Nodal Pricing and MW-mile Methods for Distribution: Have We Uncovered Missing Markets or Elements for Wholesale Power Markets?

Presented at the
Harvard Electricity Policy Group
42nd Plenary Session
March 2, 2006 La Jolla, California

Paul Sotkiewicz, Director Energy Studies
Public Utility Research Center
University of Florida
paul.sotkiewicz@cba.ufl.edu

Acknowledgements

- The presentation is based on joint work with **Jesus Mario Vignolo.**

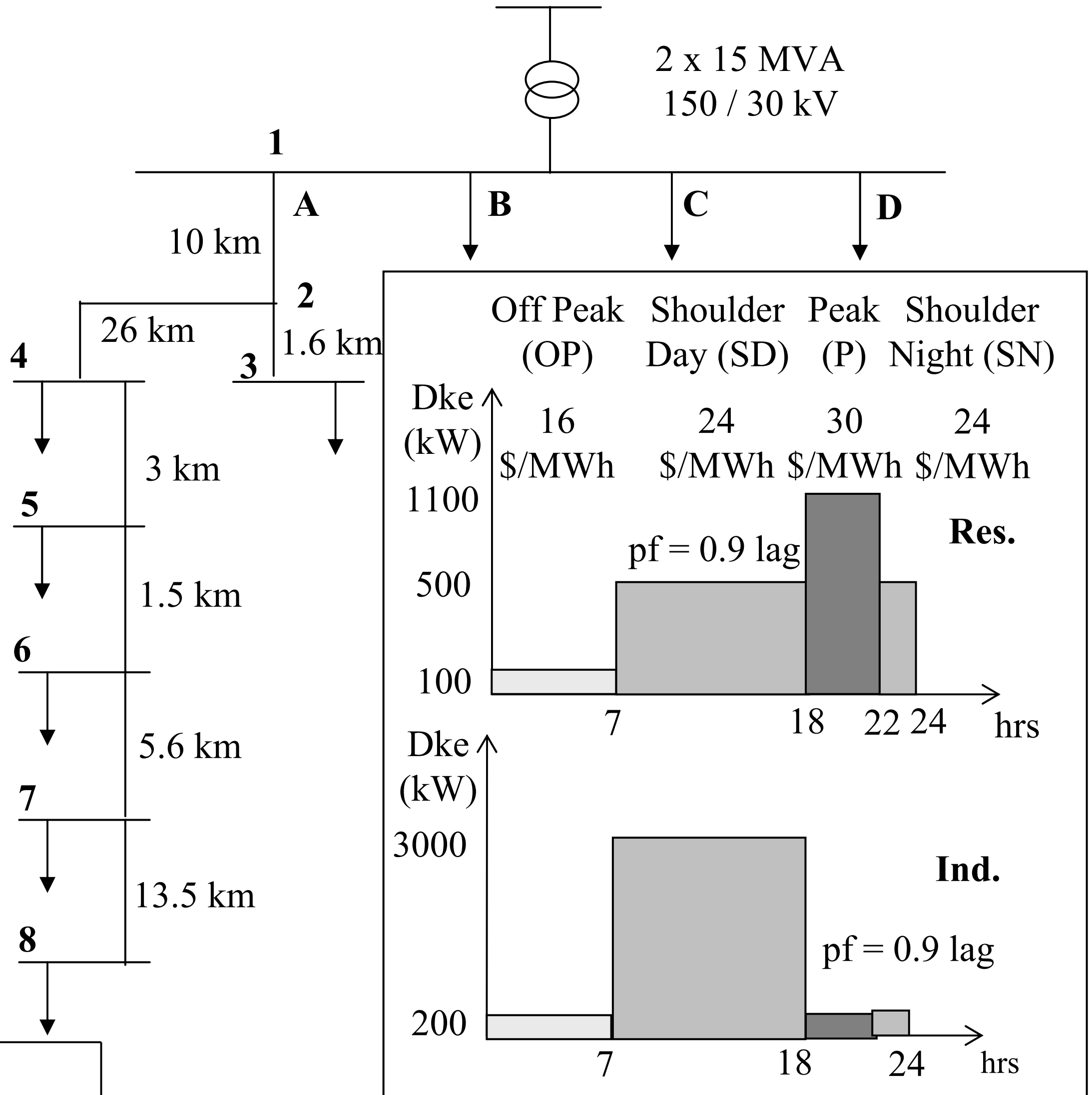
- “Nodal Pricing for Distribution Networks: Efficient Pricing for Efficiency Enhancing DG” accepted as a Letter January 2006 to be published in *IEEE Transactions on Power Systems.*
- “Allocation of Fixed Costs in Distribution Networks with Distributed Generation” accepted at *IEEE Transactions on Power Systems* October 2005.

