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Two-Sided Electricity Markets: Self Healing Systems

by

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Hypothesis:

Reduce Probability and Duration of Catastrophic, Region-wide Collapse of Electricity System by Exposing Customers to Real-Time Prices (Costs).

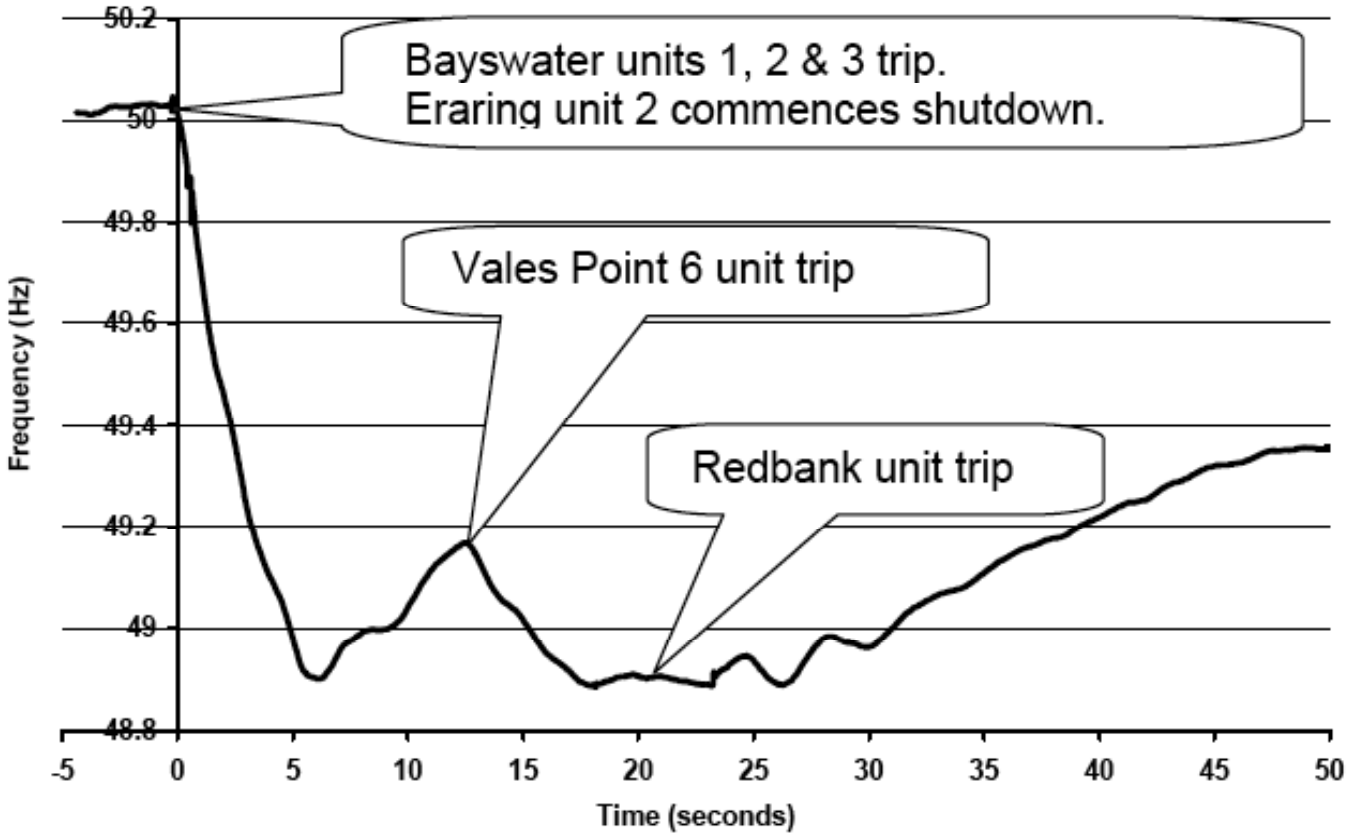
Background:

