Power Systems Lab:

The power systems laboratory of the Department of Electrical Engineering, IIT(BHU) Varanasi, was established to contribute to the study and development in various areas of the power system. The laboratory caters not only to training the undergraduate and postgraduate students of the department but also to various research and development activities pursued by faculties and research scholars of the department.

1. **Undergraduate and Postgraduate course lab:** Lab facilitates are used to impart practical training to the undergraduate and postgraduate students. Following experiments are conducted in the laboratory:

- Determine the ABCD parameters of a medium length transmission line
- Plot the receiving end power circle diagram of a medium length transmission line
- Determine the voltage efficiency and regulation of a medium length transmission line
- Plot the voltage profile of a long transmission line under different load conditions
- Obtain the string efficiency of a given model of suspension insulators
- Determine the capacitance of a three-core cable
- Study of travelling waves and recovery voltage on a Transient Network Analyser (TNA)
- Study of transient and sympathetic inrush current in a transformer
- Effect of series and shunt compensation on a long transmission line
- Control of real and reactive power in interconnected power systems
- Load flow study on a P.C. using the Newton Raphson method
- Computer simulation of different faults on transmission lines
- V-I characteristics of static VAR compensator (SVC)
- Economic Load Dispatch studies on a digital computer

- Study of directional overcurrent relay
- Measurement of positive, negative, and zero sequence impedance of a transformer
- Operating characteristic of a percentage differential relay at various bias settings
- Current time characteristic of inverse-time overcurrent relay
- Earth resistance by fall of potential method
- Earth fault relay
- Experimental simulation of a three-phase fault
- Experimental simulation of single line to ground, line to line to ground, and line to line faultsStudy of travelling waves and recovery voltage on a Transient Network Analyser (TNA)
- Study of transient and sympathetic inrush current in a transformer
- Effect of series and shunt compensation on a long transmission line
- Control of real and reactive power in interconnected power systems
- Load flow study on a P.C. using the Newton Raphson method
- Simulation of faults using MATLAB
- V-I characteristics of static VAR compensator (SVC)
- Voltage distribution along a long transmission line
- Measurement of positive, negative, and zero sequence impedance of a three-phase transformer

2. **Thrust Research Areas:** The power system group is pursuing research in the following thrust areas:
    a. EHV AC & DC Transmission Technology- Design and Development
    b. FACTS Controllers Design, Analysis and Applications
    c. Integrated Large Power System Operation & Smart Control
    d. Intelligent Grid Control Architecture
    e. High Voltage DC Transmission Technology including VSC for RE Interface Connectivity
    f. Electricity Policy and Planning
    g. Distribution System Planning & Automation
    h. Distributed Energy Resources & Management
    i. Design and Development of Integrated Smart Power Systems (Generation, Transmission and Distribution) under Large Renewable Energy, Electric Vehicle and Energy Storage Penetration in Grid
    j. Development of Cost Effective Integrated Local Energy Systems-Multi Agent based Intelligent Energy Management
    k. Design and Development of a Smart Energy Management System (SEMS): optimizing Local Renewable Energy Mix, Energy Storage with Demand Side Management
    l. Power System and Smart grid
    m. Signal processing and optimization applied to Power System Protection
    n. Application of robust control in Hybrid Power System and Micro grid
    o. Wide Area Measurement System(WAMS),
    p. Security analysis, Economic operation and Congestion Management of power systems
    q. Protection, Load forecasting, Power system optimization, AI applications in power system.
    r. Power quality and voltage stability studies

3. **Equipment and devices:**

The departmental power system laboratory is equipped with modern and functional software and hardware facilities for the conduct of research in various domains of power system. Some key facilities are as follows:

- ✓ **Real-time Digital Simulator (RTDS)**
- ✓ **DIgSILENT POWERFACTORY Software**
- ✓ **PSCAD/EMTDC Software**
- ✓ **PSSE and SINCAL Software**
- ✓ **Digital protection laboratory with numerical relays**
- ✓ **Transmission line simulator with SCADA interface**
- ✓ **Electromechanical relays**

Some Photographs

❖ Features

- Single "rack" with parallel processing cards (inter-rack communications (IRC), workstation interface (WIF), and I/O cards.)
- PB5 processor card with:
  - ❖ Two 1.7 GHz PowerPC RISC processors
  - ❖ Eight GT fiber ports facilitating interfacing with other PB5 cards and simulations of large-scale systems with small time steps
  - ❖ Two Freescale MC7448 PowerPC RISC processors with a clock frequency of 1.7 GHz
  - ❖ 90 single-phase nodes (30 three-phase buses)
  - ❖ Dual network solutions (i.e., two subsystems) in one rack.
  - ❖ 180 nodes per rack maximum number of nodes per rack can be simulated

