



COURSE OVERVIEW EE0085-3D Power System Control & Stability

Course Title

Power System Control & Stability

Course Date/Venue

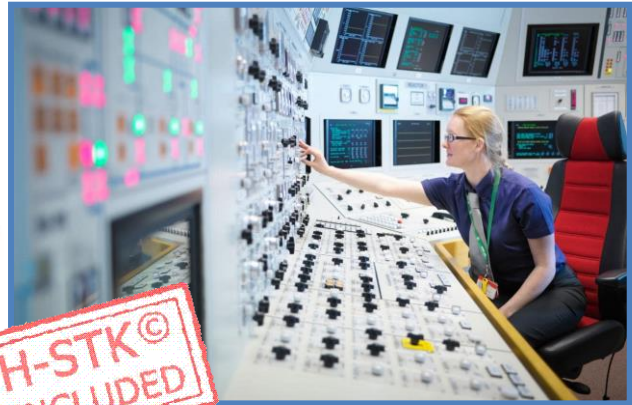
September 13-15, 2020/Boardroom 3,
Elite Byblos Hotel Al Barsha, Sheikh
Zayed Road, Dubai, UAE

Course Reference

EE0085-3D

Course Duration/Credits

Three days/1.8 CEUs/18 PDHs

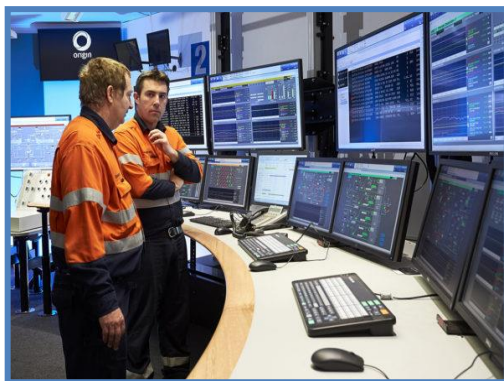


Course Description



This hands-on, highly-interactive course includes various practical sessions and exercises. Theory learnt will be applied using our state-of-the-art simulators.

The robustness of a power system is measured by the ability of the system to operate in a state of equilibrium under normal and perturbed conditions. Power system stability deals with the study of the behavior of power systems under conditions such as sudden changes in load or generation or short circuits on transmission lines.



A power system is said to be stable if the interconnected generating units remain in synchronism. The ability of a power system to maintain stability depends to a large extent on the controls available on the system to damp the electromechanical oscillations. Hence, the study and design of controls are very important. Of all the complex phenomena on power systems, power system stability is the most intricate to understand and challenging to analyze. Electric power systems of the 21st century present an even more formidable challenge as they are forced to operate closer to their stability limits.



This course is concerned with understanding, modelling, analyzing, and mitigating power system stability and control problems. Such problems constitute very important considerations in the planning, design, and operation of modern power systems.



The complexity of power systems is continually increasing because of the growth in interconnections and use of new technologies. At the same time, financial and regulatory constraints have forced utilities to operate the systems nearly at stability limits. These two factors have created new types of stability problems. Greater reliance is, therefore, being placed on the use of special control aids to enhance system security, facilitate economic design, and provide greater flexibility of system operation. In addition, advances in computer technology, numerical analysis, control theory, and equipment modelling have contributed to the development of improved analytical tools and better system-design procedures. The primary motivation for this course is to describe these new developments and to provide a comprehensive treatment of the subject.

The course is intended to meet the needs of practicing engineers associated with the electric utility industry as well as those of graduate students and researchers. The course will provide the necessary fundamentals, explaining the practical aspects, and giving an integrated treatment of the latest developments in modeling techniques and analytical tools.

Course Objectives

Upon the successful completion of this course, each participant will be able to:-

