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Power System Basics for Business Professionals in Our Industry

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power system basics

for business professionals in our industry

THE RAPID CHANGES IN THE business aspects of the electricity industry are making it necessary for engineers to communicate more frequently and more effectively with nontechnical people. With the heightened interest in electric power and energy systems, a broad range of "nonpower" people has expressed a need for a primer on power engineering fundamentals presented in a nontechnical manner. In response, the IEEE Power Engineering Society sponsored the preparation of such a course targeted towards the "business professional." The first offering of this course was in July 2002 as part of the IEEE PES Summer Meeting in Chicago. *Power System Basics for Business Professionals* was developed to improve the communication process by providing business professionals with a basic level of understanding of terminology and fundamental issues.

This tutorial article provides an overview of the scope of the course, and tutorial articles based on specific modules of the course will appear in future issues of *IEEE Power & Energy Magazine*. We hope that you will use these tutorials as refreshers for yourself and help to disseminate this material to interested groups that might benefit from future course offerings.

Please help disseminate future Techtorials on power system basics to some of the new players in our industry or encourage them to attend the course the next time it is offered.

Objectives and Instructional Media

The course was designed to expose nontechnical people associated with the electric power industry to some of the salient characteristics of power systems and the nature of the rapidly changing electric utility business. The intent was to create a vehicle that can equip the many professionals whose jobs touch on power to have more comfort in understanding the myriad terms bandied around day in and out and to understand the basic functioning of the power system.

The course was presented in five separate modules. Animation and graphics were a major part of the course instructional media used to help the audience visualize engineering phenomena.

Course Topics

Overview and Background

Evolution of Electric Power Systems

Systems have developed through history from isolated plants to individual

Power Systems Basics for Business Professionals

The IEEE Power Engineering Society is pleased to offer an outstanding training opportunity to expose business, regulatory, legal, and other professionals to the intricacies of the electric power system and to provide a good understanding of basic power concepts. This one-day course examines the basics of electricity, the fundamentals of power systems, and the key processes in power system operations. Presented in nonmathematical and nonengineering language and with a focus on real-world problems and examples, the short course provides a thorough grounding of electric power system planning, operations, economics, and possible regulatory frameworks. A team of leading specialists from academia and industry will present the course on 14 July 2003 in Toronto, Ontario, Canada, during the 2003 PES General Meeting. More information is available on the PES Web site, www.ieee.org/power.

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systems, regional, interregional, and finally international interconnections.

Power System Structure

Generation, transmission, distribution, and loads make up the fundamental structure of a power system. Energy storage is one of the major problems with electricity as a commodity. Loads have been traditionally classified into categories called commercial, industrial, and residential.

Benefits of Interconnections

Three diversity issues helped create geographical interconnections: Diversity in time zones, fuel sources, and risk/uncertainty. These three issues provide the motivation and benefits of large-scale interconnection for economics and reliability.

Electricity Basics

Terminology and Definitions

Voltage, current, power, energy, frequency, and impedance are the fundamental terms used in electricity technology. These can be related to other physical systems such as water and gas flows.

Power System Components

Generators, substations, transmission circuits, transformers, circuit breakers, metering, demand, load, are the main physical devices that make up an electric power system.

Types of Circuits and Capacity

Conductors and insulation have vastly different properties that make each of them suitable for their role in electricity use. Issues of safety, performance, and application drive their specific uses in all components. Overhead and underground circuits have their own specific advantages and disadvantages. Circuits can be typically in series or parallel.

Generation of Watts and Vars

Different types of generation provide real power. The need for reactive power can be compared to the need to balance a bicycle while moving forward.