❖ Hardware (NovaCor chassis)

NovaCor is the hardware used to solve the equations representing the power system and control system components modeled within the RTDS. Features of the hardware are as follows:

- Multi-core processor: Ten (10) nos. of 3.5 GHz IBM Power8
- Workstation Inter-Face (WIF) functionality
- Communication ports: Twenty-four fiber optic ports
- Analog output channels
- Ethernet connection to interface between non-real-time FPGA and RSCAD on workstations

PB5 Processor card

GTAI

GTAO

GTWIF

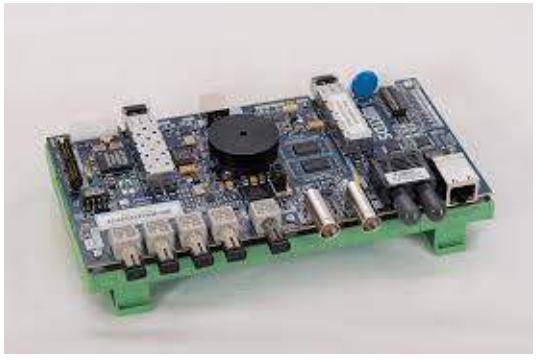
GTDI

GTDO

GTFPI

GTNETx2

GTSYNC



❖ **Software -RSCAD**

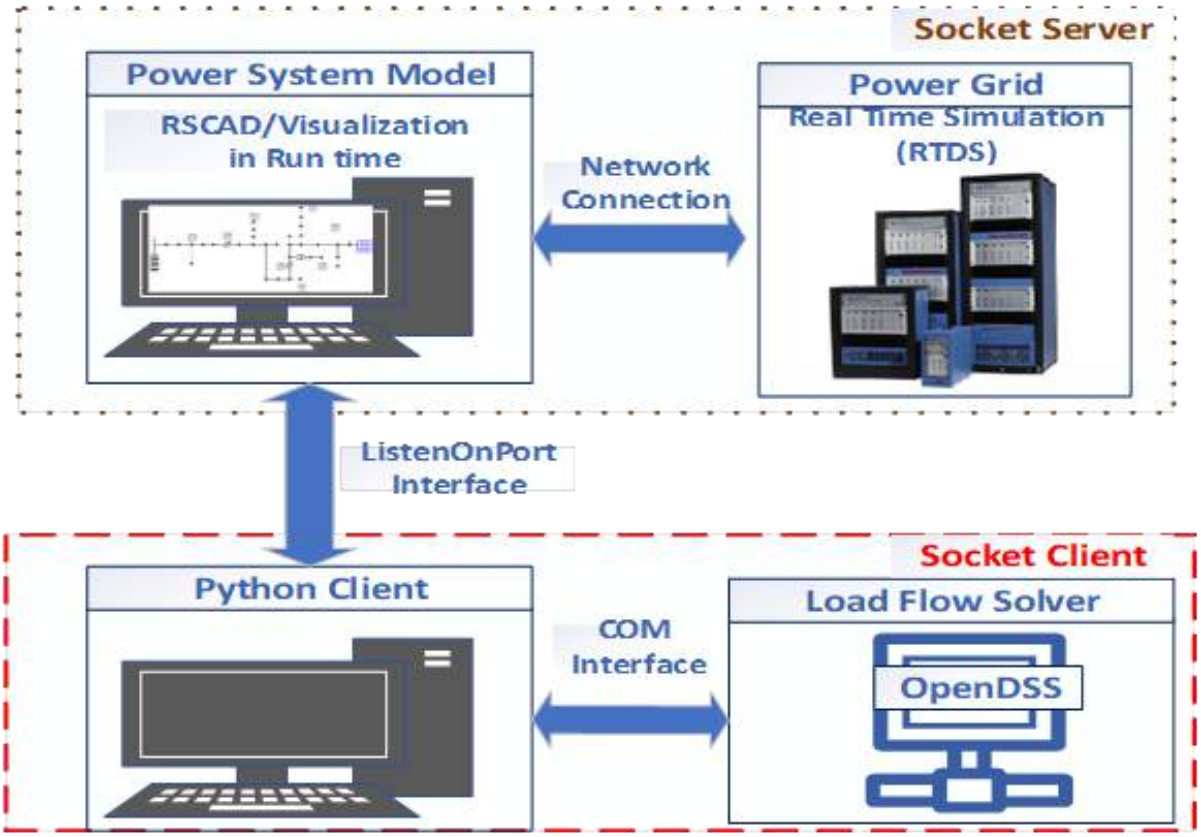
- GUI-based software tool with graphical interface to RTDS
- Library section with pre-built power systems and control components
- Different control operations like fault application, breaker operation, and set point adjustment during runtime with run-time modules

