ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ECE 476 Power System Analysis

Lecture 1

Introduction

Alejandro D. Dominguez-Garcia
Department of Electrical and Computer Engineering
aledan@illinois.edu

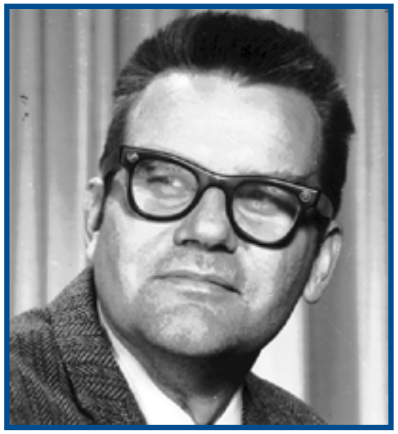
About Me

- Received Power Engineering Degree in 2001 form the University of Oviedo (Spain)

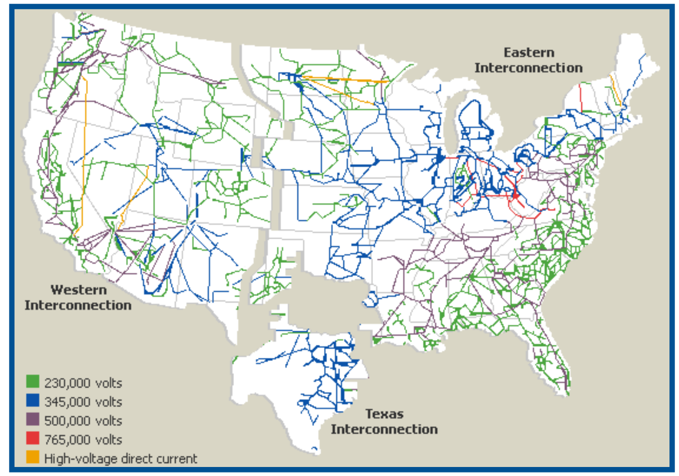
- Worked one year as an Assistant Professor at the University of Oviedo

- Received Ph.D. in Electrical Engineering from MIT in 2007
  - Worked on reliability of fault-tolerant systems for aerospace applications
- Worked one year as a Postdoc at MIT
  - Worked on GN&C system architecture for NASA's vision for exploration
- Have been in Illinois since 2008, doing teaching and doing research in the area of electric power systems reliability

Power Systems



Fred C. Schweppe (1934-1988)
Professor of Electrical Engineering, MIT



US Power grid

"I worked on aerospace problems for many years before converting to power systems, and, in my opinion at least, power problems are tougher in many respects.

...

The number of variables [in a power system] is huge, and many types of uncertainties are present.

...

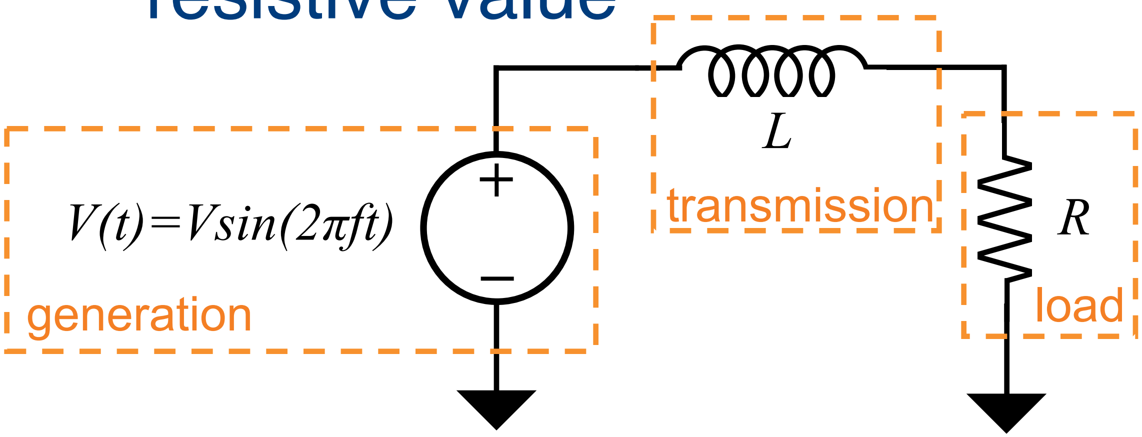
Few if any aerospace problems yield such a challenging set of conditions."