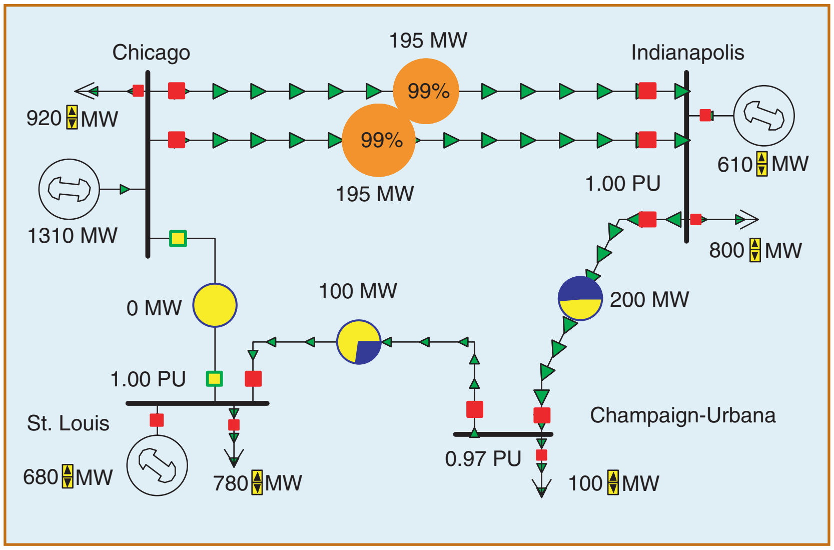

figure 1. impact of line outages on transfer capabilities.

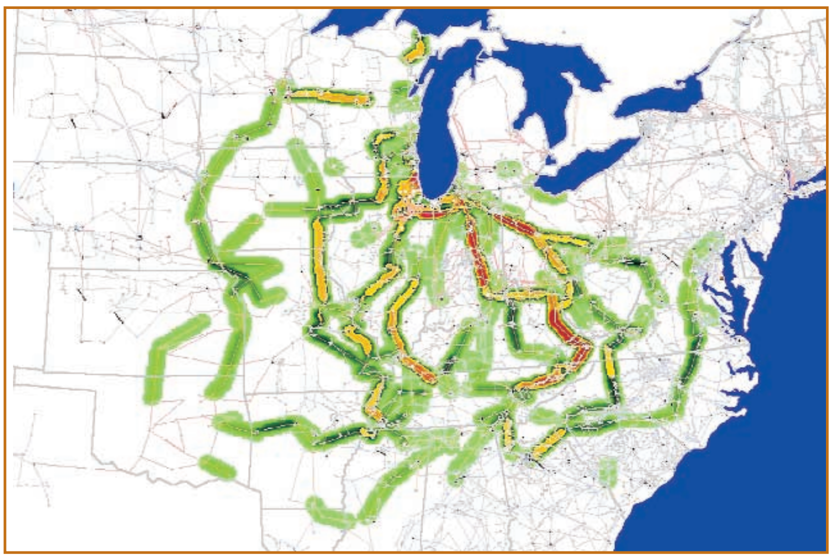

figure 2. contours of power transfer distribution factors (Wisconsin to TVA transfer).

Loop Flow and Congestion

Electric power flows according to circuit laws and not necessarily according to contractual paths. This can cause congestion because control of power flow is difficult.

The impact of loop flows on the maximum power transfer capability was illustrated using an animation based on the system shown in Figure 1. This figure shows the impact of line outages on transfer capabilities.

Technical Issues in Electricity Production

Voltage, Current, Power, and Energy

These quantities are related directly to electric and magnetic fields. There are fundamental differences between dc and ac systems. Three-phase systems have special properties that make them widely used. Energy conversion from coal to kilowatts and human power to kilowatts illustrates the value of electricity.

Fundamental Power Flow Features

Power flow in a system obeys fundamental laws and in most cases it is not easy to control. This makes it important to be able to perform studies of the impact of transfers and load/generation changes.

Reliability and Security

Reserve margins are needed to ensure reliability in the event of outages. Contingencies can cause unacceptable conditions. The North American Electric Reliability Council (NERC) has developed guidelines and procedures for operations that can avoid problems.

Available Transfer Capability

The ability of a power system to accommodate a transaction between two or more areas is important to ensure an economical and reliable system. Determining the capability of a system for this purpose is difficult and requires constant updating.

