Small Resource Optimization and Infra-marginal Gas Turbine Logic

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NYISO by the numbers

- New York population - 19 million
- 2016 Energy Demand - 160,798 GWH
- 2016 Required Installed Capacity - 39,198 MW
- 2016 Peak - 32,076 MW
- Record peak - 33,956 MW (July 19, 2013)
- Transmission - 11,000+ circuit-miles
- Power Generation - 700+ Units
- Wholesale Market Participants - 400+
- Average Annual Market Transactions - $7.5 Billion

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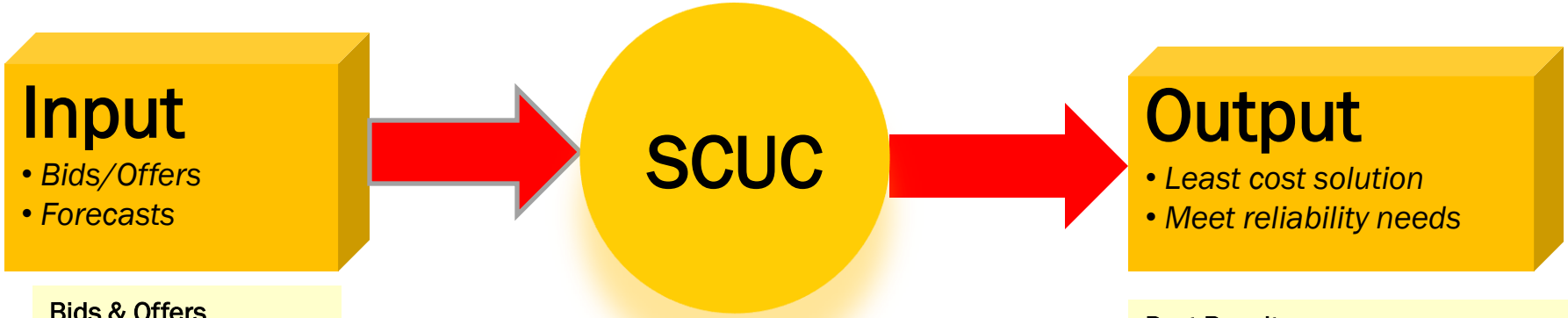
Unit Commitment is the Heart of NYISO Market Systems



Bids & Offers
- GEN Supply
- LSE
- Virtual
- Regulation
- Reserve
- Bilaterals
- Import/Exports
- Demand Response

Security Constrained Economic Commitment and Dispatch

Post Results
- Clearing Prices
  - LBMP (GEN & Zonal)
  - Reserve
  - Regulation
- GEN Schedule
- Transaction Schedule
- Bilateral Transactions
- Reserve Commitment
- Regulation Commitment

The impact of Reforming the Energy Vision

Reforming the Energy Vision (REV) 2030 Goals

40% reduction in greenhouse gas emissions from 1990 levels	50% of electricity consumed in New York to come from renewable sources	23% reduction in energy consumption of buildings from 2012 levels

Potential REV Impacts to NYISO by 2025			
	Low	Expected	*High*
Solar (MW)	*1,000*	**5,000**	*9,000*
Wind (MW)	*1,000*	**2,000**	*4,000*
Efficiency (MW)	*+1% Demand Growth*	**Flat Load Growth**	*-1% Demand Growth*
Active DERs	*1,000*	**2,000**	*4,000*

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http://energyplan.ny.gov/Plans/2015

Small Resources Integration

- **Transmission Operator ←→ Distribution Operator**
  - Contemplates many, smaller transactions
  - Currently 1 MW minimum for NYISO
- **SCUC optimization branch and bound technique leaves "MIP gap"**
  - Initial unit commitment may not be physically feasible, and SCUC must iterate to achieve a least-cost unit commitment while respecting all system constraints
  - The impact of small resources on the solution may be less than the production cost limit. In this circumstance, a branch-and-bound Mixed Integer Programming (MIP) solution does not determine when such resources' commitment will enhance efficiency
- **Commitment of small resource will require:**
  - more processing power
  - new optimization techniques, and/or
  - an active role for distribution operators

