Introduction of EE Power & Renewable Energy Track

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Dept. of Electrical and Computer Engineering

EEL3004

January 31, 2018

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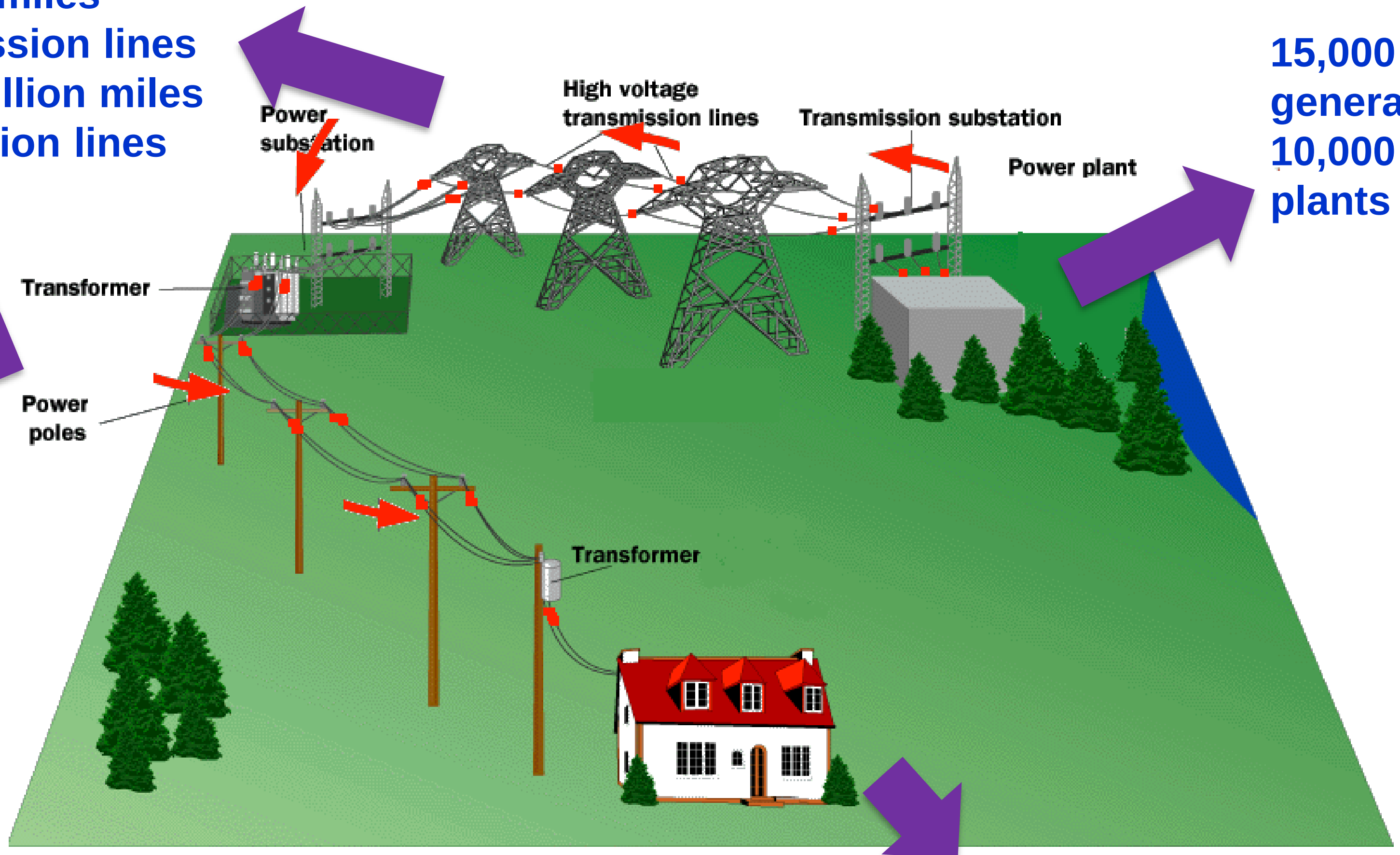
Power System

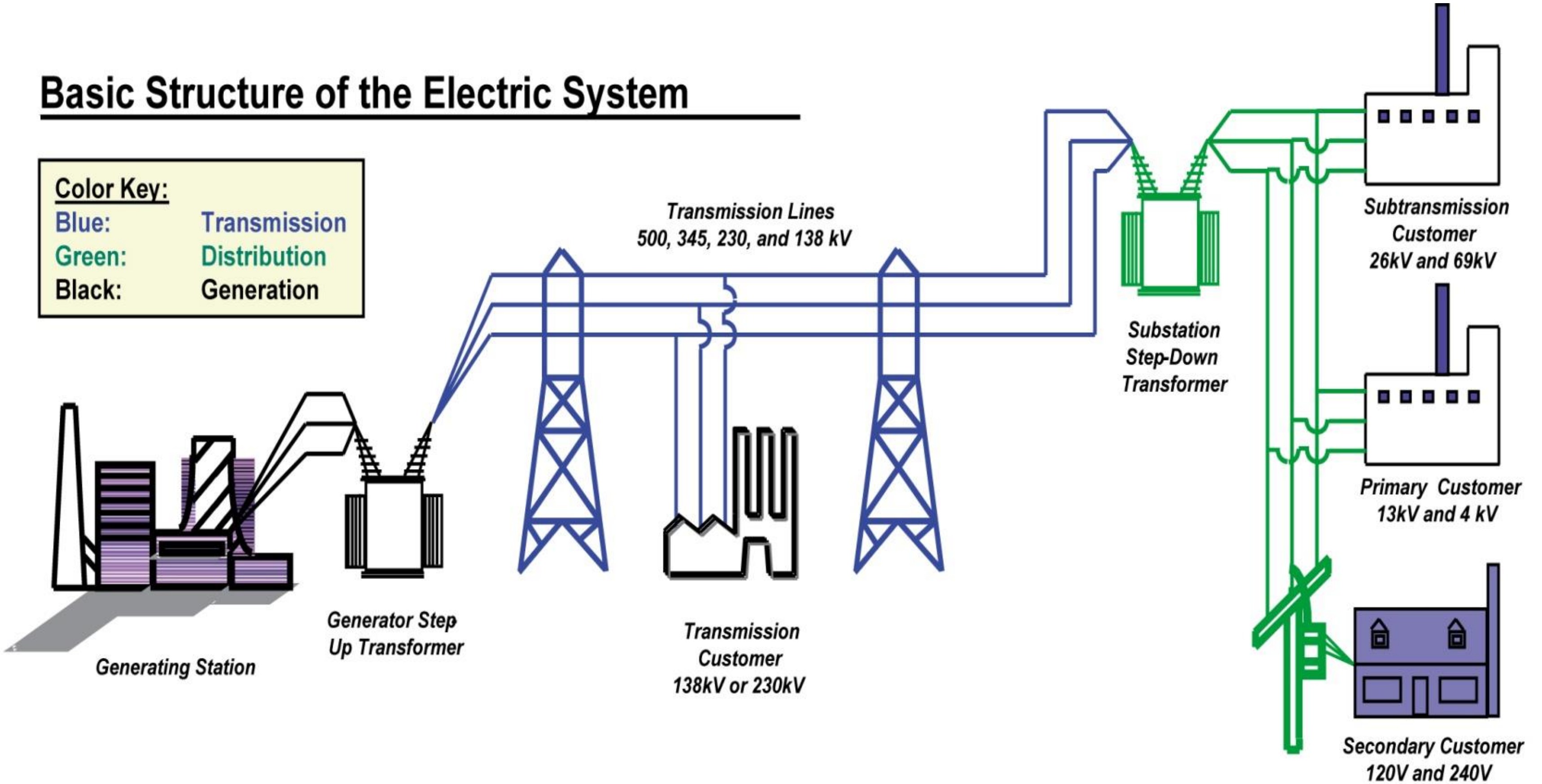
170,000 miles transmission lines and 6 million miles distribution lines



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?



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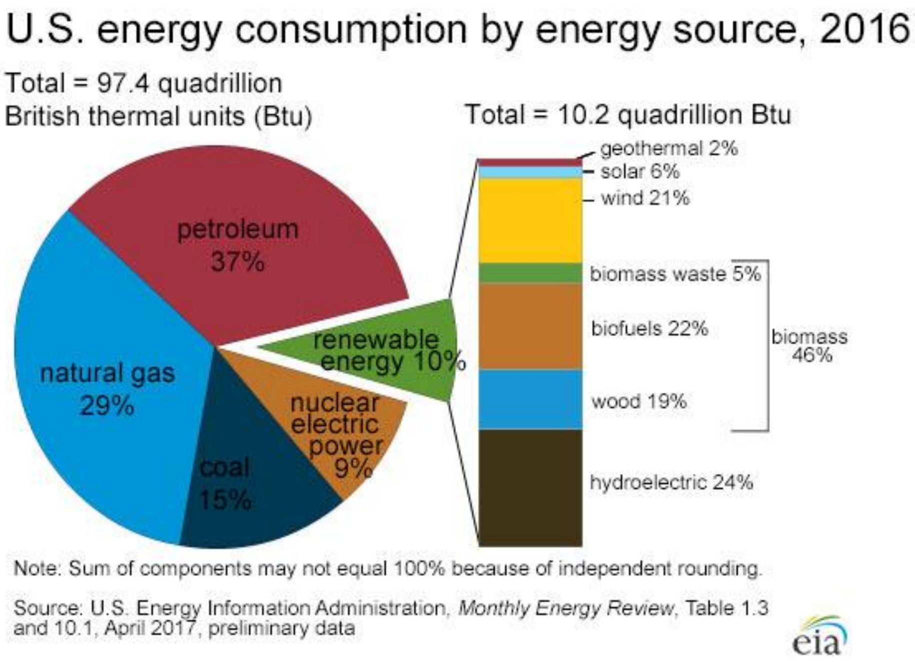
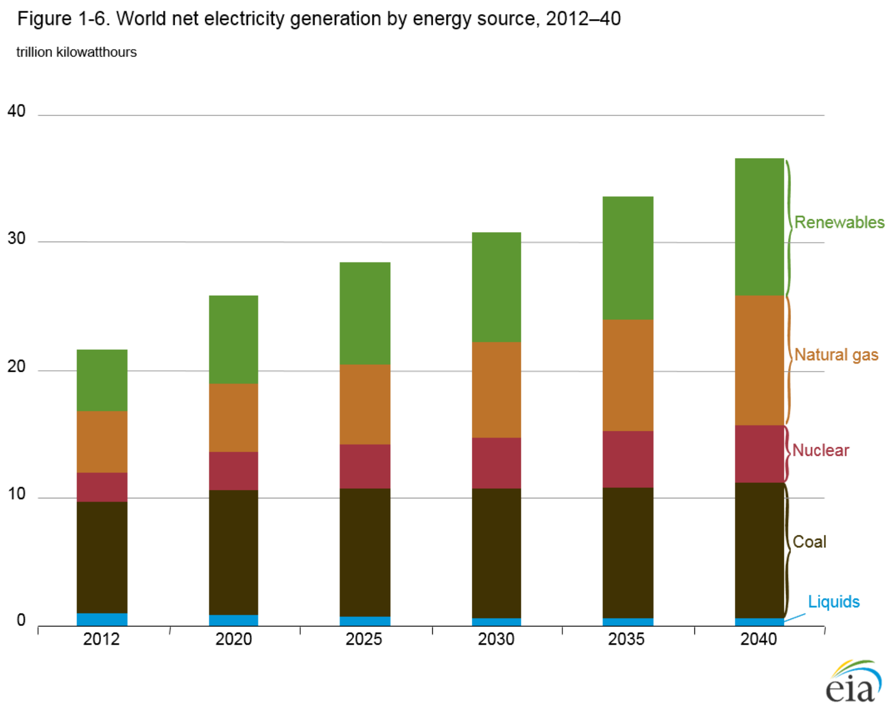
Power Plants