An important concept for which visualization was used is the illustration of the maximum power transfer limit on power transmission. While transmission line thermal limits are more easily understood and grasped, these are not the only limits on the transmission system. Other limits, such as stability and maximum power transfer limits, are much more difficult to describe in a meaningful way for nonengineers, especially without relying on equations and other analytical means. Figure 2 shows the concept of maximum power transfer as an absolute physical limit on transmission of power across tie lines.

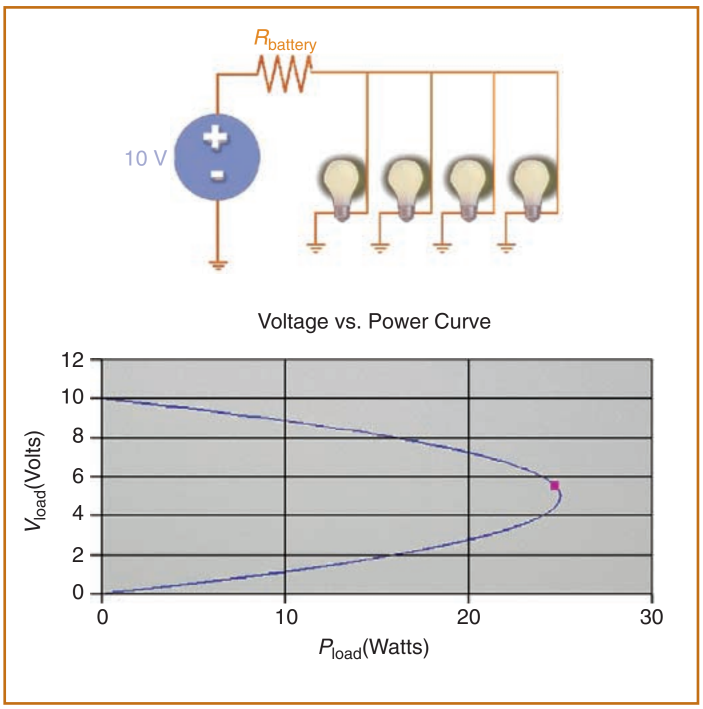

figure 3. maximum power transfer across a line.

Steady-State and Dynamic Conditions

Disturbances in power systems cause conditions to change and can result in outages or unacceptable values of voltage, current, and frequency. Severe enough disturbances can create major blackouts and cascading failures. Mathematical modeling and simulation can detect these problems and provide possible actions to avoid problems.

Figure 3 shows the dynamic response of a generator shaft to a short circuit cleared quickly enough to avoid an instability. The upper left portion shows the trajectory of the generator angle versus speed, with the fault-on period shown as the line leaving the initial equilibrium point. The right portions show the angle and speed trajectories as a function of time. This illustration can be repeated with a longer clearing time, and it will show the loss of generator synchronism.

Protection Issues

Short circuits (faults) can damage equipment and harm people. Fuses and relaying with circuit breakers provide mechanisms to isolate these faults to minimize damage. These protection devices have characteristics that must be coordinated to provide proper protection.

Power Quality Issues

Changes in the values of voltage and frequency are considered possible power quality problems. If the changes are too severe, they can shorten equipment life and create unacceptable electricity service.

Power System Operations

Generation Production and Load Variation

There are variations in sizes and types of generation production in the United States. There are also variations by geographical location and time of day. These variations are important because they impact the need to provide service at all times.

Transmission and One-Line Diagrams

Mathematical models of power systems involve diagrams that provide information about physical connections and electrical behavior.

Power Balance Constraints

The physical laws of electricity require balancing of flows into and out of locations.

Control Areas and Operating Mechanisms

Control areas exist as places where generation and flows are controlled in an effort to maintain desired frequency and interchange flows.