❖ **Communication Protocols**

- IEC 61850 GOOSE (certified)
- SCD Editor
- IEC 61850-9-2 sampled values
- DNP3
- C37.118

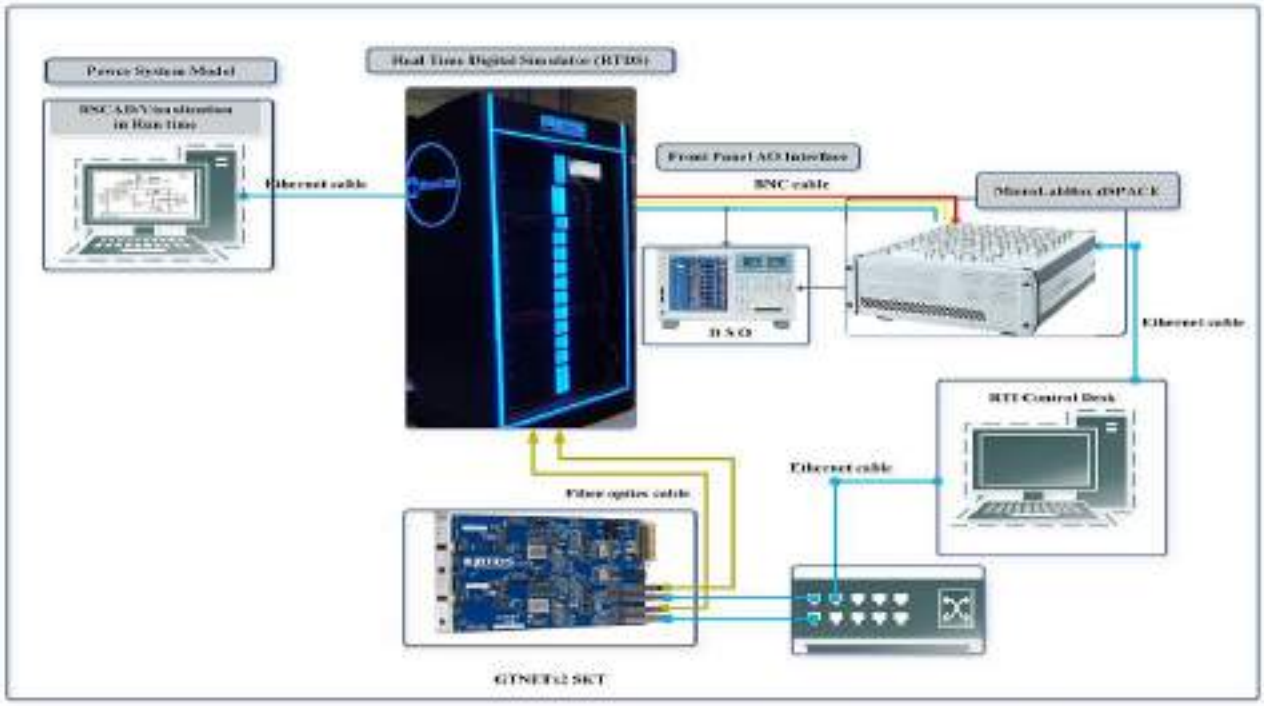
Applications: Real-Time Simulation of Smart Grid with Distributed Energy Resources, electromagnetic transient simulations, protection studies, WAM studies, etc.

