COURSE OVERVIEW EE0085-4D
Power System Control & Stability

Course Title
Power System Control & Stability

Course Reference
EE0085-4D

Course Duration/Credits
Four days/2.4 CEUs/24 PDHs

Course Date/Venue

Session(s)	Date	Venue
1	February 12-15, 2024	Boardroom 1, Elite Byblos Hotel Al Barsha, Sheikh Zayed Road, Dubai, UAE
2	May 13-16, 2024	Al Aziziya Hall, The Proud Hotel Al Khobar, Al Khobar, KSA
3	August 19-22, 2024	Ajman Meeting Room, Grand Millennium Al Wahda Hotel, Abu Dhabi, UAE
4	November 18-21, 2024	Boardroom, Warwick Hotel Doha, Doha Qatar

Course Description

This practical and 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 pψ 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

All our Courses are including **Hands-on Practical Sessions** using equipment, State-of-the-Art Simulators, Drawings, Case Studies, Videos and Exercises. The courses include the following training methodologies as a percentage of the total tuition hours:-

30% Lectures
20% Practical Workshops & Work Presentations
30% Hands-on Practical Exercises & Case Studies
20% Simulators (Hardware & Software) & Videos

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

Course Fee

Dubai	**US$ 4,500** per Delegate + **VAT**. This rate includes H-STK® (Haward Smart Training Kit), buffet lunch, coffee/tea on arrival, morning & afternoon of each day.
Al Khobar	**US$ 4,500** per Delegate + **VAT**. This rate includes H-STK® (Haward Smart Training Kit), buffet lunch, coffee/tea on arrival, morning & afternoon of each day.
Abu Dhabi	**US$ 4,500** per Delegate + **VAT**. This rate includes H-STK® (Haward Smart Training Kit), buffet lunch, coffee/tea on arrival, morning & afternoon of each day.
Doha	**US$ 5,500** per Delegate. 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 who completed a minimum of 80% of the total tuition hours.

Certificate Accreditations

Certificates are accredited by the following international accreditation organizations:-

- The International Accreditors for Continuing Education and Training (IACET - USA)

  Haward Technology is an Authorized Training Provider by the International Accreditors for Continuing Education and Training (IACET), 2201 Cooperative Way, Suite 600, Herndon, VA 20171, USA. In obtaining this authority, Haward Technology has demonstrated that it complies with the **ANSI/IACET 2018-1 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 2018-1 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 Accreditors 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 **2.4 CEUs** (Continuing Education Units) or **24 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.

- 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. William Hardi is a **Senior Electrical Engineer** with almost **35** years of extensive experience within the **Oil**, **Gas**, **Petrochemical**, **Refinery** & **Power** industries. His expertise widely covers in the areas of **Power System Analysis**, **Power System Generation and Distribution**, **Electric Power System** Design, Maintenance, Testing & Troubleshooting, **Transformer Protection**, **Transformer** Problem and Failure Investigations, **Power System Operation and Control**, Fault Analysis in **Power Systems**, **HV/MV Cable Splicing**, **Cable & Over Head Power Line**, **HV/MV Switchgear, HV Cable** Design, **Cable** Splicing & Termination, **High Voltage Electrical Safety**, **Medium & High Voltage Equipment**, **High Voltage Circuit Breaker** Inspection & Repair, **High Voltage Power** System, **HV Equipment** Inspection & Maintenance, **HV Switchgear** Operation & Maintenance, Resin / **Heat Shrink & Cold Shrink** Joints, **HV/LV Equipment**, **LV & HV Electrical System**, **LV**, **MV & HV Cable** Installations & Properties, ORHVS for Responsible and Authorized Person **High Voltage Regulation**, **Transformers** Maintenance, inspections & repairs, Commissioning of **LV & HV Equipment**, Oil Purification and **High Voltage Maintenance**, HT Switch Gear -Testing, Safe Operating, Maintenance, Inspection & Repairs on **LV & HT Cables** - Testing (Pulse & Megger), Line Patrol in **Low Voltage & Distribution**, **Transmission**, **Operating Principles up to 132KV**, Abnormal Conditions & Exceptions, Commissioning & Testing, **Transformer Inspections & Repairs**, **Live Line Work up to 33KV**, **Basic Power System Protection**, **High Voltage** Operating Preparedness Phasing (**110V to 132KV**), **HV Operating & Fault** Finding (up to 132KV), Maintenance & Construction Supervision, Line Construction & Maintenance up to **132KV**, **VSD/VFD** Installations & Testing, **Electrical Panel Design**, **VSD/VFD Installations & Testing**, Instrument Installation and wiring, Programmable Logic Controller (**PLC**), **PLC for Process Control & Automation**, **ABB Drives and other PLC Starters**, **PLC** Starters – Commissioning & fault-finding, , **AC/DC Supplies & Change Over Systems**, **AC & DC Winders** and VLF Testing, Soft Starters – **VSD's** etc.,

