Optimizing Electric Power Bidding Under Severe Uncertainty

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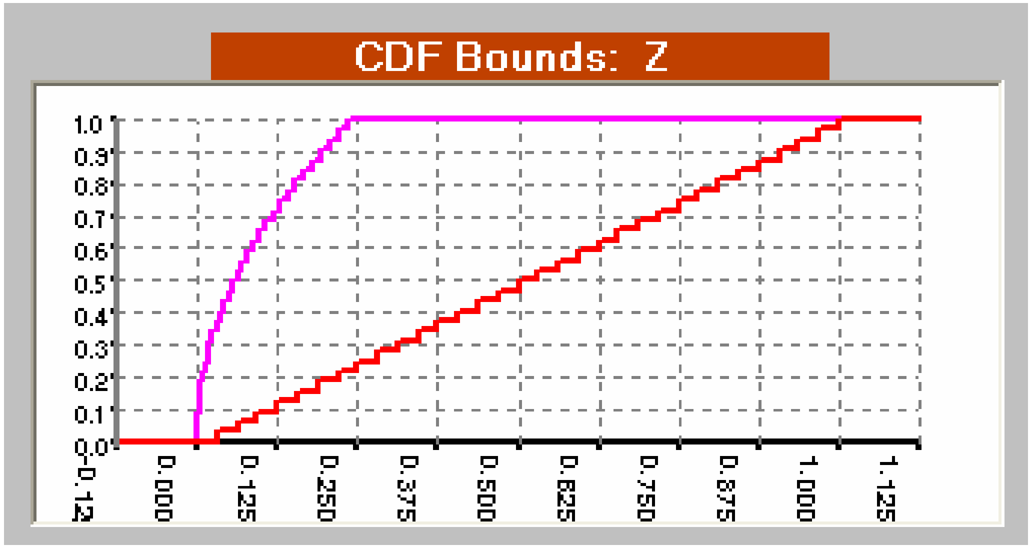
Severe Uncertainty Happens

- Distribution functions are a traditional way to represent uncertainty
- What if a precise curve is unknown?
  - Assume a “best guess” curve; or
  - Faithfully represent uncertainty about the curve
- Unsupported assumptions are not good…
- 2nd-order uncertainty methods are needed!

Representing 2^{nd}-Order Uncertainty

- One way is CDF bounds



- Cf.
  - Left and right envelopes
  - Probability boxes (p-boxes)
  - Upper and lower previsions
  - Plausibility and necessity curves