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

http://www.midamericanenergy.com/aboutus3.aspx

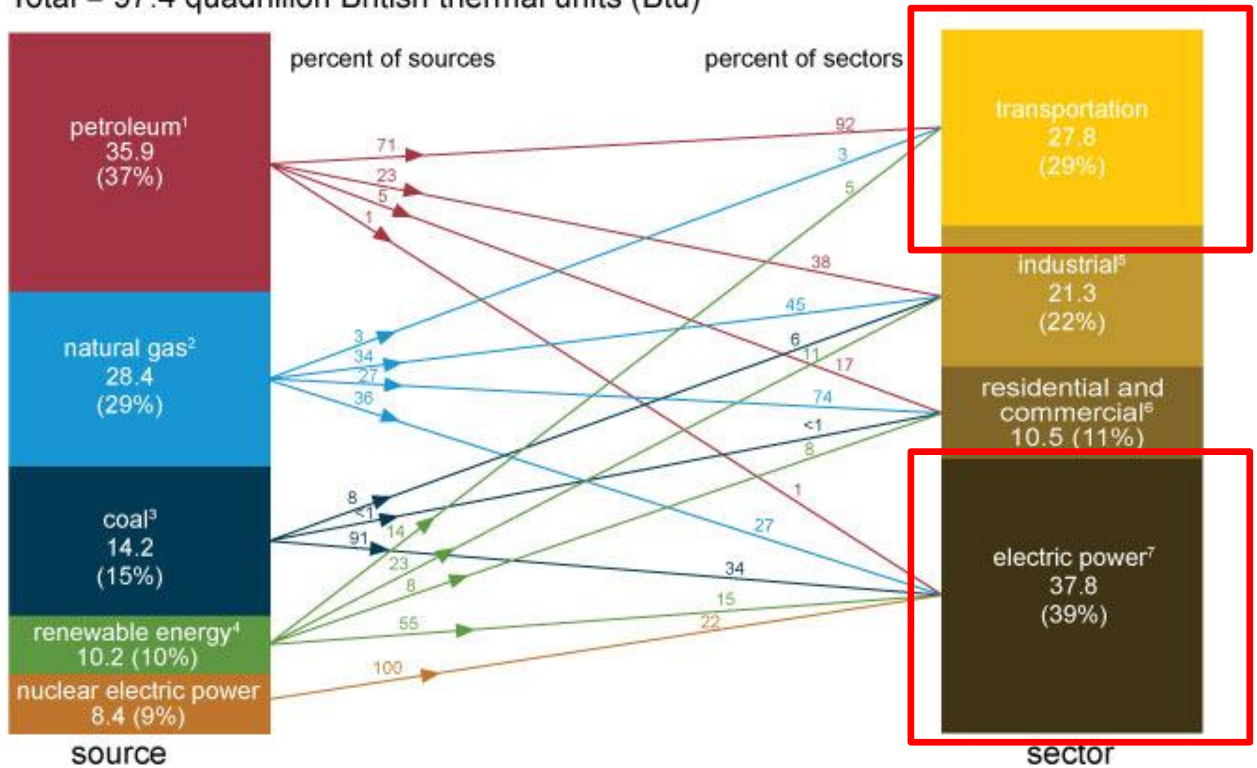
Energy Resources for Electricity Generation





U.S. primary energy consumption by source and sector, 2016

Total = 97.4 quadrillion British thermal units (Btu)



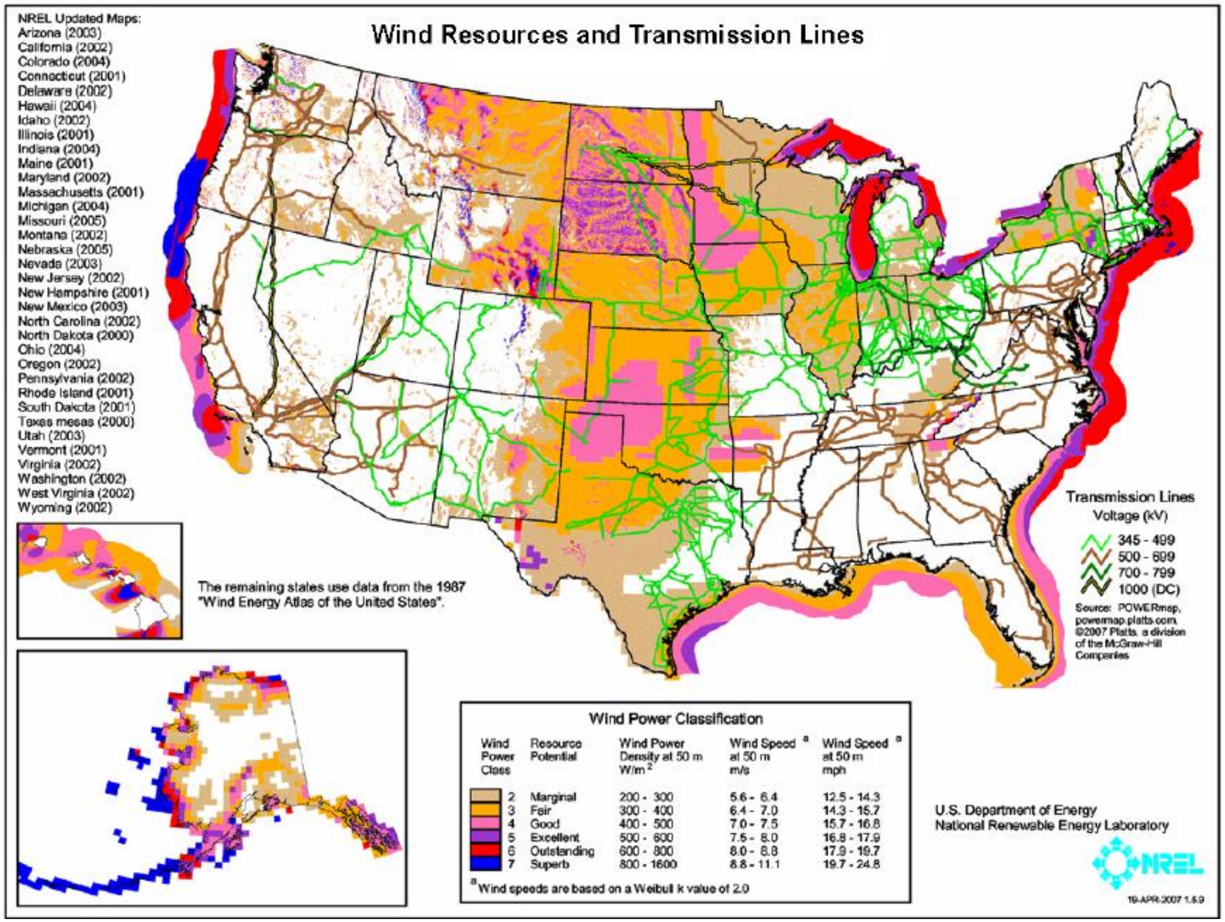
[1] Does not include biofuels that have been blended with petroleum—biofuels are included in "Renewable Energy."
[2] Excludes supplemental gaseous fuels.
[3] Includes -0.02 quadrillion Btu of coal coke net imports.
[4] Conventional hydroelectric power, geothermal, solar, wind, and biomass.
[5] Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[6] Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[7] Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes 0.24 quadrillion Btu of electricity net imports not shown under "Source."

Notes: • Primary energy is energy in the form that it is accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy occurs (for example, coal before it is used to generate electricity). • The source total may not equal the sector total because of differences in the heat contents of total, end-use, and electric power sector consumption of natural gas. • Data are preliminary. • Values are derived from source data prior to rounding. • Sum of components may not equal total due to independent rounding.