- **Real-Time Co-Simulation Framework for Smart Grid**
  (Collaborative research with National Renewable Energy Laboratory, Golden USA under Bhaskara Advanced Solar Energy (BASE) Award supported by DST, Govt. of India and Indo-US Science and Technology Forum (IUSSTF) New Delhi)



- Event-driven Multi-Time horizon real-Time Predictive framework for Smart Volt/VAR Control
- Energy Saving Algorithm using Conservation Voltage Reduction
- Coordinated Operational Methodology for Active Distribution Network considering high penetration of DERs and EV charging loads
- Adaptive Droop Control algorithm for Smart Inverter

Real-Time Controller Hardware in Loop (CHIL) Simulation Set-up



- Islanding Detection Techniques for Micro-Grid operation
- Droop controller for Micro Grid
- Real-Time Integrated Transmission and Distribution (ITD) System Framework

Laboratory Test Set UP at IIT(BHU)

DIgSILENT POWERFACTORY

Single user client license and single user server network license

❖ Features

- Network visualization in graphical format
- Supports generic interfaces (DGS), scripting interfaces(DPL and Python) and built-in converters
- Integration of SCADA and GIS system for process automation applications using the PowerFactory Application Programming Interface (API)
- **Packages:**

Basic packages:

Load Flow Analysis
Sensitivities / Distribution Factors
Power Equipment Models
Network Model Management
Results and Reporting
Short-Circuit Analysis
Basic MV/LV Network Analysis
Network Representation
Network Diagrams and Graphic Features
Various Data Converters

Add on packages:

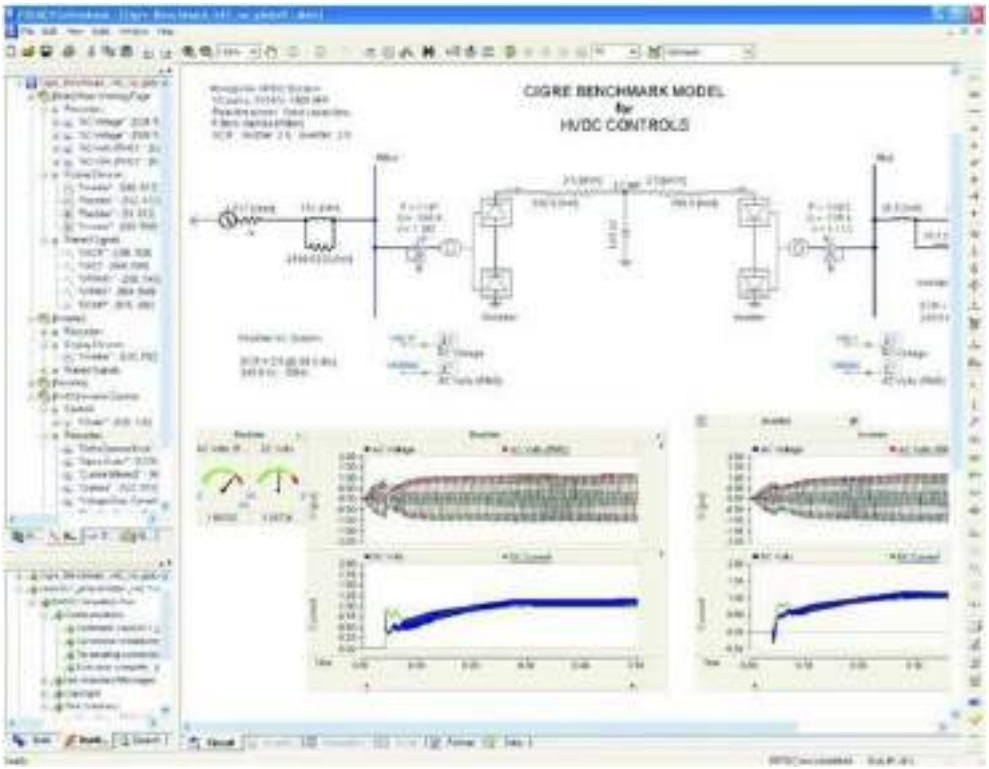
Contingency Analysis
Network Reduction
Quasi-Dynamic Simulation
Protection Functions

Arc-Flash Analysis
Power Quality and Harmonic Analysis
Transmission Network Tools
Outage Planning
Reliability Analysis Functions
Unit Commitment and Dispatch Optimisation
Cable Analysis
Connection Request Assessment
Distribution Network Tools
Probabilistic Analysis
Optimal Power Flow (OPF)
Economic Analysis Tools

State Estimation
Electromagnetic Transients (EMT)
Small Signal Stability (Eigenvalue Analysis)
Stability Analysis Functions (RMS)
Motor Starting Functions
System Parameter Identification

Applications: Steady-state (analysis and optimization) and quasi-dynamic studies of generation, transmission, distribution, and industrial systems including studies on power quality assessment, renewable integration, protection coordination, stability studies, etc.

