Introduction of EE Power & Renewable Energy Track

Dr. Wei Sun, Assistant Professor
Dept. of Electrical and Computer Engineering

EEL3004
January 31, 2018
170,000 miles transmission lines and 6 million miles distribution lines

15,000 generators in 10,000 power plants

125 million residential, 17.6 million commercial, and 775,000 industrial customers
How Does Power System Work?

Basic Structure of the Electric System

- **Color Key:**
  - Blue: Transmission
  - Green: Distribution
  - Black: Generation

- **Generating Station**
- **Generator Step Up Transformer**
- **Transmission Customer 138kV or 230kV**
- **Transmission Lines 500, 345, 230, and 138 kV**
- **Substation Step-Down Transformer**
- **Subtransmission Customer 26kV and 69kV**
- **Primary Customer 13kV and 4 kV**
- **Secondary Customer 120V and 240V**

University of Central Florida
Power Plants

- Fossil fuels
  - Oil, Gas, Coal
- Nuclear
- Renewables
  - Hydropower, Wind, Biomass, Solar

Energy Resources for Electricity Generation

U.S. energy consumption by energy source, 2016

Total = 97.4 quadrillion
British thermal units (Btu)

- Petroleum: 37%
- Natural gas: 29%
- Coal: 15%
- Nuclear electric power: 9%
- Renewable energy: 10%

Total = 10.2 quadrillion Btu
- Biomass: 46%
- Geothermal: 2%
- Solar: 6%
- Wind: 21%
- Biofuels: 22%
- Wood: 19%
- Hydroelectric: 24%

Note: Sum of components may not equal 100% because of independent rounding.

Source: U.S. Energy Information Administration, Monthly Energy Review, Table 1.3 and 10.1, April 2017, preliminary data
U.S. primary energy consumption by source and sector, 2016
Total = 97.4 quadrillion British thermal units (Btu)

- **Transportation**: 27.8 (29%)
- **Industrial**: 21.3 (22%)
- **Residential and Commercial**: 10.5 (11%)
- **Electric Power**: 37.8 (39%)

Source: [www.eia.gov/state/maps.php](https://www.eia.gov/state/maps.php)
Transmission

https://eerscmap.usgs.gov/windfarm/
Substation
Distribution

1. Fault occurs on the line
2. Local URC Recloser System detects the fault, and isolates the faulted section from the grid
3. URCs provide fast system re-configuration to restore power to effected area, via wireless communications

Common Electrical Distribution Lines:
- Primary wires up to 34,500 volts of electricity
- Secondary wires up to 240 volts of electricity
- Transformer reduces primary voltage to secondary voltage
- Electric Service to house up to 240 volts of electricity
- Phone and Cable TV lines
Power System Control Center
How to Control Power Systems?

Remote terminal unit (RTU) → Substation → Communication link → SCADA Master Station → Energy control center with EMS (Energy Management System) → Control Signal → EMS 1-line diagram → EMS alarm display
Power Grid in U.S.
Electricity Price
Grid Modernization
Smart Grid

What is the Smart Grid? - U.S. Department of Energy
Smart Grid – Domains & Sub-domains

http://smartgrid.ieee.org/domains
Smart Grid – 100% Renewable

100% UNITED STATES

Transition to 100% wind, water, and solar (WWS) for all purposes (electricity, transportation, heating/cooling, industry)

2050
PROJECTED ENERGY MIX

- Residential rooftop solar 8%
- Solar plant 25%
- Concentrated solar plant 7.3%
- Onshore wind 30.9%
- Offshore wind 17.5%
- Commercial/govt rooftop solar 7.4%
- Wave energy 0.4%
- Geothermal energy 0.5%
- Hydroelectric 3%
- Tidal turbine 0%

40-Year Jobs Created
Number of jobs where a person is employed for 40 consecutive years

- Operation jobs: 2,815,850
- Construction jobs: 2,285,816

http://thefuturesolutionsproject.org/why-clean-energy/
Smart Grid – Multidisciplinary

R&I-1: Smart Grid Domain Exploration
Identify use cases, technical requirements, and appropriate ICT infrastructure.

R&I-2: Communication Layer Improvement
Develop adaptive communication strategies to maximize the performance of smart grid.

R&I-3: Data Integration and Analytics
Investigate new data modeling, data integration and data analytics methods.

R&I-4: ICT-Power System Testbeds
Implement testbeds to validate, evaluate, and demonstrate new developed methods.