– Fred. C. Schweppe, 1970

Simple Power System

Every power system has three major components:

- generation: source of power, ideally with a specified voltage and frequency
- transmission system: transmits power; ideally as a perfect conductor
- load: consumes power; ideally with a constant resistive value



Simple power system model

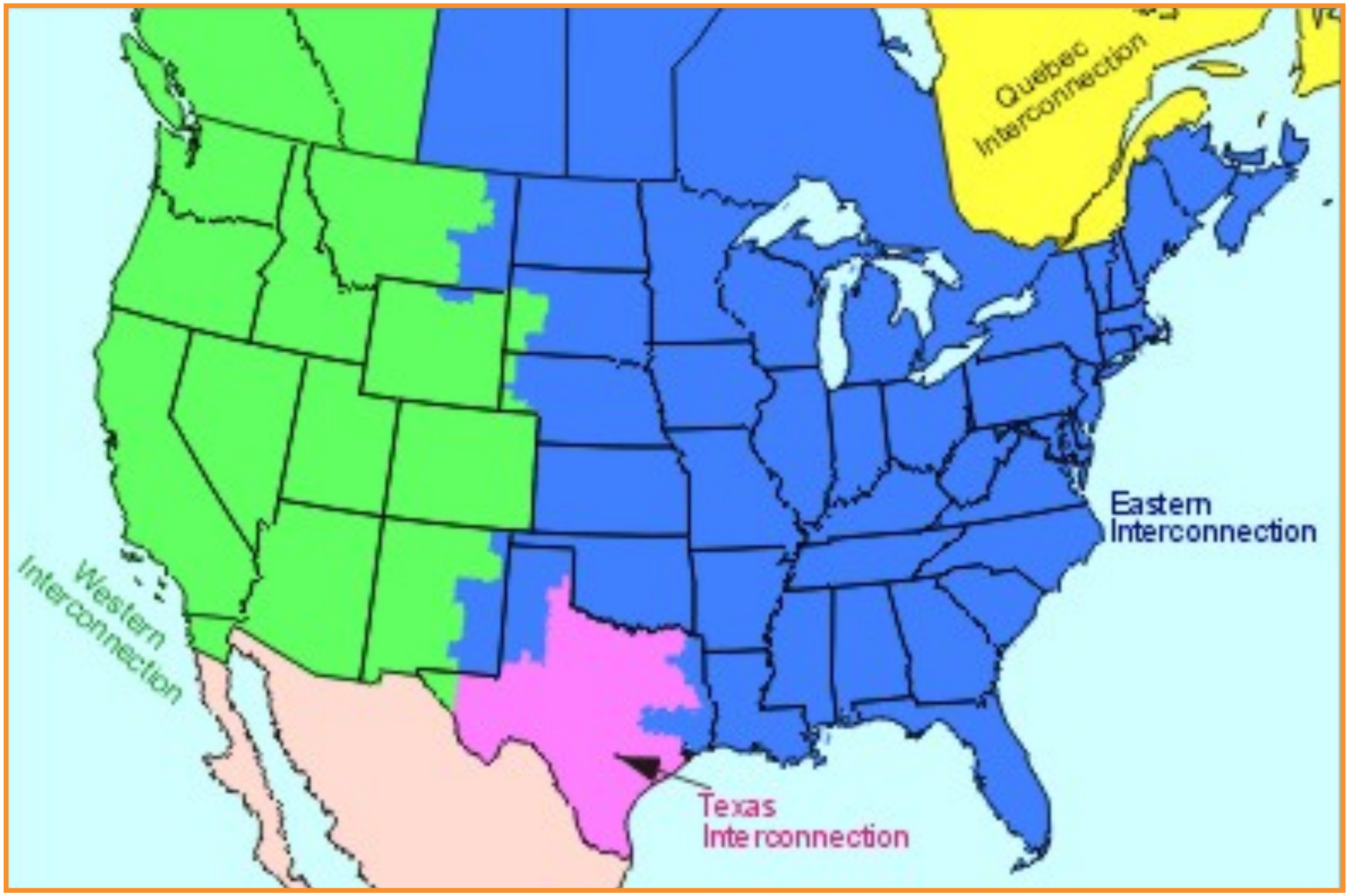
Complicating Features

- No ideal voltage sources exist
- Loads are seldom constant
- Transmission system has resistance, inductance, capacitance and flow limitations
- Simple system has no redundancy so power system will not work if any component fails

Power System Examples

- Electric utility: can range from quite small, such as an island, to one covering half the continent
  - there are four major interconnected ac power systems in North American, each operating at 60 Hz ac; 50 Hz is used in some other countries.
- Airplanes and Spaceships: reduction in weight is primary consideration; frequency is 400 Hz.
- Ships and submarines
- Automobiles: dc with 12 V standard (42 V might be introduced if more electric functionality becomes a reality)
- Battery operated portable systems: remote installations with telecommunication equipment

North America Interconnections



Course Syllabus

- Introduction, review of phasors & three phase
- Transmission-line parameter computation and transmission-line modeling
- Transformer, generator, and load modeling
- Power flow analysis
- Generation control, economic dispatch and restructuring
- Transient stability
- Short circuit analysis, including symmetrical components
- System protection

Power Notation

- Power: Instantaneous consumption of energy (or the rate at which energy is consumed)
- Power Units
  - Watts = voltage x current for dc (W)
  - kW – 1×10^3 Watt
  - MW – 1×10^6 Watt
  - GW – 1×10^9 Watt
