Fundamentals of Generation Controls:

PRACTICAL ASPECTS OF GENERATORS AND GENERATOR CONTROLS

COURSE DESCRIPTION

The course provides classroom-based instruction and utilizes a generator controls simulation software package. This software package allows each attendee to perform interactive simulation exercises related to course topics, including: Generator Reactive Capability, Generator Voltage Control, Effect of a Power System Stabilizer on Stability, Operation of Parallel Units and Governor Droop.

The simulations allow the user to adjust settings, alter system configurations, and control operation while viewing the simulated response on graphs and meters. The interactive simulations are excellent for developing a better understanding of the practical application of the course material, and to prepare for periodic NERC compliance testing.

Also, these simulations present some situations that are simply not common or expected during normal operation conditions, such as excitation limiter alarms or islanded operation.

COURSE DURATION: 1-Day (8 hours)

LOCATION: Client Location (power plant, corporate office, etc.)

AT A GLANCE: This course serves plant operators, technicians, and engineers by covering the practical aspects of synchronous generator operation, including:

- Power transfer between the generator and the power system
- Physical limitations of the generator (capability curve)
- Generator excitation systems
- Generator and power system stability, turbines, governors, and frequency control.

KESTREL POWER ENGINEERING
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Objectives

ON COMPLETION OF THE COURSE, THE PARTICIPANT WILL BE ABLE TO:

- List the customer deliverables on the power system and indicate how they are measured
- Describe how active power transfers from one point in the power system to another
- Describe how reactive power transfers from one point in the power system to another
- Identify factors limiting capabilities of a synchronous generator for on-line conditions, by labeling a conventional generator capability curve (D-Curve)
- Explain how the reactive output capability of the generator is affected by the operating voltage at the terminals of the generator
- List the main components of the typical generator excitation system
- Describe the difference between operation under AVR, MANUAL, and VAR control
- List the advantages of operation in AVR control
- Understand how exciter reactive droop promotes reactive power sharing between units
- Explain how the AVR affects stability
- Describe the basic operation of a power system stabilizer
- Describe the basic operation of a speed governor
- Explain the requirement for AGC and how it operates
- Define speed droop
- Describe the impacts of outer-loop controls, such as a load controller, on system frequency control

Course Outline

BASIC POWER SYSTEM CONCEPTS

- **Basic concepts of synchronous power systems**
  - History of the AC synchronous power system
  - The interconnected system (system operators, NERC, FERC)
- **The power system and control**
  - Customer deliverables voltage and frequency
  - Global versus local controls
  - Overview of turbine and generator control loops
- **Active and reactive power**
  - Definitions and underlying concepts
- **Power transfer in AC systems**
  - Issues affecting power transfer on an AC system

Computer Exercise: Power Transfer in AC System

SYNCHRONOUS GENERATORS

- **Energy conversion and the synchronous generator**
  - Basic physics of synchronous generators
  - Electrical speed and synchronous operation
- **Relationship between generator terminal quantities**
  - Off-line (turbine power -> speed, excitation current -> terminal voltage)
  - On-line (turbine power -> active power, excitation current -> reactive power)
  - “V” curves, saturation curves
- **Generator reactive capability (capability curves)**
  - Generator output capability (voltage, frequency, current)
  - Capability curves and generator ratings (stator current limit, field current limit, core-heating limit, mechanical limits, stability limits)

Computer Exercise: Generator Capability Testing (NERC MOD-025)

Course Outline

GENERATOR EXCITATION SYSTEMS

- **Excitation system requirements**
  - Meet generator's field current requirements
  - Meet system's requirements for reactive power source
  - Limiting and protective functions
- **Common designs**
  - Static excitation system
  - Rotating exciter systems
  - Review of station-specific design
- **Automatic voltage regulator (AVR)**
  - AVR versus MANUAL control
  - Basic AVR function
  - Power factor and Var regulators
- Reactive current compensation
  - On-line operation and generator connections
  - Sharing of reactive power
- **Excitation system limiters and protective features**
  - Over-excitation limiting (functions and alarms)
  - Under-excitation limits

