

Long Run System Planning

Smith College, EGR 325, March 13, 2008

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Complex System Analysis

- Divide the full system into sub-systems
- In power systems we can analyze...
 - By system sector: generation, transmission, distribution, customer...
 - By geographic region
 - By time scale
 - Time scale separation of events
 - By analysis question
 - Cost, environmental impacts...

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Overview

- Course overview – concept map
- Complex system analysis
- Information used in long term “system expansion planning”
 - System planning criteria
 - Characterizing generating units
- Practice with PowerPlan
 - Multiyear plan
 - Varying planning, or expansion, criteria

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Electric Energy Systems: Theory & Analytical Skills

Energy policy and sustainability

- Problem & issue identification
- Complex system analysis

Electric power generation

- Energy conversion
 - Mechanics
 - Thermodynamics

Environmental issues

- Atmospheric chemistry
- Climate change
- Technology and society

Intermittent renewable energy resources

- Probability and statistics

Load modeling, NDT modeling, System planning

- Probability and statistics
- * Production cost modeling
- * Multi-attribute tradeoff analysis
- * Reliability: component & system

Economic Dispatch

- * Linear programming
- * Constrained optimization
- * Lagrangean solutions

Power flow in an interconnected system

- AC circuits
- * Power flow equations
 - Iterative solutions

Electric motors and generators

- * Electro-mechanical systems
- Electromagnetic theory & induction
- * 3 ϕ complex power

Optimal power flow

- * Iterative constrained optimization

Government regulation and industry deregulation

- * Economic policy

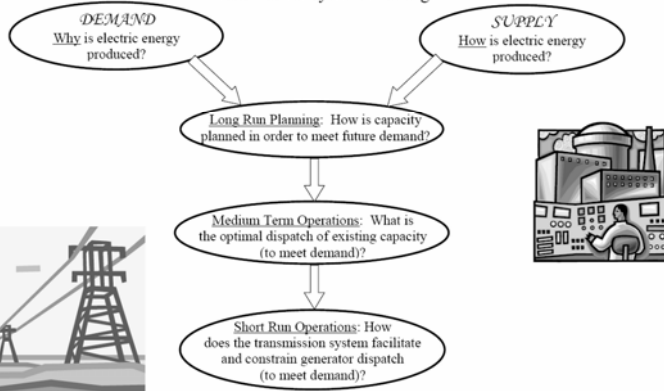
* indicates new concepts



EGR 325: Electric Energy Systems Concept Map

Analysis & Design Questions

1. What are the issues & objectives?
2. What are society's needs & responsibilities?
3. Who decides?
4. What are the analytic tools?
5. How is the system evolving?



Power System Expansion Planning

1. System planning objective and criteria
2. Reliability criteria
3. Characterize generating units
4. Production cost model
5. Analysis with production cost model PowerPlan

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1. System Planning Objective

- Determine the technology mix
 - Types of generating units to build
 - Capacity of each generating type
- ... in order to meet our planning criteria

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2. System Planning Criteria

- Meet system demand into the future
- Low cost
- **High reliability**
- Low environmental impacts (emissions)
- Fuel diversity
- Sustainability (inter-generational issues)
- Every variable will have a time series

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2. Reliability

- How is reliability defined?
- How do we measure reliability?

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2. ** Reliability **

- Unit Reliability / Availability
 - Forced outage rate – reliability
 - Maintenance (planned outage) – availability
 - Also for NDTs: availability of resource
- System Reliability
 - Input: Reserve margin
 - Output: Loss of load probability
 - Output: Cost of unmet energy

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3. Characterizing Generating Units

- Relevant unit characteristics
 - Costs, fixed and variable
 - Fuel → emissions
 - Forced outage rate → Reliability
 - Maintenance (planned outage) → Availability
 - Expected lifetime

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3. Characterizing Generating Units

- Matching generator types to operating decisions
 - Nuclear
 - Steam turbine: coal, oil, gas
 - Combustion turbine
 - Combined cycle
 - Cogeneration
 - Hydroelectric
 - NDTs: wind, photovoltaics
 - Demand side programs

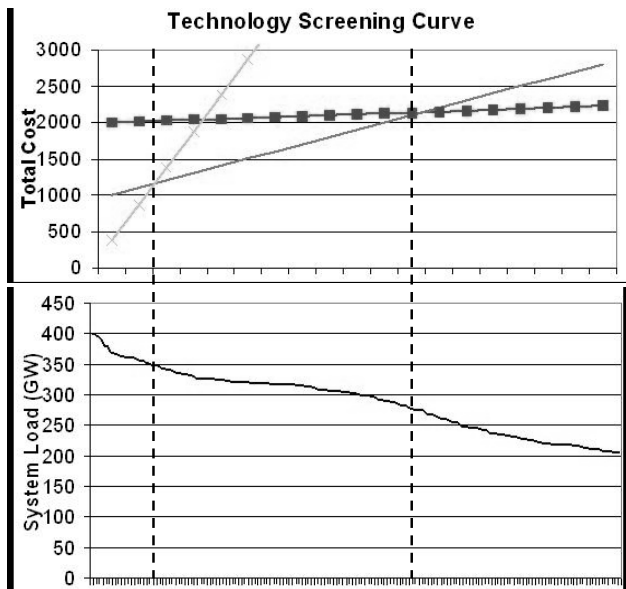
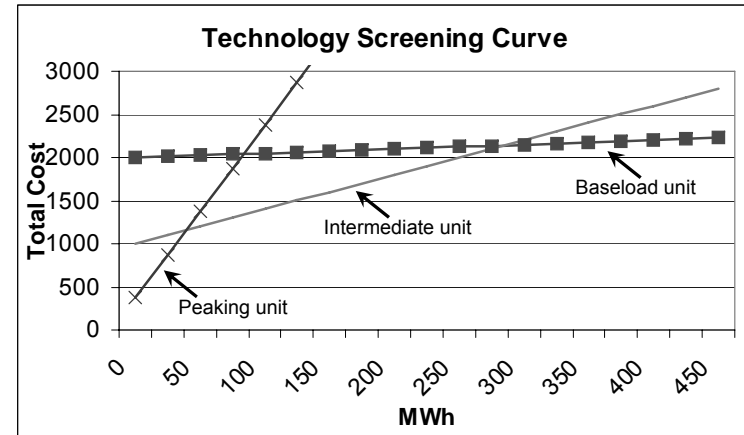
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3. Characterizing Generating Units