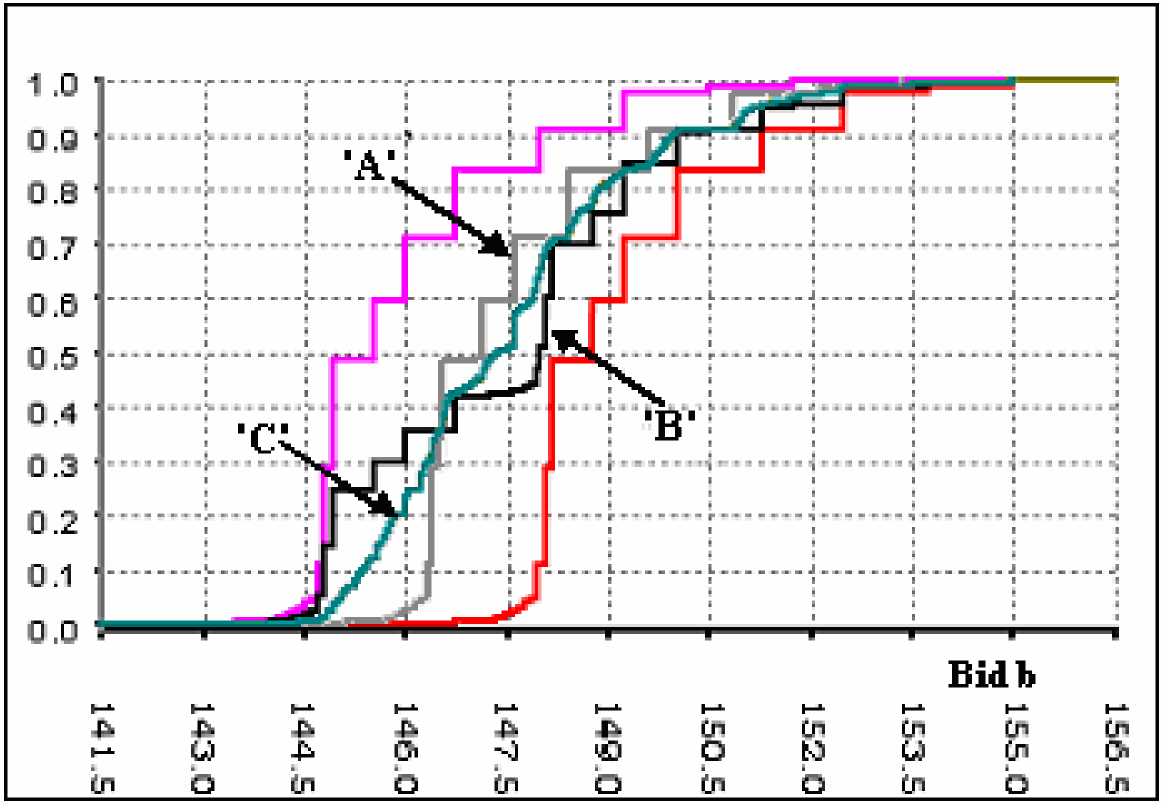
A Simple Yet Instructive Example

- Two GenCos are bidding against each other
  - (GenCo=Generation Co.)
  - They wish to sell power to meet demand X_D
- Demand X_D=1000MWh
- Cost of generation for GenCo 1=$40/MWh
  - GenCo 1 *could* meet entire demand X_D
- GenCo 2 has two generators, G_{2A} and G_{2B}
  - Capacity of G_{2A} is X_{2B}>700MWh
  - Capacity of G_{2B} is X_{2A}=300MWh

GenCo 1's Uncertainty About GenCo 2

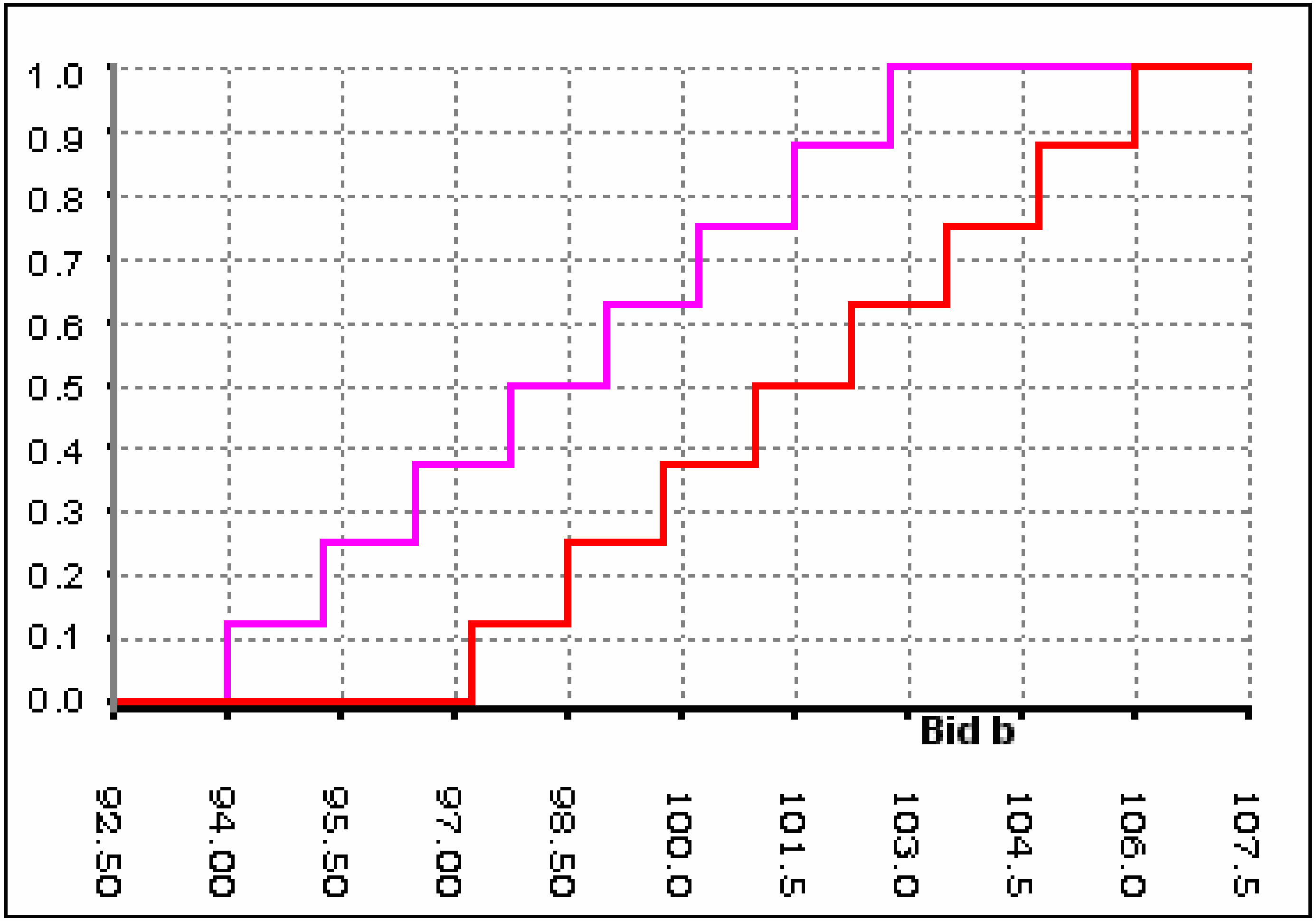
- Consider GenCo 1's predicament
  - Wishes to optimize expected profit
  - Must contend with *limited knowledge* of GenCo 2
    - GenCo 1 models knowledge about GenCo 2's bidding behavior using CDF bounds…

