanced) and Estimation of losses in Distribution systems, HVDC and grounding.

FIG. 6 TRAINEES WITH FACULTY FROM CPRI

(c) Tutorial on Computer Relaying and Wide Area Measurements

A 2-day Tutorial on *Computer relaying and wide area measurements* was organized during February 22–23rd, 2007. Prof. Arun G Phadke from Virginia Tech University delivered the Lectures. The tutorial covered topics like - History of Wide-Area Measurements, Sampling, Aliasing, and Anti-aliasing Filters, Techniques of Synchronized Phasor Measurements Architecture of Wide-Area Measurement Installations, Traditional State Estimation Principles, State Estimation with Phasor Measurements, Advanced Protection with Wide-Area Measurements, Adaptive relaying with computer relays, Principles of Power System Control, Advanced Control with Wide-Area Measurements, Phasor Measurement Systems Around the World.

Wide area measurement based Control and protection is being implemented for better control of Power system world over in the recent years. Thus, CPRI took the initiative first to conduct such a tutorial program for the benefit of Indian utilities wanting to adopt this technology.

(d) Training Programme on RTDS

Power Systems Division organized a Five Day Training Programme on 'Real Time Digital Simulation of Power Systems' during September 21–25th, 2010, as part of the Golden Jubilee Year celebrations. This training program was aimed at providing the modeling concepts of power system components in real time for transient simulation. Various topics covered as part of the training program included - Principles of Electromagnetic Transient simulation and Real Time Concept, Small Time step modeling for VSC simulation, Closed loop evaluation of FACTS controllers, Load shedding controllers and Protective relay. Apart from *technology overviews*, the training programme had hands-on tutorial for the participants thereby providing an opportunity to work through a graded sequence of exercises on Real Time Digital Simulator, state of the art tool for real time simulation of Power systems.

(e) International Conference on VSC Technology for HVDC and FACTS, May 25–27th, 2011, New Delhi

Power Systems Division of CPRI in association with CBIP organised an International Conference on Voltage Source Converter technology for HVDC and FACTS with a preconference tutorial at Vigyan Bhavan, New Delhi during May 25–27th, 2011. This conference on VSC technology was first of its kind to be held in India. The eminent invited speakers at the conference were *Dr. Narain G Hingorani,* Independent Consultant, USA, *Dr. Mohamed Rashwan*, president of Transgrid Solutions (TGS), Canada, an authority on VSC and *Prof. K.R. Padiyar*, Emeritus Professor, Department of Electrical Engineering, IISc, Bangalore, an internationally recognized expert in the areas of HVDC and FACTS.

A Half-day Tutorial by Dr. Mohammed Rashwan was held on May 25th, 2011, preceding the conference. The tutorials highlighted the fundamentals of VSC, its operating principles, control capabilities, different topologies and also applications of VSC.

This Conference was an initiative for Indian Utilities to lay a road map to adopt VSC technology in India and also initiate research by academic and research institutes in the area of VSC for HVDC and FACTS.

9.0 MEMBERSHIPS

Officers of PS Division were members of the following committees:

- ET 40-HVDC power system, BIS sectional committee
- ET 01-Basic electro technical Standards of sectional committee
- ET 40/P3-Dynamic performance of HVDC System
- ET 40/P2-DC measuring devices
- ET 40/P3-Dynamic performance of HVDC Transmission Systems
- ET 40/P2-AC/DC Harmonic and fractions
- ET 40/P14 HVDC Ground electrodes, CBIP National sub-committee of CIGRE study committee NSC-38 on Power System Analysis and Techniques
- DC measuring devices
- FACT devices committee of PGCIL, New Delhi
- BIS committee ,Surge Arrester Sectional committee ET 30
- CIGRE – India working Group for Surge arresters, Member – IERE TC Member on Network
- BIS committee on HVDC System ETD 40, Power System Transmission Planning Committee of PGCIL, New Delhi, Hyderabad
- Transformer Sectional committee BIS ET 14
- CIRGE NSC B5 Power systems Protection and local controls, IEEE Member
- ET35 Committee on Power systems Relay

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