PSCAD/EMTDC



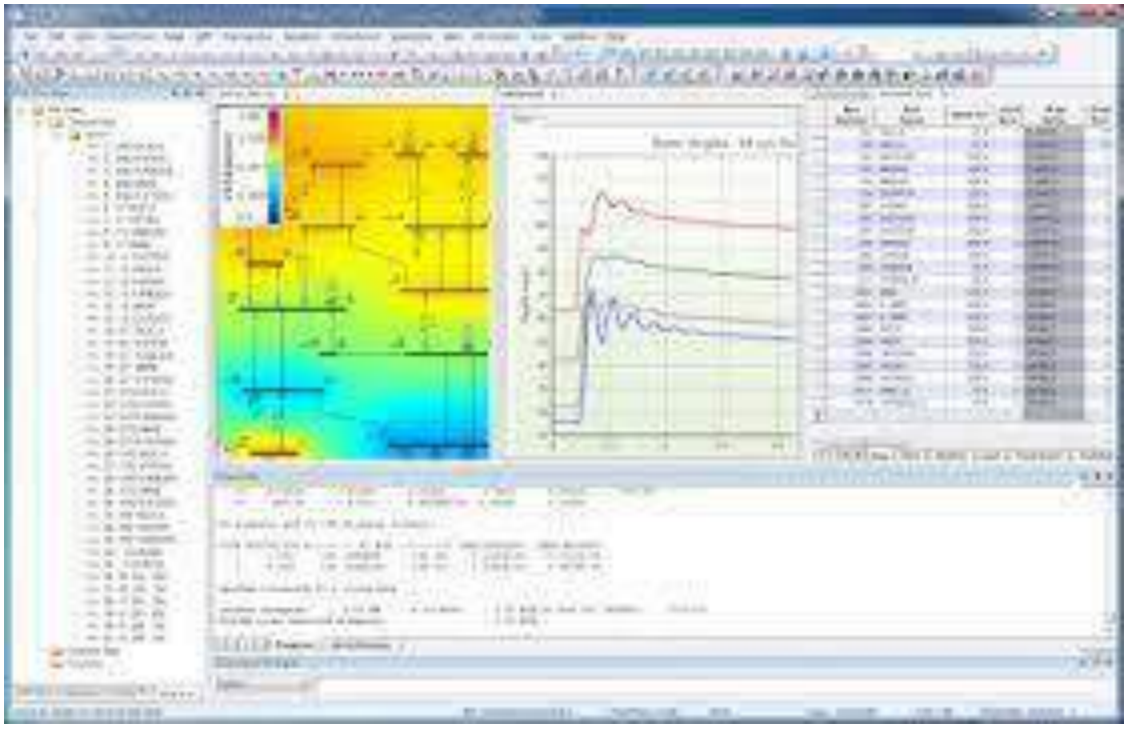
A single-user professional license and 10 users educational license facility of PSCAD/EMTDC simulation software is available.