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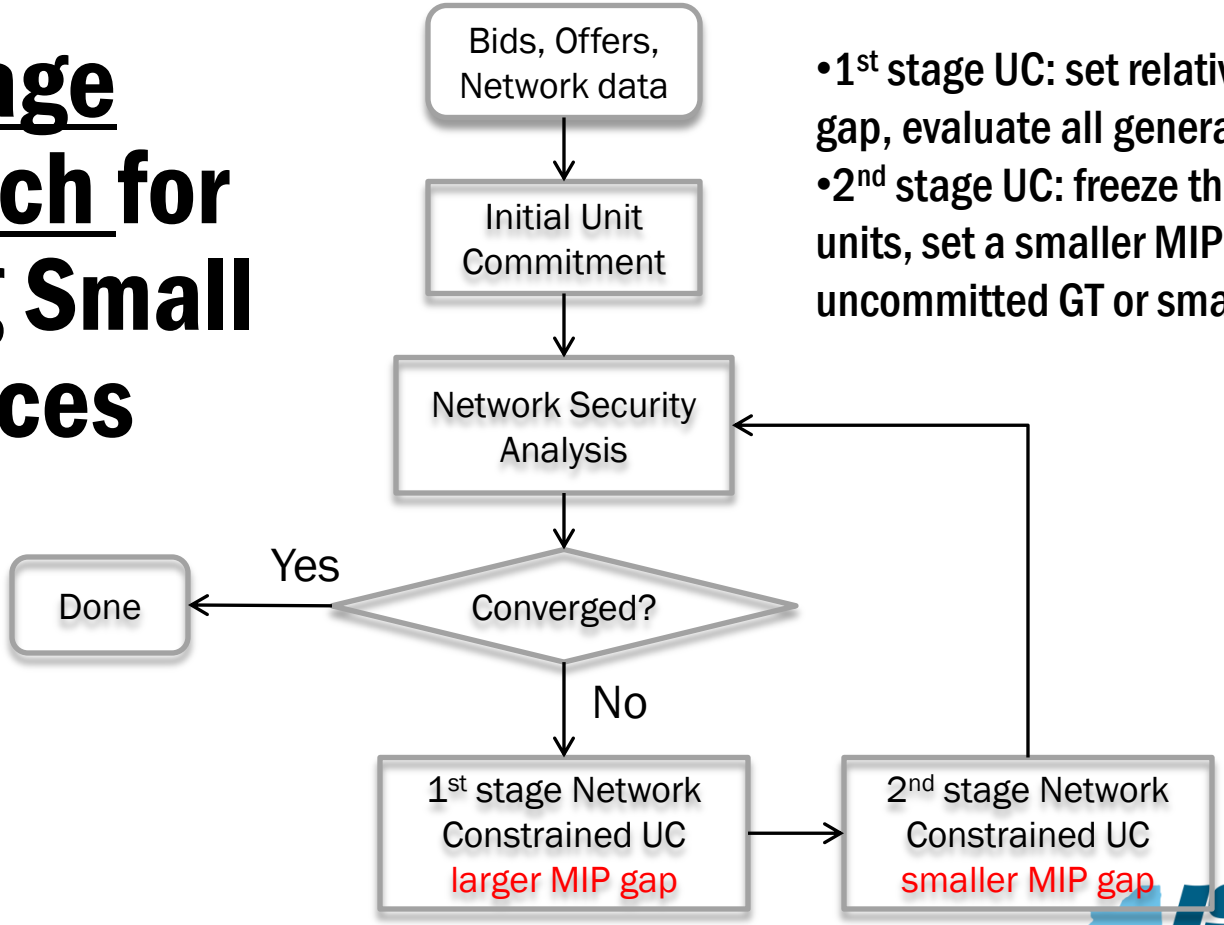
Two-stage approach for Solving Small Resources



- 1st stage UC: set relatively large MIP gap, evaluate all generating units
- 2nd stage UC: freeze the committed units, set a smaller MIP gap, evaluate uncommitted GT or small resources