1. Nature is our worst enemy.
2. Widespread blackout is a photo-opportunity

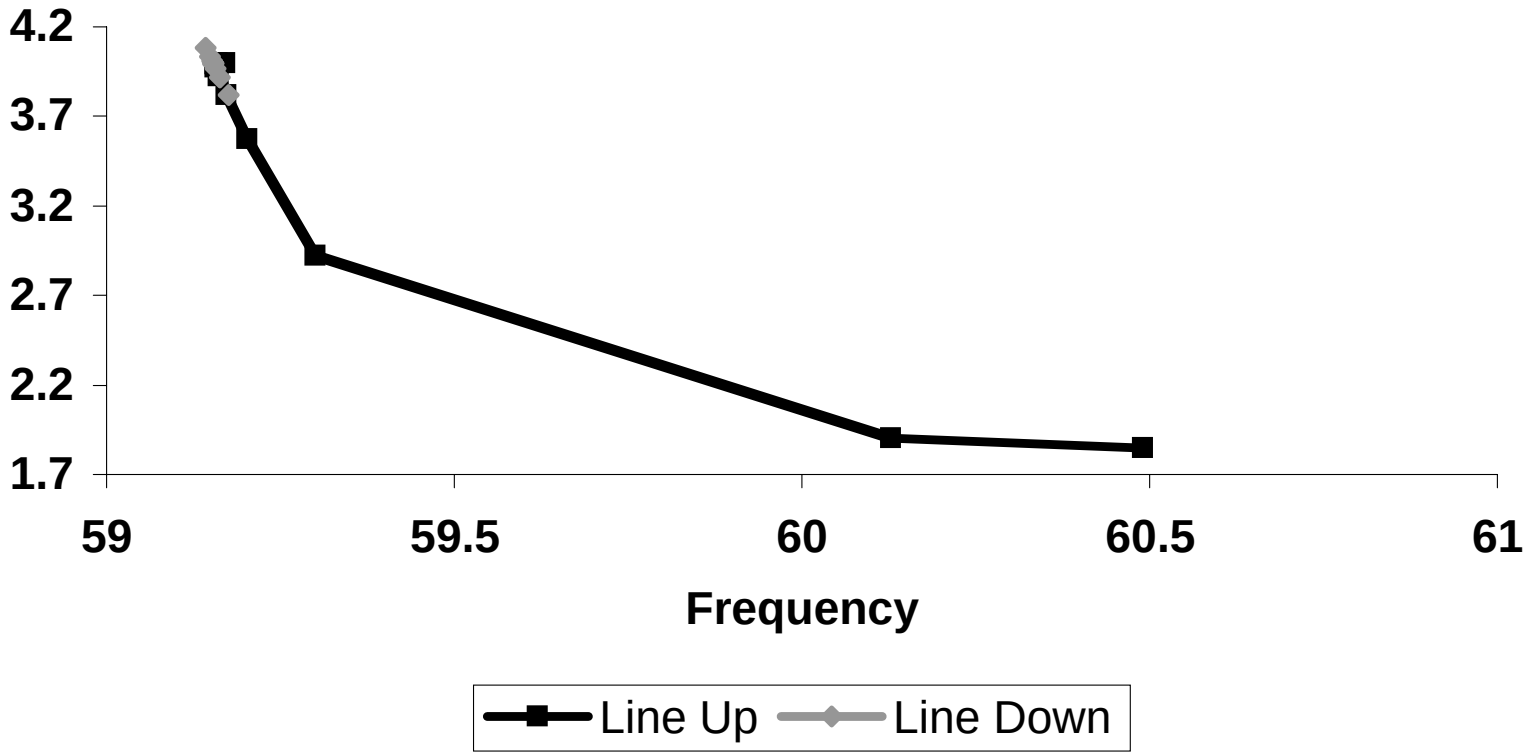
   --- but ---

3. Most blackouts are short-lived and therefore impose relatively small social costs.

Frequency Response to System Failure



