A Procedure for Calculation of Opportunity Costs of Use Limitations: Starts, Operation Hours & Energy

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Question Addressed

- **What are the opportunity costs of *starts*, *operation hours*, and *energy* for quick-start thermal units that have monthly or other limits on one or more of those?**

- **That is, how much profit (and, market surplus, assuming competitive conditions) is foregone if we use up one more start, run-hour, or MWh today?**
  - **One more start today could mean one less start later in the year, and a loss of benefit then**
  - **Likewise for one more operating hour, and one more MWh**

- **Proposed use: as adders in values of proxy start-up cost, proxy minimum-load cost, and default energy bid used by LMPM**

Assumptions

- **Limits on numbers of starts, operating hours, and/or MWh for a unit over some period (1 week ↔ 1 yr)**
  - **Defined as "season"**

- **RTUC can be used to start-up or shut-down**

  → 15 minute prices relevant

- **Future distribution of 5 minute prices known**
  - **Can construct a representative time series of prices for remainder of month**
  - **Actual profitability can be approximated by deterministic SCUC**
  - **Not actually true: prices might be higher or lower than expected and are not perfectly known**
    - ***Ideal: stochastic programming (SDP; see Oren et al.)***
    - ***Could have multiple scenarios (hot/cool summer; major outages; etc.)***

Basic Approach

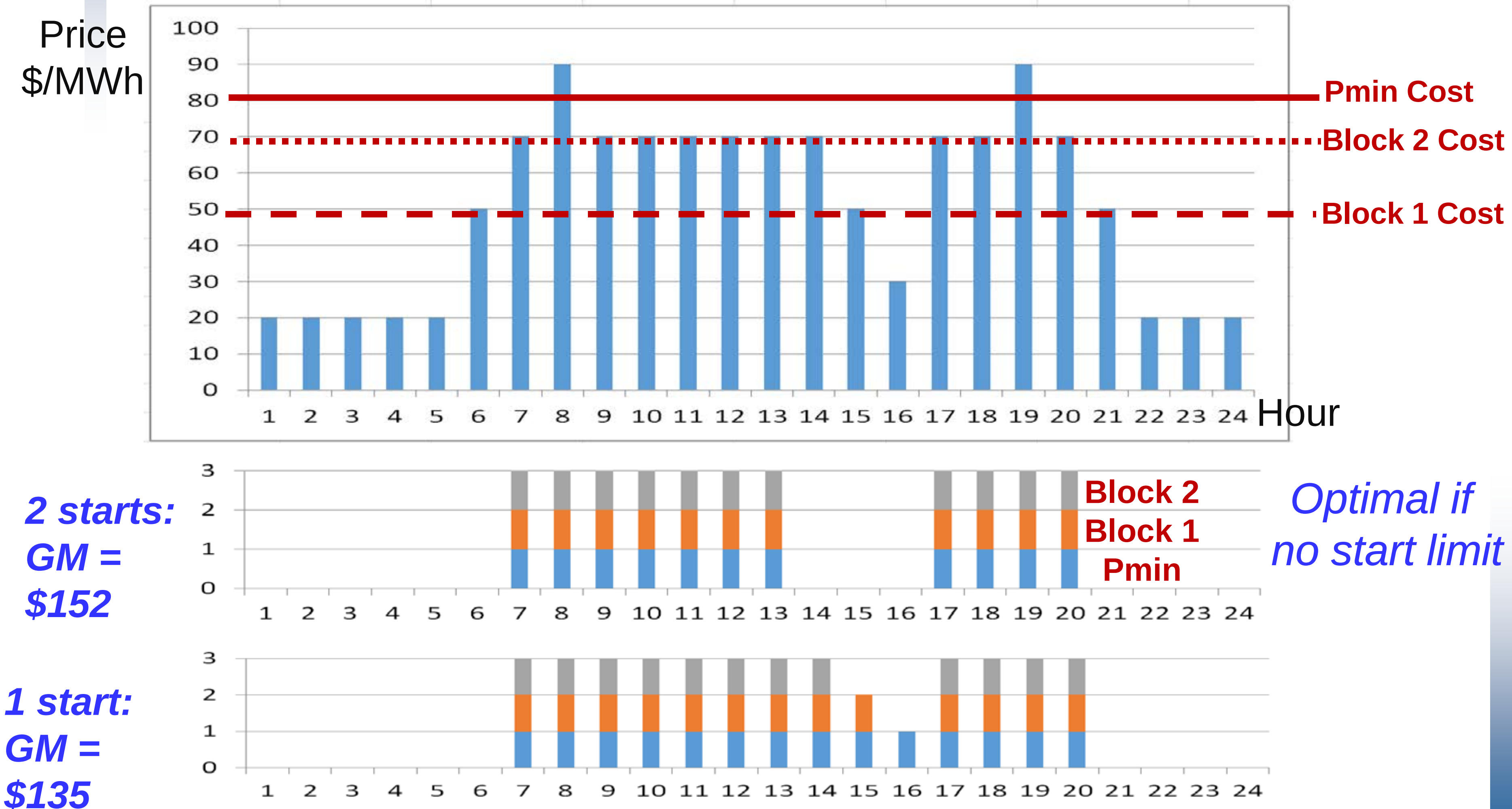
- ***Solve over entire season***
  - ***Decisions***: **timing of starts & shut-downs, and energy (& ancillary services) production by 15 minute interval**
  - ***Objective:***