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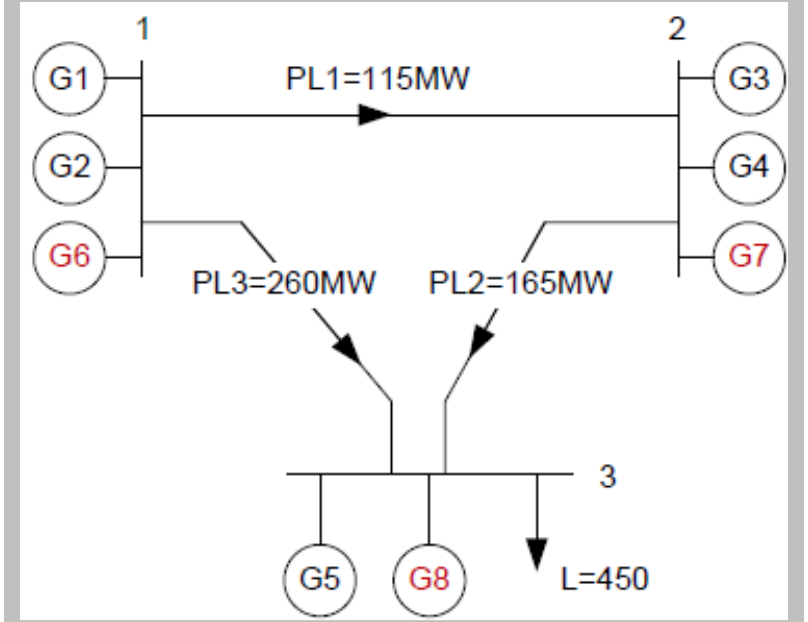
Small Resource Integration



Unit	Startup Cost ($)	Mingen Cost ($/h)	Pmin (MW)	Pmax (MW)	Incremental Cost ($/MWh)	
G1	500	1270	150	300	10	12
G2	700	1660	205	305	10	11
G3	200	310	105	135	12	21
G4	200	316	105	135	12	19
G5	300	430	55	95	13	23
G6	3	8	1	3	10	11
G7	2	3	1	2	12	20
G8	6	8	1	2	13	20

Notes:

- Line impedances are equal
- Units offer two equal MW segments between [Pmin, Pmax]