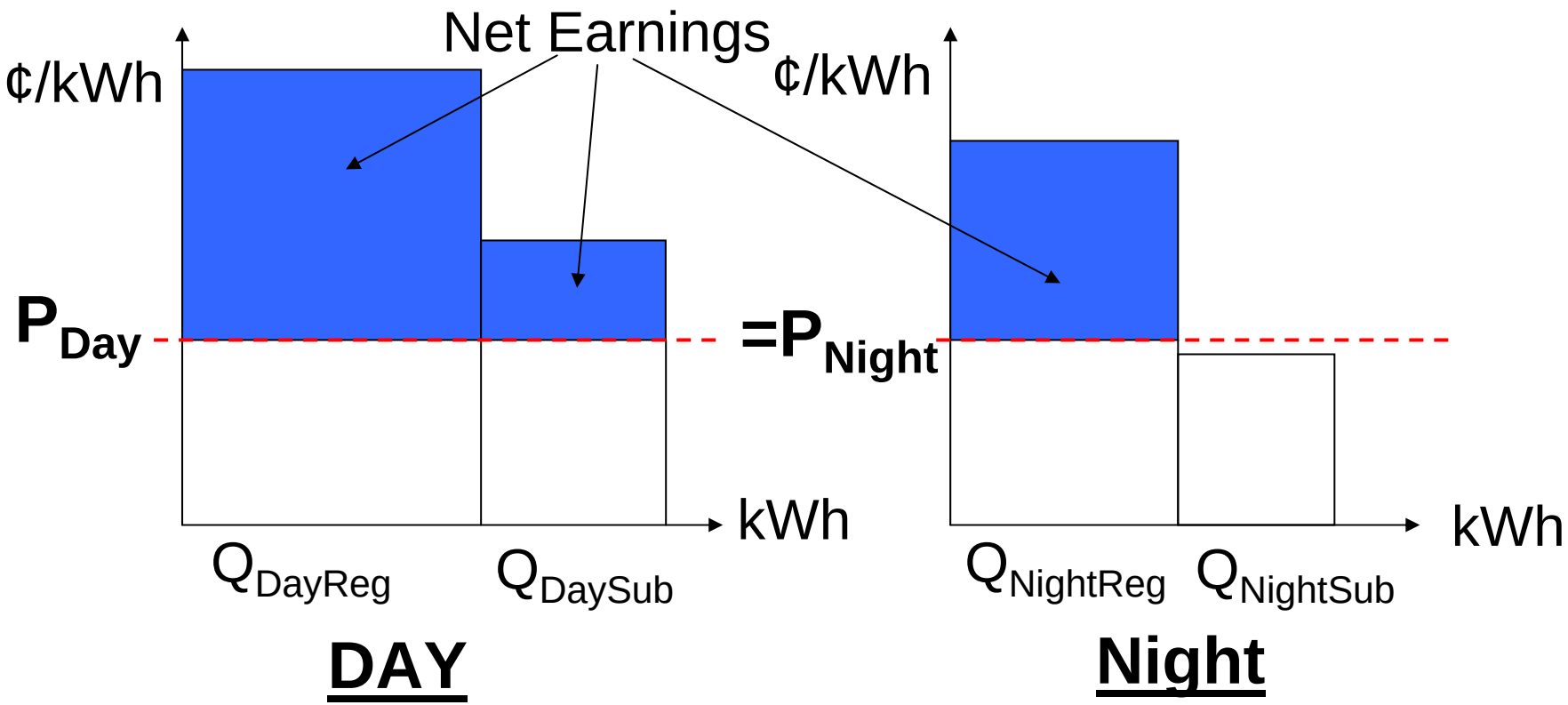
Australian Generation-Loss Experience: System Frequency Over Time (Aug. 13, 2004)



Relationship of Price to System Frequency in a Simple Three Bus Simulated Power System

Experimental Results at Cornell

(Illustration of Buyer's Problem)