    Maximize Gross Margin = [Revenues – Variable Costs]
  - ***Constraints:***
    1. *Internal unit commitment, dispatch constraints:*
       a) *Energy: ramp limits, Pmin, Pmax*
       b) *Minimum shut-down and start-up times*
       c) *(Ancillary service capabilities)*
    2. *Operating constraints:*
       a) *Total number of starts over season $\leq$ NSTARTS*
       b) *Total number of operating hours over season $\leq$ NHOURS*
       c) *Total energy over season $\leq$ NMWH*

- ***Opportunity Cost calculations:***
  a) **Decrease NSTARTS by 1 (or other number), and note ΔGross Margin**
  b) **Decrease NHOURS by 1, note ΔGM**
  c) **Note shadow price on NMWH constraint**

Example: Unit Commitment to Calculate GM

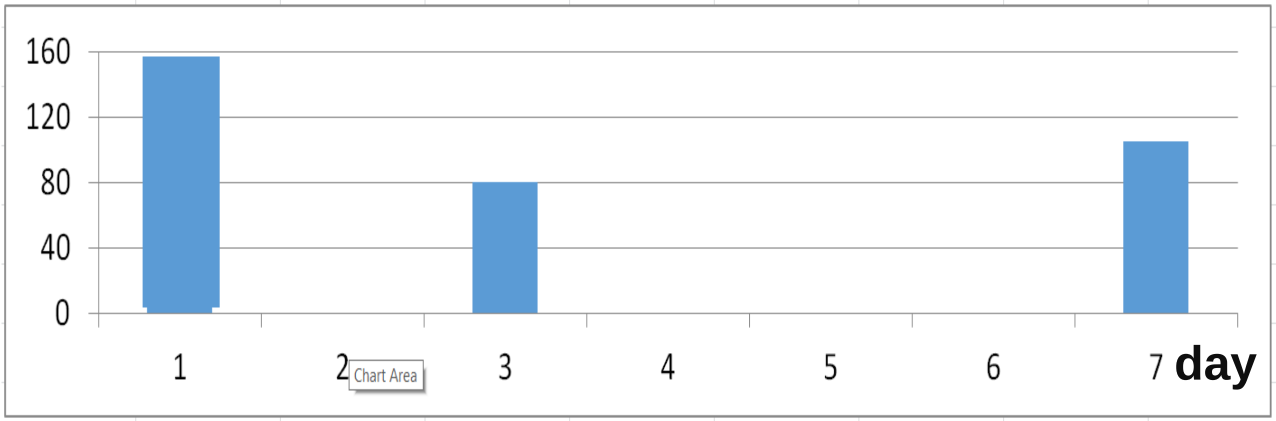
- *3 MW unit 24 hrs: Pmin = 1 MW, 2 variable blocks*
  - *$50 start up cost; $80/hr Pmin cost; 3 hr min down time*
  - *Variable cost block 1 $49/MWh; block 2 $69/MWh*



Optimal Starts over Season (7 days)

- *Say: NSTARTS = 4, NHOURS = 2, NMWH = 50 for 1 week: What is optimal operation?*