- Working paper versions can be found at *http://www.ksg.harvard.edu/hepg/* and *http://bear.cba.ufl.edu/centers/purc/primary/psotkiewicz.htm*

Why Nodal Pricing for Distribution?

- Provides better incentives for the siting of distributed generation (DG) and other distributed resources (DR).
  - Rewards sources that reduce line losses and line utilization
  - Penalizes those sources that increase line losses and utilization
- Provides increased revenue source to DG and DR by getting the prices right rather than through subsidies or other *ad hoc* means.
- Current practices
  - Net metering?
  - Paid the same average price charged to loads.
  - No recognition for contributions to the system (positive and negative)
- Not as worried about the congestion component as most distribution systems are designed to avoid congestion.
  - But as system become increasingly loaded this becomes important

Example Distribution System and Loads



Comparison Undertaken: Nodal Pricing

- Option 1: Receive the price at the interface with transmission in each hour ignoring marginal losses in distribution.
- Option 2: Nodal pricing including marginal losses in distribution.
- 1 MW DG resource at Node 8 with lagging power factor of 0.95.
- Pricing both active and reactive power.
- Southern Cone context in terms of prices (based on natural gas…prior to the Argentine curtailments).

Results

Prices at Node 8				
	No DG		DG	
Time	P_{active}	$P_{reactive}$	P_{active}	$P_{reactive}$
OP	16.2976	0.1456	15.6928	-0.0512
SD	28.8336	2.6496	27.1704	1.9056
P	36.732	3.702	34.473	2.634
SN	25.9872	1.0176	24.8448	0.5832

DG Revenue		
Option 1: No Nodal	Option 2: Nodal	Percent Difference
188632	210448	12

Discussion and Implications for Wholesale Markets

1. Nodal prices at the distribution level (time and locational differentiation) brings the demand back into the wholesale market equation as a DR.
   - Demand will receive the same type of price signals as players at the EHV level and can react accordingly.
   - There will be shifts in cost burden as marginal losses and any congestion have been socialized at lower voltages.
   - Demand at lower voltages can be a player in the reserve markets more easily helping to equalize ancillary service prices across zones (NYISO) and make these markets more competitive.
   - Our results show that perhaps there is a market for reactive power as well as active power.

2. Nodal prices at the distribution level may induce more DG deployment.
   - DG adds to the potential supply of ancillary services ranging from reserves to voltage support to black start and adding supply to capacity markets and would help drive prices down to MC.
   - We assumed that there is no wholesale market price for reactive power, yet if there were opportunity cost prices (NYISO, PJM), the revenue accruing to DG would be even greater.

Discussion and Implications for Wholesale Markets

3. Operationally, the wholesale market would need to consider medium and lower distribution voltages in the market unit commitment and dispatch algorithms to avoid a “seams” problem at the interface between transmission and distribution.
   - May bring up jurisdictional fights between FERC and the states.
   - As long as there is close coordination to make that interface seamless distribution could operate separately from the RTO market.
4. Nodal pricing at the distribution level may lead to changes in transmission access charges with likely increases.
   - If demand responds to price and/or DG is deployed, the MWh flowing over the transmission system will decrease leading to higher per MWh charges for transmission access, all else equal.
   - Maybe a move toward fixed transmission charges based on use at peak?

Why MW-mile Methods for Distribution?