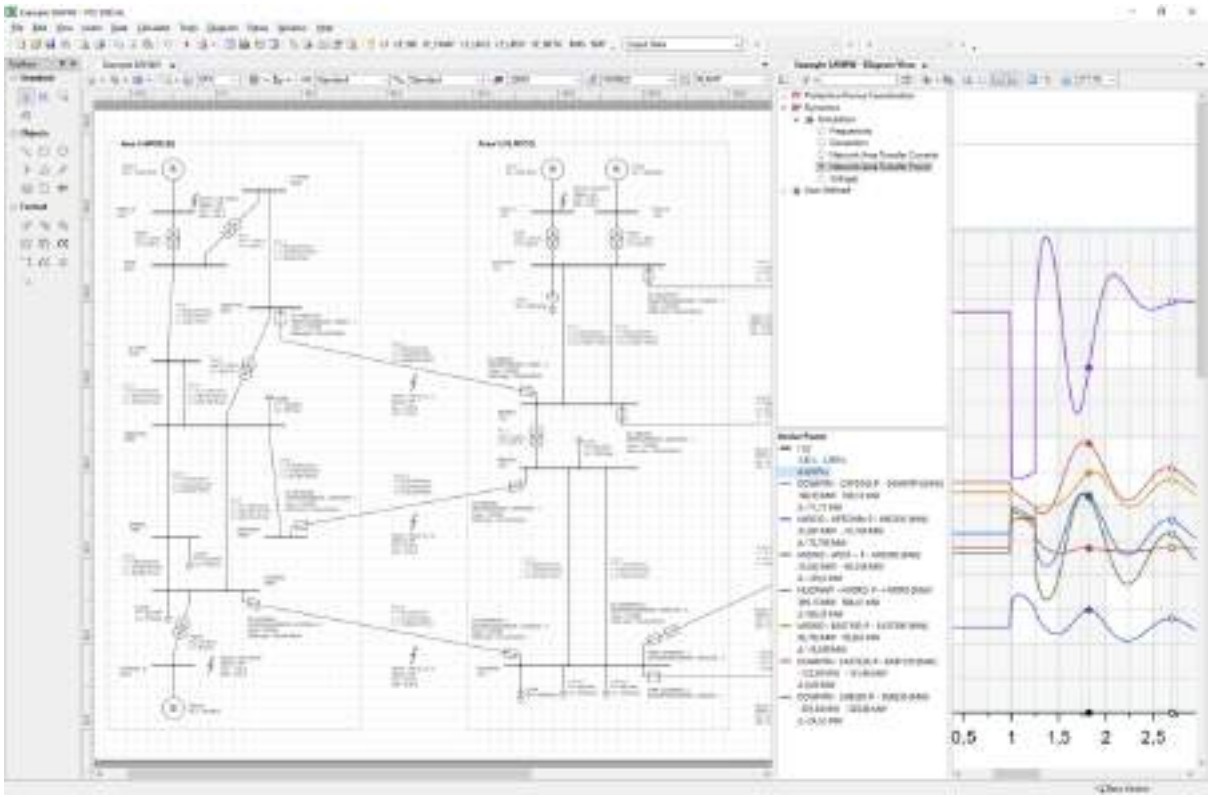
❖ Features

- Time-domain simulation software for studies of power system electromagnetic transients
- Built-in library with detailed models of power system components, control, and protection functionalities
- Graphical interface facilitating schematic construction of circuits

Applications: Electromagnetic transient analysis, short circuit analysis, Protective device coordination, Power flow study, Power system stability, harmonic analysis, modeling of FACTS devices and converter-based units with detailed control blocks, insulation coordination studies, etc.

PSSE and SINCAL





The power system laboratory is equipped with PSSE and SINCAL with perpetual license and unlimited nodes for one user.

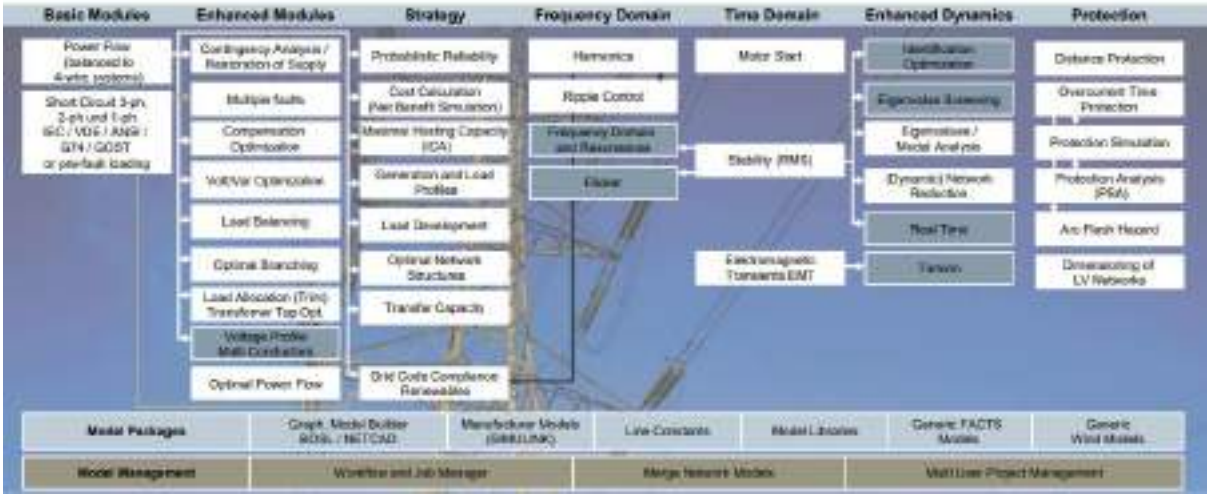
❖ Features

- GUI Interface
- Visualization of network models in schematic, geographic or multi-layer diagrams
- Extensive data modeling of all types of equipment including smart grid data models
- Advanced algorithms with multiple modules
- Open architecture for easy data exchange and IT integration
- Multi View on the same network model (e.g. schematic, geographical, network levels or areas)
- Model Management based on different data bases (Access, Oracle, SQL Server) -> access from outside
- Multi Project Management – maintaining models of different users in one database system (Oracle, SQL Server)
- Programming can be done extensively and with standards languages (VBA, VBS, C++, .net, Python, Java)
- Integration into other systems without depending on Siemens – Integrators
- Interfaces (Adaptors) for import and export are free of charge – “open system” •
- Interfaces to Smart Meter Systems (MDM) are available
- Handling of large networks in the GUI without delay

