Overview of the Generation-Transmission Maximization (GTMax) Model

The Premier Analysis Tool for Deregulated Electricity Markets

Argonne National Laboratory Center for Energy, Environmental, and Economic Systems Analysis
Around the World, Deregulation is Fundamentally Changing the Way Electricity Markets Function

**Past**
Natural Monopoly

**Present**
Transition Phase

**Future**
Open Market

Vertically Integrated

Generation
Transmission
Distribution

Unbundled

Generation
Transmission
Distribution

Around the World, Deregulation is Fundamentally Changing the Way Electricity Markets Function
The Traditional Markets Are Dominated by Single, Vertically-Integrated Energy Companies
Argonne Developed GTMax to Study the Complex Marketing and Operational Issues in Today’s Deregulated Power Markets

GTMax Can be Used by Different Market Agents in Support of their Analytical Needs

- Generation Companies, Independent Power Producers, and Power Merchants
- Transmission Companies, Independent System Operators, and Power Exchanges
- Government, Regulatory, and Oversight Bodies
Generation Companies, Independent Power Producers, and Power Merchants

- Use GTMax to estimate how much power each unit will generate and how much power they can sell in each hour at what price

- Use GTMax to estimate purchases and sales from long-term firm contracts and IPP agreements

- Use GTMax to study if their investment in power or transmission assets will yield an attractive return

- Use GTMax to develop a sound market strategy - when should they buy and/or sell power in the spot market
Transmission Companies, Independent System Operators, and Power Exchanges

- Use GTMax to estimate the locational hourly market clearing price for energy at different points in the network.
- Use GTMax to estimate the projected available transmission capability on individual links or user-specified paths each hour in the region for posting on OASIS systems.
- Use GTMax to determine the optimal path of contractual power flows.
- Use GTMax to identify operational and network bottlenecks and the marginal value of relieving system obligations and constraints.
- Use GTMax to conduct screening and siting analyses for new transmission lines.
Government Agencies and Regulatory or Oversight Bodies

- Use GTMax to analyze different bidding behaviors or strategies and game playing and the impacts on the markets (market power)

- Use GTMax to study open market policies

- Use GTMax to simulate the effects of environmental and institutional limits on power plant operations and compute compliance costs

- Use GTMax to analyze the value of demand-side management and distributed generation resources
GTMax Objective

- Maximize the economic or financial value of an electric utility system within physical and institutional operating constraints

  Electric utility system
  - Hydro and thermal power plants
  - Firm purchase and sales contracts
  - Spot market interconnections
  - Customers (electricity demand)
  - Transmission and distribution systems

- Physical and institutional constraints
  - Capacity
  - Technical minimum
  - Ramping limits (change in operations over time)
  - Reservoir limits
GTMax Balances Supply & Demand (Simplified Example)

- Generators are loaded according to marginal production costs or market bid price.
- High prices result in demand curtailments.
- Due to transmission congestion, this point must be determined for each zone or region.
GTMax Operates at a One Hour Time-Step and Takes into Account Many Input Variables

Hydro & Thermal Resources → Operational Restrictions → Spot Market Prices → Firm Contracts → Hydro Cascade Specifications

Demand & Curtailments → Value of Energy & Energy Savings

GTMax Model

Hourly Generation → Unit Commitments

Purchase & Sales → Revenues & Expenses

Reservoir Operations → Transmission & Distribution System → Contractual Power Flows
GTMax Uses a Network of Nodes & Links to Represent a Power System

- **Nodes**
  - Thermal & hydro power plant
  - Firm purchases & sales contracts
  - Spot market interconnections
  - Power interchange points
  - Heat production
  - Electricity & heat demand

- **Links**
  - Transmission lines
  - River systems
  - Heat flows
There are Several Types of Supply Resources in the Model

- Thermal units
- Hydro power plants (limited energy)
  - Run-of-river
  - Storage
  - Pumped storage
  - Hydro plants can be specified in a cascade
  - Water is spilled (non-power release) under some conditions
- Long-term firm purchase contracts & Independent Power Producer (IPP) contracts
- Spot market purchases
- Combined Heat & Power Plants
GTMax Has Detailed Thermal & Hydro System Representations

- Power plant or unit capacity
- Marginal production cost or bid price by block
- Total energy release in a week period
- Daily minimum & maximum energy
- Change in daily energy production
- Minimum hourly output
- Maximum hourly output
- Hourly up & down ramp rate restrictions
  - Change in generation from one hour to the next
- Daily up & down ramp rate restrictions
  - Change in generation over a 24 hour period
The GTMax Hydropower Dispatch is also Constrained by Reservoir Limitations

- Maximum reservoir elevation level
- Minimum reservoir elevation level
- Daily reservoir elevation change
- Change over a 2-day & 3-day period
- Elevation levels are functions of:
  - Initial reservoir conditions
  - Hourly up-stream reservoir releases
  - Side flows
  - Pumped water from a lower reservoir
  - Hourly reservoir releases
  - Water extracted for irrigation of other uses
  - Elevation change per volume of water released
Supply Resources Satisfy Different Types of Demands

- Service territory load centers
- Firm contract loads (if any)
- Spot market demands (if economical)
- Heat demands

Note: Additional electricity must be produced because of T&D losses
The Transmission System Links Different Types of Activities

Overlay of a U.S. Utility System on a Transmission System Map
GTMax Employs a User-Friendly Geographical Information System (GIS) Interface
GTMax Accounts for Composite Transfer Capability (The Total Is Less Than The Sum of The Parts)
GTMax Users Define Both the Path of Firm Transmission Contracts & Hourly Obligations
GTMax Allows the User to Define Regions
Argonne is Developing a Transmission Model for Computing PTDFs in GTMax

- EXAMPLE: Hypothetical power transfer from utility in eastern Wisconsin to TVA

- Transfer affects lines as far away as Nebraska and eastern Virginia

- Of the 45,000 lines modeled in the case, 171 had PTDFs above 5%, while for 578 the PTDFs were above 2%
Transmission Constraints Played a Critical Role in U.S. Midwest Price Spikes of up to $7.5/kWh in June 1998
Application: Hydropower Plant Operations of a Large U.S. Utility are Usually Driven by the Market Price of Electricity
Analyzing the Economic and Financial Viability of Two Transmission Lines in the Balkans for a Large International Power Merchant
Three Distinct Regions were Modeled in the Balkan Transmission Lines Project
GTMax Projected Market Clearing Prices in the Balkans Based on Marginal Production Costs

- Price Country Y
- Price Country X
- Uncongested Price

$/MWh

Mon Tue Wed Thu Fri Sat Sun
GTMax Estimated Bulk Power Transfers Between Regions

- Energy Transfer X to Y
- Energy Transfer Y to X

[Graph showing daily energy transfers between regions with specific peak times and trends]
Analyzing the Financial Viability of Small-Scale Cogenerators in Poland’s Deregulated Power Markets
Poland's Pumped Storage Units Increased Loads Off-Peak (Pumping) to Satisfy Peak Demand (Generation)
Poland’s Pumped Storage Operations Respond to Market Price Signals
Operation of New Cogenerators in Poland is Driven by Market Prices
Revenues From the New Cogeneration Plant Are Greater Than Production Costs
GTMax Calculated Available Transfer Capabilities for Three Paths From East to West Across Poland

![Graph showing load in MWh for three paths: Central, Southern, and Northern, with daily load variation from Sunday to Saturday.](image-url)
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