Sources: U.S. Energy Information Administration, *Monthly Energy Review* (April 2017), Tables 1.3, 1.4a, 1.4b, and 2.1−2.6.

https://www.eia.gov/state/maps.php

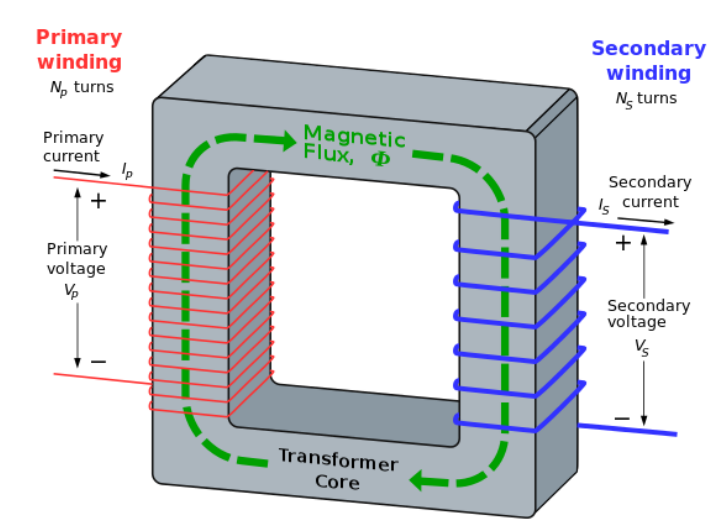
Transmission



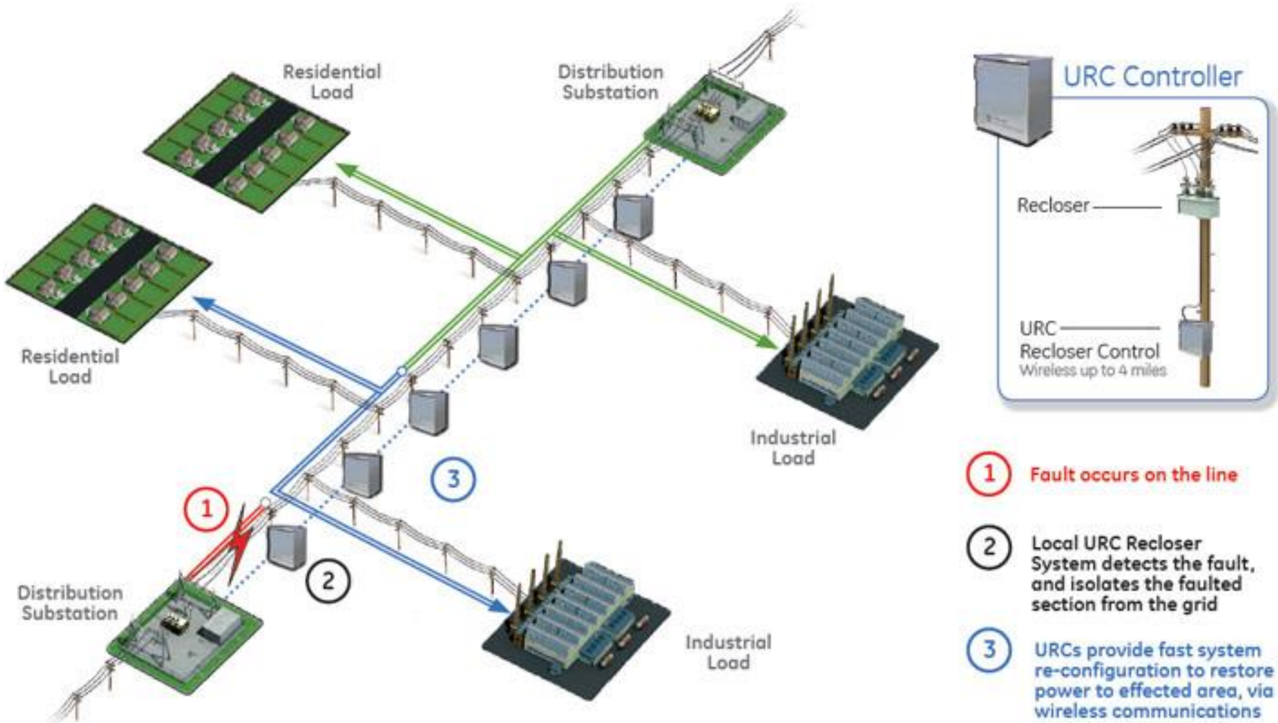
https://eerscmap.usgs.gov/windfarm/

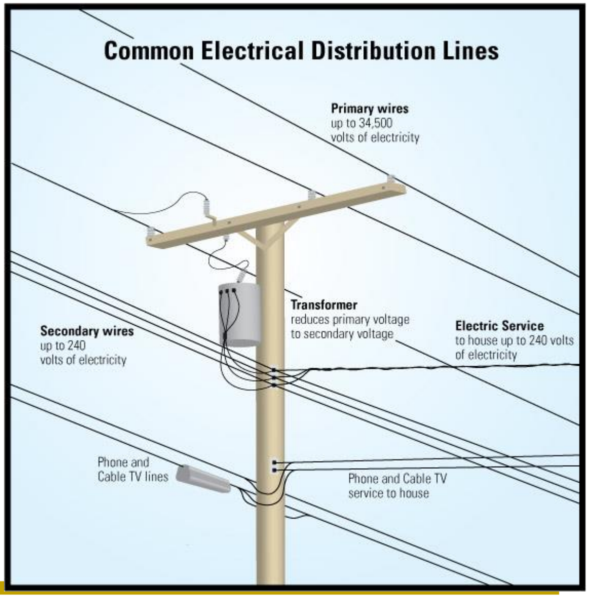
Substation


Incoming Subtransmission Lines
Electric power path through substation
34 KV in
Lightning Arresters
Air-break Switches
Outgoing Distribution Lines
Step-down Transformer
Distribution Bus
7.2 KV out
Cutout
Switches
Oil Circuit Breakers
Voltage Regulators
Metal-clad
Switchgear
Control House


Primary winding
N_p turns
Primary current
I_p
+
Primary voltage
V_p
−
Magnetic Flux, Φ
Transformer Core
Secondary winding
N_S turns
Secondary current
I_S
+
Secondary voltage
V_S
−

Distribution





Power System Control Center

How to Control Power Systems ?

Remote terminal unit (RTU)

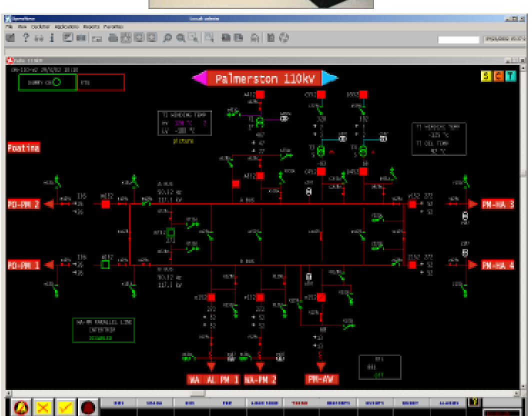
Substation

Communication link

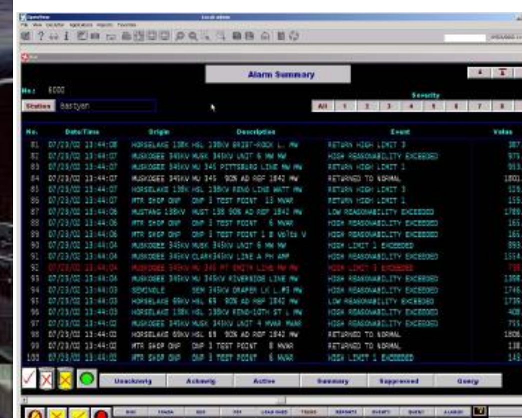
SCADA Master Station

Energy control center with EMS (Energy Management System)

Control Signal

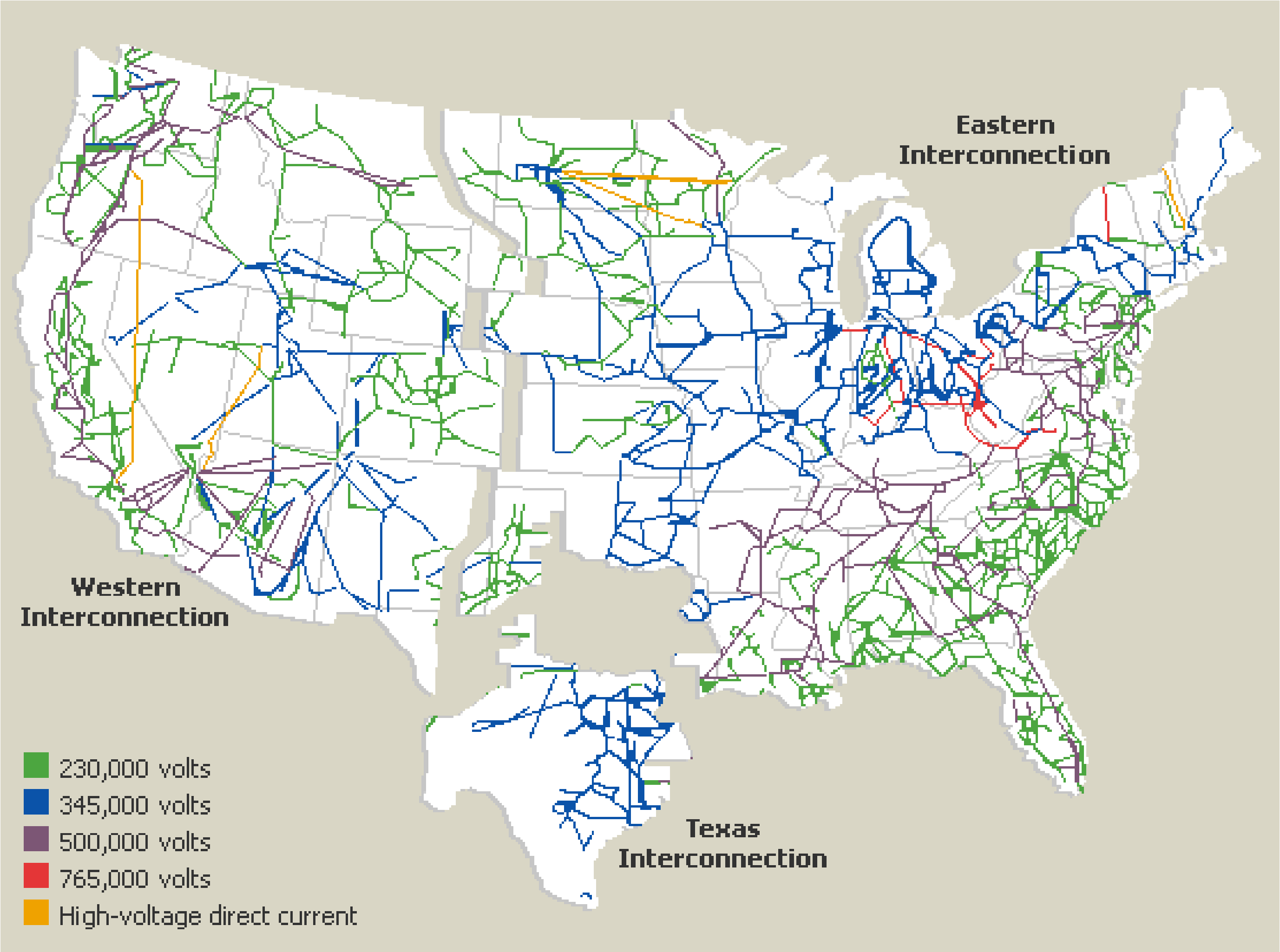


EMS 1-line diagram



EMS alarm display

Power Grid in U.S.