- Apply and gain an in-depth knowledge on power system control and stability
- Discuss the basic concepts, definitions, classification of stability and historical review of stability problems
- Recognize synchronous machine theory and modeling, physical description and mathematical description of a synchronous machine
- Describe the $dq0$ transformation, per unit representation, equivalent circuits for direct and quadrature and steady-state analysis
- Identify electrical transient performance characteristics, magnetic saturation and equations of motion
- Differentiate synchronous machine parameters, operational parameters, standard parameters, frequency-response characteristics and determination of synchronous machine parameters
- Explain synchronous machine representation in stability studies, simplifications essential for large-scale studies, neglect of stator $p\psi$ terms and neglecting the effect of speed variations on stator voltages
- Illustrate simplified model with amortisseurs neglected and constant flux linkage model
- Recognize reactive capability limits, AC transmission, transmission lines, transformers, transfer of power between active sources, power flow analysis, power system loads, basic load-modelling concepts, modeling of induction motors, acquisition of load-model parameters and excitation systems
- Enumerate the elements and the various types of excitation systems
- Carryout dynamic performance measures, control and protective functions, excitation systems and field testing for model development and verification

Exclusive Smart Training Kit - H-STK®



Participants of this course will receive the exclusive “Haward Smart Training Kit” (H-STK®). The H-STK® consists of a comprehensive set of technical content which includes **electronic version** of the course materials, sample video clips of the instructor’s actual lectures & practical sessions during the course conveniently saved in a **Tablet PC**.

Who Should Attend

This course provides an overview of all significant aspects and considerations of power system control and stability for electrical managers, engineers, planners, supervisors and other technical staff involved in the stability and control of electrical power systems.

Training Methodology

This interactive training course includes the following training methodologies as a percentage of the total tuition hours:-

- 30% Lectures
- 20% Workshops & Work Presentations
- 20% Case Studies & Practical Exercises
- 30% Videos, Software & Simulators

In an unlikely event, the course instructor may modify the above training methodology before or during the course for technical reasons.

Course Fee

US\$ 3,750 per Delegate + **5% VAT**. This rate includes H-STK® (Haward Smart Training Kit), buffet lunch, coffee/tea on arrival, morning & afternoon of each day.

Accommodation


Accommodation is not included in the course fees. However, any accommodation required can be arranged at the time of booking.

Course Certificate(s)

Internationally recognized certificates will be issued to all participants of the course.

Certificate Accreditations


Certificates are accredited by the following international accreditation organizations:-

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USA International Association for Continuing Education and Training (IACET)

Haward Technology is an Authorized Training Provider by the International Association for Continuing Education and Training (IACET), 2201 Cooperative Way, Suite 600, Herndon, Virginia 20171, USA. In obtaining this authority, Haward Technology has demonstrated that it complies with the **ANSI/IACET 1-2013 Standard** which is widely recognized as the standard of good practice internationally. As a result of our Authorized Provider membership status, Haward Technology is authorized to offer IACET CEUs for its programs that qualify under the **ANSI/IACET 1-2013 Standard**.

Haward Technology's courses meet the professional certification and continuing education requirements for participants seeking **Continuing Education Units (CEUs)** in accordance with the rules & regulations of the International Association for Continuing Education & Training (IACET). IACET is an international authority that evaluates programs according to strict, research-based criteria and guidelines. The CEU is an internationally accepted uniform unit of measurement in qualified courses of continuing education.

Haward Technology Middle East will award **1.8 CEUs** (Continuing Education Units) or **18 PDHs** (Professional Development Hours) for participants who completed the total tuition hours of this program. One CEU is equivalent to ten Professional Development Hours (PDHs) or ten contact hours of the participation in and completion of Haward Technology programs. A permanent record of a participant's involvement and awarding of CEU will be maintained by Haward Technology. Haward Technology will provide a copy of the participant's CEU and PDH Transcript of Records upon request.

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British Accreditation Council (BAC)

Haward Technology is accredited by the **British Accreditation Council** for **Independent Further and Higher Education** as an **International Centre**. BAC is the British accrediting body responsible for setting standards within independent further and higher education sector in the UK and overseas. As a BAC-accredited international centre, Haward Technology meets all of the international higher education criteria and standards set by BAC.