Knowledge of GenCo 2's Bid for power from its Generator G_{2A}



- **Curve A is the horizontal average**
- **Curve B is the vertical average**
- **Curve C is the fixed-point average**

Knowledge of GenCo 2's Bid for power from its Generator G_{2B}

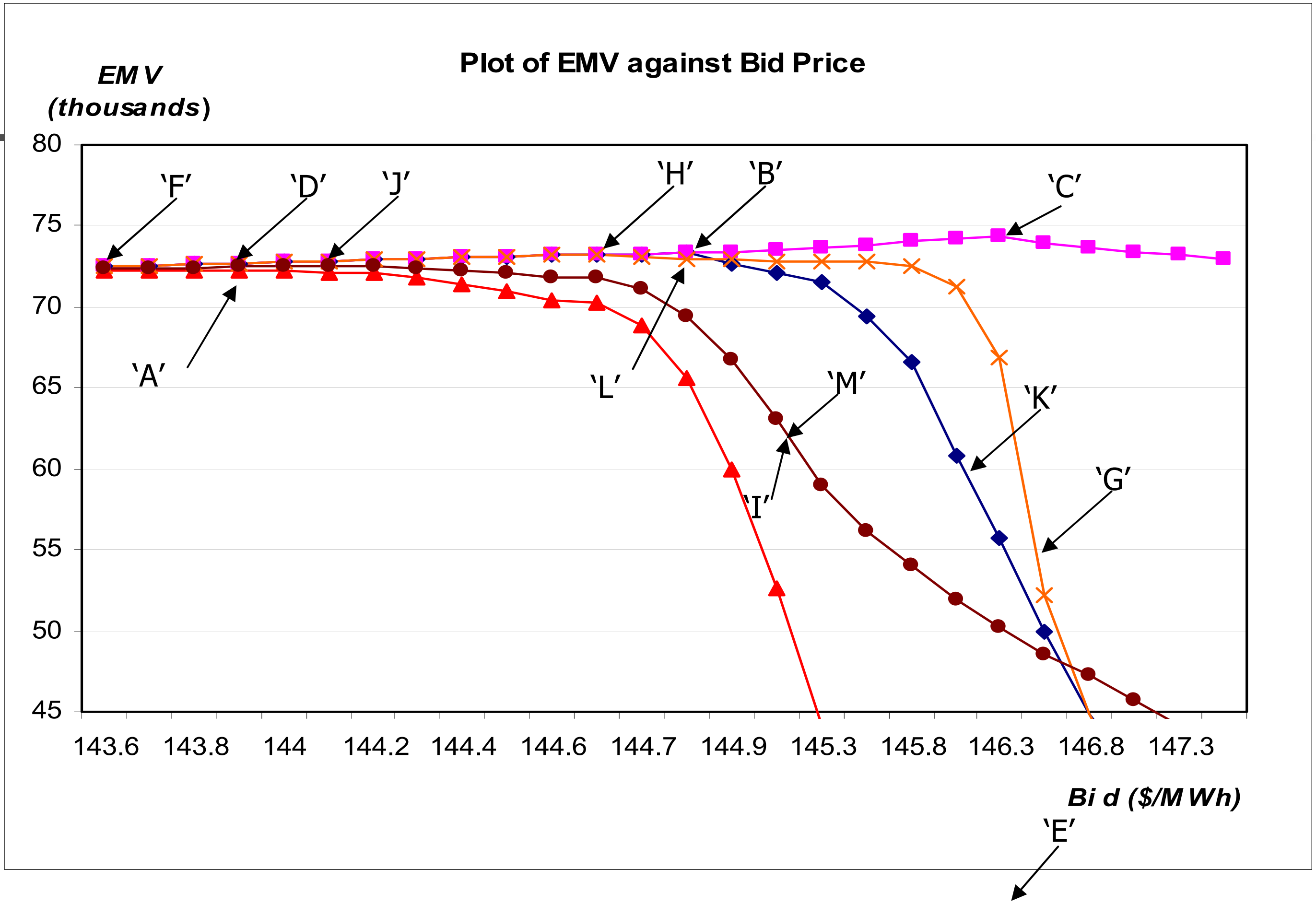


Bidding Strategies for GenCo 1

Recall G_{2B} is cheaper to run than G_{2A}:

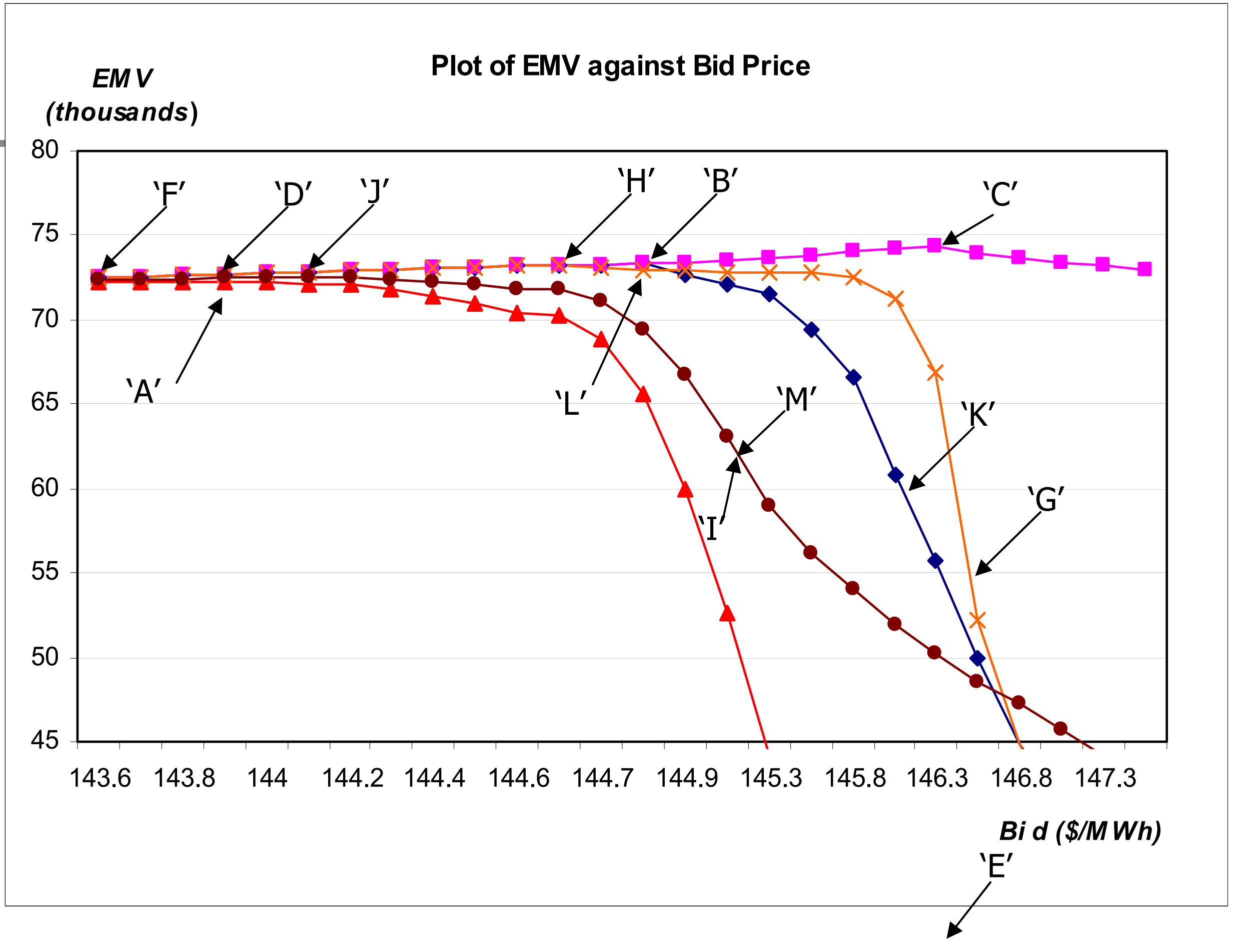
- Underbid G_{2B}, resulting in sale of entire 1000MWh
- Underbid G_{2B} with 300MWh and G_{2A} with 700MWh
- Underbid G_{2A} to sell 700MWh
  - This is the best strategy (Cheong et al. 2003)

GenCo 2's EMVs for Bids *b*



- Some possible curves for the EMV as a function of bid value
- Each EMV curve corresponds to some CDF for GenCo 2's bid from G_{2A}
- GenCo 1's EMV for b is $p_{win}(b)*700*(b-40)$