During Mr. Hardi career life, he has gained his practical experience through several significant positions and dedication as the **Branch Manager**, **Maintenance Manager**, **Project Manager**, **Site Superintendent**, **Construction Supervisor**, **Shift Supervisor**, **Maintenance & Production Shift Supervisor**, **HT Specialist, Electrical & Instrumentation Supervisor**, **High Voltage Specialist & Commissioning Supervisor**, **Electrical Supervisor**, **Principal Technical Official**, **Winder & Conveyor Technician** and **Instructor/Trainer** from various companies, like the Armcoil Africa, JR Compressors, ELGER Electrical, Saaiplaas 3 Shaft, ESCOM and Target Mining.

Mr. Hardi is a **Qualified Electrician** certified by the Engineering Trades Training Board. Further, he is a **Certified Instructor/Trainer** and has delivered various trainings, seminars, conferences, workshops and courses globally.

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

0730 – 0745	*Registration & Coffee*
0745 – 0800	*Welcome & Introduction*
0800 – 0815	***PRE-TEST***
0815 – 0830	***Introduction to the Power System Stability Problem***
0830 - 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	*Break*
0915 – 1130	***Classification of Stability***
1130 - 1200	***Historical Review of Stability Problems***
1200 - 1230	***Synchronous Machine Theory & Modelling***
1230 - 1245	*Break*
1245 – 1300	***Physical Description*** *Armature & Field Structure • Machines with Multiple Pole Pairs • MMF Waveforms • Rotating Magnetic Field • Direct & Quadrature Axes*
1300 – 1330	***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*
1330 – 1345	***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*
1345 - 1410	***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*
1410 – 1420	***Equivalent Circuits for Direct & Quadrature Axes***
1420 – 1430	***Recap*** *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*
1430	*Lunch & End of Day One*

Day 2

0730 – 0800	***Steady-State Analysis*** *Voltage, Current, & Flux Linkage Relationships • Field Current • Phasor Representation • Rotor Angle • Procedure for Computing Steady-State Values*
0800 – 0830	***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*
0830 - 0900	***Magnetic Saturation*** *Open-circuit & Short-circuit Characteristics • Representation of Saturation in Stability Studies • Improved Modelling of Saturation • Use of Potier Reactance*
0900 – 0915	*Break*
0915 – 1000	***Equations of Motion*** *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*
1000 - 1100	***Synchronous Machine Parameters***
1100 – 1230	***Operational Parameters***
1230 – 1245	*Break*
1245 – 1315	***Standard Parameters*** *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*
1315 – 1330	***Frequency-response Characteristics*** *Armature Time Constant*
1330 – 1400	***Determination of Synchronous Machine Parameters*** *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*
1400 – 1410	***Synchronous Machine Representation in Stability Studies***
1410 – 1420	***Simplifications Essential for Large-scale Studies***
1420 – 1430	***Recap*** *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*
1430	*Lunch & End of Day Two*