- Locational signals for the fixed cost portion of the system are desirable from a cost causality perspective.
  - Nodal prices cannot cover all of the fixed costs of the system.
  - Can be argued nodal prices may not provide a complete long-term signal.
- Charge customers based on their “extent of use”
  - Customer’s contribution to total flows on an asset (line, transformer).
- Unlike other implementations of MW-mile in transmission, compensate customers that, in effect, “create” more capacity via counterflow.
  - DG or DR located in the right spots can do this.
- Can provide financial incentives for service provided (more capacity) without subsidies.

Amp-mile Application

- Take the observation that distribution systems are designed to handle current flows (amps) rather than MW since voltages may fluctuate more at distribution levels.
- Follow up on Baldick's idea that thermal constraints in transmission are current driven rather than MVA drive.
- Consequently we use PIDFs (power to current distribution factors) to determine contributions to flows on lines.
  - We also factor in reactive power contributions.
- Extent of use for a customer at a particular bus of an asset is the (PIDF * use)/total current flow on the asset.

Charges under Amp-mile

- Here we will consider charges based on the coincident system peak.
  - One could consider the peak in different seasons or months as well.
- In our paper we will only consider locational charges for the used circuit capacity at peak. The cost of the unused capacity will be spread over all load based on peak consumption/generation on a non-locational basis.
  - We could have made all the charges on a locational basis for a stronger signal.
  - But perhaps more politically acceptable to not differentiate so much.
  - Argument that the excess capacity benefits all in a reliability sense?
  - Property that when the asset is fully loaded, all charges are locational!

Amp-mile Charges

- Charges are directionally based:
  - If contributing to flows in the direction of net flow, the charge is positive
  - If providing flows opposite the net flow, the charge is negative and the resource is paid for creating capacity in effect.

- Locational Charge for use of an asset equals:

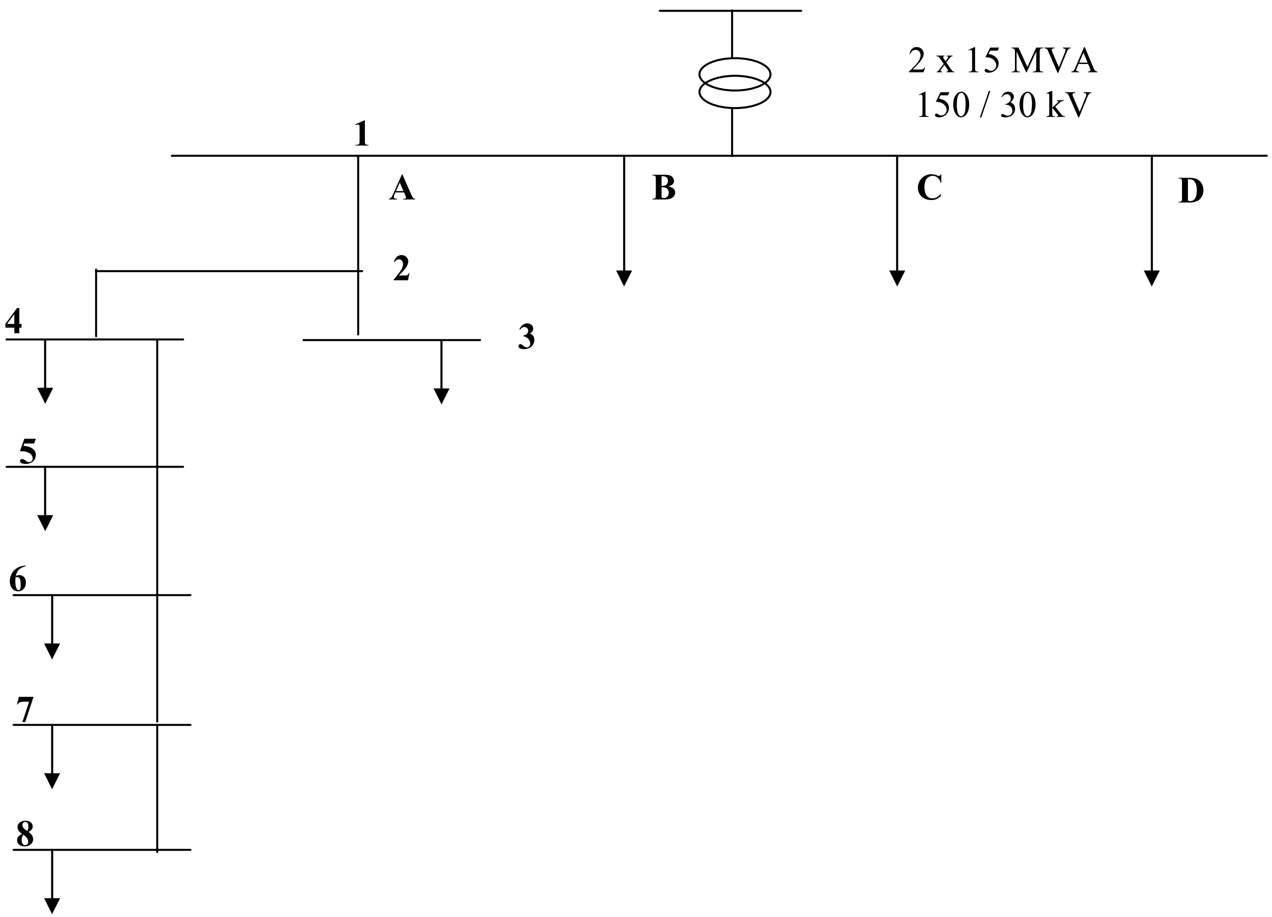
Extent of use * (levelized cost / asset utilization at peak)