Applications:

PSSE: Transmission operations & planning as per Industry standards

SINCAL: All-in-one simulation tool for the modeling, analysis, planning, and design of all types of power networks – from high to low voltage



Numerical Relays

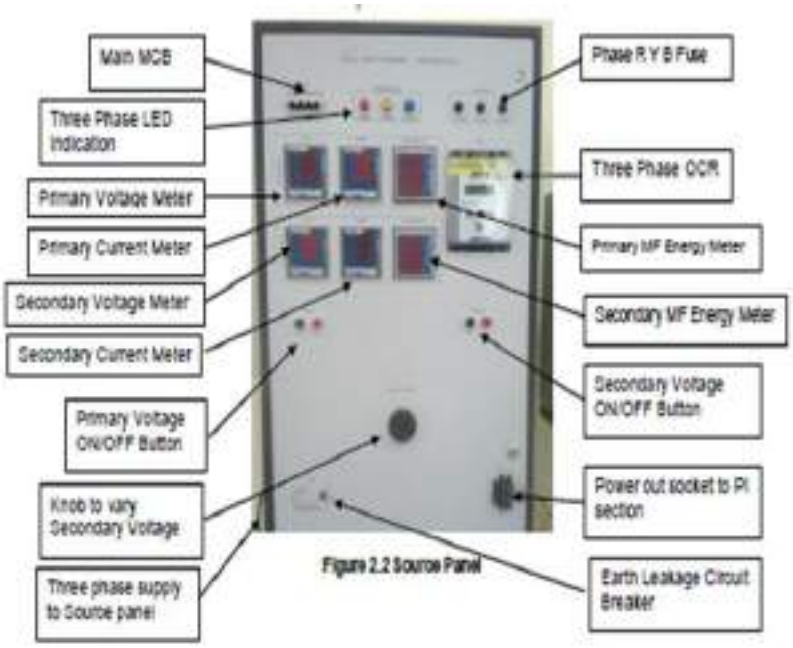
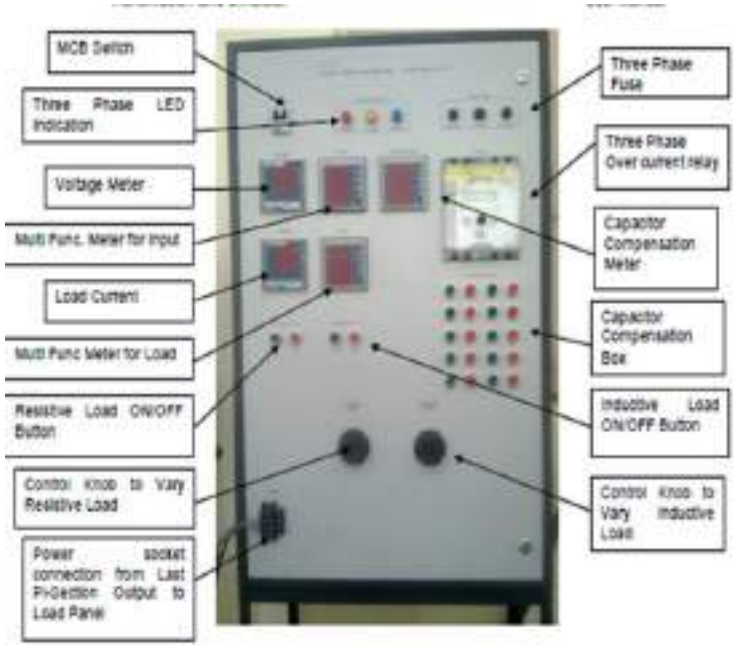
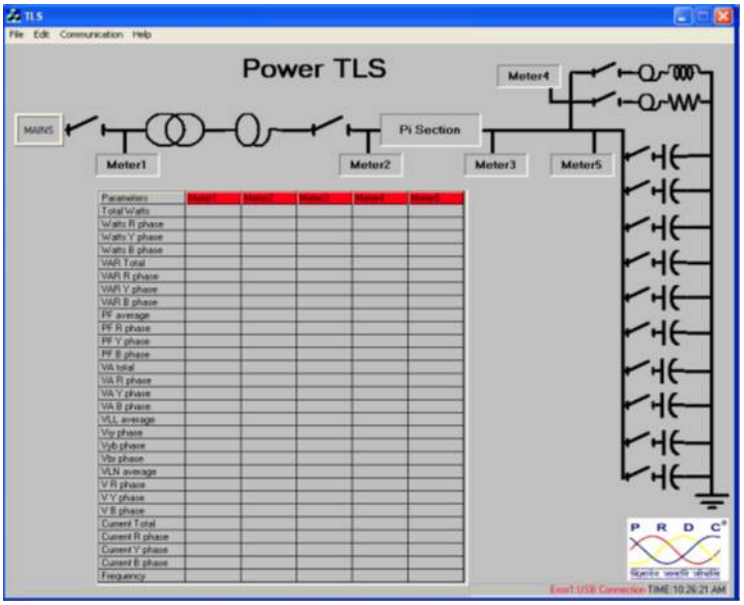