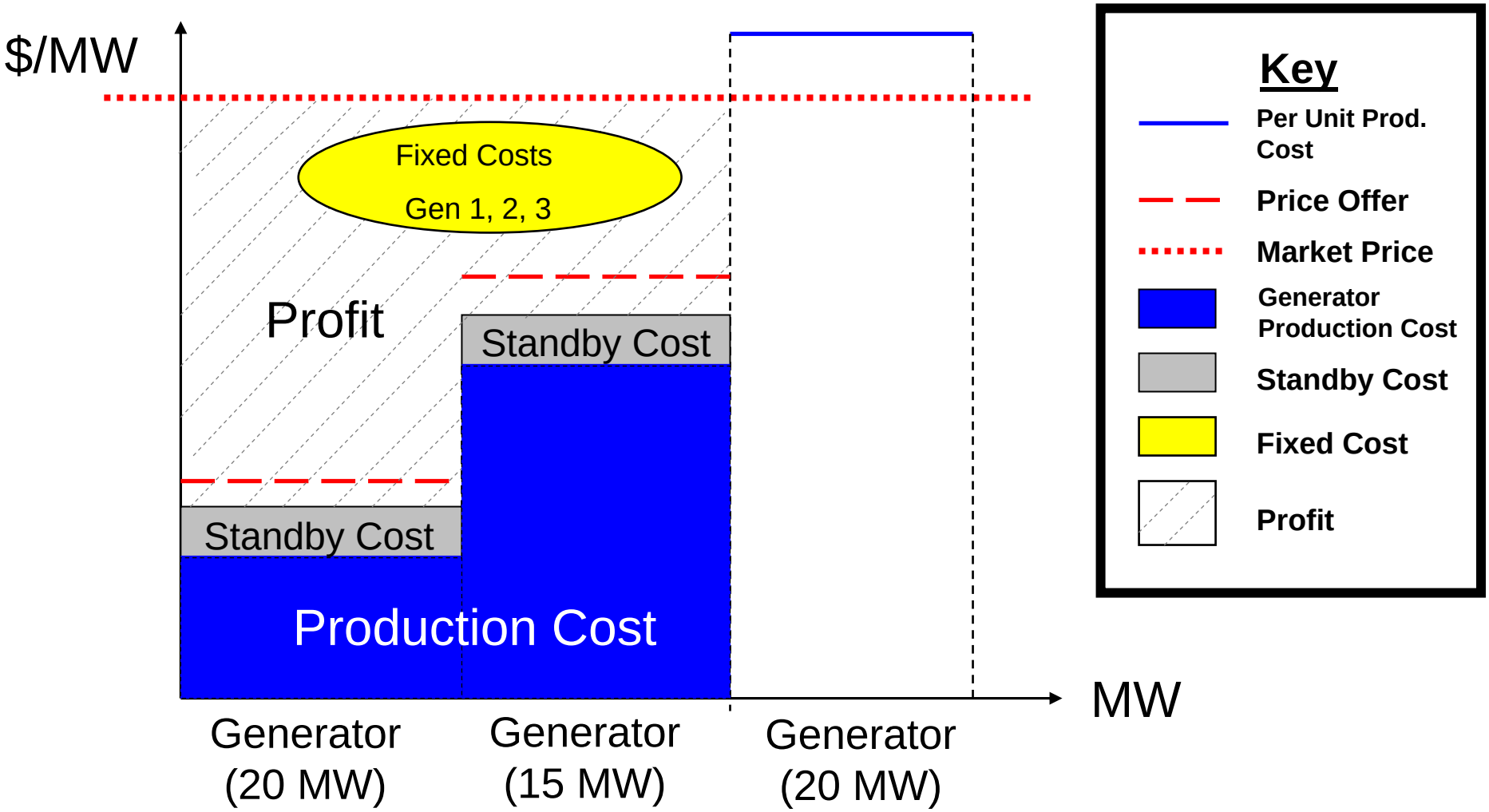
In this Example: $Q_{Day} = Q_{DayReg} + Q_{DaySub}$

