# How Advances in Algorithms and Processors Will Impact Power System Markets and Operations

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# IBM ILOG Optimization software

- ILOG -- recognized industry leader in mathematical programming and supply chain solutions -- is now part of IBM.
- IBM ILOG Optimization products:
  - **IBM ILOG CPLEX Optimization Studio**
    - Fully integrated development environment, combining multiple high-performance optimization engines for mathematical optimization (**CPLEX Optimizer**) and constraint programming (CPLEX CP Optimizer), with productivity tools for model development with the OPL modeling language, application prototyping and model deployment.
  - **IBM ILOG ODM Enterprise**
    - Enterprise-class platform for building optimization-based custom planning and scheduling applications
  - **IBM ILOG Supply Chain Applications**
    - Optimization-based decision support solutions addressing the common challenges associated with global supply chain design and sourcing strategies, production planning and detailed scheduling, transportation planning, and the optimal flow and placement of inventory

# IBM ILOG CPLEX Optimizer

- CPLEX 1.0 released in 1988
- CPLEX 12.2 in general availability June 2010

- Today: State of the art implementations of linear and quadratic solvers for continuous and mixed-integer formulations:
  - Simplex
  - Barrier
  - Branch & Cut

- The de facto standard for mathematical programming, in use at thousands of commercial and academic sites
- Noted for both speed and reliability
- Carefully tuned default settings for normal usage, plus all the controls needed by power users for the most demanding applications
- IBM now backs research and development

# LP Solvability – orders of magnitude of progress

(Operations Research, Jan 2002, pp. 3—15, updated in 2004)

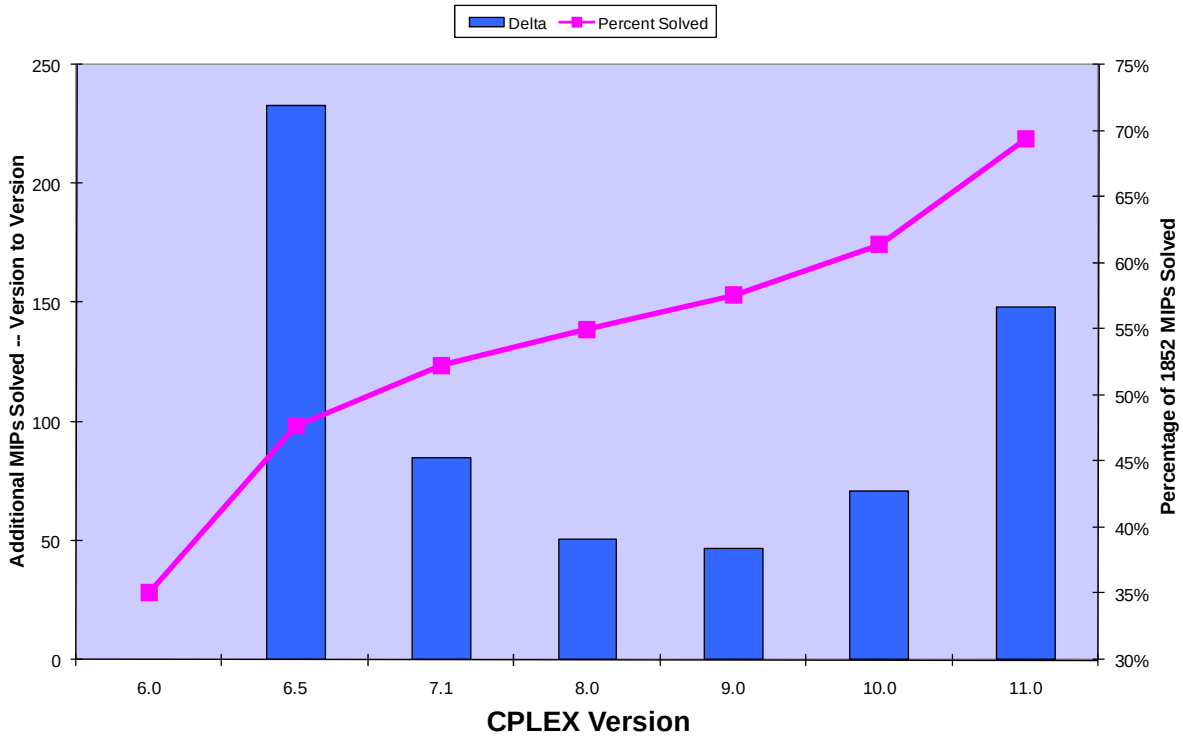
- **Algorithms (*machine independent*):**

  Primal ***versus*** **best of** Primal/Dual/Barrier 3300x
- **Machines (workstations →PCs):** 1600x
- NET: Algorithm × Machine 5 300 000x

**(2 months/5300000 ~= 1 second)**

**As with any statistics, interpretation requires care**

# MIP Solvability – Steady Progress



# Unit Commitment Problem

**Some history:**

**Electrical Power Industry, EPRI GS-6401, June 1989:** Mixed-integer programming (MIP) is a powerful modeling tool, “They are, however, theoretically complicated and computationally cumbersome”.