Course Instructor(s)

This course will be conducted by the following instructor(s). However, we have the right to change the course instructor(s) prior to the course date and inform participants accordingly:



Mr. Carlos Monterrosa, PE, MSc, BSc, is a **Senior Electrical Engineer** with over **30 years** of extensive experience in the **Oil & Gas, Refinery, Petrochemical, Power and Utilities** industries. His expertise widely covers in the areas of **High Voltage Electrical Safety, HV/MV Cable Splicing, Jointing & Termination, High Voltage Circuit Breaker Inspection & Repair, High Voltage Power System Safe Operation, High Voltage Safety, High Voltage Transformers, Safe Operation of High Voltage & Low Voltage Power Systems, Transformer Operation & Maintenance, Electrical Maintenance & Inspection, Electrical Isolation, Circuit Breakers, Switchgears & 132 KV Cables, Power System Control & Stability, Economic Dispatch of Power Plants, Electrical Power Systems Quality & Troubleshooting, UPS & Battery Maintenance & Troubleshooting, Motors & Variable Speed Drives Troubleshooting & Maintenance, Generator Excitation Systems & AVR Commissioning & Troubleshooting, Power Generation & Transmission, Electrical Distribution Systems, Power System Blackouts Preventive Measures, Power System Protection & Relaying, Electrical Networks & Distribution Cables Fault Analysis, Motor Control Circuit Troubleshooting, Power Factor Correction, Load Forecasting & System Upgrade, National Electrical Code (NEC), Earthing & Bonding, Power Distribution Systems, Overhead Power Line Construction, Generator Operation & Maintenance, PdMA Motor Testing Data Analysis, Power System Blackouts & Restoration, Siemens Master Drives, Substation Automation Systems, Power Factor Correction, Practical Electrical Wiring, Schematic & Wiring Diagrams Analysis, Energy Management, Electrical Equipment & Control Circuits, Practical Fiber-Optics Technology, Structured Cabling System (SCS), Industrial Process Control & Instrumentation, Programmable Logic Controllers (PLC) & SCADA System, Renewable Energy, Industrial Data Communication, Root Cause Failure Analysis (RCFA) for Control & Instrumentation. Further, he is also well-versed in National Electrical Code (NEC), National Electrical Safety Code (NESC), Power System Distribution, Electromechanical Maintenance, Power Systems Security, Power Electronics, Custody Measurement, Process Control & Instrumentation, PLC, SCADA, DCS, Power Generation, Industrial Data Communication and Telecommunication.**

Mr. Monterrosa has built-up a formidable reputation in his design, inspection, installation and maintenance of High Voltages Distribution, **Transformers**, Substation, AC & DC **Drives**, Power Electronics, **Instrumentation & Control Systems** and **Data Communications**. While he has performed significant consultancy projects in these areas, he was also involved in generator **excitation systems**, generator protection, LV/MV Drives, ACS/DCS drives and Electrical AC **motors** and **drives**. He spends most of his time on consultancy projects in which he is **world renowned** for his professionalism and practical problem-solving abilities.

He gained his expertise & thorough practical experience through several positions and dedication as a **Project Manager, Technical Services Manager, Application & Product Engineer, Electrical Engineer, Instrumentation Engineer, Design Engineer, Project Engineer, Electrical Designer, Laboratory Instructor, Chief Technician, LAN Technician, Project Coordinator** and **Research Assistant** for various international companies and institutions such as the **ABB Inc.**, Ecole de Technologie Supérieure (ETS), Woods Electronics, Formatronique Ltd. and COCLA just to name a few.

Mr. Monterrosa has a **Bachelor** degree in **Electrical Engineering & Power Electronics** from Ecole de Technologie Supérieure, **Canada** and holds various Certification in **Industrial Robotics & Automated Systems** from Institut Supérieur d'Electronique, Canada, a Certificate in **Electronic Systems** Technology from Formatronique, Canada and a Certificate in Computer **Applied Digital Technologies** from Formatronique, Canada. Further, he is a **Certified Instructor/Trainer** and has delivered numerous trainings, workshops, courses, seminars and conferences internationally.



Course Program

The following program is planned for this course. However, the course instructor(s) may modify this program before or during the course for technical reasons with no prior notice to participants. Nevertheless, the course objectives will always be met:

Day 1: Sunday, 13th of September 2020

0730 – 0800	Registration & Coffee
0800 – 0815	Welcome & Introduction
0815 – 0830	PRE-TEST
0830 – 0845	Introduction to the Power System Stability Problem
0845 – 0900	Basic Concepts & Definitions Power System Stability • Rotor Angle Stability • Synchronous Machine Characteristics • Power Versus Angle Relationship • The Stability Phenomena • Voltage Stability & Voltage Collapse • Mid-Term & Long-Term Stability
0900 – 0915	Classification of Stability
0915 – 0930	Historical Review of Stability Problems
0930 – 0945	Break
0945 – 1000	Synchronous Machine Theory & Modelling
1000 – 1030	Physical Description Armature & Field Structure • Machines with Multiple Pole Pairs • MMF Waveforms • Rotating Magnetic Field • Direct & Quadrature Axes
1030 – 1100	Mathematical Description of a Synchronous Machine Review of Magnetic Circuit Equations Single Excited Circuit • Coupled Circuits • Basic Equations of a Synchronous Machine • Stator Circuit Equations • Stator Self-Inductances • Stator Mutual Inductances • Mutual Inductance Between Stator & Rotor Windings • Rotor Circuit Equations
1100 – 1130	The dq0 transformation Stator Flux Linkages in dq0 Components • Rotor Flux Linkages in dq0 Components • Stator Voltage Equations in dq0 Components • Electrical Power & Torque • Physical Interpretation of dq0 Transformation
1130 – 1145	Per Unit Representation Per Unit System for the Stator Quantities • Per Unit Stator Voltage Equations • Per Unit Rotor Voltage Equations • Stator Flux Linkage Equations • Rotor Flux Linkage Equations • Per Unit System for the Rotor • Per Unit Power & Torque • Summary of per Unit Equations • Complete Set of Electrical Equations in Per Unit • Per Unit Reactances
1145 - 1200	Equivalent Circuits for Direct & Quadrature Axes
1200 – 1215	Break
1215 – 1245	Steady-State Analysis Voltage, Current, & Flux Linkage Relationships • Field Current • Phasor Representation • Rotor Angle • Procedure for Computing Steady-State Values
1245 – 1315	Electrical Transient Performance Characteristics Short-circuit Current in a Simple RL Circuit • Three-phase Short-circuit at the Terminals of a Synchronous Machine • Elimination of DC Offset in Short-Circuit Current





1315 - 1345	Magnetic Saturation <i>Open-circuit & Short-circuit Characteristics • Representation of Saturation in Stability Studies • Improved Modelling of Saturation • Use of Potier Reactance</i>
1345 - 1420	Equations of Motion <i>Review of Mechanics of Motion • Swing Equation • Per Unit Moment of Inertia • Mechanical Starting Time • Calculation of Inertia Constant • Calculation of H from Moment of Inertia in MKS Units • Calculation of H from WR^2 in English Units • Typical Values of H • Representation in System Studies</i>
1420 - 1430	Recap <i>Using this Course Overview, the Instructor(s) will Brief Participants about the Topics that were Discussed Today and Advise Them of the Topics to be Discussed Tomorrow</i>
1430	Lunch & End of Day One

Day 2: Monday, 14th of September 2020

0730 - 0800	Synchronous Machine Parameters
0800 - 0830	Operational Parameters
0830 - 0900	Standard Parameters <i>Parameters Based on Classical Definitions • Accurate Expressions for Standard Parameters • Parameters Including Unequal Mutual Effects • Parameters of Salient Pole Machines • Typical Values of Standard Parameters</i>
0900 - 0915	Frequency-response Characteristics <i>Armature Time Constant</i>
0915 - 0930	Break
0930 - 1000	Determination of Synchronous Machine Parameters <i>Enhanced Short-Circuit Tests • Decrement Tests • Frequency-Response Tests (Standstill Frequency Response (SSFR), Open-Circuit Frequency Response (OCFR), On-Line Frequency Response (OLFR)) • Calculation of Machine Parameters from Design Data</i>
1000 - 1030	Synchronous Machine Representation in Stability Studies
1030 - 1100	Simplifications Essential for Large-scale Studies
1100 - 1130	Neglect of Stator P_{ψ} Terms
1130 - 1145	Neglecting the Effect of Speed Variations on Stator Voltages <i>Relationship between Per Unit P_e & T_e</i>
1145 - 1200	Simplified Model with Amortisseurs Neglected <i>Alternative form of Machine Equations • Phasor Diagram for Transient Conditions</i>
1200 - 1215	Break
1245 - 1300	Constant Flux Linkage Model <i>Classical Model • Constant Flux Linkage Model Including the Effects of Subtransient Circuits • Summary of Simple Models for Different Time Frames</i>
1300 - 1330	Reactive Capability Limits <i>Reactive Capability Curves • Armature Current Limit • Field Current Limit • End Region Heating Limit • V Curves and Compounding Curves</i>
1330 - 1400	AC Transmission