- Again, the greater the utilization, the stronger the locational signal.

Comparison Undertaken: Amp-mile

- Option 1: Per MWh charges used for the recovery of fixed network costs
- Option 2: Amp-mile method calculated at coincident system peak.
- 1 MW DG resource at Node 8 with lagging power factor of 0.95.
- Accounting for both active and reactive power.
- Southern Cone context in terms of prices (based on natural gas…prior to the Argentine curtailments).
- Uruguayan context in terms of load profiles for residential and industrial consumers with real data from UTE.
- Applied that data to a simplified distribution system.

Example System



Total Yearly Charges per MWh Basis, No Locational Component (no DG)

Bus	3	4 (industrial)	5	6	7	8	Total
Total Charges	20146	33909	20146	20146	20146	20146	134640

- $5.40/MWh is the average cost for this example system
- We assume DG if it were located on the system would be exempt from network charges.
  - But if it were not, the revenue difference will be even greater!

Total Yearly Charges Amp-mile (no DG)

Bus	3	4 (industrial)	5	6	7	8	Total
Total Location	827	36230	3039	3145	3535	4455	51230
Total Non-Location	4675	60035	4675	4675	4675	4675	83410
Total	5502	96265	7714	7820	8210	9130	134640

Total Yearly Charges Amp-mile (w/DG)

Bus	3	4 (industrial)	5	6	7	8 (load)	8 (DG)	Total Load
Total Location	819	35200	2940	3004	2668	1764	-4472	46395
Total Non-Location	5196	66737	5196	5196	5196	5196	------	92717
Total Load	6015	101937	8136	8200	7864	6960	-4472	139112

Discussion and Implications for the Wholesale Market

- Moving to a coincident peak, locational charge result in lower charges for residential consumers, but larger for industrial consumers.
- But, because fixed capital is taken out of the variable cost for power, this should be a more efficient pricing mechanism.
  - Multi-part pricing
- In essence, we recognize another service akin to relieving congestion and reducing losses in the short term, creating effectively more capacity in the long term.
- While everybody pays more for the network with DG, capacity is greater.
  - Losses will also be less!
  - Examining the trade-off is the next step.

Discussion and Implications for the Wholesale Market

- In terms of attracting DG and DR, an Amp-mile/MW-mile scheme provides a greater revenue stream bringing resources to the market as we discussed previously under nodal pricing.
  - The difference is even greater if one compares the proposed regime to one where DG pays in spite of creating counter flows and capacity.
- Perhaps allows DG and DR to compete with merchant transmission for capacity additions?