*In Other Words:* MIP is an interesting “toy”, but it just isn’t going to work in practice.

**California 7-Day Model**

**`UNITCAL_7:`** 48939 constraints, 25755 variables (2856 binary)

Reported Results 1999 – machine unknown

2 Day model: 8 hours, no progress

7 Day model: 1 hour to solve only the initial LP

# Unit Commitment Problem

**California 7-Day Model**

**1999 results on a desktop PC:**

CPLEX 6.5: 22 minutes, optimal

**2007 results on a desktop PC:**

CPLEX 11.0: 71 seconds, optimal

- **The result:**
  - MIP early adopters gained a competitive advantage
  - Applications have expanded and changed
    - 1000-2000 generation units simultaneously (Day Ahead Market)
    - Solution cycles down to 5 minutes (Real Time Market)
  - MIP has become the standard approach for unit-commitment applications.

# The past as prologue

- The preceding twenty years have witnessed massive increases in capability.
- While CPLEX is a general purpose solver, the benefit to the power industry has been demonstrable.
- Where are the opportunities going forward?
  - Advanced computing platforms
  - Modeling paradigms
  - Research collaborations
- Note: some of the advances of the past 20 years came from serendipity or unplanned research, so we can continue to “expect the unexpected”.

- Where are the opportunities going forward?
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  - Modeling paradigms
  - Research collaborations

# Advanced computing platforms

- Parallel cores on commodity chips have become standard in recent years.
- CPLEX has pioneered advances in parallelism since 1995.
- CPLEX maintains state of the art parallel implementations of MIP and Barrier for shared memory architectures.
- Parallelism is enabled by default on these machines.

- The challenge now: extend this reach to other architectures

# Advanced computing platforms

- **The Cloud**

- It's here already from a variety of sources including IBM.
- With suitable software licenses you can transition from desktops and servers to a cloud.

- Can we do more? What is the right role for the cloud?
  - To replicate the Service Bureau mode from the 1970s?
  - To save money on hardware?
  - As a throughput platform for many problems at a time?
  - To speed the solution of a single problem?
  - What role does data security play?

- An active area of study at IBM Research (Watson Research Center)

# Advanced computing platforms

- **High Performance Computing (HPC)**

- Distributed memory architectures represent a challenge for sparse matrix methods and binary search.
- IBM Blue Gene supercomputers represent an unharnessed capability for Optimization.
  - At present, can be a strong throughput platform for Optimization
- Algorithms may at last be at a threshold of opportunity.

- An active area of study at IBM Research

- Where are the opportunities going forward?
  - Advanced computing platforms
  - Modeling paradigms
  - Research collaborations

# Modeling paradigms

- **Constraint Programming (CP)**

- IBM ILOG CP Optimizer introduced a “model and run” framework unique in the world of Constraint Programming.
- Strong for detailed scheduling problems
- Provides novel “interval” type for variables representing time periods
- IBM ILOG CPLEX Optimization Studio 12.2 now includes CP

# Modeling paradigms

- **Stochastic Programming**

- Optimization under uncertainty is a necessity in many domains.
- Power generation certainly is among the forefront of these.
- Current probabilistic methods depend greatly on modeling skill.
- Can a better framework be devised?

- An active area of study at IBM Research

- Where are the opportunities going forward?
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# Research collaborations

- Mathematical Programming engines such as CPLEX are general purpose tools.
- Nevertheless progress is made by studying individual models.
- Progress in one problem domain often carries over to others.
  - The broad scope of CPLEX's user base represents a source of opportunity for continual enhancements in both solution speed and reliability.

- IBM Research invests in study of the models of interest to the power generation community.
- The feedback to the CPLEX development team then serves all its users.

# Research collaborations

- The efforts by FERC to bring together a critical mass of users and developers is a welcome undertaking.
- A carefully chosen collection of test problems from the industry can help advance the state of the art.
- Insight to these models is as helpful as the models themselves.

- Note also, CPLEX is virtually ubiquitous in centers of optimization at major universities and research facilities

# Impact on Power System Markets and Operations

- Solver speed is only a proxy for the real purposes of development.
  - Turn overnight runs into daytime runs, or daytime runs into nearly realtime, for better feedback and response
  - Include wider geographic impact and constraints
  - Expand models with monthly detail into weekly detail, etc.
  - Expand models with weekly scope into monthly scope, etc.
  - Model full systems instead of decompositions
  - Enable more what-if modeling
  - Solve probabilistic scenarios
- Of course, this is a never ending cycle of need for more speed.

# Summary and conclusions

- These are exciting times for Optimization
- Power generation can help push forward the state of the art
- Opportunities exist through advanced computing platforms, modeling paradigms, and research collaborations
- The intersection of IBM Research with applied product development like CPLEX is unmatched anywhere