Figure 2.2 Source Panel



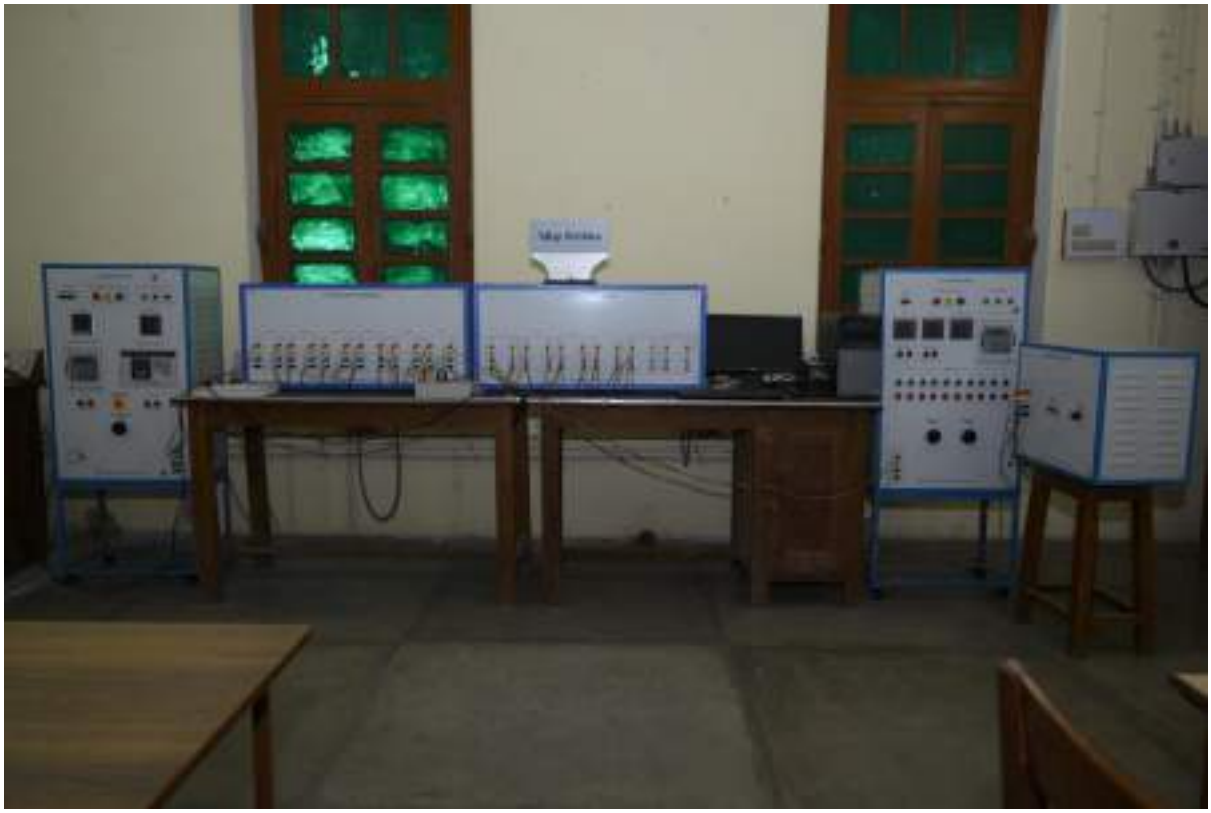
Transmission Line simulator



SCADA Interface of the transmission line simulator

Electromechanical Relay


Earth Fault Relay



Experimental set up with transmission line simulator

Students working in the laboratory

Some View Of Power System Laboratory