Small Resource Integration

```
/*********************************************
 * OPL 12.6.3.0 Model
 * Author: nguyencp
 * Creation Date: Apr 27, 2016 at 9:13:01 AM
 *********************************************/
Minimize

 obj: YY

Subject To

\objective function terms
  EOJ: 1770 I1 + 10 P12 + 12 P13
     + 2360 I2 + 10 P22 + 11 P23
     +  510 I3 + 12 P32 + 21 P33
     +  516 I4 + 12 P42 + 19 P43
     +  730 I5 + 13 P52 + 23 P53
     +   11 I6 + 10 P62 + 11 P63
     +    5 I7 + 12 P72 + 20 P73
     +   14 I8 + 13 P82 + 20 P83 - YY = 0

\energy balance
 _EQ_SYS: P1 + P2 + P3 + P4 + P5 +P6 +P7 +P8 = 450

\generator constraints
 _EQ_G1: P1 - 150 I1 - P12 - P13 = 0
 _EQ_G2: P2 - 205 I2 - P22 - P23 = 0
 _EQ_G3: P3 - 105 I3 - P32 - P33 = 0
 _EQ_G4: P4 - 105 I4 - P42 - P43 = 0
 _EQ_G5: P5 -  55 I5 - P52 - P53 = 0
 _EQ_G6: P6 -   1 I6 - P62 - P63 = 0
 _EQ_G7: P7 -   1 I7 - P72 - P73 = 0
 _EQ_G8: P8 -   1 I8 - P82 - P83 = 0

 _LE_G1: P1 - 300 I1 <= 0
 _LE_G2: P2 - 305 I2 <= 0
 _LE_G3: P3 - 135 I3 <= 0
 _LE_G4: P4 - 135 I4 <= 0
 _LE_G5: P5 -  95 I5 <= 0
 _LE_G6: P6 -   3 I6 <= 0
 _LE_G7: P7 -   2 I7 <= 0
 _LE_G8: P8 -   2 I8 <= 0

\network constraints
 _LE_L1:  0.3333333 P1 + 0.3333333 P2 + 0.3333333 P6  -0.3333333 P3 - 0.3333333 P4  - 0.3333333 P7 <= 115
 _LE_L2: -0.3333333 P1 - 0.3333333 P2 - 0.3333333 P6  +0.3333333 P3 + 0.3333333 P4  + 0.3333333 P7 <= 115

 _LE_L3:  0.3333333 P1 + 0.3333333 P2 + 0.3333333 P6  +0.6666667 P3 + 0.6666667 P4  + 0.6666667 P7 <= 165
 _LE_L4: -0.3333333 P1 - 0.3333333 P2 - 0.3333333 P6  -0.6666667 P3 - 0.6666667 P4  - 0.6666667 P7 <= 165

 _LE_L5:  0.6666667 P1 + 0.6666667 P2 + 0.6666667 P6  +0.3333333 P3 + 0.3333333 P4  + 0.3333333 P7 <= 260
 _LE_L6: -0.6666667 P1 - 0.6666667 P2 - 0.6666667 P6  -0.3333333 P3 - 0.3333333 P4  - 0.3333333 P7 <= 260


Bounds
0<= P12 <=75
0<= P13 <=75
0<= P22 <=50
0<= P23 <=50
0<= P32 <=15
0<= P33 <=15
0<= P42 <=15
0<= P43 <=15
0<= P52 <=20
0<= P53 <=20
0<= P62 <=1
0<= P63 <=1
0<= P72 <=0.5
0<= P73 <=0.5
0<= P82 <=0.5
0<= P83 <=0.5

0<= I1 <=1
0<= I2 <=1
0<= I3 <=1
0<= I4 <=1
0<= I5 <=1
0<= I6 <=1
0<= I7 <=1
0<= I8 <=1

End
```

