

*For utility, plant, or consulting engineers and technicians involved in transmission or distribution system protection, planning, operations, or engineering...*

# **Power System Analysis Skills for Engineers and Technicians**

## **Emphasizing Symmetrical Components and Fault Calculations**

**February 6-8, 2008**  
**Las Vegas, Nevada**

**October 6-8, 2008**  
**Madison, Wisconsin**

*Gain valuable knowledge to help you*

- ▶ *Solve power system problems*
- ▶ *Calculate fault currents*
- ▶ *Build computer models*

*Printed on recycled paper.*



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THE UNIVERSITY  
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**WISCONSIN**  
MADISON

**COLLEGE OF ENGINEERING ■ DEPARTMENT OF ENGINEERING PROFESSIONAL DEVELOPMENT**

# **Power System Analysis Skills for Engineers and Technicians**

**February 6-8, 2008**  
**Las Vegas, Nevada**

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**Madison, Wisconsin**

**Learn skills that make you more effective on your job**

- **Three-phase power calculations**
- **The per-unit system**
- **Phasor analysis**
- **Symmetrical components for calculating unbalanced faults and loads**
- **Fault calculations and modeling for computer studies**

Transformer Bank Connection	Positive and Negative Sequence Connection	Zero Sequence Connection

# Power System Analysis Skills for Engineers and Technicians

February 6–8, 2008 in Las Vegas, Nevada

October 6–8, 2008 in Madison, Wisconsin

Save time and money!  
Inquire about our on-site courses.  
Call 800-462-0876 today!

## Upgrade Your Skills in Solving Power System Problems

### Analysis skills needed

Power system engineers and technicians must know how to apply several analytical tools to understand and solve power system problems they regularly face on the job. Among the skills they need are basic phasor algebra, the per-unit system, and symmetrical components. These tools are at the heart of solving power system problems involving balanced and unbalanced loads and faults, and all power system engineers and technicians should be familiar with them.

### Tools needed for computer modeling

Computer models sometimes produce unexpected, non-intuitive results, or results that do not match actual data measurements observed in the field. Whether solving problems by computer or by hand, or when computer results differ from field data measurements, you need these analytical skills to develop models, uncover modeling errors and arrive at the correct solution.

### Learn necessary skills

This introductory course begins with a review of three-phase power calculations, the per-unit system, and phasor algebra – basic tools used in modeling and solving nearly all types of power system problems. It then introduces and explains symmetrical components and shows you how to use them to calculate balanced and unbalanced short-circuit faults, and open-circuit faults on three-phase power systems. You will learn how to correctly model the various types of transformer connections, phase shifts through delta-wye transformers, and transmission and distribution line impedances. The skills you learn at this course will make you more effective at solving the power system problems you face at your job.

## Solve Problems in Class

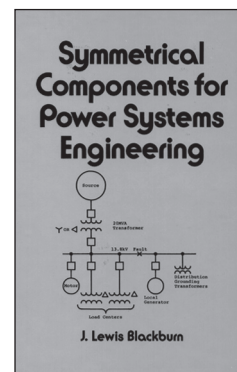
Classroom problem-solving sessions will give you the opportunity to apply your new skills and reinforce your learning. Bring a calculator for classroom workshops that will show you how to create power system models and calculate fault currents for the various types of power systems faults and open-phase conditions.

## Key Topics

- Review of three-phase power calculations
- Phasor algebra review
- The per-unit system for analyzing power systems
- Transformer connections and winding polarity
- Phase shifts in delta-wye transformers
- Symmetrical components fundamentals and sequence networks
- Impedance and sequence network connections for modeling transformer banks
- Fault calculations for three-phase and unbalanced faults
- Open-phase fault calculations

## Textbook by J. Lewis Blackburn Included

Attend this course and receive a copy of the text, *Symmetrical Components for Power Systems Engineering*, by J. Lewis Blackburn. This clear, well-written textbook, authored by one of the most respected engineers in the industry, forms the basis for much of the material covered in this course.



## Who Will Benefit

This course is designed for utility, plant, or consulting engineers and technicians involved in transmission or distribution system protection, planning, operations, or engineering. If you are beginning a career or assignment in these areas, this course will be of value to you. Those doing fault studies, maintaining computer fault study or power flow databases, or coordinating and setting overcurrent relays and fuses will especially benefit from this course.

Topics will begin at the fundamentals level and move to more advanced content as the course progresses. Prerequisites include a basic understanding of vector algebra and a familiarity with the voltage, current, watt, var, and phase angle measurement terms used in three-phase power systems.

## Emphasis on Symmetrical Components

This course will emphasize the use of symmetrical components, a powerful tool for understanding and determining unbalanced currents and voltages in three-phase power systems. The course will focus on how to apply this analysis tool to model equipment and calculate fault currents on three-phase power systems.