- Installed US generation capacity is about 900 GW (about 3 kW per person)
- Maximum load of Champaign/Urbana about 300 MW (0.033% of US generation capacity)

Energy Notation

- Energy: Integration of power over time; energy is what people really want from a power system
- Energy Units
  - Joule = 1 Watt-second (J)
  - kWh – Kilowatthour (3.6×10^6 J)
  - Btu – 1055 J; 1 MBtu=0.292 MWh
- U.S. electric energy consumption is about 3600 billion kWh (about 13,333 kWh per person, which means on average we each use 1.5 kW of power continuously)

Electric Systems in Energy Context

- Class focuses on electric power systems, but we first need to put the electric system in context of the total energy delivery system
- Electricity is used primarily as a means for energy transportation
  - Use other sources of energy to create it, and it is usually converted into another form of energy when used
- About 40% of US energy is transported in electric form
- Concerns about need to reduce CO_2 emissions and fossil fuel depletion are becoming main drivers for change in world energy infrastructure

Energy Economics

- Electric generating technologies involve a tradeoff between fixed costs (costs to build them) and operating costs
  - Nuclear and solar high fixed costs, but low operating costs
  - Natural gas/oil have low fixed costs but high operating costs (dependent upon fuel prices)
  - Coal, wind, hydro are in between
- Also the units capacity factor is important to determining ultimate cost of electricity
- Potential carbon “tax” major uncertainty

Ball park Energy Costs

- Nuclear: $15/MWh
- Coal: $22/MWh
- Wind: $50/MWh
- Hydro: varies but usually water constrained
- Solar: $150 to 200/MWh
- Natural Gas: 8 to 10 times fuel cost in $/MBtu

Note: to get price in cents/kWh take price in $/MWh and divide by 10.