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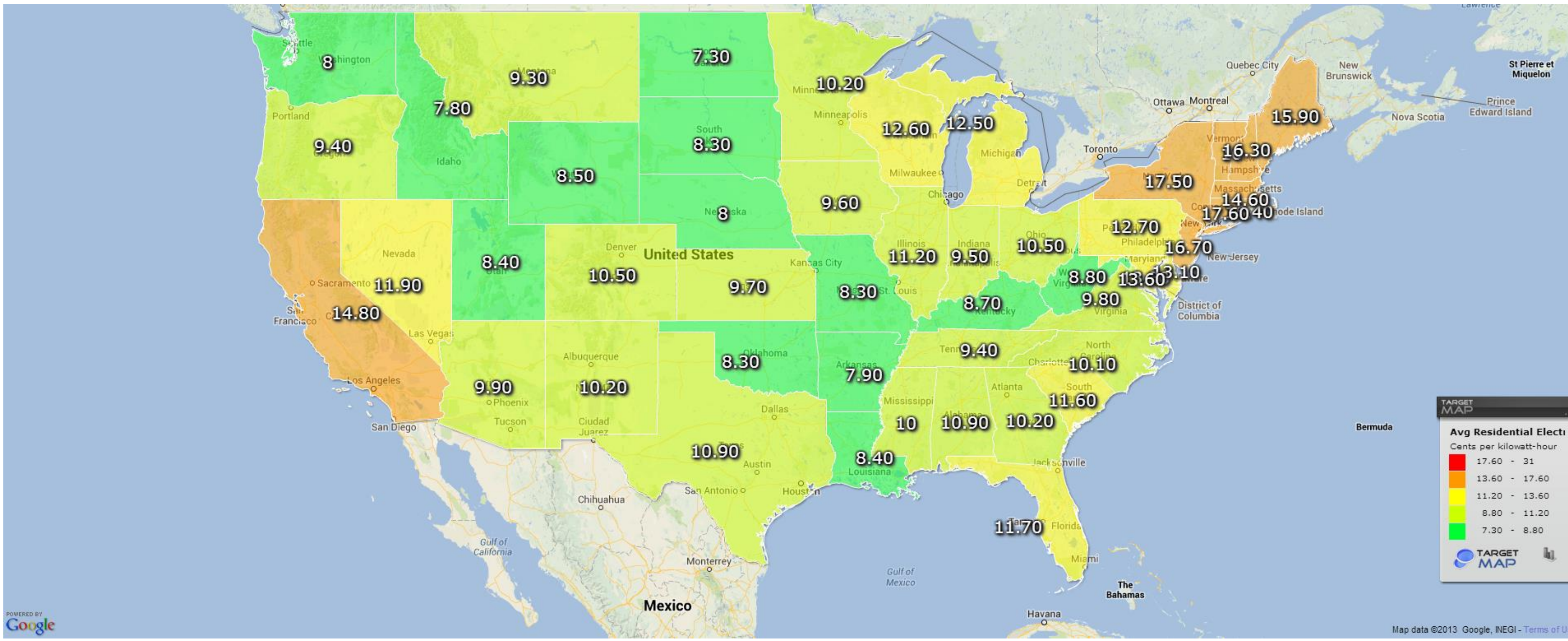
Electricity Price



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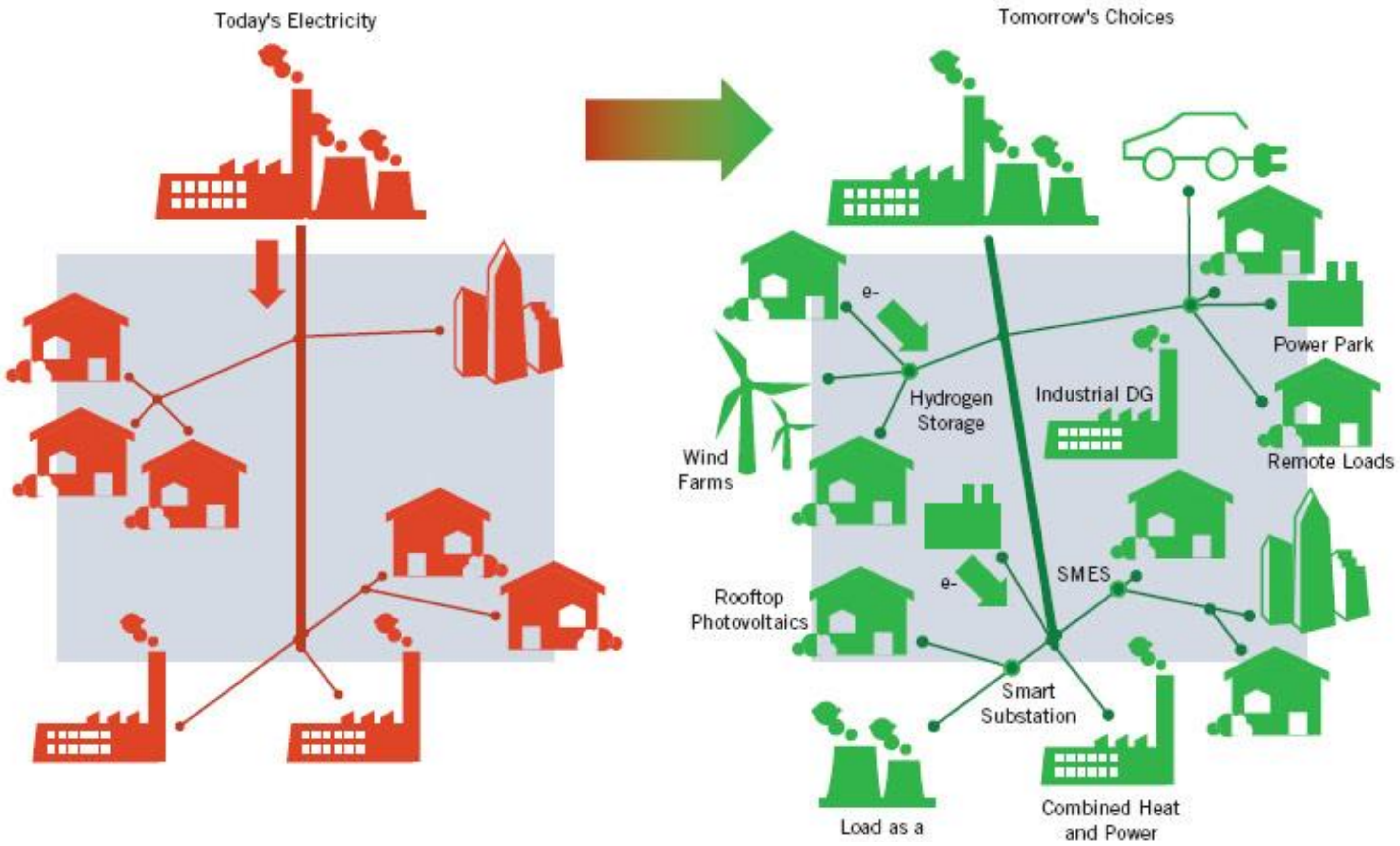
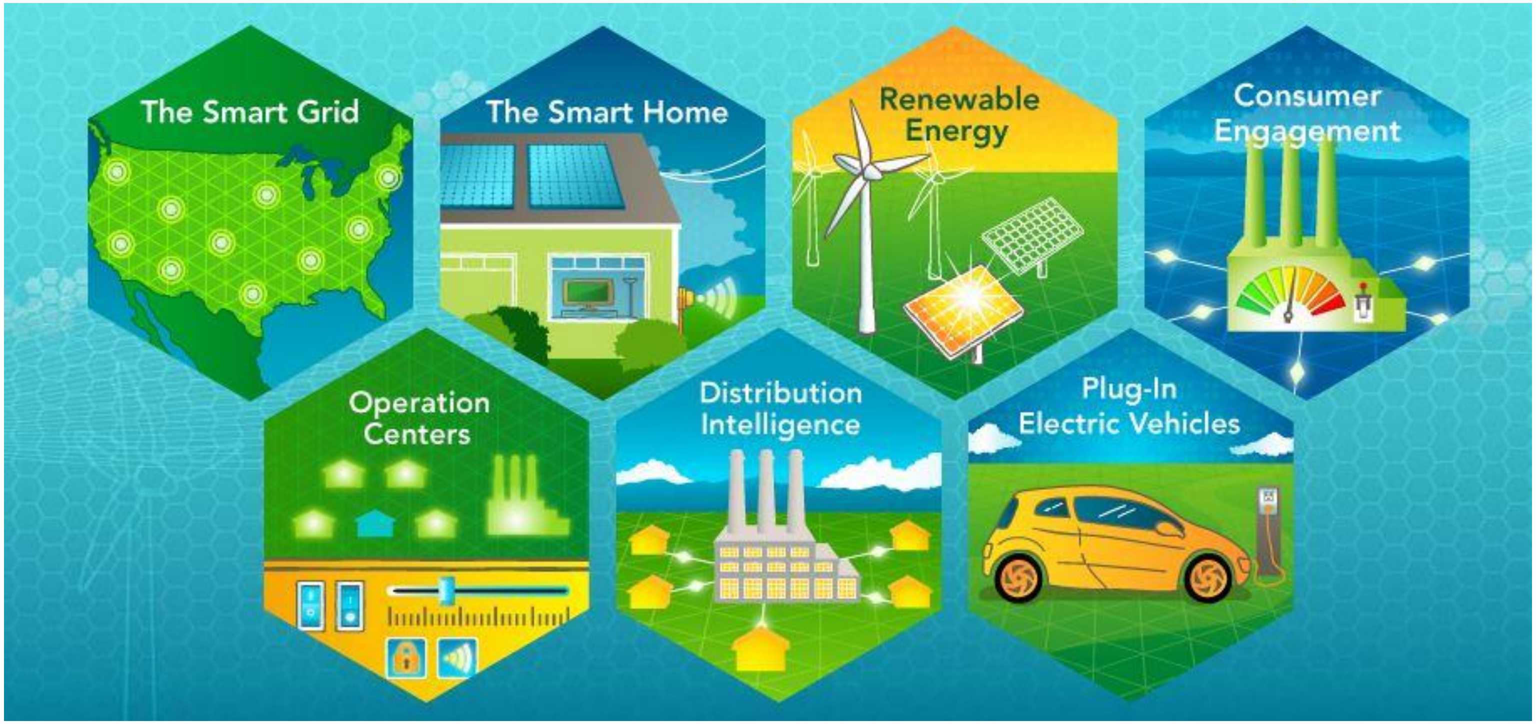
Grid Modernization