GM by day

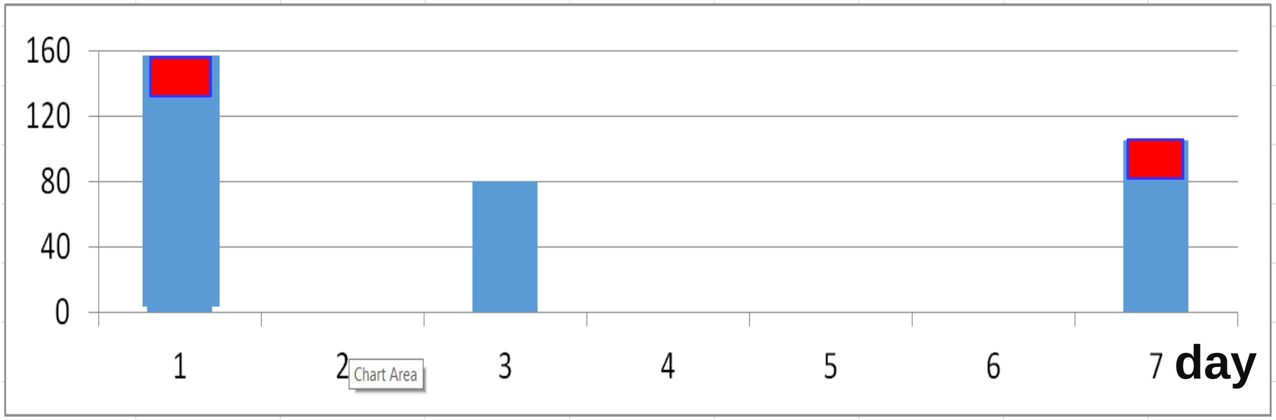


					Total
GM	**152**	**80**	**105**	**=**	**$337**
Starts	**2**	**1**	**1**	**=**	**4**
Hours	**11**	**5**	**9**	**=**	**25 hr**
MWh	**21**	**13**	**16**	**=**	**50 MWh**

NSTART Opportunity Cost

- Decrease NSTARTS from 4 to 3, reoptimize
  - Red is decrease
  - Green is increase

GM by day



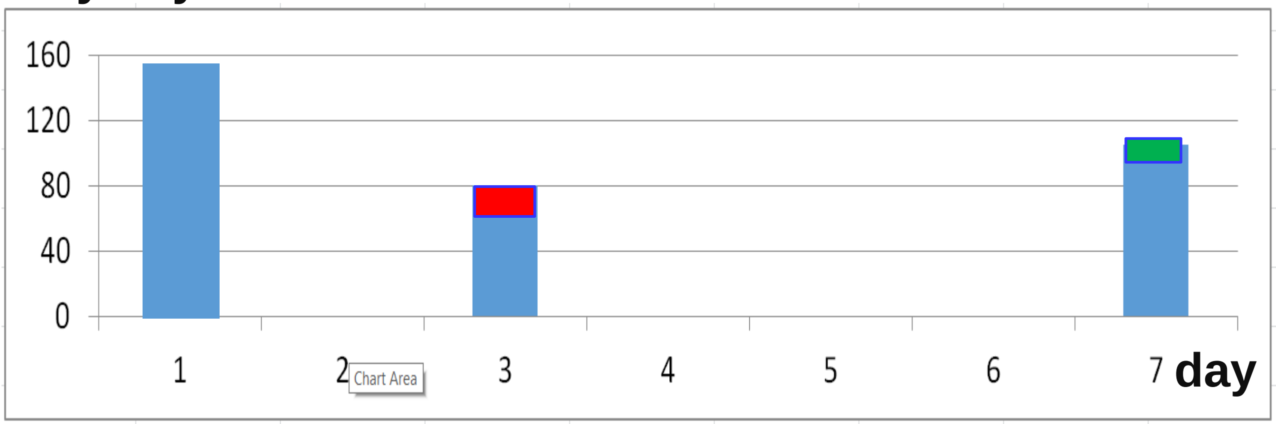
					Total
GM	135	80	80	=	$295
Starts	1	1	1	=	3
Hours	14	5	6	=	25 hr
MWh	27	13	10	=	50 MWh

GM Decrease = $337 - $295 = $42 opportunity cost of start

NHOURS Opportunity Cost

- **Decrease NHOURS from 25 to 24, reoptimize**
  - **Red is decrease**
  - **Green is increase**