1400 - 1420	<p>Transmission Lines <i>Electrical Characteristics (Overhead Lines, Underground Cables) • Performance Equations • Natural or Surge Impedance Loading • Equivalent Circuit of a Transmission Line • Nominal π Equivalent Circuit • Classification of Line Length • Typical Parameters (Overhead Lines, Underground Cables) • Performance Requirements of Power Transmission Lines • Voltage & Current Profile Under No-Load (Receiving End Open-Circuited, Line Connected to Sources at both Ends) • Voltage-Power Characteristics [4,10] (Radial Line with Fixed Sending End Voltage, Line Connected to Sources at Both Ends) • Power Transfer & Stability Considerations • Reactive Power Requirements • Effect of Line Loss On V-P and Q-P Characteristics • Thermal Limits • Loadability Characteristics • Effect of Using Bundled Conductors</i></p>
1420 - 1430	<p>Recap <i>Using this Course Overview, the Instructor(s) will Brief Participants about the Topics that were Discussed Today and Advise Them of the Topics to be Discussed Tomorrow</i></p>
1430	<p><i>Lunch & End of Day Two</i></p>

Day 3: Tuesday, 15th of September 2020

0730 - 0800	<p>Transformers <i>Representation of Two-Winding Transformers (Basic Equivalent Circuit in Physical Units, Per Unit Equivalent Circuit, Standard Equivalent Circuit, Equivalent π Circuit Representation, Consideration of Three-Phase Transformer Connections) • Example of Modelling Two-Winding Transformers • Representation of Three-Winding Transformers (Example of Modelling Three-Winding Transformers) • ULTC Data • H-L Branch • L-T Branch • Phase-Shifting Transformers (Example of Modelling a Phase-Shifting Transformer)</i></p>
0800 - 0830	<p>Transfer of Power Between Active Sources</p>
0830 - 0900	<p>Power-Flow Analysis <i>Bus Classification • Representation of Network Elements • Network Equations • Nonlinear Power-Flow Equations • Gauss-Seidel Method • Newton-Raphson (N-R) Method • Application of the N-R Method to Power-Flow Solution • Sensitivity Analysis Using the Jacobian • Fast Decoupled Load-Flow (FDLF) Methods • Comparison of the Power-Flow Solution Methods • Sparsity-Oriented Triangular Factorization • Network Reduction</i></p>
0900 - 0915	<p>Power System Loads</p>
0915 - 0930	<p><i>Break</i></p>
0930 - 1000	<p>Basic Load-modelling Concepts <i>Static Load Models • Dynamic Load Models • Thermostatically Controlled Loads • Discharge Lighting Loads</i></p>
1000 - 1030	<p>Modelling of Induction Motors <i>Equations of an Induction Machine • Basic Equations of an Induction Machine • The d-q Transformation • Basic Machine Equations in d-q Reference Frame • Electrical Power & Torque • Acceleration Equation • Steady-state Characteristics • Equivalent Circuit • Torque-slip Characteristic • Effect of Rotor Resistance on Efficiency • Alternative Rotor Constructions • Representation of Saturation • Per Unit Representation • Representation in Stability Studies • Simplified Induction Machine Model • Induction Motor Parameters</i></p>

