Northwestern | INSTITUTE FOR SUSTAINABILITY AND ENERGY

Course Syllabus – DRAFT
VERSION 2.0

ISEN 402 Fundamentals of Natural Resources Distribution

Northwestern University

Possible Instructors:
John Dirkman, VP Product Management, Nexant
Dan Hahn, Partner, Guidehouse

NU Faculty Sponsor:
Ermin Wei, Assistant Professor of Electrical and Computer Engineering

Potential Guest Lecturers:
Paul Schipper, Howard University (John – are you using this person? I am not)
George Wells, Northwestern University

Office Hours: TBD
Class Room: Tech LR3
Class Timing: Fall Quarter (September 17 – December 7, 10 weeks); Tuesday and Thursday 9:40 to 11:00am.

Course Synopsis:
This course will cover the engineering fundamentals of natural resource distribution systems, spanning both energy (electricity, hydrocarbon fuels) and water. Basic theory and properties of electric energy and hydrology will be covered to provide underlying context as to how and why distribution systems are built and operate. Curriculum will focus primarily on current-state systems, whereas historical evolution and development are separately covered in *ISEN 401*.

Course Goals:
Gain an understanding of the technical fundamentals of the distribution and delivery of two primary natural resources – energy, and water.

Energy: includes topics such as primary vs. useful energy, generation and source, grid operation and management, transmission and distribution, distributed generation and distributed energy resources, etc. The differences across distribution for electricity and hydrocarbon fuels will be highlighted. Include recent trends in the future role of gas, including renewable hydrogen and decarbonization.

Water: includes topics such as hydrology and the water cycle (surface- and groundwater), engineered distribution and treatment systems, management and urban planning, and water quality.

Grading/Assessment:

Grading will be based on the following rubric:

Component	Weight	Details	Due
Homework/ Participation	20%	Homework may consist of: • Problem sets • Case study analyses • Short essays • Reading responses/presentations Participation: Be present, prepared, and open to discussing the readings and other course content through summarizing content, expressing opinion, and posing pertinent questions.	Ongoing
Midterm Exam	40%	Serves as a benchmark of students' mastery of the basics of this fundamentals course (Topics 1-5)	
Final Exam	40%	Serves as a benchmark of students' mastery of the basics of this fundamentals course (Topics 6-10). Presentation relevant to course topics based on hypothesis	

Grading Policy:

- Grades will be assigned based on all the work you have completed during the semester following the traditional practice of A=90-100, B=80-89, C=70-79, D=60-69, F<60.

Course Readings:

Fundamental books: (books are optional)

- *Electric Power System Basics for the Nonelectrical Professional,* 2nd Edition by Steven W. Blume, 2018
- *Renewable and Efficient Electric Power Systems,* 2nd Edition by Gilbert M. Masters, June 2013.
- *Water and Wastewater Technology* by Mark Hammer Sr. and Mark Hammer Jr. , January 2011.

Supplemental Videos:

Electric System:

- **Electricity Generation 101 (5 min.)** http://www.youtube.com/watch?v=20Vb6hlLQSg&feature=related
- **Overview of the Electricity Grid (4 min.)** http://www.youtube.com/watch?v=38EEmWHI0C8
- **Smart Grid (Institute of Electrical and Electronics Engineers, 9 min.)** http://www.youtube.com/watch?v=YrcqA_cqRD8&feature=related
- **A day in the life of the grid, July 21, 2011 (MISO, 33 min.) – Well worth the investment** https://www.youtube.com/watch?v=RdrMpElZWSM
- **Anatomy of a Transmission System (AEP, 4 min.)** http://www.youtube.com/watch?v=WTIQ_xcp0sU&feature=related
- **Anatomy of a Distribution System (AEP, 10 min.)** http://www.youtube.com/watch?v=YcBgxVfD70Q&feature=relmfu

By Power Source:

- **Coal Power Plant (MidAmerican Energy, 6 min.)** http://www.youtube.com/watch?v=j0e772Vo73k
- **Combined Cycle Natural Gas (Duke Energy, 7 min.)** http://www.youtube.com/watch?v=iNspo_s-1jY
- **Co-generation Plant at NYU (3 min.)** http://www.youtube.com/watch?v=9m9SgsTTgiA&feature=related
- **Biomass Co-Generation Plant at Nagda site (4 min.)** http://www.youtube.com/watch?v=tARuhig03To
- **Hydro Power (2 min.)** http://www.youtube.com/watch?v=Pj4dZM4SIls
- **Nuclear Power – How it works (5 min.)**
    - http://www.youtube.com/watch?v=_UwexvaCMWA Wind Turbines (UVSAR, 10 min.)
    - http://www.youtube.com/watch?v=LNXTm7aHvWc&feature=related
- **Offshore Wind Construction (Belwind, 14 min.)**
    - http://www.youtube.com/watch?v=x9IntSh2K7c Utility Scale Solar PV (ABB, 2 min.)
    - http://www.youtube.com/watch?v=edYNj_TrTXY&hd=1 Concentrating
- **Solar Thermal (2 min.)**
    - https://www.youtube.com/watch?v=tdivW7inP0k Geothermal (Chevron, 3 min.) http://www.youtube.com/watch?v=oVDpwwmNJV0
- **Tidal and Wave Power (5 min.)** http://www.youtube.com/watch?v=tSBACzRE3Gw&feature=related
- **Columbia Social Enterprise Forum – Energy Storage and Battery Technology (56 min.)**
- http://www.youtube.com/watch?v=661-GIswZco&hd=1
- **Pumped Hydro Storage – in German with translation (2 min.)** http://www.youtube.com/watch?v=GJ7ltJlMY9E
- **Grid Storage – A123 Batteries (DoE, 9 min.)** http://www.youtube.com/watch?v=6C8Ji05UJaw

Hydrocarbons:

- **Coal Power Plant (MidAmerican Energy, 6 min.)** http://www.youtube.com/watch?v=j0e772Vo73k
- **Full Oil Value Chain (Chevron, 6 min.)** http://www.youtube.com/watch?v=KpxctsUJ3hw
- **Refinery (14 min.)** http://www.youtube.com/watch?v=9Py8-Xy9MKo
- **Transportation Fuels – GHG implications (5 min.)** http://www.youtube.com/watch?v=hq2uWWBqe4M
- **Megastructures - Oil Sands (48 min.)** https://www.youtube.com/watch?v=4sPJgmcYcQ4
- **Shale Oil (Energy Now, 28 min.)** http://www.youtube.com/watch?v=U_T-AwYOhp4&feature=related
- **Ethanol from Sugar Cane- Production Process (15 min.)** http://www.youtube.com/watch?v=kP1S2HGf5-E Ethanol
- **From Corn – Production Process (5 min.)** https://www.youtube.com/watch?v=uE7DJVCa5h0
- **How it is made – Biodiesel (4 min.)** http://www.youtube.com/watch?v=xLa83KIaEyw
- **Biofuels, Beyond Ethanol (10 min.)** http://www.youtube.com/watch?v=CkJJ-x7U5NI
- **Natural Gas Production and Marketing (Chesapeake Energy, 10 min.)** http://www.youtube.com/watch?v=2Gw_Bn-JqDg
- **Natural Gas Pipelines Operation (9 min.)** http://www.youtube.com/watch?v=aTTJeTaYDyc
- **Hydraulic Fracturing (Marathon Oil, 3 min.)** https://www.youtube.com/watch?v=VY34PQUiwOQ
- **Natural Gas: The Energy to move Forward (Conoco Philips, 5 min.)** http://www.youtube.com/watch?v=BzLZnidztpI
- **LNG Value Chain (Chevron, 3 min.)** http://www.youtube.com/watch?v=5LplbGd8aXI&feature=relmfu
- **History – I am Natural Gas – 1959 (3 min.)** http://www.youtube.com/watch?v=PKX0GeF9w-k
- **History – Natural Gas Pipeline Development – 1959 (1 min.)** http://www.youtube.com/watch?v=Wodvxh6WEs4