Some Attributes of the Set of EMV Curves



Suppose the pessimistic curve is assumed to apply…

•'A' determines the best bid

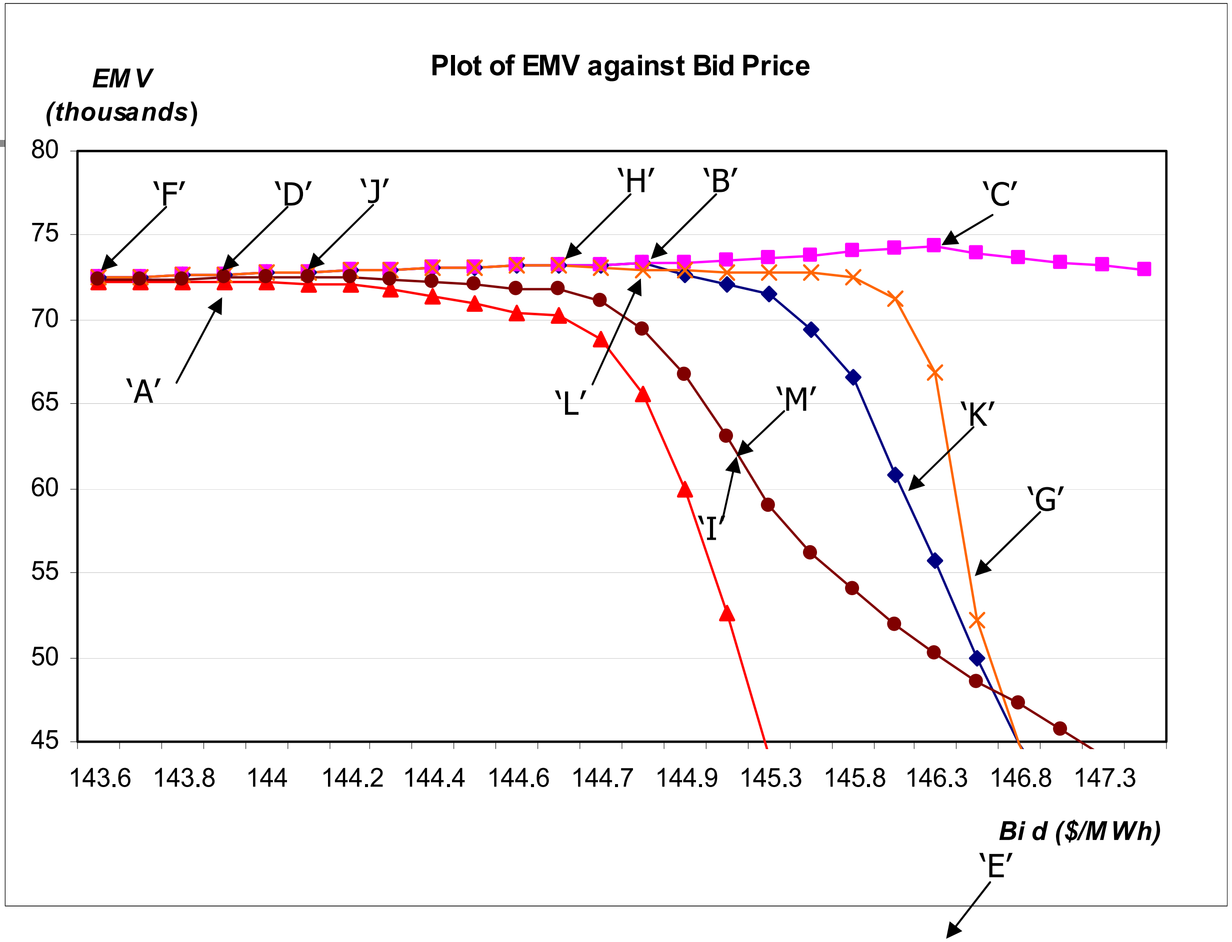
What if the optimistic curve actually applies?

•'D' determines the EMV

•'C' would have been a better bid

•Suboptimality is EMV(C)-EMV(D)

More Attributes of the Set of EMV Curves



Suppose the *optimistic* curve is assumed to apply…

•'C' determines the best bid

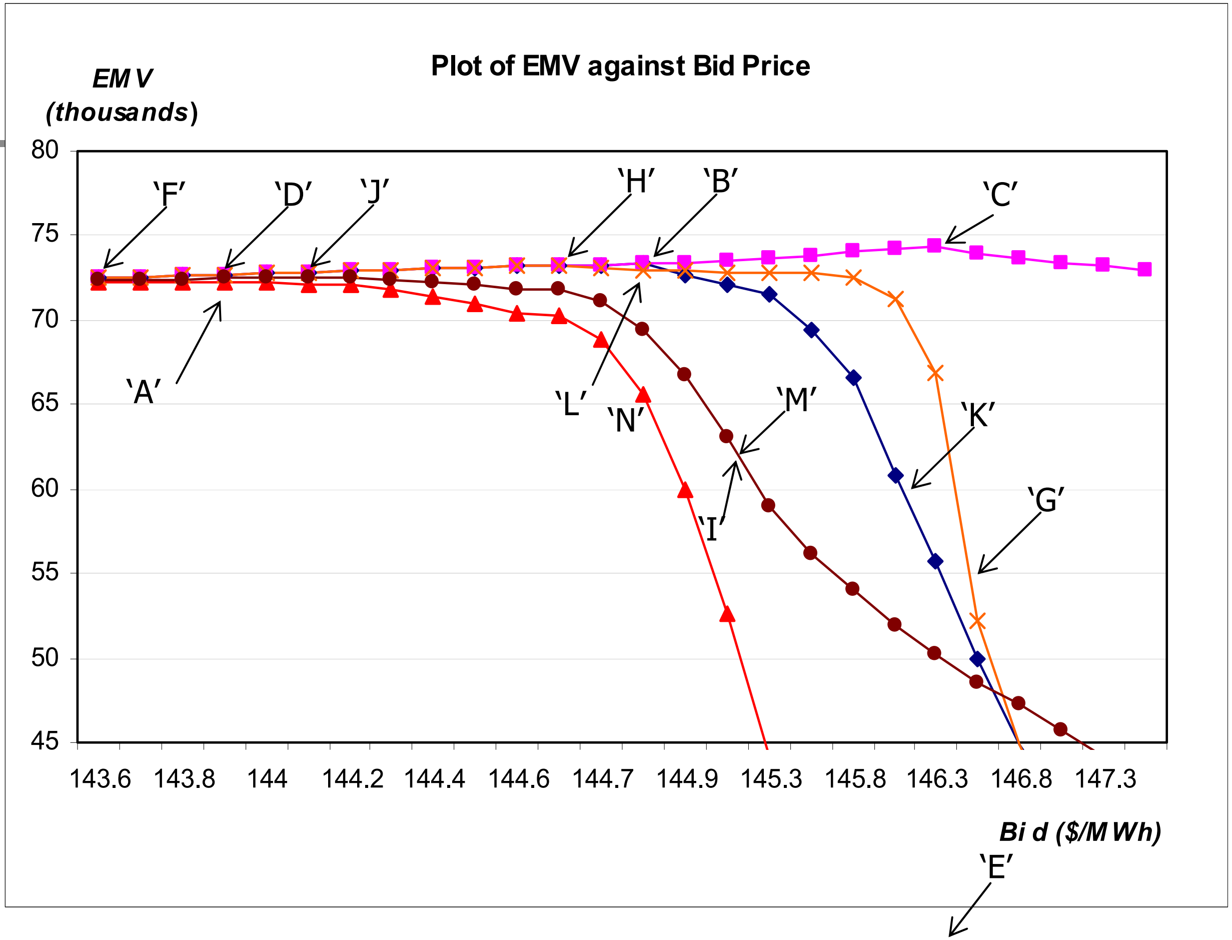
What if the pessimistic curve actually applies?