Automatic Generation Control

Traditional generation control involves economic considerations as well as the

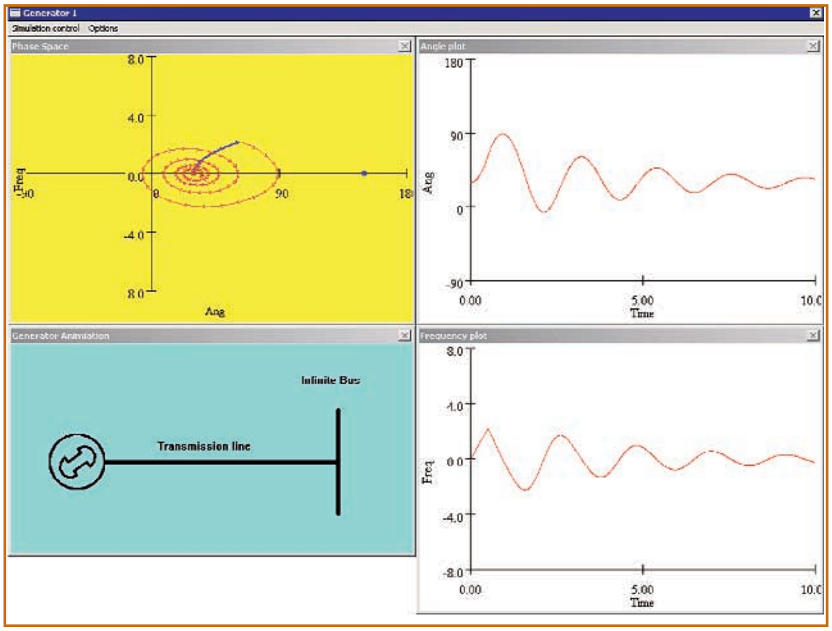

figure 4. dynamic response of a single generator to a fault cleared in time to remain stable.

need to maintain frequency and interchange flows at desired values.

Power Transfer Distribution Factors

Distribution factors are a mathematical prediction of how transactions impact power flow in lines. These factors can be contoured in color to easily visualize their magnitude and geographical influence.

The loop flow phenomenon was further visualized with the graphic shown in Figure 4. The powerful illustration helped the participants to understand the notion that power flows across numerous paths outside of the transaction, or contract, path. Since a significant portion of the short course audience had a legal and/or policy background, it was important for the course to stress the engineering challenges and physical realities associated with power flow through the system. We stressed that while legislatures can repeal laws made by man, it is impossible for them to do anything to change Kirchhoff's laws.

Locational Marginal Pricing

With the diversity of generation type and age, the price of electricity varies significantly across the United States. Congestion in the transmission systems can aggravate the difference in these prices. These prices can be visualized through color contouring to indicate severity of price differences and the possible impact of changes in the system.

Evolving Competitive Marketplace

Power and Energy Demand

Electricity is an important commodity in modern society, and it can be compared to trends in U.S. gross national product (GNP).

Ownership, Customers, and Regulators

The traditional ownership of electricity equipment could be classified as investor, public, cooperative, and the federal government. Classification of load is typically done as residential, commercial, and industrial.

Business Structures and Federal Acts

There have been many changes in the traditional electricity business. These changes have been prompted by a sequence of federal and state actions.

Open Access and Ancillary Services

Recent orders by the U.S. Federal Energy Regulatory Commission (FERC) have created new concepts in the electricity business, including open access issues, ancillary services, and market designs.

Marketing, Trading, and Brokering

The electricity power market is by far the largest of all commodities. Marketers and brokers utilize extensive computer/communications systems to permit activities in various regional markets.

Regional Transmission Organizations

The operation of transmission facilities is undergoing change. This includes transmission pricing and the motivation for investment in new facilities.

Independent System Operators

Overall operation of power systems is undergoing change. This includes competitive bidding environments, operational decisions, and consolidation of control functions.

Investments, Mergers, and Acquisitions

Business functions are changing in response to regulatory orders and economic choice. These changes are rapid and far reaching.

Acknowledgment

Power System Basics for Business Professionals is a special tutorial sponsored by the IEEE PES Power Engineering Committee. It was written and presented by M. Crow, G. Gross, R. Snow, T. Overbye, and P. Sauer. The course will be presented next during the 2003 IEEE PES General Meeting.

Biographies

Mariesa Crow is a professor of electrical engineering at the University of Missouri at Rolla. **George Gross** and **Peter W. Sauer** are professors of electrical engineering at the University of Illinois at Urbana-Champaign. They all teach courses and direct research in the electric power area.