$Q_{Night} = Q_{NightReg} + 0$

$Q_{DaySub} + Q_{NightSub} \leq Q_{SubMAX}$

Experimental Results at Cornell

(Illustration of Seller's Problem)



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Market Effects

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Two-Sided Experiments: Overall Efficiency for Combined Trials

1. Deviations Re-Stated as % of FP Revenues without Regulation:

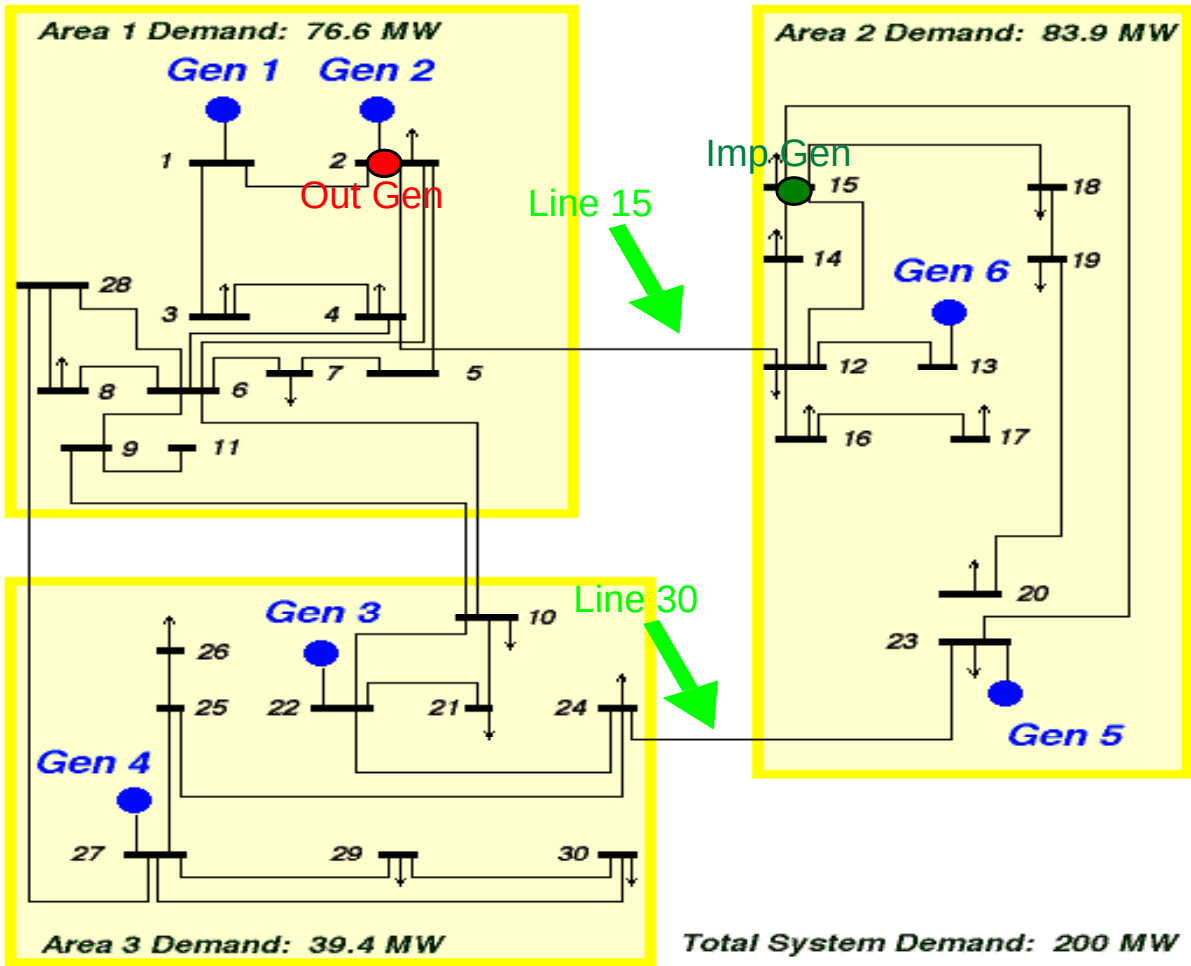
	% Added Consumer Value	% Changes Supplier Profit	Combined Change
RTP	9.02	-6.99	2.02%
DRP	13.86	-17.52	-3.67%
Social Optimum (as comparison)	29.32	-22.57	6.75%