Supplementary books:

- *Consuming Power: A social history of American energy* by David Nye
- *Electric Power Distribution System Engineering*, 2nd Edition by Turan Gonen

CLASS OUTLINE

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Weekly Topics	Description

1: Understanding power; basic terminology and system overview
John Dirkman
	• Electricity fundamentals
	  ○ Electromechanical generators
	  ○ Voltage, current, resistance; electric power flow
	  ○ AC vs. DC
	• Power vs. energy
	• Active and reactive power
	• Load by economic sector – residential, commercial, industrial, and transportation
	• Grid function and structure overview

2: Electric Generation
John Dirkman
	• Fuel Source Comparatives
	  ○ Capacity Factor
	  ○ Dispatch Flexibility, intermittency
	  ○ Carbon intensity
	• Distributed generation
	  ○ C&I
	  ○ Residential
	  ○ DSM as a "negawatt"
	• Supply and demand
	  ○ Baseload vs. Peak
	  ○ Load profiles
	  ○ Forecasting
	• Regulation of power generation and backup power supply

3: Electric Transmission and Distribution
John Dirkman
	• Transmission Infrastructure
	  ○ Substation equipment; step-up/-down transformers, voltage regulators
	• Distribution Infrastructure
	  ○ Distribution substation equipment; system redundancy; last-mile wires and poles; service drop; safety
	• Consumer metering & metering technology

4: Grid management and control
John Dirkman
	• North American power grid interconnections
	• Grid stability
	  ○ load balancing
	  ○ real time network modelling
	  ○ SCADA
	  ○ fault detection / propagation prevention
	• Physical and cyber resilience
	• Impact of grid safety and regulation

5: Smart grid, multidirectional flow, DERMS, DSM, behind the meter John Dirkman	• Distributed resource integration and the impacts of bidirectional flow • IoT and "edge" device network communications • DERMS, Microgrids and partially/fully "islanded" systems • Behind-the-meter resource management

6. Future Role of Gas – renewable hydrogen Dan Hahn	• Renewable (green) hydrogen principles • Renewable hydrogen value chain • Growth of renewable hydrogen in the markets globally • Government efforts to support green hydrogen • Future outlook for green hydrogen
7. Decarbonization Dan Hahn	• Decarbonization principles • Changing landscape of energy providers • Low-carbon pathways
8: Hydrocarbon distribution – oil & gas Dan Hahn	• Hydrocarbon value chain: upstream (exploration, extraction/production) vs. downstream (refining, distribution, retail) • Distribution – inter/intrastate pipeline infrastructure, product compression, refining hubs • Physical storage options • End user – domestic consumption vs. export • Process impact of hydrocarbon safety and regulation
9: Hydrology and human use; water system design and distribution, water and wastewater treatment Dan Hahn	• Water cycle & source - surface/groundwater (lakes, rivers/streams, reservoirs, icepack, wells/aquifers); salinity • End user – Public/Municipal Supply (residential, commercial, industrial), Mining, Agriculture/Irrigation, Livestock, Energy • Distribution infrastructure: water pressure, flow under pressure, gravity flow, flow measurement, centrifugal pumps, water pressure requirements • Water treatment: coagulation, sedimentation, filtration, disinfection • Wastewater treatment: screening, grit disposal, clarification, aeration, disinfection; sludge treatment & disposal • Process impact of water quality standards, safety and regulation
10: Managing system stressors and Energy-water nexus Dan Hahn	• Stormwater runoff control systems and management practices • Managing drought/inadequate supply re: conflicting need • Addressing source contamination (either in the watershed, or via distribution infrastructure) • Safety, flooding and water systems • Defining key contributors to WEN a. Water for energy – thermoelectric cooling, extraction, hydropower b. Energy for water – water supply and treatment, distribution, irrigation, desalination, fertilizer