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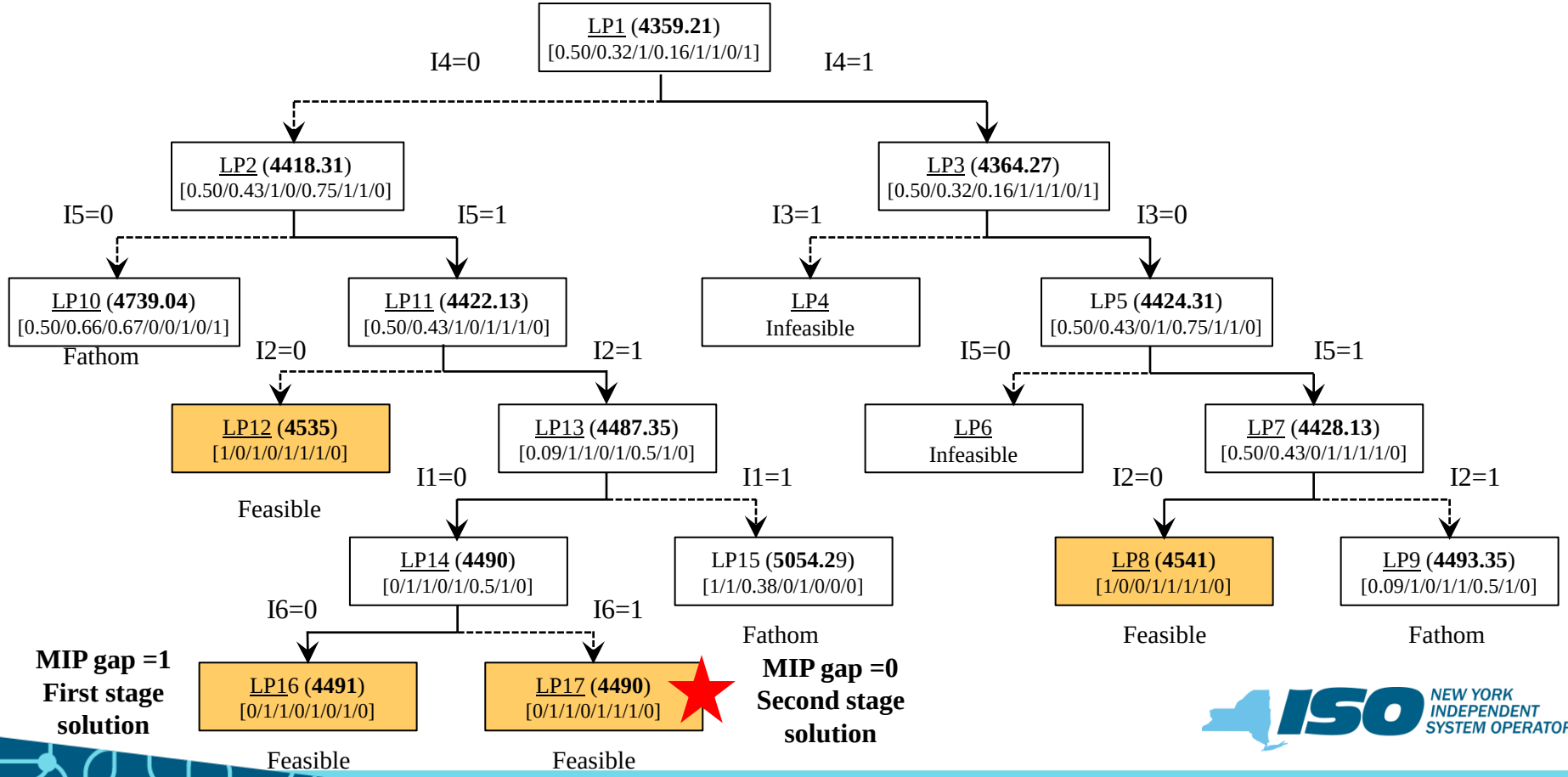
Classic Branch-and-Bound MIP Solution Procedure

- **Solution technique**
  - Branch-and-bound method is used to illustrate the solution procedure
  - Depth-first search strategy is applied for selecting the node to branch
  - Least fraction strategy is adopted to choose binary variables to branch

Impact of MIP gap on commitment solution



Production cost impact

- System production cost are approximately -$1M
- Most of the day, infra-marginal GT logic can save the production cost

Date	New Logic - OrgMIP (<0 indicate SAVINGs)
7/1/2015	0
7/2/2015	-10
7/3/2015	97
7/4/2015	0
7/5/2015	-1081
7/6/2015	-258
7/7/2015	-929
7/8/2015	-37
7/9/2015	0
7/10/2015	0
7/11/2015	0
7/12/2015	0
7/13/2015	-1091
7/14/2015	-8
7/15/2015	-1221
7/16/2015	-863
7/17/2015	11
7/18/2015	-79
7/19/2015	-167
7/20/2015	-410
7/21/2015	-471
7/22/2015	-369
7/23/2015	-1746
7/24/2015	0
7/25/2015	0
7/26/2015	7
7/27/2015	90
7/28/2015	-158
7/29/2015	-1336
7/30/2015	-807
7/31/2015	-733

Technical Challenges

- **System boundaries**
  - How far is NYISO prepared to push the boundary of the large scale day-ahead security constrained unit commitment?
  - What is the maximum number of small resources can be integrated into the system?
- **Solution techniques**
  - Multi-stage approach?
  - Tighter MIP reformulation to exploit special characteristic of energy system?
  - Smarter cuts and heuristic?
- **Computing resources**
  - Hi-Performance Computing
  - Cloud computing

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The Mission of the New York Independent System Operator, in collaboration with its stakeholders, is to serve the public interest and provide benefits to consumers by:

- Maintaining and enhancing regional reliability
- Operating open, fair and competitive wholesale electricity markets
- Planning the power system for the future
- Providing factual information to policy makers, stakeholders and investors in the power system

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Questions?

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