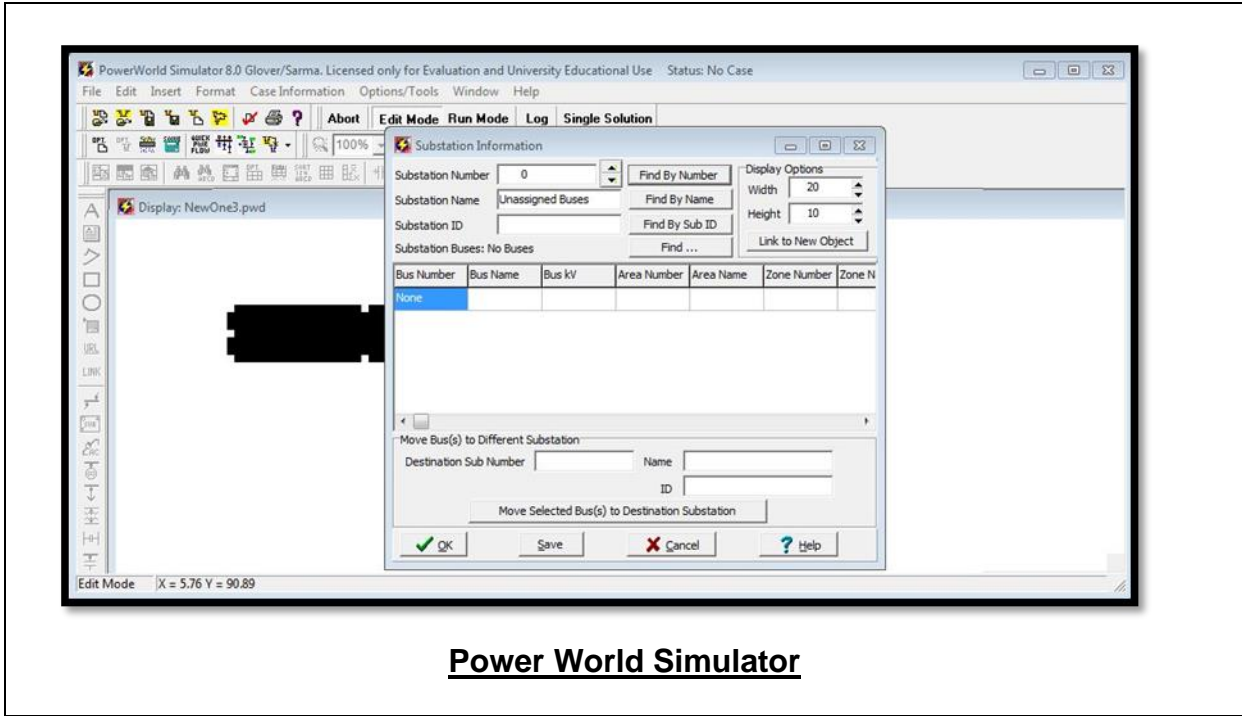




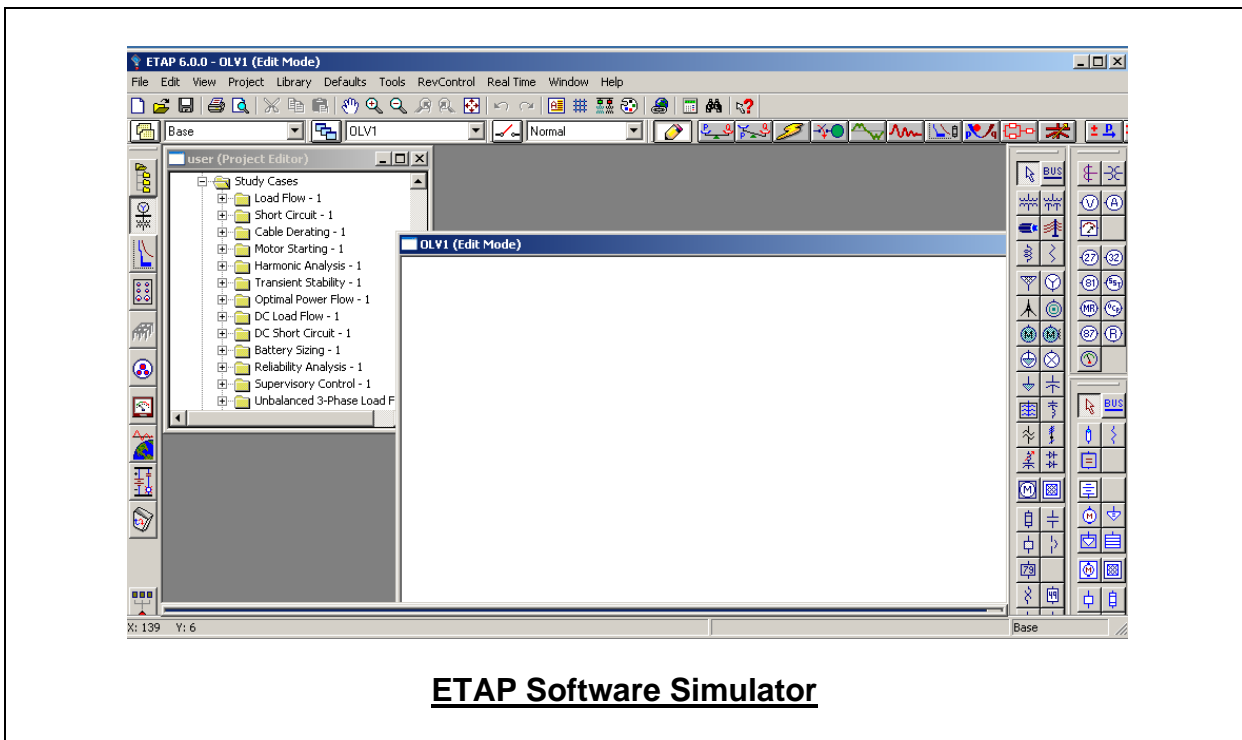
1030 – 1100	<p>Acquisition of Load-Model Parameters <i>Two Basic Approaches to the Determination of System-Load Characteristics (Measurement-based Approach, Component-based Approach)</i> • <i>Measurement-Based Approach</i> • <i>Steady State Load-Frequency Characteristics</i> • <i>Dynamic Load-Voltage Characteristics</i> • <i>Component-Based Approach</i> • <i>Sample Load Characteristics (Component Static Characteristics, Load Class Static Characteristics, Dynamic Characteristics)</i></p>
1100 – 1130	<p>Excitation Systems <i>Generator Considerations</i> • <i>Power System Considerations</i></p>
1130 – 1145	<p>Elements of an Excitation System <i>Exciter</i> • <i>Regulator</i> • <i>Terminal Voltage Transducer & Load Compensator</i> • <i>Power System Stabilizer</i> • <i>Limiters and Protective Circuits</i></p>
1145 - 1200	<p>Types of Excitation Systems <i>DC Excitation Systems</i> • <i>AC Excitation Systems (Stationary Rectifier Systems, Rotating Rectifier Systems (Potential-Source Controlled-Rectifier Systems, Compound-Source Rectifier Systems, Compound-Controlled Rectifier Excitation Systems))</i> • <i>Field Flashing for Static Exciters</i> • <i>Recent Developments & Future Trend</i></p>
1200 - 1215	Break
1245 – 1300	<p>Dynamic Performance Measures <i>Large-Signal Performance Measures (Excitation System Ceiling Voltage, Excitation System Ceiling Current, Excitation System Voltage Time Response, Excitation System Voltage Response Time, High Initial, Response Excitation System, Excitation System Nominal Response)</i> • <i>Small-Signal Performance Measures</i></p>