Day 3

0730 – 0800	***Neglect of Stator $P\psi$ Terms***
0800 - 0830	***Neglecting the Effect of Speed Variations on Stator Voltages*** *Relationship between Per Unit P_e & T_e*
0830 - 0900	***Simplified Model with Amortisseurs Neglected*** *Alternative form of Machine Equations • Phasor Diagram for Transient Conditions*
0900 – 0915	*Break*

0915 – 1015	***Constant Flux Linkage Model*** *Classical Model • Constant Flux Linkage Model Including the Effects of Subtransient Circuits • Summary of Simple Models for Different Time Frames*
1015 - 1115	***Reactive Capability Limits*** *Reactive Capability Curves • Armature Current Limit • Field Current Limit • End Region Heating Limit • V Curves and Compounding Curves*
1115 – 1215	***AC Transmission***
1215 - 1230	*Break*
1230 – 1315	***Transmission Lines*** *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*
1315 – 1330	***Transformers*** *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)*
1330 -1345	***Transfer of Power Between Active Sources***
1345 -1400	***Power-Flow Analysis*** *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*
1400 - 1420	***Power System Loads***
1420 – 1430	***Recap***
1430	*Lunch & End of Day Four*

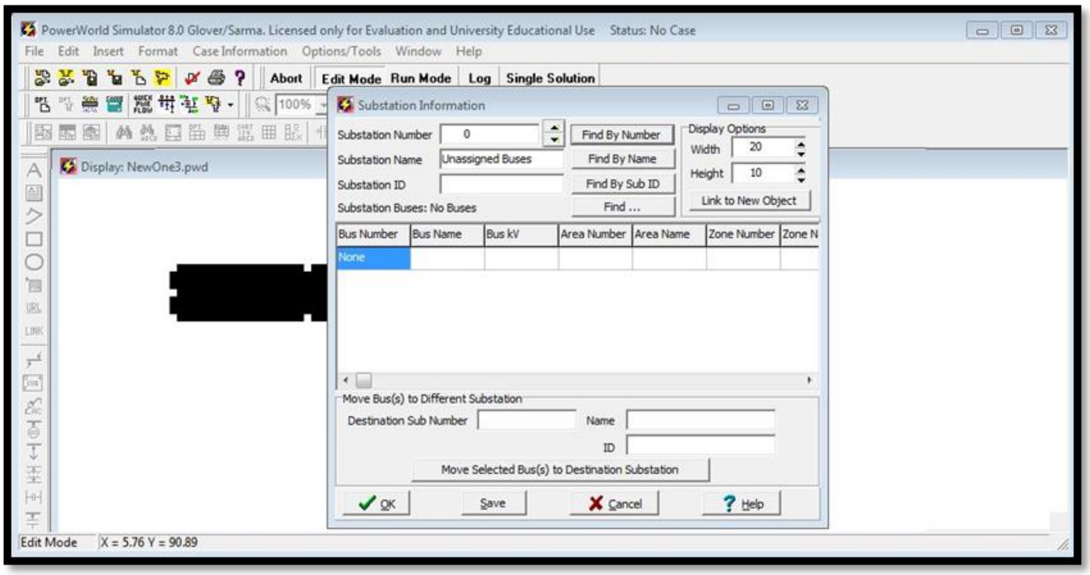
Day 4

0730 – 0800	***Basic Load-modelling Concepts*** *Static Load Models • Dynamic Load Models • Thermostatically Controlled Loads • Discharge Lighting Loads*
0800 – 0830	***Modelling of Induction Motors*** *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*