# Power System Analysis Skills for Engineers and Technicians

February 6–8, 2008 in Las Vegas, Nevada

October 6–8, 2008 in Madison, Wisconsin

## Course Instructor

**Ralph E. Fehr PhD, PE** is an independent engineering consultant and instructor in power system engineering at the University of South Florida, where he teaches courses in power systems engineering. He has more than 20 years of experience in the electric power industry. Dr. Fehr has held various positions in transmission and distribution engineering design, operations, planning, and maintenance at Tampa Electric Company, Florida Power Corporation, Public Service Company of New Mexico, the U.S. Air Force, and Gilbert/Commonwealth Engineers and Consultants. He is an experienced instructor of university engineering courses and continuing education short courses. Dr. Fehr has written technical articles for *EC&M* magazine and is author of the textbook, *Industrial Power Distribution*. Dr. Fehr received a Bachelor of Science degree in electrical engineering from the Pennsylvania State University, a Master of Engineering degree in electrical power engineering from the University of Colorado at Boulder, and a Doctor of Philosophy in electrical engineering from the University of South Florida. He is a registered engineer in Florida and New Mexico.

### For Related Course Descriptions

<http://epd.engr.wisc.edu/catalogs/electrical.lasso>

## Course Outline

### Day 1

#### 7:30 Registration

**February 6–8, 2008 in Las Vegas:**

The Riviera Hotel and Casino  
2901 Las Vegas Boulevard South

**October 6–8, 2008 in Madison:**

The Pyle Center  
702 Langdon Street

#### 8:00 Welcome

*John A. Raksany PE*  
Program Director  
Department of Engineering Professional Development  
University of Wisconsin–Madison

#### 8:15 Instruction Begins

*Ralph Fehr PE*

#### 1 Review of Three-Phase Power Systems

- Single-phase systems
- Three-phase systems
- Phase angle and time relationships
- Wye and delta connected loads
- Real and reactive power
- Workshop – three-phase power calculations

#### 2 Review of the Per-Unit System

- Definitions
- Advantages of per-unit system
- General circuit quantity relationships
  - three-phase power
  - line-to-neutral and line-to-line voltage and current relationships
- Base quantities
- Per-unit relationships
- Per-unit impedances of transformers and other equipment
- Changing per-unit quantities to different bases
- Workshop – per-unit calculations

#### 3 Review of Phasors

- Phasor defined

- Phasor representation of voltage, current, and power
- Combining phasors
- Phasor and circuit diagrams for balanced three-phase systems
- Phasors and phase rotation
- Balanced system calculations
  - single-phase equivalent

#### 5:00 Adjournment

### Day 2

#### 8:00 Instruction Continues

#### 4 Transformer Polarity and Phase Shift

- Polarity markings
- Subtractive and additive polarity
- Delta-wye transformer phase shift

#### 5 Symmetrical Components

- Unbalanced systems of phasors
- Method of symmetrical components
- Derivation of sequence impedances
- Sequence networks
- Synthesis of sequence networks
  - positive, negative, zero
- Workshop – sequence networks

#### 6 Modeling Power System Equipment for Fault Calculations

- Transmission lines
- Distribution lines
- Power transformers
  - transformer winding configurations
  - autotransformers
  - zero sequence models
- Motors
- Generators

#### 5:00 Adjournment

### Day 3

#### 8:00 Instruction Continues

#### 7 Fault Calculations

- Fault impedance
- Types of three-phase short-circuit faults
  - three-phase
  - line-to-ground
  - double line-to-ground
  - line-to-line

- line-to-ground
- double line-to-ground
- line-to-line
- Short-circuit fault calculations
- Workshop – short-circuit fault calculations

#### 8 Open-Circuit Faults

- Types of three-phase open-circuit faults
  - one line open
  - two lines open
- Open-circuit fault calculations
- Workshop – open-circuit fault calculations

#### 4:00 Final Adjournment

## Daily Schedule

The daily schedule includes morning and afternoon refreshment breaks and lunch at noon. Daily sessions will begin at 8:00 a.m. and adjourn at 5:00 p.m. Final adjournment will be at 4:00 p.m. on the last day. The course will be conducted in a smoke-free environment.

## Airline Flights and Hotel Room Availability in Las Vegas

Please note that airline flights and hotel rooms may be scarce in Las Vegas during the February 3–8, 2008 period. The 2008 Super Bowl, played on February 3 in Arizona, will draw many people to Las Vegas to wager on the game and watch it in the hotels and casinos. If you plan, or tentatively plan, to attend this course, please make flight arrangements early and reserve your hotel room early and before the January 13, 2008 cut-off date listed in the February 6–8, 2008 accommodations section!