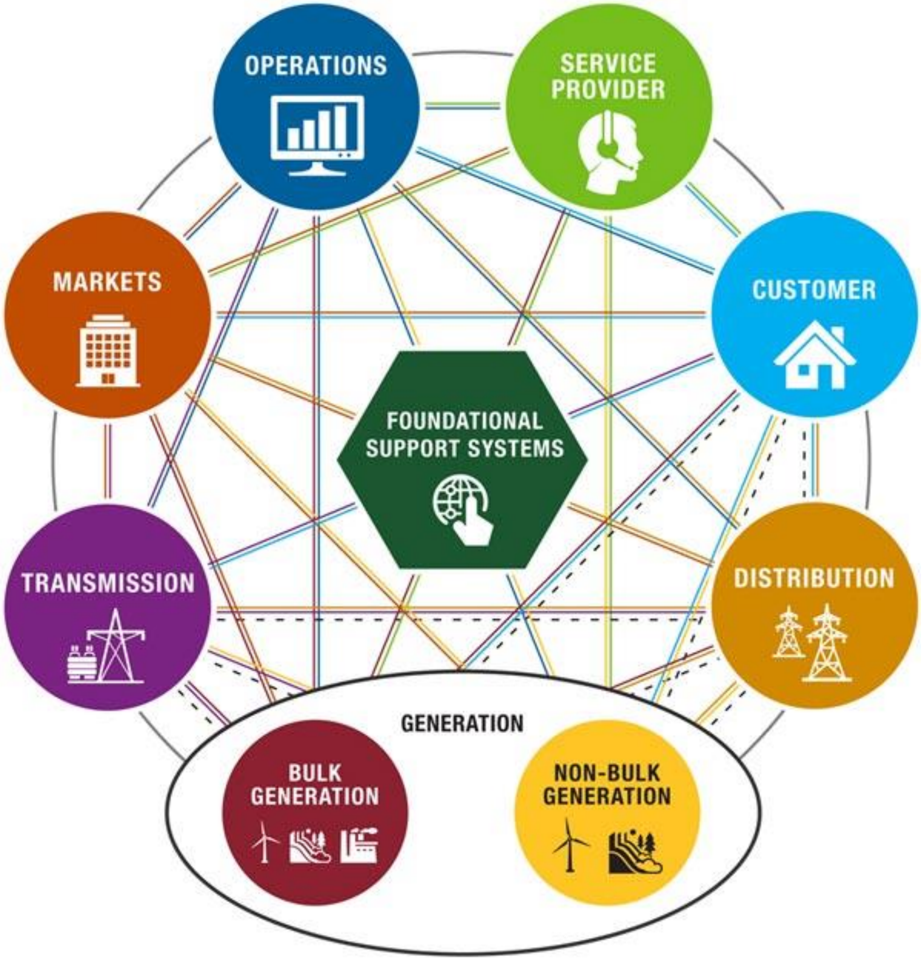


Smart Grid



[What is the Smart Grid? - U.S. Department of Energy]

Smart Grid – Domains & Sub-domains



http://smartgrid.ieee.org/domains

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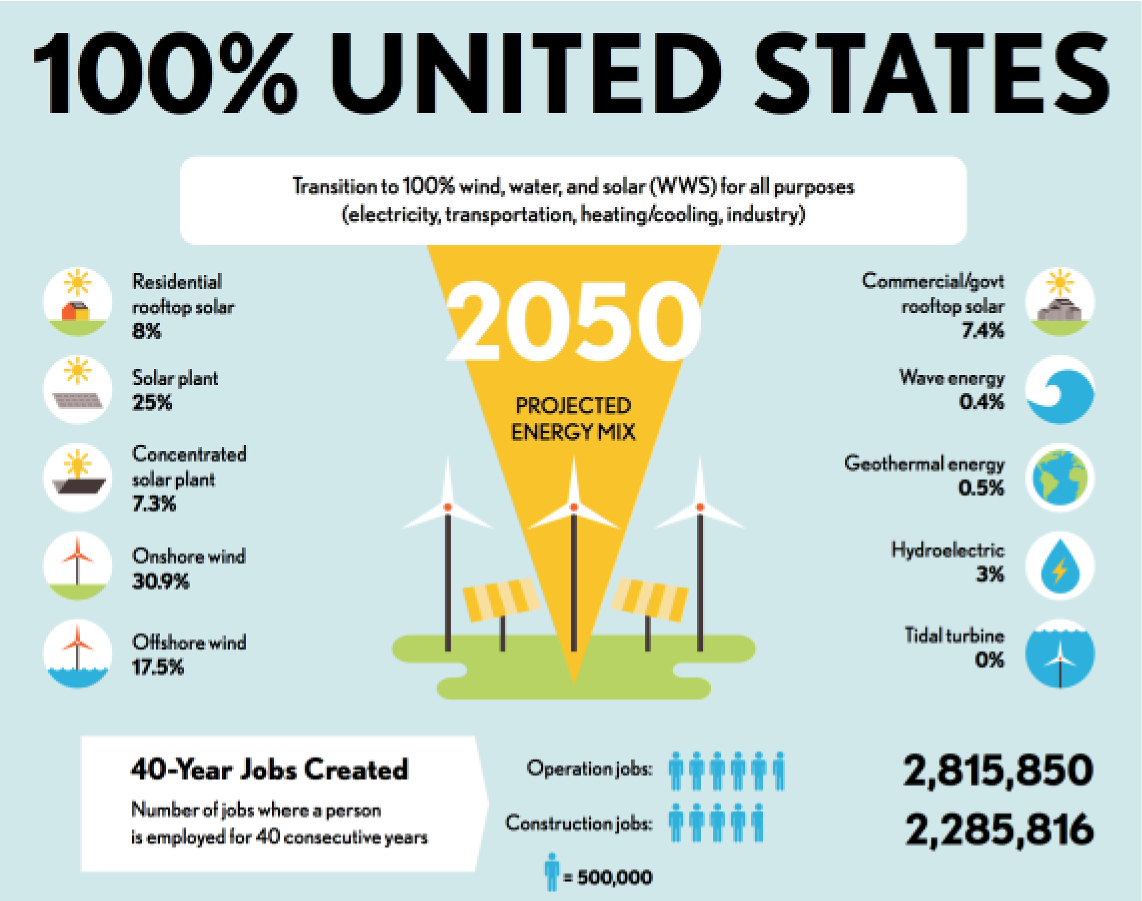
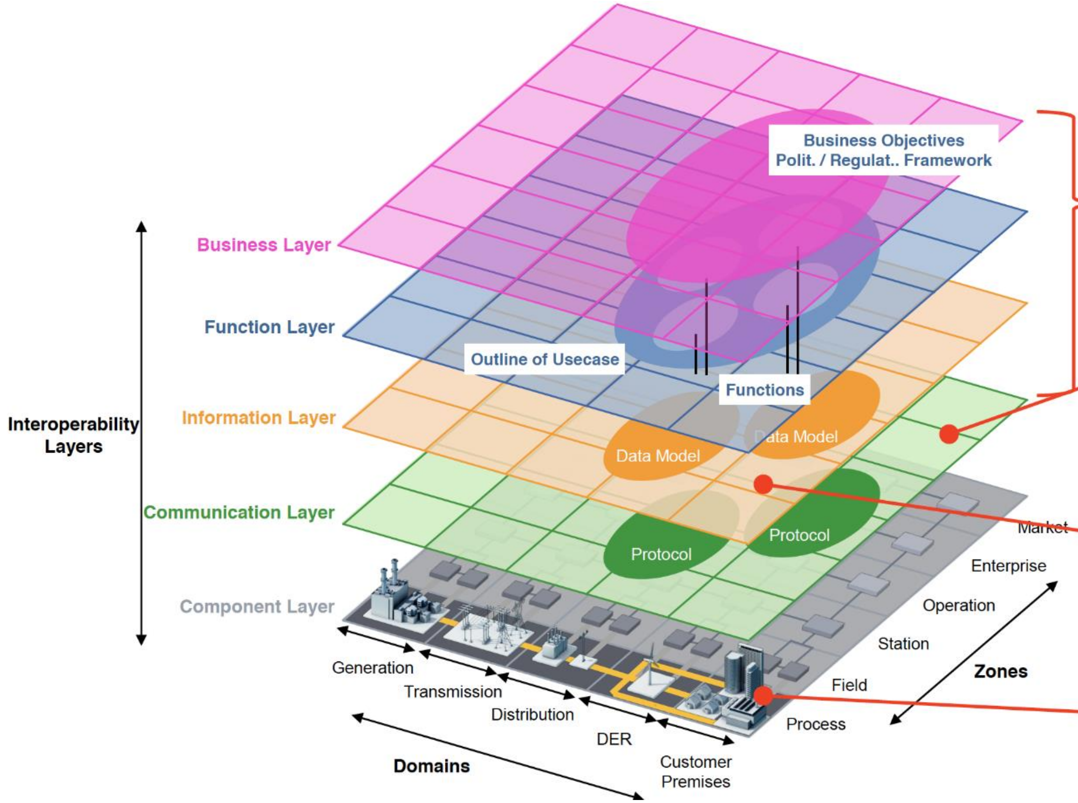
Smart Grid – 100% Renewable



http://thesolutionsproject.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

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US Electric Industry Structure

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

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

* Dr. K. Sun @ UTK

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)

FERC FEDERAL ENERGY REGULATORY COMMISSION

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Argonne NATIONAL LABORATORY

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Positions: Scientists, engineers, analyst, etc.