•'E' determines the EMV

•'A' would have been a better bid

•Suboptimality is EMV(A)-EMV(E)

Attributes of the Set of EMV Curves III



Suppose intermediate curve 'k' is assumed to apply…

•'B' determines the best bid

What if the pessimistic curve actually applies?

•'N' determines the EMV

•'A' would have been a better bid

•Suboptimality is EMV(A)-EMV(N)

•If the optimistic curve actually applied, suboptimality would be EMV(C)-EMV(B)

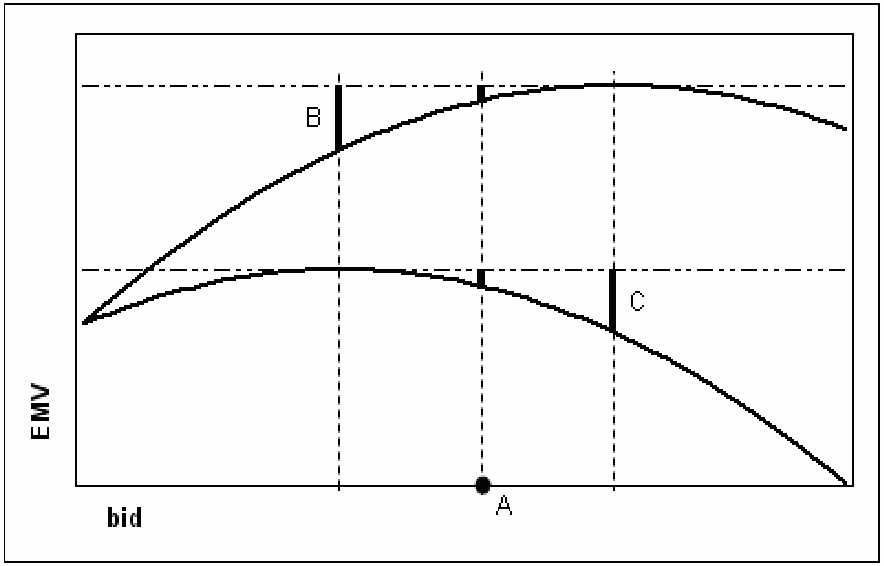
Decision Criteria Based on Analysis of Extreme Scenarios

#1: Minimize potential suboptimality

- Find the bid such that

  assuming the wrong EMV curve

  …is least serious



- Segment B shows a serious shortfall
- Segment C likewise
- The best choice is bid A

Some Other Decision Criteria

#2: Maximize the Minimum Possible EMV

#3: Maximize the Maximum Possible EMV

Criteria based on averaging scenarios

#4: Use Horizontal Averaging (curve G & next slide)