Computer Exercise: Manual and AVR Control of Excitation

GENERATOR & POWER SYSTEM STABILITY

- **Definitions of power system stability and associated terminology**
  - Steady-state stability
  - Transient stability
  - Oscillatory stability
- **Effect of excitation system on stability**
- **Effect of governor on stability (islanded operation)**
- **Power system oscillations**
  - Rotor swings
  - Damping of rotor swings
- **Power System Stabilizer (PSS)**
  - Basic functional design
  - Generator operation as affected by PSS

Computer Exercise: Effect of PSS on Stability

TURBINES, GOVERNORS AND FREQUENCY CONTROL

- **Frequency control**
  - Local control of speed/frequency – the governor
  - System control of frequency – control areas and AGC
- **Basic functional design of governors**
  - Speed sensing
  - Speed setting
  - Shutdown and start-up
- **Speed droop**
  - Definition
  - Isochronous operation
  - Parallel operation of multiple units
  - Operation when synchronized to large grid
- **Synchronizing controls**
  - Frequency matching
  - Phase matching
  - Voltage matching

Computer Exercise: Operation of Parallel Units and Droop

FAQ

1. HOW MANY PARTICIPANTS CAN ATTEND THE COURSE?

The course is limited to 20 attendees. Kestrel has found that it is difficult to address individual questions in a larger class scenario, and the benefit of the computer simulations diminishes if the class size is too large.

2. WILL KESTREL PERFORM MORE THAN ONE COURSE IF WE HAVE MORE THAN 20 STAFF MEMBERS THAT WANT TO ATTEND?

Yes, the course can be presented multiple times in the same trip. It can even be presented on different shifts if required. Ask Kestrel for more details.

3. WILL KESTREL CUSTOMIZE THE COURSE TO OUR SITE?

Yes, the course material will is specific to the plant. The training material and examples center on site-specific equipment. The course emphasizes the equipment type used and testing requirements of a particular plant or plant group.

4. WILL KESTREL CUSTOMIZE THE COURSE CONTENT?

Yes, content can be tailored based on the specific needs of the plant personnel. For example, power stability and stabilizer content are replaceable or open to removal if the plant does not have a power system stabilizer. Relay/limiter coordination content or hydro turbine governor tuning for stability replaces that portion if preferred.

5. DOES THE COURSE HAVE TO BE 8 HOURS LONG?

Based on the material covered, 8 hours is the minimum recommended time for this course. Content, such as relay limiter coordination or hydro governor stability, can be added. That extends the course to 12 or 16 hours. Contact Kestrel if you are interested in having more material covered.

6. DOES THE COURSE INCLUDE INFORMATION ON NERC STANDARDS?

The course outline addresses technical content associated with NERC standards such as MOD-025, MOD-026, MOD-027, and PRC-019. These standards can be covered, but do not have to be if they do not pertain to the staff attending the training.

Additional Info

INSTRUCTORS:

Experienced field engineers instruct all courses with formal and practical expertise on generators, generator controls systems, and their tuning, testing, modeling, and operation.

WHAT YOU WILL RECEIVE:

1. Electronic copy of the course slides
2. Electronic copy of course exercise handout
3. Computer simulation software to be installed on client/attendee provided computer
4. Certificate of Completion for each attendee

WHAT YOU WILL NEED TO PROVIDE:

1. Classroom space and desired refreshments for participants
2. TV/Screen for Kestrel training presentation
3. Printed copies of course handout and course slides (if hard copies are desired)
4. Computers for participants to use for performing simulation exercises. Kestrel recommends no more than 2 students per computer. If computers are limited, Kestrel may be able to supply some for participants to use during the course.
5. Installation of Kestrel provided software on client owned computers