Power Program @ UCF – UG Education

2017 ELECTRICAL ENGINEERING: Power and Renewable Energy Track — DEGREE REQUIREMENT CHECKSHEET

COLLEGE OF ENGINEERING & COMPUTER SCIENCE — UNIVERSITY OF CENTRAL FLORIDA

GENERAL EDUCATION PROGRAM			
* Indicates "C-" minimum required by the Gordon Rule			
** Indicates minimum "C" or better grade			
COMMUNICATION (9 SEM HRS)	*SH*	*Grd*	*Trans Equiv*
ENC 1101	3	*	
ENC 1102	3	*	
SPC 1603	3		
CULTURAL & HISTORICAL (9 SEM HRS)			
Select 2: AMH 2010, AMH 2020, EUH 2000, EUH 2001, HUM 2211, HUM 2230, WOH 2012, WOH 2022	6	*	
Approved Cultural Foundations course:	3		
SOCIAL FOUNDATION - (6 SEM HRS)			
ANT 2000/ PSY 2012/ SYG 2000	3		
ECO 2013 *or* ECO 2023	3		
SCIENCE - 6 SH			
GEO 1200 *or* GEO 2370 (either GEO is preferred) *or* BSC 1050C *or* BSC 1005C *or* GLY 1030	3		
PHY 2048C Physics I for Engrs	4		
MATHEMATICAL - 6 SH			
MAC 2311 Calculus I	4	**	
GPA Gen Ed Prog =	*38*		
*ENGINEERING CORE***	*SH*	*Grd*	*Trans Equiv*
MAC 2311 Calculus I	GEP	**	
MAC 2312 Calculus II	4	**	
MAC 2313 Calculus III	4	**	
MAP 2302 Differential Equations	3	**	
CHS 1440 Chem for Engrs (or CHM 2045C)	4	**	
PHY 2048C Physics I for Engrs	GEP	**	
PHY 2049C Physics II for Engrs	4	**	
SUBTOTAL SEM HRS	*19*		

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

Transfer students please see your faculty advisor before registering for these classes.

LOWER AND JUNIOR LEVEL REQUIRED COURSES	*SH*	*Grd*	*Trans Equiv*
EGS 1006C Intro to Engr Prof	1	#	
EGN 1007C Engr Concepts and Methods	1	#	
STA 3032 Probability & Statistics for Engrs	GEP		
PHY 3101 Physics for Engr and Sci III	3		
EEL 3926L Junior Design	1		
EGN 3211 Engineering Analysis & Comp.	3	**	
EEL 3004C Electrical Networks	3	**	
EEL 3123C Networks and Systems	3	**	
EEE 3307C Electronics I	4		
EEE 3342C Digital Systems	3	**	
EEL 3801C Computer Organization	4	**	
EEL 3657 Linear Control Systems	3		
JUNIOR LEVEL ELECTIVE COURSES (CHOOSE 2)	*SH*	*Grd*	*Trans Equiv*
EEL 3470 Electromagnetic Fields	3		
EEL 3552C Signal Analysis & Communications	4		
EEE 3350 Semiconductor Devices I	3		
EEL 3290 Global Energy Issues	3		
SENIOR LEVEL REQUIRED COURSES	*SH*	*Grd*	*Trans Equiv*
EEL 4216 Fund. Of Electric Power Systems	3		
EEL 4742C Embedded Systems	3		
RECOMMENDED SENIOR LEVEL ELECTIVE COURSES	*SH*	*Grd*	*Trans Equiv*
(CHOOSE MINIMUM 3 FROM LIST)			
EEL 4612C Robust Control	4		
EEL 4750 Digital Signal Processing Fund.	3		
EEL 4294 Introduction to Smart Grids	3		
EEL 4205 Electric Machinery	3		
EEL 5185 Systems Identification	3		
EEL 5268 Communications and Networking for Smart Grid	3		
EEL 5291 Distributed Control and Optimization for Smart Grid	3		
EEL 5173 Linear Systems Theory	3		
EEL 5XXX Advanced Power Systems Analysis	3		
EEL 5245 Power Electronics I	3		
REQUIRED			
Technical Electives (EEE or EEL 4XXX or 5XXX)	15	~	
EEL 4914 Senior Design I	3		
EEL 4915L Senior Design II	3		
SUBTOTAL SEM HRS	*71*		
GPA Engr Option = (2.250 minimum)			

ADVISOR COMMENTS:

~BS-MS students should choose (3 SH) 5000 level courses as electives.

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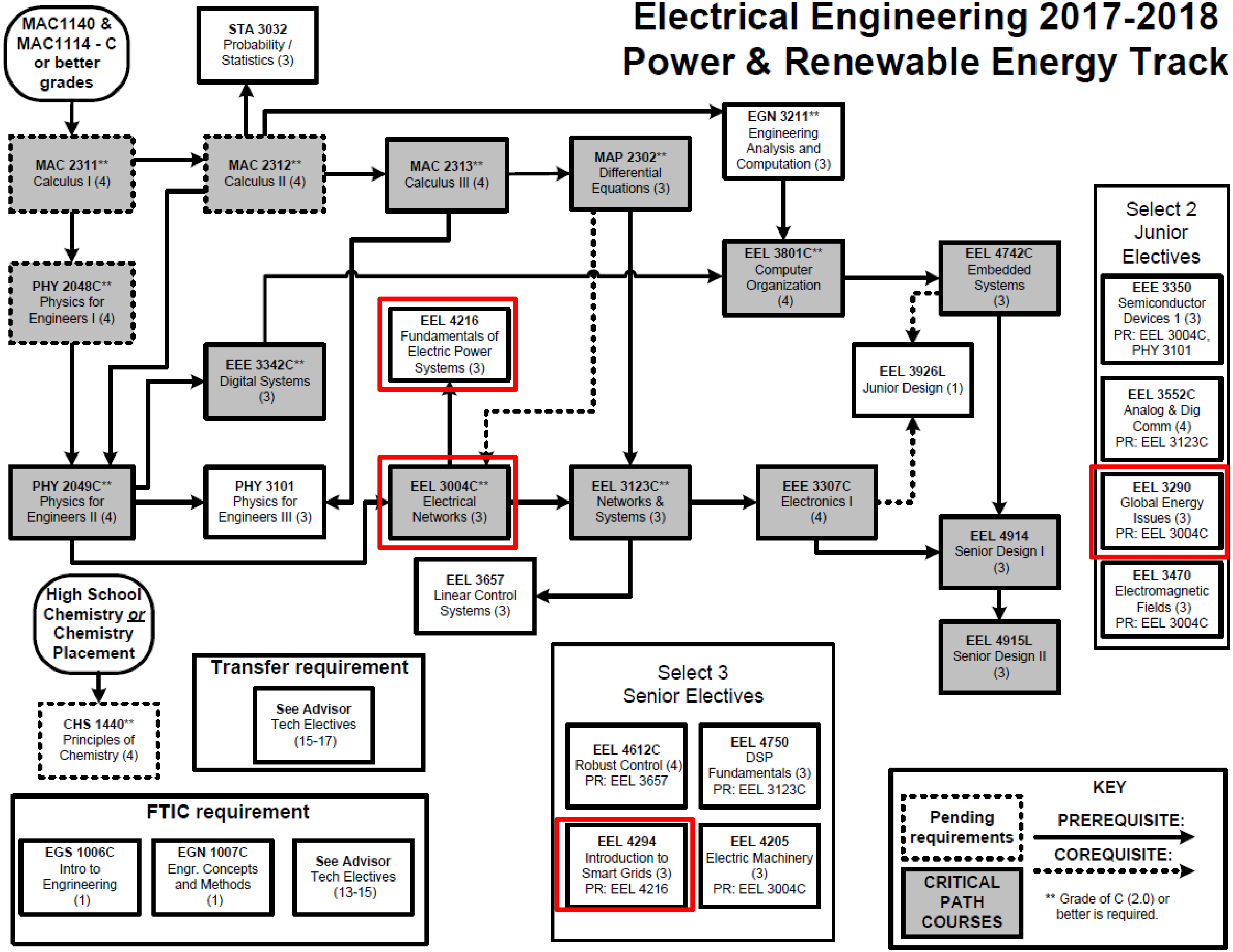
Electrical Engineering 2017-2018
Power & Renewable Energy Track



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

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Power Program @ UCF – Grad Education

FEEDER Shared Courses

Course Name	Host Institution
Power quality	Auburn
Advanced electric machinery and drives	Univ Pitts
Modern electrical grids and electricity markets for 100% renewable energy	U. Hawaii
Power system transients	FSU
Design of advanced power distribution systems	Uark
Power system analysis I	UK
Power system reliability	UCF
Data analytics in power systems	UCF

Course Name	Host Institution
Introduction to smart grid	UCF/UK
Integration of photovoltaics	USC
Power system analysis II	UPitts
Global energy issues	UCF
Cybersecurity of electric power SCADA system	Uark
Advanced power systems analysis	UCF

http://feeder-center.org/index.php

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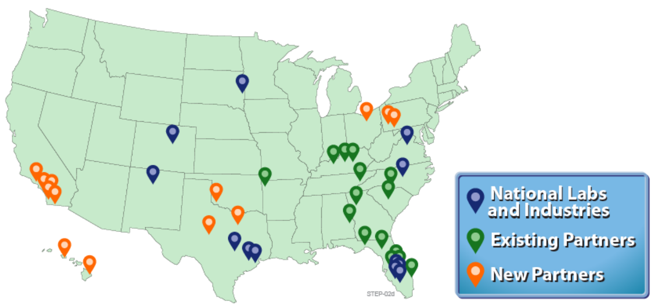
Power Program @ UCF – Organizations