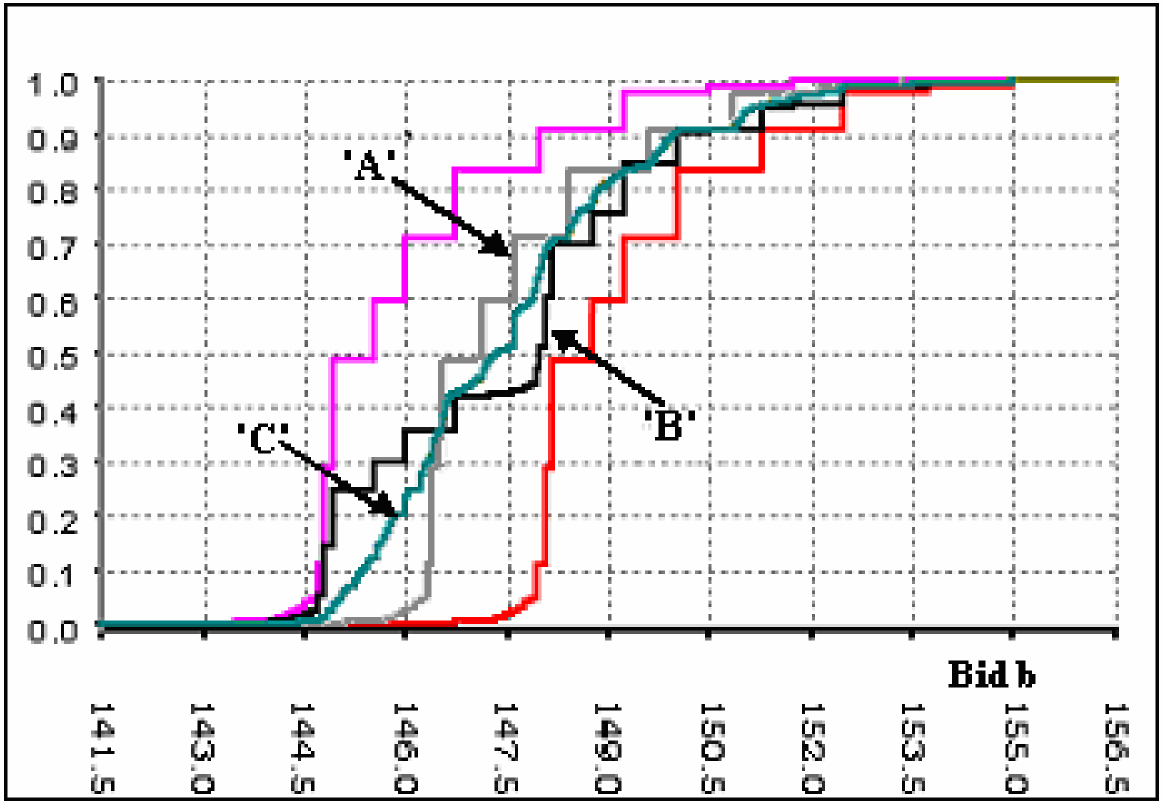
#5: Use Vertical Averaging (curve I)

#6: Use Fixed-Point Averaging (curve K)

#7: Use Vertical Averaging of the EMV Curves (curve M)

#8: Use More Information for Wiser Averaging

Knowledge of GenCo 2's Bid for power from its Generator G_{2A}



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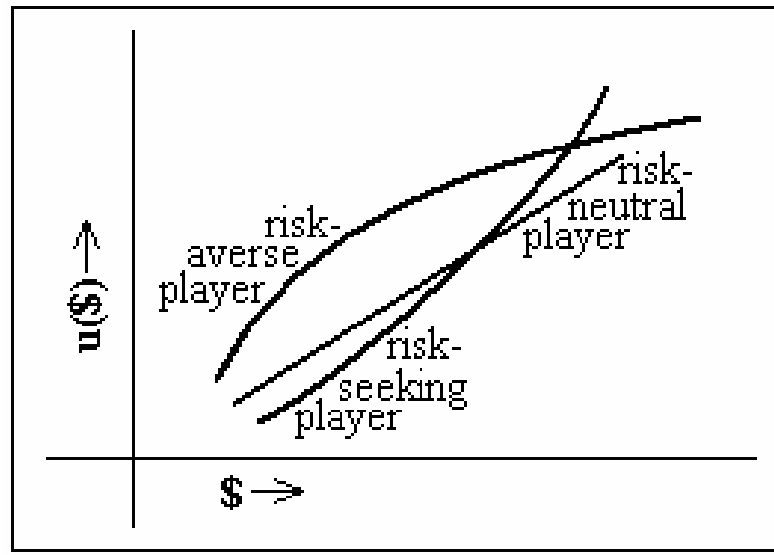
Decision Criteria Based on Risk

#9: Use EMV Utility Instead of EMV

First identify a risk profile curve

- Next, transform each EMV curve
  - For each bid value *b*
    - Read off its EMV on *y*-axis (back 4)
    - Consult utility function or graph
    - Find location of EMV on $-axis
    - Read off its utility on *u*-axis
- The EMV curves have been
  - transformed into utility curves