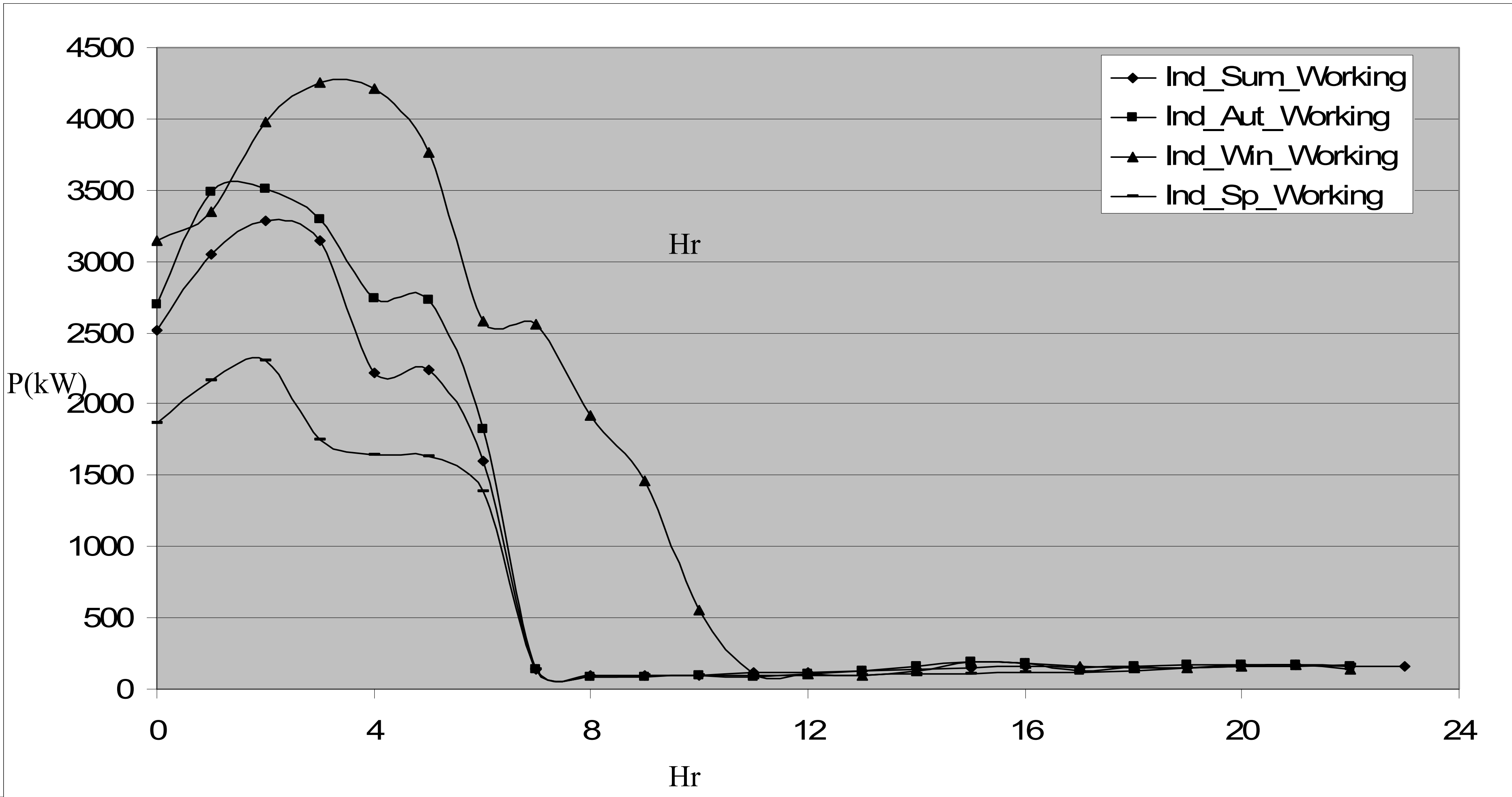
Concluding Thoughts

- Nodal pricing and MW-mile methods in distribution probably indicate some missing elements in wholesale markets…
  - Hello, demand response! Markets should not be the sound of one hand (supply) clapping.
  - Additional supply for energy and ancillary service markets.
  - All brought about by getting the prices and rate design “right”.
- Are there missing markets?
  - Is there a market for reactive power? Or is it implicit in real power markets?
  - Is there a market for “new transmission/distribution” capacity?
- Operational and Implementation issues
- Looking forward:
  - Pinning down trade-offs between capacity and losses when combined
  - Is this a way to deal with the EPAct 2005 desire to reduce congestion costs without increasing rate of return “incentives”?