* Durham University Smart Grid Laboratory
# US Electric Industry Structure

- 3,195 utilities in the US in 1996. Fewer than 1000 engaged in power generation

<table>
<thead>
<tr>
<th>Categories</th>
<th>Examples</th>
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<tbody>
<tr>
<td><strong>Investor-owned utilities</strong></td>
<td>AEP, American Transmission Co., ConEd, Dominion Power, Duke Energy,</td>
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<tr>
<td>240+, 66.1% of electricity</td>
<td>Entergy, Exelon, First Energy, HECO, MidAmerican, National Grid,</td>
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<tr>
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<td>Northeast Utilities, Oklahoma Gas &amp; Electric, Oncor, Pacific Gas &amp;</td>
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<td></td>
<td>Electric, SCE, Tampa Electric Co., We Energies, Xcel,</td>
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<td><strong>Publicly owned utilities</strong></td>
<td>Nonprofit state and local government agencies, including</td>
</tr>
<tr>
<td>2000+, 10.7%</td>
<td>Municipal, Public Power Districts, and Irrigation Districts, e.g. NYPA,</td>
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<td>LIPA,</td>
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<tr>
<td><strong>Federally owned utilities</strong></td>
<td>Tennessee Valley Authority (TVA), Bonneville Power Authority (BPA),</td>
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<td>~10, 8.2%</td>
<td>Western Area Power Administration (WAPA), etc.</td>
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<tr>
<td><strong>Cooperatively owned utilities</strong></td>
<td>Owned by rural farmers and communities</td>
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<tr>
<td>~1000, 3.1%</td>
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<tr>
<td><strong>Non-utilities, 11.9%</strong></td>
<td>Generating power for own use and/or for sale in wholesale power markets,</td>
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<td></td>
<td>e.g. Independent Power Providers (IPPs)</td>
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</table>
Hiring Companies

- Power utilities, e.g.
  - IOU (Xcel Energy, MidAmerican Energy)
  - Cooperative (Florida Electric Cooperatives Association)
  - Public Power (Orlando Utilities Commission)
- Independent System Operators (ISO) / Regional Transmission Operators (RTO)
  - PJM, SPP, ISO New England, NYISO, Midcontinent ISO, CAISO and ERCOT

*Positions: planning/operation engineers*
Hiring Companies (cont’d)

• Manufacturers and service providers
  – GE, ABB, Siemens, Alstom, etc.

Positions: R&D, engineers, consultants, etc.
Hiring Companies (cont’d)

- Government and Non-profit organizations
  - FERC (Federal Energy Regulation Commission)
  - National Laboratories (ORNL, PNNL, ANL, NREL, etc.)
  - EPRI (Electric Power Research Institute)

Positions: Scientists, engineers, analyst, etc.
### Power Program @ UCF – UG Education

#### 2017 ELECTRICAL ENGINEERING: Power and Renewable Energy Track

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* A Grade of C (2.00) or higher required.

- Transfer students please see your faculty advisor before registering for these classes.
- BS-MS students should choose (3 SH) 5000 level courses as electives.

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Power Program @ UCF – Curriculum

EEL 3290 Global Energy Issues (Introduction to Renewable Energy)
EEL 4205 Electric Machinery
EEL 4216 Fundamentals of Electric Power Systems
EEL 4294 Introduction to Smart Grids
MSE/EEL4xxx Introduction to PV

EEL 5245 Power Electronics I
EEL 5255 Advanced Power Systems Analysis
EEL 5268 Communications and Networking for Smart Grid
EEL 5291 Distributed Control and Optimization for Smart Grid
EEL 5xxx Power System Economics

EEL 6208 Advanced Machines
EEL 6246 Power Electronics II
EEL 6269 Advanced Topics in Power Engineering
EEL 6272 Smart Power Grids Protection
EEL 6674 Data Analytics in Power System
EEL 6xxx Power System Resilience
EEL 6938 Power System Reliability
EEL 6xxx Power System Detection and Estimation
## FEEDER Shared Courses

<table>
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<tr>
<th>Course Name</th>
<th>Host Institution</th>
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<tr>
<td>Power quality</td>
<td>Auburn</td>
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<tr>
<td>Advanced electric machinery and drives</td>
<td>Univ Pitts</td>
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<tr>
<td>Modern electrical grids and electricity markets for 100% renewable energy</td>
<td>U. Hawaii</td>
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<tr>
<td>Power system transients</td>
<td>FSU</td>
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<tr>
<td>Design of advanced power distribution systems</td>
<td>Uark</td>
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<tr>
<td>Power system analysis I</td>
<td>UK</td>
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<tr>
<td>Power system reliability</td>
<td>UCF</td>
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<tr>
<td>Data analytics in power systems</td>
<td>UCF</td>
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<td>Integration of photovoltaics</td>
<td>USC</td>
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<td>Power system analysis II</td>
<td>UPitts</td>
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<td>Global energy issues</td>
<td>UCF</td>
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<td>Cybersecurity of electric power SCADA system</td>
<td>Uark</td>
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<tr>
<td>Advanced power systems analysis</td>
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Power Program @ UCF – Organizations

**FEEDER** Foundations for Engineering Education for Distributed Energy Resources

12 Universities
- University of Arkansas
- Auburn University
- Florida State University
- Hawaii University
- University of Kentucky
- University of Pittsburgh
- San Diego State University
- UC San Diego
- University of South Carolina
- UT Dallas
- UCF
- University of Florida

