A MODEL FOR THE INTEGRAL PLANNING OF ELECTRIC POWER SYSTEMS AND NATURAL GAS TRANSPORTATION NETWORKS

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BACKGROUND

- THE NEED FOR THE INTEGRAL PLANNING OF ELECTRICITY TRANSMISSION AND NATURAL GAS TRANSPORTATION NETWORKS
  - INCREASED USE OF NATURAL GAS IN ELECTRICITY PRODUCTION
  - LARGE ECONOMIES OF SCALE IN BOTH TYPES OF NETWORKS
  - SITING DECISIONS OF GENERATION CAPACITY LEADING TO LOWER OVERALL INVESTMENT + OPERATION COSTS

- A PREVIOUS MODEL
  - PEGyT: A MODEL FOR THE LONG-TERM PLANNING OF ELECTRICITY GENERATION AND TRANSMISSION CAPACITIES
  - NO EXPLICIT CONSIDERATION OF NATURAL GAS TRANSPORTATION NETWORK
SCOPE OF THE MODEL

- A TOOL FOR THE LONG TERM PLANNING OF ELECTRICITY GENERATION CAPACITY
- TECHNOLOGY SELECTION, AND DETERMINATION OF SIZE, LOCATION AND INSTALLATION DATES OF THE REQUIRED NEW GENERATION CAPACITY
- MINIMIZING THE PRESENT VALUE SUM OF:
  - ELECTRICITY PRODUCTION COSTS
  - NEW GENERATION CAPACITY COSTS
  - NEW ELECTRICITY TRANSMISSION CAPACITY AND OPERATION COSTS
  - NEW NATURAL GAS TRANSPORTATION CAPACITY AND OPERATION COSTS
SCOPE OF THE MODEL

GUIDELINE PARAMETERS AND CONSTRAINTS
• RESERVE MARGIN & OPERATING RESERVE
• LENGTH OF PLANNING HORIZON
• DISCOUNT RATE
• INVESTMENT & EXPANSION CONSTRAINTS

EXISTING INFRASTRUCTURE
• ELECTRIC POWER GENERATION & TRANSMISSION NETWORK
• NATURAL GAS TRANSPORTATION NETWORK
• PRODUCTION CAPACITY OF NATURAL GAS SOURCES

CAPACITY EXPANSION PLAN
• ELECTRIC POWER GENERATION & TRANSMISSION
• NATURAL GAS TRANSPORT
INVESTMENT AND OPERATIONAL COST ESTIMATES

LONG TERM PLANNING MODEL (PEGyT II)

CAPACITY ADDITION AND DECOMMISSION PROGRAMS

TECHNOLOGY OPTIONS FOR CAPACITY EXPANSION

SCENARIO DEFINITION
• DEMAND PROJECTIONS (ELECTRICITY & NATURAL GAS FOR INDUSTRIAL USE)
• FUEL COST TRENDS
• TECHNOLOGY COST TRENDS
MODEL FEATURES

- LARGE SCALE, MIXED-INTEGER, NONLINEAR, MULTISTAGE OPTIMIZATION PROBLEM
- SOLUTION TECHNIQUES:
  - COMBINATION OF MODERN HEURISTICS (EVOLUTIONARY PROGRAMMING) AND MATHEMATICAL PROGRAMMING TECHNIQUES
SOLUTION SCHEME: AN EVOLUTIONARY PROGRAMMING APPROACH

- A set of initial plans for the expansion of electric power generation capacity is formed. These plans may be either the result of other planning models or “expert judgment”, or may be randomly generated.

- For each proposed plan, the required new transmission and NG transport capacities are determined and the objective function evaluated.

- The objective function is the present value sum of investments, variable production costs of electricity and NG transport. Other objective functions may be adopted, such as the “maximum regret” defined over a set of possible scenarios.

- One or more alternative plans are obtained from each individual in the current population of candidate plans.

- Alternative plans are obtained by introducing few changes in the parent individual. The changes may be selected either by a random process or heuristic rules, which may be based on sensitivity measures.

- The size of the population of candidate plans is maintained by selection of the best and elimination of the worst plans.

