Outline

– Class logistics
– Introductory lecture on Intelligent Energy Systems
Instructors

• Daniel O’Neill, Consulting Professor in EE
  – Networks and Demand Response
  – Executive and venture capital experience
  – www.stanford.edu/~dconeill

• Dimitry Gorinevsky, Consulting Professor in EE
  – Information Decision and Control Applications
  – Broad industrial experience in advanced systems
  – www.stanford.edu/~gorin
Logistics for the Course

• 1 unit CR/NC

• Weekly on Tuesdays
  – The room and time might change!
  – Watch the class website announcements

• Two introductory lectures
  – Grid Overview – Dan
  – Monitoring Basics – Dimitry

• Eight lectures by industry leaders

• Final class
Current Speakers

• April 17, Grid Analytics - T&D power equipment diagnosis/prognosis thru Smart Grid technologies, Alex Rojas, GE
• April 24, Advanced Sensors and Monitoring & Diagnostics for Gas Turbines in GE, Vivek V. Badami and Scott Hoyte, GE Energy
• May 1, Data mining techniques to enhance sustainability of data centers, Manish Marwah - HP
• May 8, GridSpice, Amit Narayan
• May 15, Trevor Baily - UTC
• May 22, Communication Methods for Energy Management, John Parello - Cisco
• May 29, The Promise of Renewables, Rick Geiger - Cisco
• June 5, Datta Godbole - Honeywell
Course Requirements

• Requirements:
  – Attendance

• 1-2 page proposal for intelligent energy concept, research, or product, based on class presentations
  – Teams of up to three people, one person is acceptable
  – Due June 5

• Top three proposals will be presented at the scheduled final time
  – Will be considered by Stanford faculty and industrial presenters to receive research funding
  – The best proposal will be archived on class website including author info; expect PageRank 4 to 5.
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- Introductory lecture on Intelligent Energy Systems
  - Definition
  - The Grid
  - Why its changing
Intelligent Energy Systems

- Look at intelligent energy systems from a systems point of view
- Nearer term evolution of the grid leading to the Smart Grid
- Focus monitoring
Why Intelligent Energy System Now?

- Incorporating renewables – supply(t)
- Replacing old equipment, $1.5T
  - Electrical efficiency
  - Reliability
- Reducing costs – Energy Summit Comment…
  - TCO
  - CAPX
- Deregulating – markets for power
  - Consumer participation
  - De-commoditization
- New business models
  - Consumer behavior based
  - POS advertising

$850B - grid
$650B - users

Home EMS

Building EMS
Intelligent Energy Systems

- What technology trends?
- Convergence
  - Internet of things (embedded internet)
  - Virtualization
    - Computation
    - Networking
    - Storage
- Economics of high performance computing (Moore’s law)
Monitoring

• Monitoring vs. control
• Why monitoring?
  – ROA
  – Frequency and severity
• Types
  – Operational
  – Maintenance
• Industrial structure
  – Equipments, to
  – Services
Backup:

Intelligent Energy Systems

• Definition: Connected, context aware adaptive systems that provide energy services.

• Includes all aspects of energy usage
  – Generation to commercial and residential EMS to
  – Individual devices

• New services (analytics)
  – Operational efficiency
  – Asset monitoring
  – Consumer behavior

• New infrastructure
  – Communications and IT
  – Big Data analytics

• Comment: Large scale IP connected embedded systems w/ emphasis on
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The Traditional Grid

• Worlds Largest Machine!
  – 3300 utilities
  – 15,000 generators, 14,000 TX substations
  – 211,000 mi of HV lines (>230kV)
  – SCADA control
  – Mostly unidirectional

• Capacity constrained graph
Interconnect
Traditional Grid

Conventional Electric Grid

Conventional Internet

Generation
Transmission
Distribution
Load
Power and Data Flow

Generators

Transmission 275-400’s KV

Substations

Distribution 10-20KV

ISO

Fiber and uWave

Slow speed wired and wireless/ nothing

Manual

Industrial
Commercial
Business
Residential

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Backup: Capital Plant Age

Plant Age in Years

Installed Net Capacity in MW

≥400 MW, < 15 years

< 400 MW, < 15 years

≥ 15 years

< 15 years

I

II

III

IV

≥ 400 MW, ≥ 15 years

< 400 MW, ≥ 15 years

4/3/12

EE392N Intelligent Energy Systems
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Nearer Term Initiatives

- Renewables
- Demand Response
- Grid optimization
- All drive need for connected embedded systems
Renewables: The System Problem

Net Load

Dispatch

Need for conventional plants to cycle and ramp

National Renewable Energy Laboratory

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Demand Response

Campus and Buildings

Home

• AMI
• EMS
• Smart devices
Grid Optimization

• Adjusting
  – Supply(t)
  – Connectivity
    • Transmission routing
    • Distribution Automation
  – Aggregating DR users
• Commercial buildings
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  • The Smart Grid
Three Planes

- **Electrical power**
  - Supply(t)=Demand(t)
  - Real and reactive power

- **Management and Control (MC)**
  - Local protection systems
  - SCADA: Supervisory Control and Data Acquisition

- **Data systems**
  - Billing
Segment Characteristics

– Energy is an *entangled multi-time scale* application
  • milliseconds for protection and control
  • Subsec for human in the loop interaction
  • Sec for Renewables variability management
  • Minutes for DR and building management…

– *Hierarchy of loops*
  • One optimizes the next
  • Latency sensitive
  • Computationally intensive
    – Iterative algorithms
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– Sense, Communicate, Transform, Services
Sense -> *Communicate* -> Transform

-> Services

- Standards NIS & IEEE

\[ \text{WiMAX} \]
\[ \text{LTE} \]

\[ \text{ZigBee} \]
\[ \text{HomePlug} \]

4/3/12  
EE392N Intelligent Energy Systems
Sense -> Communicate -> Transform -> Services

– Transform data into information
– Hierarchy of entangled applications and computation
  • Intelligence at all levels of system
    • Issues in
      – Reliability – How many 9’s?
      – Security – Residential gate ways…substation…plant
      – Storage – Brewers CAP and Hadoop?
      – Energy efficiency – Hugh issue: always on and unattended
      – System manageability
      – Interface with the cloud
        » Hybrid Cloud?
Sense -> Communicate -> Transform -> Services

- Streaming data for
  - Near real time control
  - Asset Monitoring (Longer time scale)
  - Not the same as “click” data

- Algorithms
  - Iterative and computationally intensive
  - De-centralized computation possible, But
  - Can be sensitive to data coherence and consistency
  - EVT – Extreme Value Theory issues (No Blackouts!)

- Big Data - Yes, But Hadoop maybe not.
Next Week

- Dimitry will talk on Monitoring Basics
Many Different Segments and Players

- Traditional Power, Transmission and Distribution
- Big Data/Analytics
- Consumer Preference / Behavior Data
- IT/Comm
- Monitor, Optimize, Control
- Devices
Backup: Traditional Grid

Three major interconnects