2. Statistically Valid Differences in Behavior from FP Results (@ .95 level):

	RTP vs. FP		DRP vs. FP	
	Consumers	Sellers*	Consumers	Sellers*
Value/Profit	+	—	+ ?	—
Quantities Bought/Sold:				
Days	—	— ?	—	—
Nights	+	+ ?	—	+ ?

*Note: With fewer sellers, statistical significance is harder to attain.

Power Web Simulated Electricity Network with Monitored Lines



Implied Line and Generation Capacity Requirements by Market Treatment: Simulated Results

Regime	FP	DRP	RTP	REG	SO
Sum Across All Lines in the System of Maximum Absolute Value in Flow (MW) Across 22 Time Periods for Each of 39 Lines					
Average All Trials 1-30	649.57	588.74	604.03	645.15	604.76
% Difference from REG	**0.7%**	**-8.7%**	**-6.4%**	**0.0%**	**-6.3%**
Avg. Difference from REG	4.42	(56.41)	(41.12)	-	(40.40)
Paired T-Statistic	2.32	(6.93)	(10.33)	-	(20.48)
P-Value	0.027	0.000	0.000	-	0.000
Summary of System Load (MW)					
Average System Load All Trials 1-30	178.58	158.56	172.43	178.58	176.14
% Difference from REG	**0.0%**	**-11.2%**	**-3.4%**	**0.0%**	**-1.4%**
Max System Load All Trials 1-30	275.00	275.00	254.01	275.00	252.00
% Difference from REG	**0.0%**	**0.0%**	**-7.6%**	**0.0%**	**-8.4%**

Operating Implications: Statistical Relationship Between Line Flows and System Load

		Results with Active Participants			
	Social Optimum	(Reg. Regime) Fixed Price with Regulated Sellers	Fixed Price	Demand Reduction Program	Real Time Pricing
Regression Results for Tie Line 15					
Intercept	40.1779	39.1761	17.9780	29.9462	33.0568
Std Err	3.0375	2.1514	3.1385	3.8662	3.5013
Slope Coefficient	**(0.1982)**	**(0.1901)**	**(0.1025)**	**(0.1789)**	**(0.1909)**
Std Err	0.0167	0.0116	0.0168	0.0236	0.0197
R-Squared	**0.7701**	**0.8657**	**0.4695**	**0.5777**	**0.6906**
F-Statistic	140.6651	270.7614	37.1714	57.4517	93.7394
P-value	0.0000	0.0000	0.0000	0.0000	0.0000
Regression Results for Tie Line 30					
Intercept	(17.5262)	(18.5527)	(9.1573)	(13.9666)	(17.5818)
Std Err	1.5631	1.7259	2.4566	3.0202	3.1587
Slope Coefficient	**0.0751**	**0.0753**	**0.0437**	**0.0802**	**0.1024**
Std Err	0.0086	0.0093	0.0132	0.0184	0.0178
R-Squared	**0.6449**	**0.6111**	**0.2079**	**0.3104**	**0.4409**
F-Statistic	76.2617	66.0480	11.0260	18.9069	33.1193
P-value	0.0000	0.0000	0.0019	0.0001	0.0000

Note: The following linear regression equation was estimated with OLS.
Line Power Flow = Bo + B1 x System Load
N = 44 for all regressions

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Inferences (Hypotheses):

1. Link Between Price & Reliability (Frequency)
2. Confronting Customers with Price may Improve Reliability.
3. Frequency Detection Devices and Potential for Automated Response.
4. Advantages of Islanding during Widespread System Instability.
5. Australian Example (Friday the 13th):

   Extend to Many Customers
6. Get Customers Actively into the Electricity Game!