Powered by SunShot U.S. Department of Energy

FEEDER Foundations for Engineering Education for Distributed Energy Resources

GEARED



12 Universities

- University of Arkansas
- Auburn University
- The Florida State University
- University of Hawai'i
- UK University of Kentucky
- University of Pittsburgh
- San Diego State University
- UC San Diego
- University of South Carolina
- UT Dallas
- UCF
- UF University of Florida

8 GEARED/FEEDER Utility Partners

- AEP Kentucky Power
- OUC The Reliable One
- Southern Company
- TVA
- East Kentucky Power Cooperative
- Lakeland Electric
- Duke Energy
- FPL

9 STEP/FEEDER Utility Partners

- Dominion
- DLC Duquesne Light Co.
- Entergy
- Hawaiian Electric, Maui Electric, Hawai'i Electric Light
- Oncor – We deliver.
- reliant – an NRG company
- SDG&E
- SCE&G – A SCANA Company
- Southern California Edison – An Edison International Company

10 SUPPORTING INDUSTRY PARTNERS

- OSIsoft
- Schneider Electric
- SAIC – From Science to Solutions
- NPPT Northern Plains Power Technologies
- ABB
- S&C
- leidos
- Siemens
- Texas Instruments
- Mitsubishi Power Systems

2 NATIONAL LABORATORIES

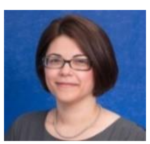
- Los Alamos National Laboratory – Est. 1943
- NREL National Renewable Energy Laboratory

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



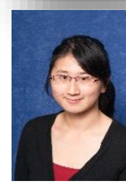
Azadeh Vosough
- Communication
- Wireless networks

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

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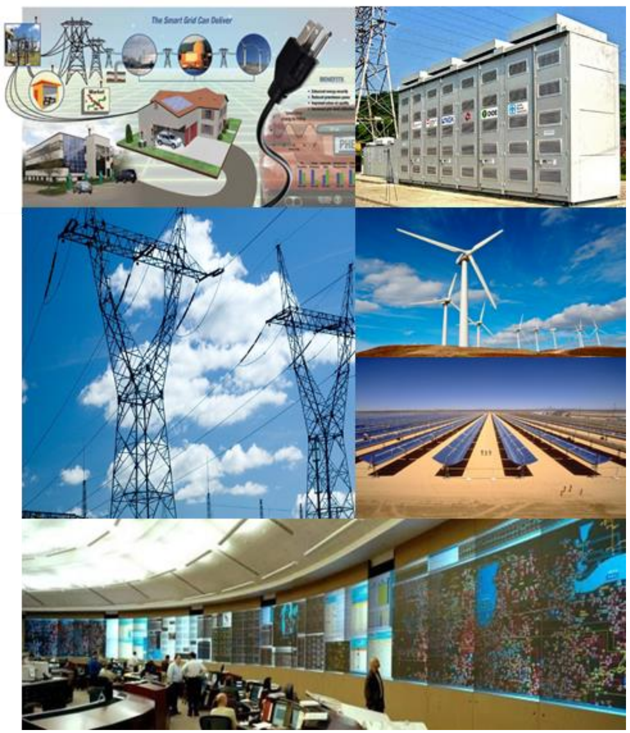
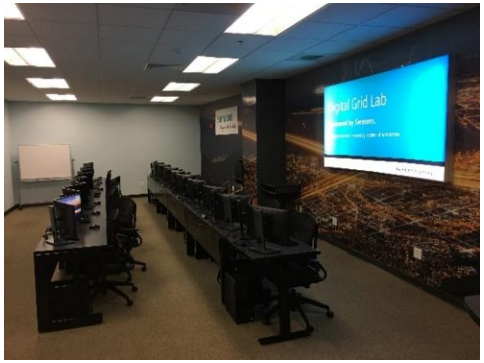
Power Program @ UCF – Research



- **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



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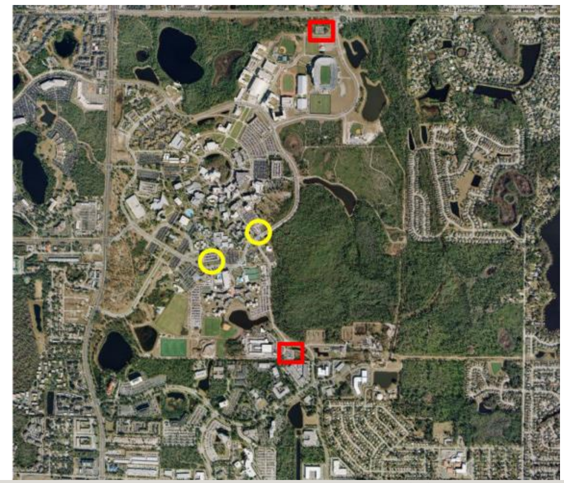
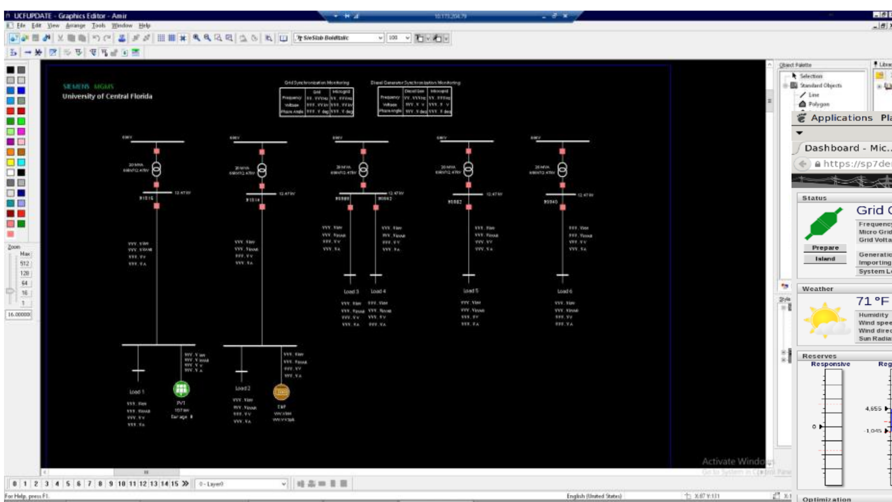
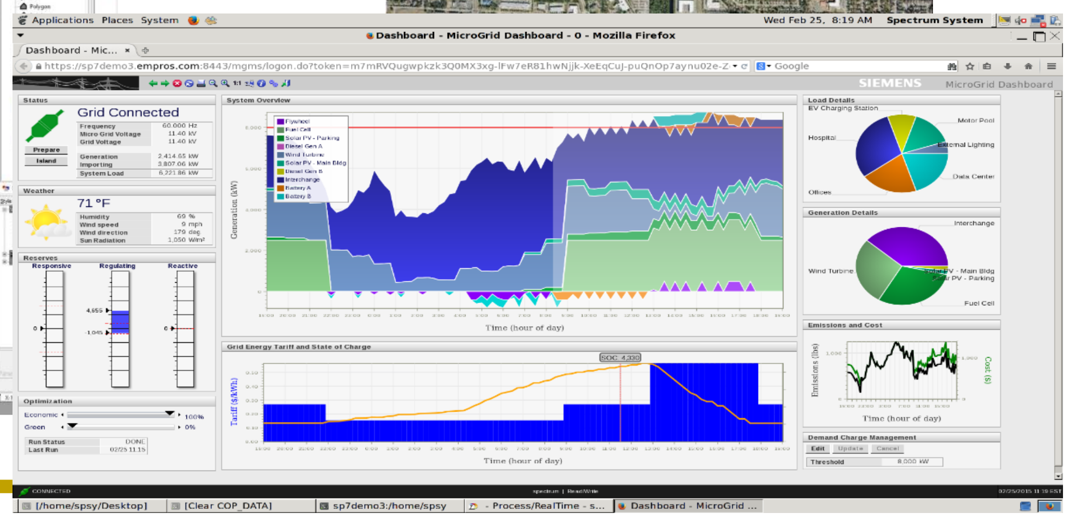
Power Program @ UCF – Lab/Facilities