## Past Participants Say...

*"I have taken over 7 sessions like this, and this one was the best by a wide margin! Dr. Fehr is a great instructor. It is not common to have someone who has real-world experience, a strong academic background, and excellent presentation skills."*

Jeff Bragg, Lead Engineer – Electrical Distribution Engineering, Central Maine Power Company

*"I never understood symmetrical components prior to this course. With the analysis methods and techniques learned in this course, they now seem intuitive."*

James Wells, Engineer Supervisor, Northrop Grumman Newport News, Newport News, VA

*"I thought this course was excellent and will recommend it to others. Good content and well presented."*

Gary Kopps, Supervisor-System Protection, Nevada Power, North Las Vegas, NV

*"Great instructor. In fact, the best I have worked with."*

Aseem Bhatia, Engineer, Nevada Power, Las Vegas, NV

*"All power engineering companies should offer this course to all their engineers. I learned a lot of things that were not taught to me on the job. I think the speaker was well prepared. The examples presented were excellent and well explained."*

Sheldon Lockhart, Engineer, Omaha Public Power District, Omaha, NE

*"The instructor's delivery of the course was one of the best I have seen."*

Alan Day, Senior Engineer, Entergy, Saint Gabriel, LA

*"Great speaker. He knew when to go into something in more detail, but stayed away from tiny details. Gave a great 'feel' of the material."*

Joel Ocmand, Electrical Engineer, Motiva Enterprises, LLC, Deer Park, TX

## Four Easy Ways to Enroll

### Need to Know More?

Call toll free **800-462-0876** or **608-262-2061** and ask for

**Program Director:** John A. Raksany PE

**Program Associate:** Mary Danielson

Or e-mail [custserv@epd.engr.wisc.edu](mailto:custserv@epd.engr.wisc.edu)

### General Information

**Fee of \$1395 Covers** Course materials, textbook, break refreshments, lunches, and certificate.

**Cancellation** If you cannot attend, please notify us at least 7 days prior to the first day of the course, and we will refund your fee. Cancellations received after this date and no-shows are subject to a \$150 administrative fee. You may enroll a substitute at any time before the course starts.

#### Location

**February 6–8, 2008 Course:** The Riviera Hotel and Casino, 2901 Las Vegas Boulevard South, Las Vegas, Nevada. If you must be contacted during the course, phone messages may be left for you at 702-734-5110.

**October 6–8, 2008 Course:** The Pyle Center, 702 Langdon Street, Madison, Wisconsin. If you must be contacted during the course, phone messages may be left for you at 608-262-1122.

#### Accommodations

**February 6–8, 2008 Course:** We have reserved a block of rooms for course participants for the nights of February 5–8 at the Riviera Hotel and Casino, 2901 Las Vegas Boulevard South, Las Vegas, Nevada. To reserve a room (\$89 sgl/dbl), call the Riviera Hotel and Casino by January 13 at 800-634-6753 in the continental U.S. or 702-794-9412 direct and request the group rate ID: University of Wisconsin–Madison. Room requests made after January 13 will be subject to availability and at prevailing rates.

**October 6–8, 2008 Course:** We have reserved a block of rooms for course participants (\$109 sgl/\$124 dbl) at the Campus Inn, 601 Langdon Street, Madison, Wisconsin. To reserve a room, call the Campus Inn at 800-589-6285 or 608-257-4391 by September 14 and mention this course and group code 64549. Your enrollment confirmation will include other hotel/motel information.

**Continuing Education Credit** By participating in this course, you will earn 2.0 Continuing Education Units (CEU) or 20 Professional Development Hours (PDH).



**Phone:**  
800-462-0876 or  
608-262-1299 (TDD 265-2370)



**Internet:**  
<http://epd.engr.wisc.edu/>

**Mail to:**

Engineering Registration, The Pyle Center  
702 Langdon Street, Dept. 108  
Madison, Wisconsin 53706



**Fax:**

800-442-4214 or 608-265-3448



### Course Information

Please enroll me in **Power System Analysis Skills for Engineers and Technicians**

- Course #J676** February 6–8, 2008 in Las Vegas, Nevada Fee (by January 9): \$1295  
Fee (after January 9): \$1395 **Save \$100! Enroll by January 9.**
- Course #J865** October 6–8, 2008 in Madison, Wisconsin Fee (by September 8): \$1295  
Fee (after September 8): \$1395 **Save \$100! Enroll by September 8.**
- I cannot attend at this time. Please send me brochures on future courses.

### Personal Information (Please print clearly.)

Name \_\_\_\_\_

Title \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

City/State/Zip \_\_\_\_\_

Phone (\_\_\_\_) \_\_\_\_\_ Fax (\_\_\_\_) \_\_\_\_\_

E-mail \_\_\_\_\_

### Additional Enrollees

Name \_\_\_\_\_

Title \_\_\_\_\_

E-mail \_\_\_\_\_

Name \_\_\_\_\_

Title \_\_\_\_\_

E-mail \_\_\_\_\_

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