1300 -1315	<p>Control & Protective Functions <i>AC & DC Regulators</i> • <i>Excitation System Stabilizing Circuits</i> • <i>Power System Stabilizer (PSS)</i> • <i>Load Compensation</i> • <i>Underexcitation Limiter</i> • <i>Overexcitation Limiter</i> • <i>Volts-Per-Hertz Limiter and Protection</i> • <i>Field-Shorting Circuits</i></p>
1315 – 1330	<p>Modelling of Excitation Systems <i>Per Unit System</i> • <i>Specification of Temperature</i> • <i>Modelling of Excitation System Components (Separately Excited DC Exciter, Self-Excited DC Exciter, AC Exciters & Rectifiers, Amplifiers, Excitation System Stabilizing Circuit, Windup & Non-Windup Limits, Gating Functions, Terminal Voltage Transducer & Load Compensator, Modelling of Complete Excitation Systems)</i> • <i>Type AC4A Exciter Model</i> • <i>Type ST1A Exciter Model</i> • <i>Type ST2A Exciter Model</i> • <i>Modelling Of Limiters</i> • <i>Underexcitation Limiter (V/Hz Limiter, Field-Current or Overexcitation Limiter)</i></p>
1330 - 1345	Field Testing for Model Development & Verification
1345 – 1400	<p>Course Conclusion <i>Using This Course Overview, The Instructor(S) Will Brief Participants About The Course Topics That Were Covered During The Course</i></p>
1400 – 1415	POST-TEST
1415 – 1430	<i>Presentation of Course Certificates</i>
1430	<i>Lunch & End of Course</i>

Simulators (Hands-on Practical Sessions)

Practical sessions will be organized during the course for delegates to practice the theory learnt. Delegates will be provided with an opportunity to carryout various exercises using our state-of-the-art simulators “Power World” and “ETAP software”.



Power World Simulator



ETAP Software Simulator

Course Coordinator

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