Initial “population” of proposed expansion plans

Evaluation of expansion plans

Creation of new, alternative plans (offspring)

Evaluation of new expansion plans

Competition and Selection

Convergence test

Set of best solution plans
SOLUTION SCHEME

EVALUATION STEP: A MATHEMATICAL PROGRAMMING APPROACH

A PROPOSED PLAN FOR GENERATION CAPACITY EXPANSION

- Calculation of variable production costs
- Optimal transmission expansion
- Optimal NG transport expansion
- Calculation of the objective function

- Electricity production cost are computed for each year in the planning horizon, by solving a “Hydro-Thermal Coordination Problem” with electricity transmission and NG transportation constraints (an LP programming problem)
- Cost estimates of required new transmission and NG transport capacities are calculated at incremental cost of expansion
- A sequence of nonlinear programming problems is solved (nonlinear objective function and linear constraints)
- The objective function is the present value sum of fixed and variable costs
APPLICATION EXPERIENCE

- THE NEW MODEL (PEGyT II) HAS BEEN APPLIED TO SEVERAL CASE STUDIES
  - THE MEXICAN NORTHWEST ELECTRIC POWER SYSTEM
  - THE MEXICAN INTERCONNECTED ELECTRIC POWER SYSTEM
- COMPARISON OF SOLUTIONS (NEW VS OLD MODEL) SHOW:
  - LESS CONCENTRATION OF NEW ELECTRIC GENERATION CAPACITY; SAME TRENDS (TECHNOLOGY, SIZE, LOCATION AND INSTALLATION DATES)
  - REDUCED REQUIREMENTS OF NEW INTERREGIONAL TRANSMISSION CAPACITY, SAME TRENDS
- SLOW CONVERGENCE
  - 80-100 HOURS (PENTIUM IV, 1.4GHZ)
AREAS FOR IMPROVEMENT

- REDUCING COMPUTATION TIME
  POSSIBLE SOLUTION: PARALELL COMPUTATION
  ✓ THE “EVALUATION” OF PROPOSED “INDIVIDUALS” (CANDIDATE GENERATION EXPANSION PLANS) IS COMPUTATIONALLY EXPENSIVE
  ✓ EVALUATION OF INDIVIDUALS IS AMENABLE TO PARALELL COMPUTATION
APPLICATION EXAMPLE

THE MEXICAN INTERCONNECTED ELECTRIC POWER SYSTEM

- PLANNING HORIZON: 2002-2025
- ALL DATA TAKEN FROM PUBLIC REFERENCES: NATIONAL AND INTERNATIONAL
- ELECTRIC NETWORK REPRESENTATION: 32 REGIONS, 40 INTERREGIONAL TIES
- TECHNOLOGICAL OPTIONS FOR CAPACITY EXPANSION:
  - 9 TYPES OF THERMOELECTRIC GENERATING UNITS
  - 14 HIDROELECTRIC POWER PROJECTS
  - ELECTRIC INTERREGIONAL TIES AT 230 KV AND 400 KV
- NATURAL GAS TRANSPORTATION NETWORK: 96 NODES AND 101 LINKS
- NATURAL GAS SOURCES: 6 NATIONAL, 4 BORDER INTERCONNECTIONS, 1 LNG FACILITY
APPLICATION EXAMPLE

THE MEXICAN INTERCONNECTED ELECTRIC POWER SYSTEM
(2002-2025)

PROJECTED DEMAND GROWTH AND ELECTRIC POWER GENERATION CAPACITY

FUEL MIX FOR ELECTRIC POWER GENERATION IN 2005

*Thermoelectric generation capacity: 127,014 MWatts
APPLICATION EXAMPLE

THE MEXICAN INTERCONNECTED ELECTRIC POWER SYSTEM
(2002-2025)

EXISTING (2002) AND ADDITIONAL TRANSMISSION CAPACITY (2025)
APPLICATION EXAMPLE

THE MEXICAN INTERCONNECTED ELECTRIC POWER SYSTEM
(2002-2025)

REGIONAL ALLOCATION OF NATURAL GAS BASED ELECTRIC POWER GENERATION CAPACITY

EXISTING AND ADDITIONAL NATURAL GAS TRANSPORTATION CAPACITY
APPLICATION EXAMPLE

THE MEXICAN INTERCONNECTED ELECTRIC POWER SYSTEM
(2002-2025)

NATIONAL PRODUCTION OF NATURAL GAS

NATURAL GAS IMPORTS
THANK YOU