- Which units are best for:
 - Baseload – operate continuously
 - Intermediate – operate much but not all of the time
 - Peaking – operate a small number of hours during the year (perhaps up to 500 hours)

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3. Simple Technology Mix Tool: Using a Screening Curve...



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3. Match Technology to Operations

- Which technology characteristics represent a baseload, an intermediate and a peaking plant?

Techn.	Cap. Cost	Var. Cost	Emissions	Reliability
1	high	high	high	high
2	low	high	low	high
3	low	low	low	high
4	high	low	high	medium
5	medium	medium	high	low

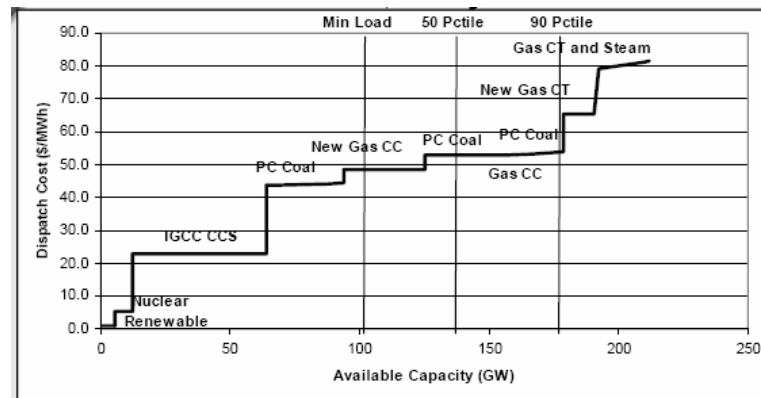
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3. Terminology: Loading Order

- Once the generating units are built,
- The order in which they are used is called,
- The “loading order”
 - Or the “merit order,” or the “dispatch order”
- The bottom of the loading order
 - The units that run for the most time
 - The baseload units
- The top of the loading order
 - The units that run rarely – the peaking units

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Example: ECAR Electric Supply Curve / Loading Order



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4. Production Cost Models

- A computer model to perform the task of system planning
 - Instead of using the LDC + Screening curve for hand calculations
- A computer model to calculate
 - The cost of producing the specified amount of electricity (*i.e.*, to serve the specified load)
 - Over “the planning horizon” (*i.e.*, a specified number of years)
 - Given a set of generation technologies and energy conservation programs

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4. Additional Analysis with Production Cost Models

- Define reliability requirement
 - Input: reserve margin
 - Output: LOLP, EUE, ...
- Include demand side management
- Include NDTs
- Allow for uncertainty in
 - Load growth forecasts
 - Fuel cost forecasts
- Quantify pollutant emissions

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Summary of Terminology

- Reliability terms
 - Unit
 - Forced outage and planned maintenance
 - System
 - Reserve margin
 - LOLP
 - Cost of unmet energy
- Loading order
 - *aka* dispatch order and merit order

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5. Using PowerPlan

- Find PowerPlan in the available programs
- File > New scenario
 - Then open Neth 2004.cdt
 - or any <... .cdt> file
- Calculate – one year, to be able to view other interesting information
- Decisions > Add Power Plants
 - To develop your ‘plan’ for building new generators
- Decisions > Retrofit
 - To extend the life of existing generators



PowerPlan.Ink

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5. Using PowerPlan

- Edit the input file with a text editor, for example:

[Starting Variables]

2003 Starting year
25 Simulation length
1 Period Length
11843 11843 was :14212 SMD in year 0 (2690 in 1960)
1.30 Economic optimal reserve factor percentage
13376 GDP (€) per capita
15400000 Population in year 0
0 Use chronological data (1) or not (0)

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5. Using PowerPlan

- View input data in the “Advanced” menu
 - Beware of the “> Expert variables > Load Duration Curve” option, which will lead to an annoying pop-up error window if you move your cursor over the graph
- Also view model output in the “Output” menu options, including
 - The “> Electricity Generation” tables
 - **To save** these results, copy and paste the text into excel, word, text editor...
 - Note the reliability indices are in these tables
 - Environmental characteristics of your plan
- To save plots, the easiest way *may* be to use “cntl-alt-Print Screen” to copy, and then paste into Word
- Final annoyance: The computers in room 203 seem to be unable to exit the program. Use cntl-alt-delete...²⁴

5. Using PowerPlan

- We will use PowerPlan
 - To get experience using the model in general
 - Develop “system expansion plans” and compare the different plans according to our planning criteria
 - To model options for Honduras
- To use the model
 - First run the model a number of times to get familiar with the input, actions and output. Discard these results.
 - Then, develop an expansion plan to implement → How will you meet the demand into the future?
 - Modify the input data base as needed to begin your plans
 - You will probably need to extend the life of many plants initially
 - Keep track of **ALL** your changes
 - Run the model and implement your plan
 - Keep track of all relevant results
 - Characterize/critique your plan according to the planning criteria ²⁵

Summary

- Analysis of complex systems
- Method and terminology to develop system expansion plans
- Experience with production cost computer model – PowerPlan
 - Developing a long term expansion plan

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