

Energy Analytics

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Part I

Week 1

LECTURE

1

COURSE INTRODUCTION

1.1 Syllabus

The course syllabus is available on eLearning and coursebook. Professor and TA office hours are in MTeams. Every Tuesday and Thursday 10 am - 11 am and 3 pm - 4 pm. Lectures will be posted Mondays and Wednesdays on MS Stream.

1.1.1 Homework

Homeworks are coding assignments that are submitted to elearning. Schedule is available in the syllabus.

1.1.2 Exams

The final exam will be open book. It will be assigned and submitted through elearning.

1.1.3 Final Project

Recorded presentation and report through MS Teams and eLearning.

1.1.4 Course Description

Understand the basic concept of analytics, including describing analytics and predictive analytics. Understand applications of analytics in energy industry. Know how to use mathematical software and other commercial packages. Know how to develop load, price, wind and solar forecasts.

1.2 Discussion

1.2.1 Who makes up the most emissions?

China takes up the biggest share of global emissions at about 30%. Electricity and heat make up 24.9% of world greenhouse gas emissions (highest portion). There are several end uses for electricity and heat like buildings, refining, food. These processes create lots of CO_2 . The majority of CO_2 emissions in the US come from the Electricity sector, followed by transportation, and industry.

1.2.2 How do renewable technologies compare?

Renewable and carbon neutral technologies are utilized a lot less than coal and natural gas. Coal use has gone down from about 50% of electricity generation in the US to 32.3% (less than one third!). Natural gas however, has increased from 21.4% to 32.3%. Nuclear energy has remained constant throughout the years, due to the effort required to build the plant. Hydropower has also remained constant through out the years. Other renewable sources are growing very fast (solar, wind power, biofuels, etc).

1.2.3 Wind and Solar Energy

Wind has the highest capacity of non-hydro renewables. By the end of 2018 the world was generating 591 Gigawatts of wind energy. Wind energy has also been growing very fast in the US as well. In Q3 2019 the US generated 100,128 MW, with Texas leading at 27,000 MW. However in some parts of the US, the conditions are not suitable for wind turbines.

PV (solar energy storage) has been steadily growing in the US as well. PV installations are split between Residential, Non-residential, and Utility. Solar energy resources vary with location as well.

1.2.4 What are the biggest drivers of renewable installations and penetration rates?

Policy is a big driver, states have different renewable portfolio standard targets. The costs to implement renewable energy has been decreasing over the years. Solar is a little more expensive than wind, but they are both becoming competitive with non-renewables. Utility-Scale PV costs have dropped from \$5.52 per W to \$1.13 per W.

1.3 Renewables Integration

Power generation and energy consumption must be balanced. This balance becomes more challenging with renewables, because you cannot control how much wind blows or how much the sun shines.

Part II

Week 2

LECTURE

2

ENERGY ANALYTICS AND R

2.1 Energy Quiz

1. How much of the energy in burning coal reaches the consumer as electricity? (33%)
2. Which State consumes the most energy? (Texas)
3. Which state produces the most coal? (Wyoming)
4. What country produces the most coal? (China)
5. Which country generates the most electricity from nuclear power? (United States)
6. What country generates the greatest share of its electricity from wind power? (Denmark)
7. Electricity is called a secondary energy source because ... (We get it from converting other energy sources)
8. Most of the energy we use originally came from? (The sun)

2.2 Power System Background

Power systems have transitioned from centralized to distributed generation (Solar panels on roofs, batteries, PV panels, small generators). One challenge is that the energy flows in two directions, instead of one. Another challenge is that renewable energy is variable and uncertain. However, advanced communication has allowed decentralized control of devices.

2.2.1 Power System Operations Timescales

The power system load changes throughout the day. As your load changes, your power generation should change as well. Regulation is seconds to minutes, load following is minutes to hours, and scheduling is the entire day. Unit commitment refers to several days.

2.2.2 Energy Sector

Electricity is only one part of the energy sector. There is a trade off between fixed costs and operating costs.

- Nuclear and Solar have high fixed cost, low operating costs
- Natural gas/oil have low fixed costs, high operating costs (depends on fuel prices)
- Coal, wind, hydro are in between

A unit's **Capacity Factor** is important to determining ultimate cost of electricity. Wind has a low capacity factor (50%). Some renewables have tax credits, which affect the economics. Different renewables have different levelized costs (USD/kWh). The levelized cost of Solar PV has decreased from 2010 to 2014.

2.2.3 Conventional Power System

The conventional power system is a one way system. You generate the power and send it to the customer. In later lectures we will talk about different changes in power systems to centralized systems to decentralized systems.

1. Generation (Source)
2. Transmission Substation (Change voltage to a suitable value)
3. Transmission System (Carry energy long distances)
4. Distribution Substation (Change voltage, smaller than transmission substation)
5. Distribution System (Power lines, distribute to customer)
6. Customer (Loads)

2.2.4 Power Plant Classification

There are 3 categories.

1. Base-Load Generating Units
 - Constant power generation over time
 - Long start-up and shut-down times
 - Low cost of production, but high capital investment
 - ex. Nuclear, Hydroelectric, High-Performance Steam Turbine Plant
2. Intermediate (Load Following) Generating Plant
 - Typically runs at full-load between 2,000 - 5,000 hrs/yr
 - Operation and economic characteristics somewhere between base-load and peak-load
 - ex. Simple Steam Turbine Plant, Old Base-Load Plant, combined Gas and Steam Turbine Plant, Selected Hydroelectric Power Plant
3. Peak-Load Generating Units
 - Quick starting and shutdown capability
 - Runs between 100 - 2,500 hrs/yr during peak loads
 - Standby and emergency units
 - ex. Gas Turbine, Diesel Engine, Hydro - Pumped Storage

2.2.5 Interconnections

The US has 3 synchronous grids (interconnections). The Eastern Interconnection, Western Interconnection, Texas Interconnection (cool!).

2.2.6 Renewable Energy and Distributed Generation

Most renewable energy will be converted into electricity. The resource will be distributed geographically and mostly dependent on changing weather and climate. However, the resource cannot be directly controlled in the manner of conventional generation (variable and uncertain output).

Renewable resources are more distributed than conventional types. They are often connected at low voltages. Increasing the input from renewable energy sources requires a revision of the way power systems are designed and operated in order to better accommodate these sources better.

2.3 Analysis

2.3.1 Actionable Decision Support & Automation

The amount of analytics and human input depends on the type of analysis. Our goal is to use prescriptive analytics, so the computer will either support a decision, or make the decision automatically.

- Descriptive - What happened?
- Diagnostic - Why did it happen?
- Predictive - What will happen?
- Prescriptive - What should I do?

2.3.2 Behind the Meter (BTM) Solar Forecasting

Different levels of difficulty associated with solar forecasting. BTM is for very small systems.

- Bottom-up approach
- Multi-timescale Forecasting
- Distributed Solar Ramp forecasting

2.3.3 Types of Load Forecasting

- Short term forecasts (one hour to a week)
- Medium forecasts (a month up to a year)
- Long term forecasts (over one year)

2.3.4 Key Methods

- Time series models, visualization, regression models, decomposition
- Machine Learning models
- Deep learning models
- Probability, distribution, visualization

2.4 Distributions

We will talk about probability distributions more in-depth in the future.

2.4.1 Normal Distribution

- Probability density function
- Cumulative distribution function