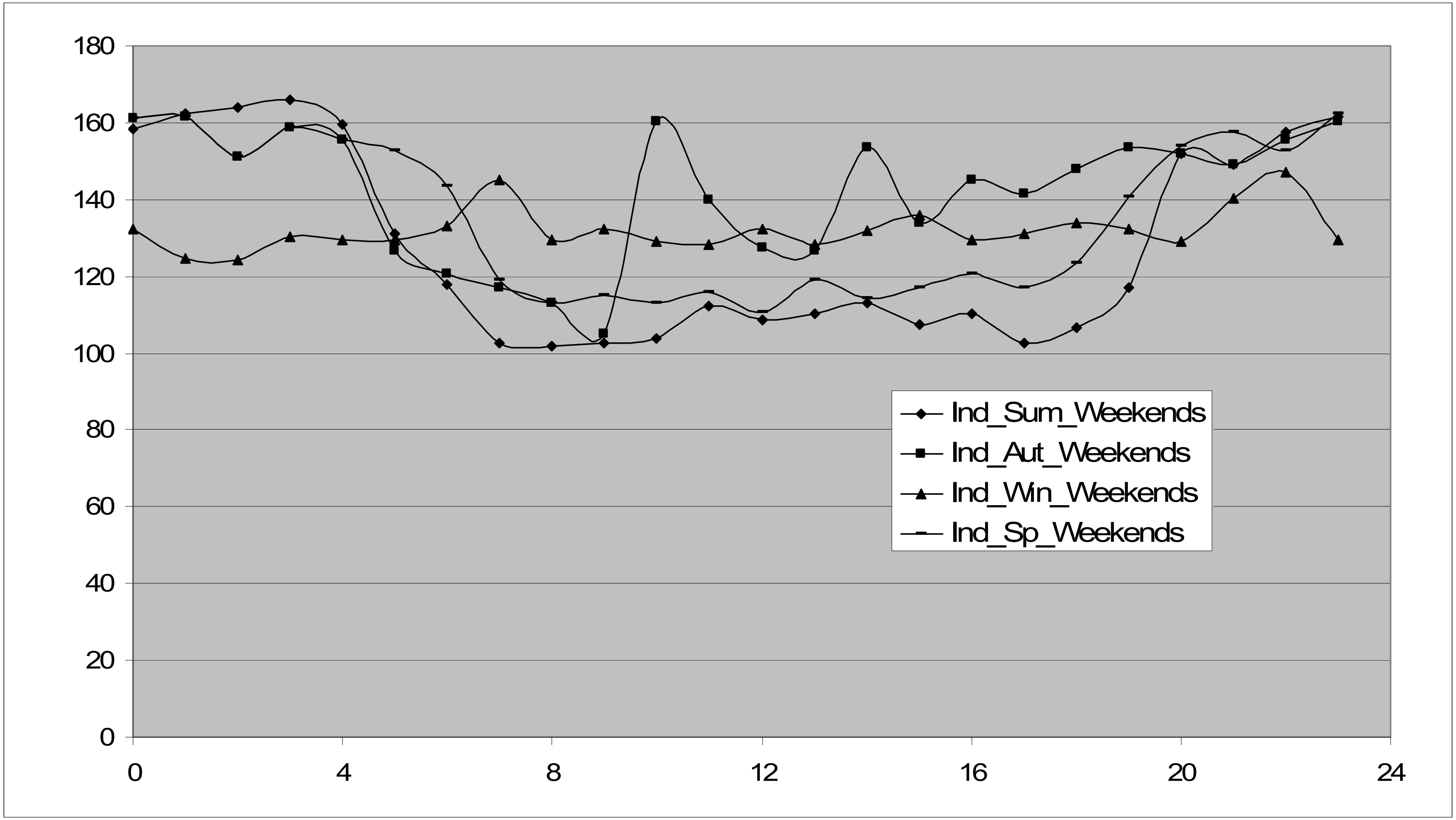
Appendix: Load Profiles for Amp-mile Case