8 GEARED/FEEDER Utility Partners
- Kentucky Power
- OUC - The Reliable One
- Southern Company
- TVA
- Duke Energy
- FPL
- East Kentucky Power Cooperative
- Lakeland Electric

9 STEM/FEEDER Utility Partners
- Dominion
- Maui Electric
- Hawaii Electric Light
- Oncor
- Entergy
- We Deliver
- Reliant
- SCE&G
- Southern California Edison

10 Supporting Industry Partners
- OSIsoft
- Schneider Electric
- SAIC
- NERA
- Siemens
- Texas Instruments
- Mitsubishi Power Systems
- Leidos

2 National Laboratories
- Los Alamos National Laboratory
- NREL
**Power Program @ UCF – Faculty**

**Zhihua Qu**  
Cooperative control of networked systems  
Distributed optimization

**Marwan Simaan**  
Optimization of dynamic systems  
Game theory

**Winston Schoenfeld**  
Wide band gap materials  
Nanophotonics device

**Azadeh Vosough**  
Communication  
Wireless networks

**Robert Reedy**  
Electric utility operations & design  
Grid integration of PV systems

**Issa Batarseh**  
Power electronics  
Solar energy conversion

**Aleksandar Dimitrovski**  
Power system protection  
High performance computing

**Wei Sun**  
Power system restoration  
Self-healing smart grid

**Qun Zhou**  
Energy forecasting and power economics  
Data analytics in power system

**Junjian Qi**  
Cascading failure  
Cybersecurity

**Kristopher Davis**  
Photovoltaics  
Optical and electronic materials

**Qifeng Li**  
Convex optimization  
Nonlinear systems
Power Program @ UCF – Research

- Advanced controls of networked systems
- Cyber-physical security
- Data analytics and electricity market
- Microgrids
- Integration of renewable resources
- Optimization of complex systems
- PV modules and systems
- Public policy of resilient energy systems
- Resilient infrastructure systems
- Transportation and smart city
Power Program @ UCF – Lab/Facilities

Siemens Digital Grid Lab – HEC 302
1. Microgrid Management System (MGMS)
   - A new grad-level course to be offered in Spring 2018 – *Advanced Microgrid Design and Operation*
Power Program @ UCF – Lab/Facilities

Siemens Digital Grid Lab – HEC 302

2. Siemens Distribution Feeder Automation (SDFA)
   • Distribution automation
   • Protection, communication

3. PSS/E
   • Power Transmission System Planning Software

4. PSS/SINCAL
   • Integrated Power System Engineering Software
Power Program @ UCF – Lab/Facilities

- **Architecture**
  - Opal-RT connected with multiple hardware for real-time digital simulation and HIL testing

- **Key Specifications**
  - **Opal-RT** (CPU 3.46 GHz, 12 core, red hat linux intel C compiler & optimized real-time kernel, 32 static digital I/O channels, 16 analog I/O channels, HIL controller Interface eMEGAsim and ePHASORsim licenses, IRIG/ GPS Synchronization board, Diver IEC61850 and C37.118)
  - **PMU** (National Instruments Advanced PMU Development System)
  - **PDC** integration (SEL 3373), protection **relays** (SEL 411-L), Ethernet switches, etc.
  - **Amplifier** (Omicron CMs 356 current amplifier)

- **Applications**
  - Real-time digital simulation and control prototyping for power grids, power electronics, model validation, optimization, frequency and power control, real-time simulation of microgrid systems, protection relays testing, etc.
Power Program @ UCF – Opportunities

• IEEE Power & Energy Society (PES) Scholarship Plus Initiative
  ✓ Deadline 06/30/2017
• IEEE PES UCF Student Branch Chapter
  ✓ Contact Michael Rathbun <rathbun.michael@Knights.ucf.edu>
• Siemens Digital Grid Lab
  ✓ Contact Michael Rathbun
One Example for EEL 3004

Reactive Power Compensation

Generators are shown as circles

Transmission lines are shown as a single line

Arrows are used to show loads
One Example for EEL 3004

Reactive Power Compensation

Black – W/ capacitor
Red – W/O capacitor
One Example for EEL 3004

Reactive Power Compensation

\[ I = \frac{40000\angle0^\circ V}{100\angle0^\circ \Omega} = 400\angle0^\circ \ A \]

\[ V = 40000\angle0^\circ + (5 + j40) 400\angle0^\circ \]
\[ = 42000 + j16000 = 44.9\angle20.8^\circ \ kV \]

\[ S = V I^* = 44.9 \times 10^3 \angle20.8^\circ \times 400\angle0^\circ \]
\[ = 17.98\angle20.8^\circ \text{ MVA} = 16.8 + j6.4 \text{ MVA} \]

\[ Z_{Load} = 70.7\angle45^\circ \quad \text{pf} = 0.7 \text{ lagging} \]

\[ I = 564\angle-45^\circ \ A \]

\[ V = 59.7\angle13.6^\circ \ kV \]

\[ S = 33.7\angle58.6^\circ \text{ MVA} = 17.6 + j28.8 \text{ MVA} \]