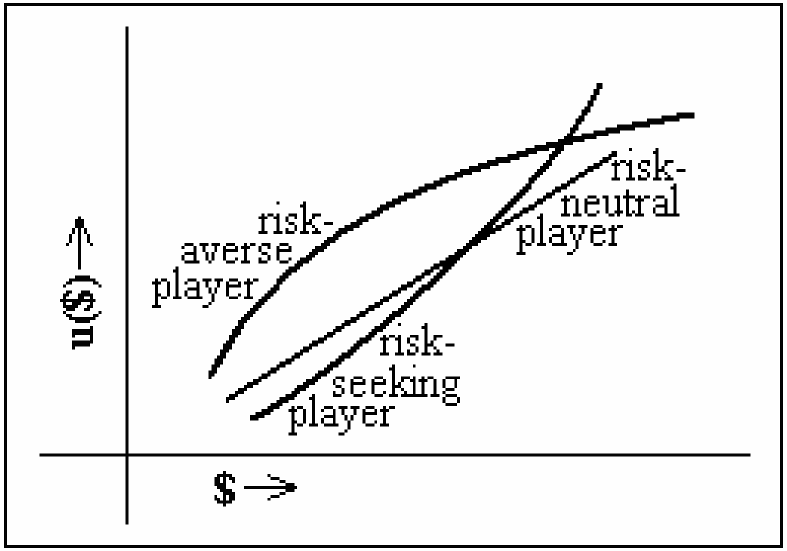


Now, apply decision criteria to utility curves instead of to EMV curves

This makes sense when the risk of a particular auction is of no concern

Decision Criteria Based on Risk II

#10: Convert Bid to Utility Instead of EMV



Let utility of bid b be u_b

Let monetary value of winning the auction be v_b

Then $u_b=(1-p)*u(v_b)+p*u(0)$

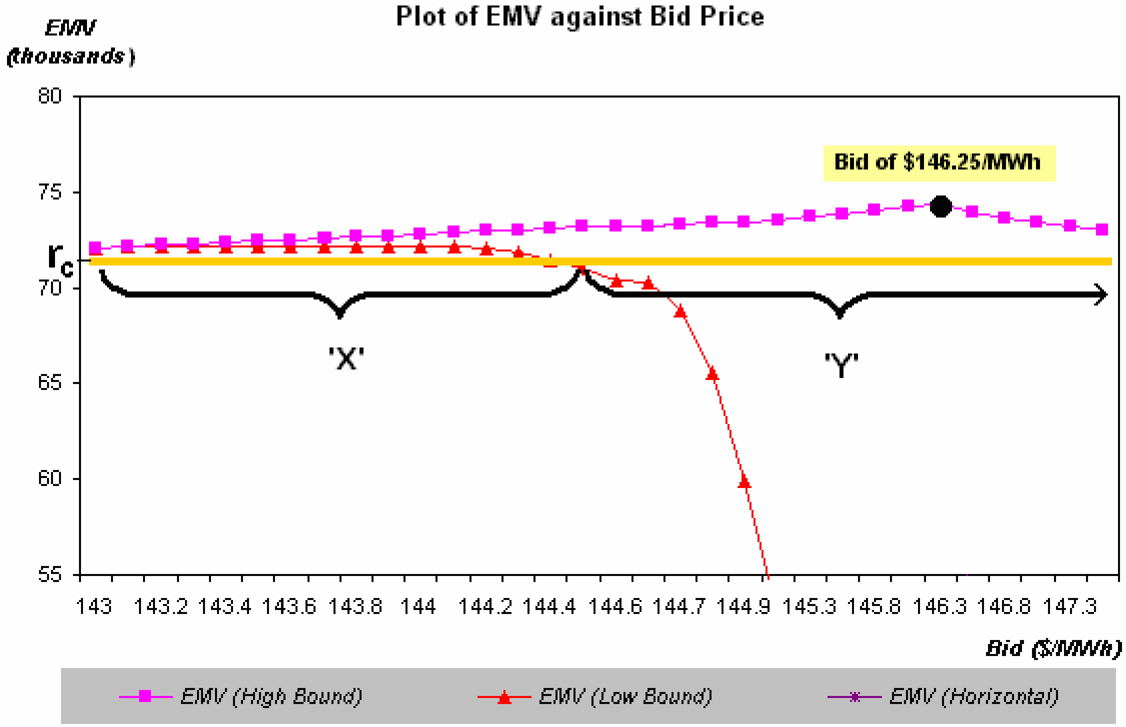
Use this to create utility curves instead of EMV curves

Now, apply decision criteria to utility curves

(instead of EMV curves or EMV utility curves)

Decision Criteria Based on Risk III

- **#11: Apply VaR and PaR with Bernoulli Processes**
  - This will constrain the admissible range of bids
  - At the beginning of the time period
    - Statistical smoothing may prevail
  - At the end of the time period
    - Few auctions are left
    - If things have gone well, can take extra risks now
    - If not meeting VaR is a danger
      - Must bid conservatively *even if this does not maximize EMV*



Decision Criteria Based on Risk III

#12: Use Information Gap Theory

Info Gap Theory (Ben-Haim 2001) could be an entire talk

- **We can note basic intuitions more briefly**
- **Notice the high & low EMV curves shown earlier**
- **Given: minimum acceptable expected reward level r_c**
- **r_c implies ranges of bid values X, Y**
- **Bids in range X are admissible**
- **Bids in range Y are inadmissible**

Future Work

- Integrate the multiple decision criteria into a decision process
  - Example: Analytic Heirarchy Process
    - (T. L. Saaty, 1980)
- Extend modeling to more closely match real-world complexities
  - Example: equilibrium bidding
  - Example: multiple players
- And more!