GM by day



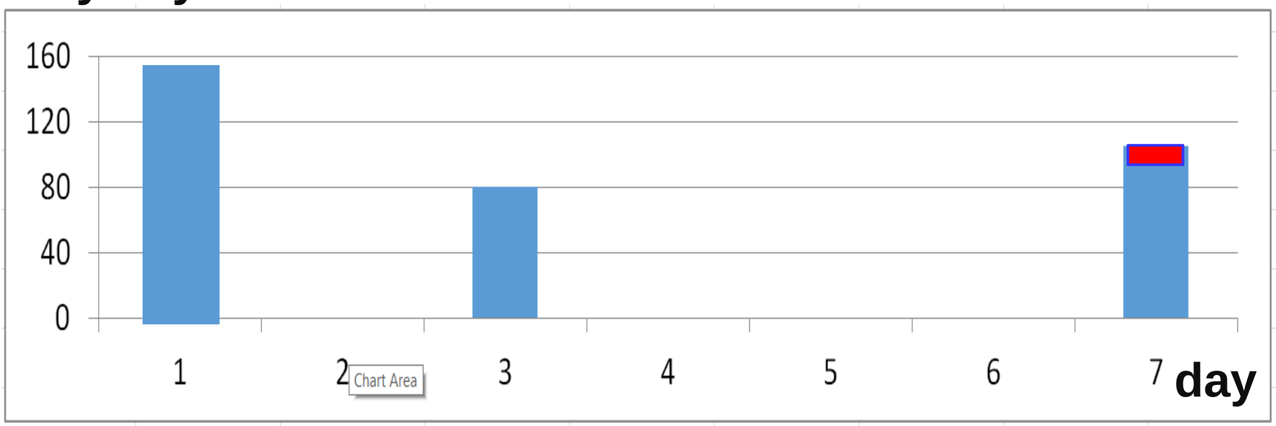
					Total
GM	152	72	108	=	$332
Starts	2	1	1	=	4
Hours	11	4	9	=	24 hr
MWh	21	11	18	=	50 MWh

GM Decrease = $337 - $232 = $5 opportunity cost of operating hours

NMWH Opportunity Cost

- **Use -1*shadow price from NHOURS constraint (= increase in GM from ΔNMWH = +1).**
- **Effect of ΔNMHW = -1:**

GM by day



					Total
GM	**152**	**80**	**101**	**=**	**$333**
Starts	**2**	**1**	**1**	**=**	**4**
Hours	**11**	**5**	**9**	**=**	**25 hr**
MWh	**21**	**13**	**15**	**=**	**49 MWh**

GM Decrease = $337 - $333 = $4 opportunity cost of energy

Carrie Bentley, CAISO

Estimating real time prices: Preliminary comparison northern pricing node

LMP Price ($/MWh)	Apr-13		Sep-13	
	Actual LMP	Estimated LMP	Actual LMP	Estimated LMP
Less than $0/MWh	4%	7%	0%	1%
Between $0/MWh and $25/MWh	7%	13%	4%	8%
Between $25/MWh and $50/MWh	81%	67%	88%	87%
Between $50/MWh and $100/MWh	6%	12%	6%	4%
Between $100/MWh and $250/MWh	2%	1%	0%	1%
Greater than $250/MWh	1%	1%	0%	1%

- September estimations were fairly accurate
- April estimations more distributed around the $25/MWh and $50/MWh price bin
- Congestion during base year (2012) impacted the implied heat rate calculation
  - If congestion does not materialize in 2013, estimated prices vary

Estimating real time prices: Preliminary comparison southern pricing node

LMP Price ($/MWh)	Apr-13		Sep-13	
	Actual LMP	Estimated LMP	Actual LMP	Estimated LMP
Less than $0/MWh	3%	3%	2%	2%
Between $0/MWh and $25/MWh	6%	11%	7%	8%
Between $25/MWh and $50/MWh	81%	67%	82%	80%
Between $50/MWh and $100/MWh	8%	15%	8%	8%
Between $100/MWh and $250/MWh	1%	2%	1%	1%
Greater than $250/MWh	1%	2%	0%	2%

- In September, estimated 80% of LMPs to be between $25/MWh and $50/MWh, only 2% less than actual LMPs
- April estimated LMPs are more distributed around the $25/MWh and $50/MWh price range than actual LMPs