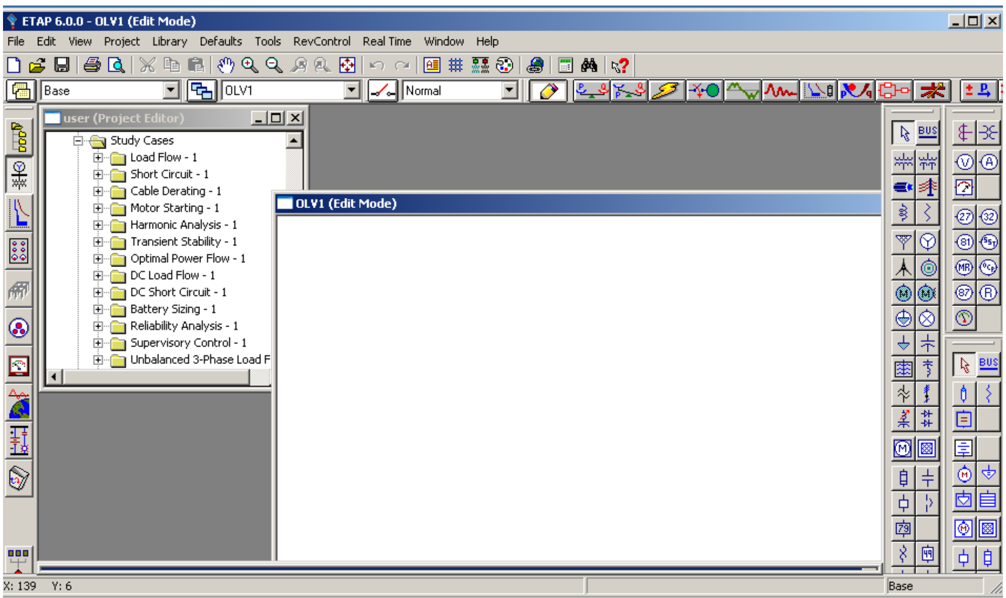
0830 – 0845	***Acquisition of Load-Model Parameters*** *Two Basic Approaches to the Determination of System-Load Characteristics (Measurement-based Approach, Component-based Approach) ● Measurement-Based Approach ● Steady State Load-Frequency Characteristics ● Dynamic Load-Voltage Characteristics ● Component-Based Approach ● Sample Load Characteristics (Component Static Characteristics, Load Class Static Characteristics, Dynamic Characteristics)*
0845 - 0900	***Excitation Systems*** *Generator Considerations ● Power System Considerations*
0900 – 0915	*Break*
0915 – 1000	***Elements of an Excitation System*** *Exciter ● Regulator ● Terminal Voltage Transducer & Load Compensator ● Power System Stabilizer ● Limiters and Protective Circuits*
1000 - 1100	***Types of Excitation Systems*** *DC Excitation Systems ● AC Excitation Systems (Stationary Rectifier Systems, Rotating Rectifier Systems (Potential-Source Controlled-Rectifier Systems, Compound-Source Rectifier Systems, Compound-Controlled Rectifier Excitation Systems)) ● Field Flashing for Static Exciters ● Recent Developments & Future Trend*
1100 – 1230	***Dynamic Performance Measures*** *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) ● Small-Signal Performance Measures*
1230 - 1245	*Break*
1245 – 1300	***Control & Protective Functions*** *AC & DC Regulators ● Excitation System Stabilizing Circuits ● Power System Stabilizer (PSS) ● Load Compensation ● Underexcitation Limiter ● Overexcitation Limiter ● Volts-Per-Hertz Limiter and Protection ● Field-Shorting Circuits*
1300 -1330	***Modelling of Excitation Systems*** *Per Unit System ● Specification of Temperature ● 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) ● Type AC4A Exciter Model ● Type ST1A Exciter Model ● Type ST2A Exciter Model ● Modelling Of Limiters ● Underexcitation Limiter (V/Hz Limiter, Field-Current or Overexcitation Limiter)*
1330 - 1345	***Field Testing for Model Development & Verification***
1345 – 1400	***Course Conclusion*** *Using This Course Overview, The Instructor(S) Will Brief Participants About the Course Topics That Were Covered During the Course*
1400 – 1415	***POST-TEST***
1415 – 1430	*Presentation of Course Certificates*
1430	*Lunch & End of Course*

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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