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***





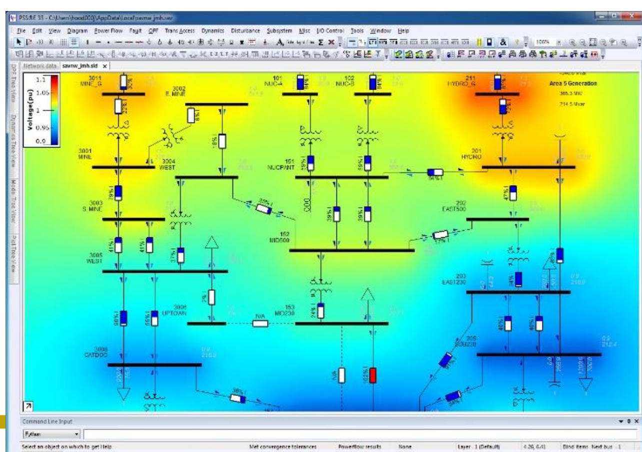


Power Program @ UCF – Lab/Facilities

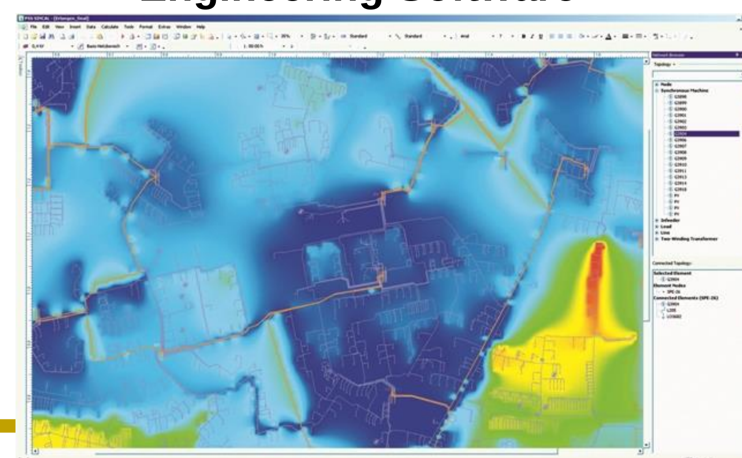
Siemens Digital Grid Lab – HEC 302

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

3. **PSS/E**
   - **Power Transmission System Planning Software**

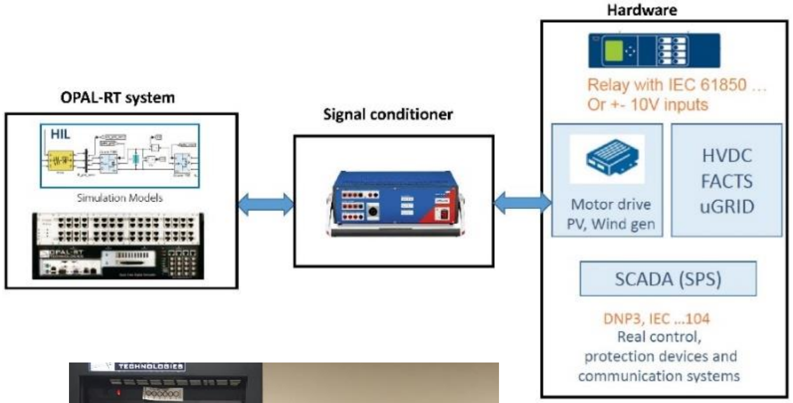


4. **PSS/SINCAL**
   - **Integrated Power System Engineering Software**



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.



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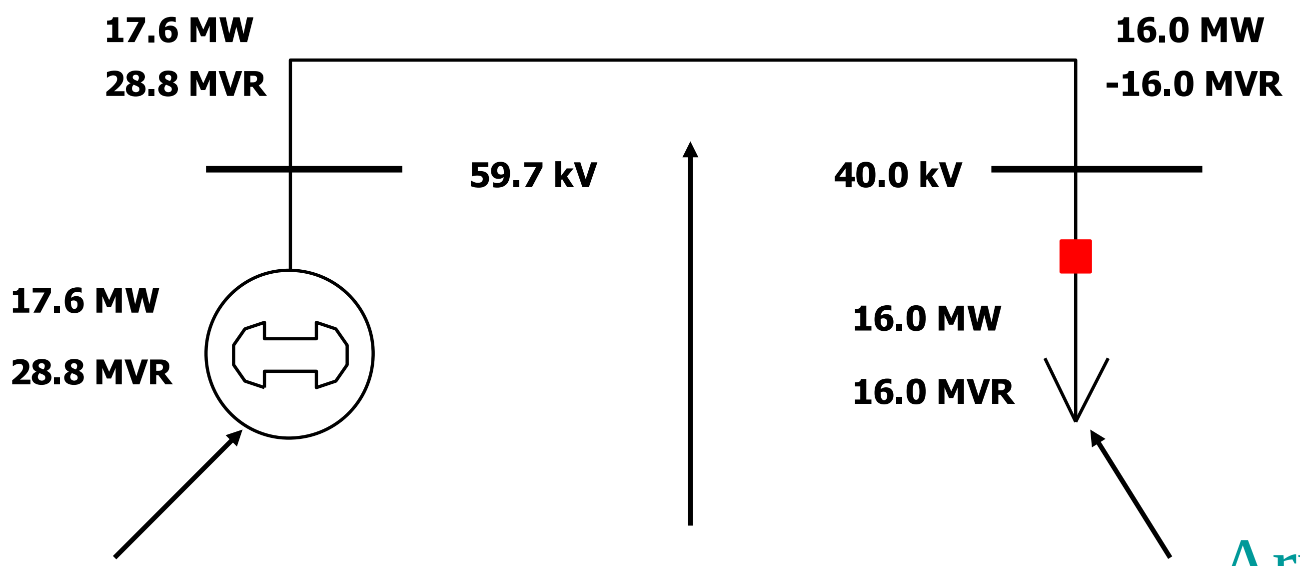
Power Program @ UCF – Opportunities

- **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

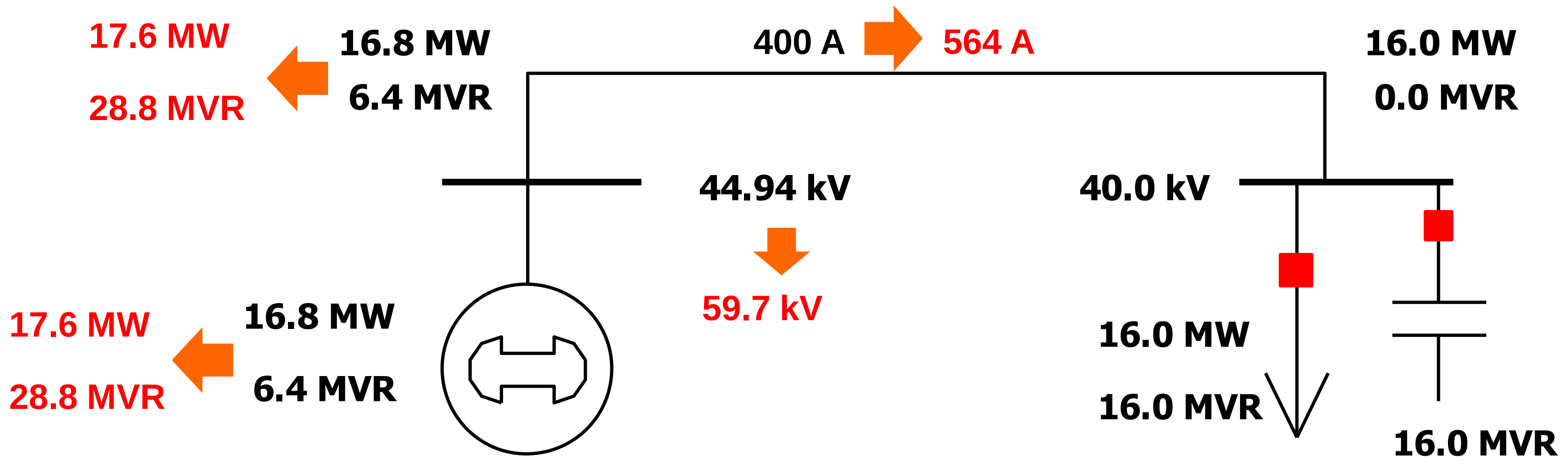
Transmission lines are shown as a single line

Arrows are used to show loads

One Example for EEL 3004

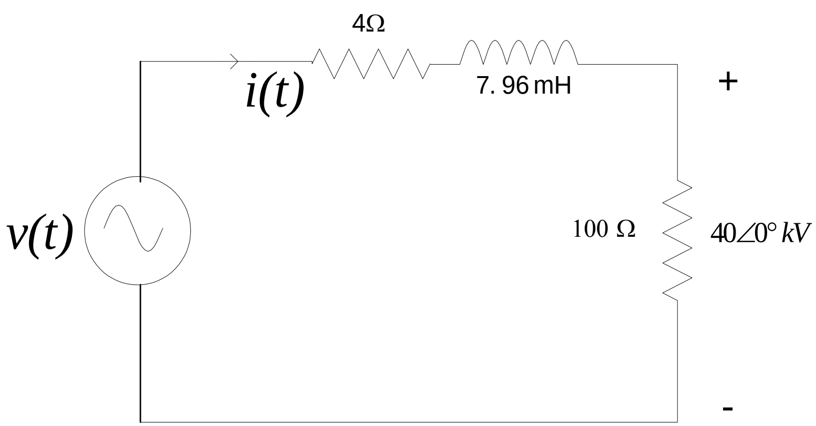
Reactive Power Compensation

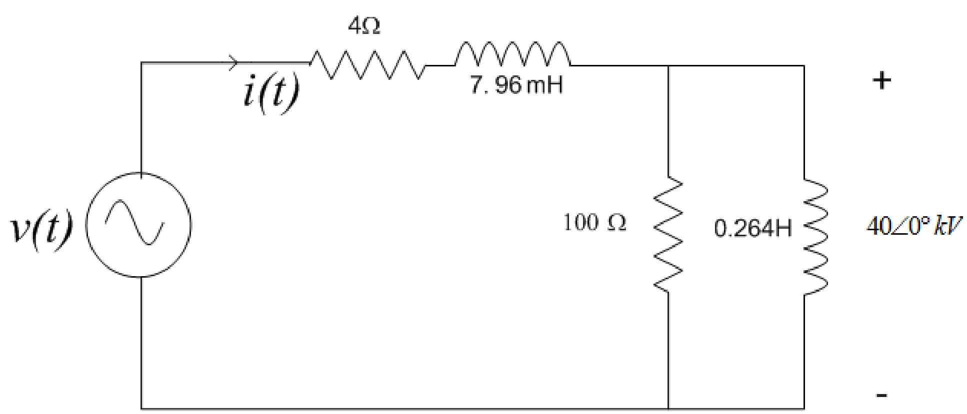
Black – W/ capacitor
Red – W/O capacitor



One Example for EEL 3004

Reactive Power Compensation





$$
\begin{aligned}
I &= \frac{40000\angle 0^\circ\, V}{100\angle 0^\circ\, \Omega} = 400\angle 0^\circ \text{ A} \\
V &= 40000\angle 0^\circ + (5 + j40)\, 400\angle 0^\circ \\
&= 42000 + j16000 = 44.9\angle 20.8^\circ \text{ kV} \\
S &= VI^* = 44.9\times 10^3\angle 20.8^\circ \times 400\angle 0^\circ \\
&= 17.98\angle 20.8^\circ \text{ MVA} \quad = 16.8 + j6.4 \text{ MVA}
\end{aligned}
$$

$$
\begin{aligned}
Z_{Load} &= 70.7\angle 45^\circ \qquad pf = 0.7 \text{ lagging} \\
I &= 564\angle -45^\circ \text{ A} \\
V &= 59.7\angle 13.6^\circ \text{ kV} \\
S &= 33.7\angle 58.6^\circ \text{ MVA} \quad = 17.6 + j28.8 \text{ MVA}
\end{aligned}
$$

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