P(kW)

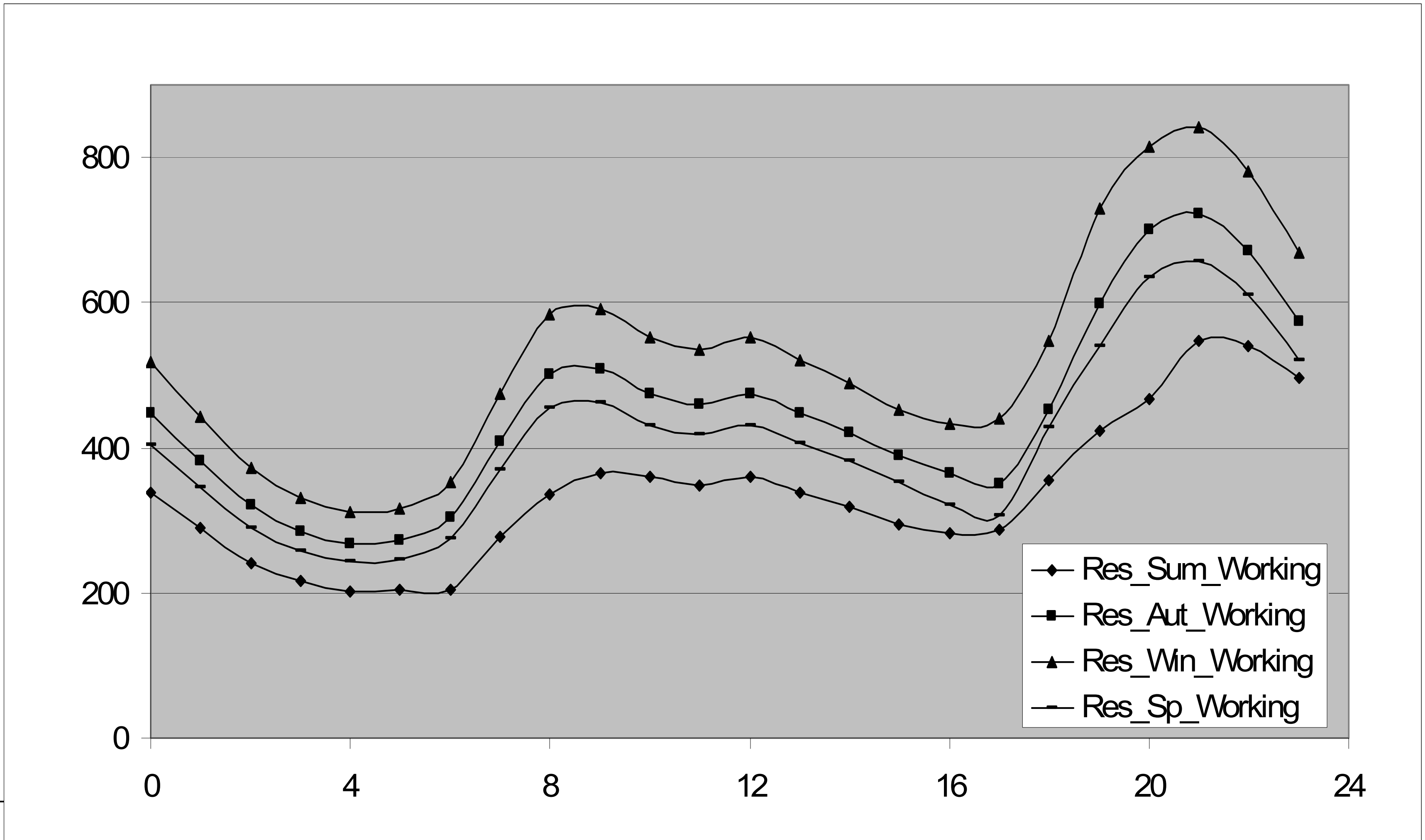
Industrial Load Weekdays



Industrial Load Weekends



Residential Load Weekdays



Residential Load Weekends