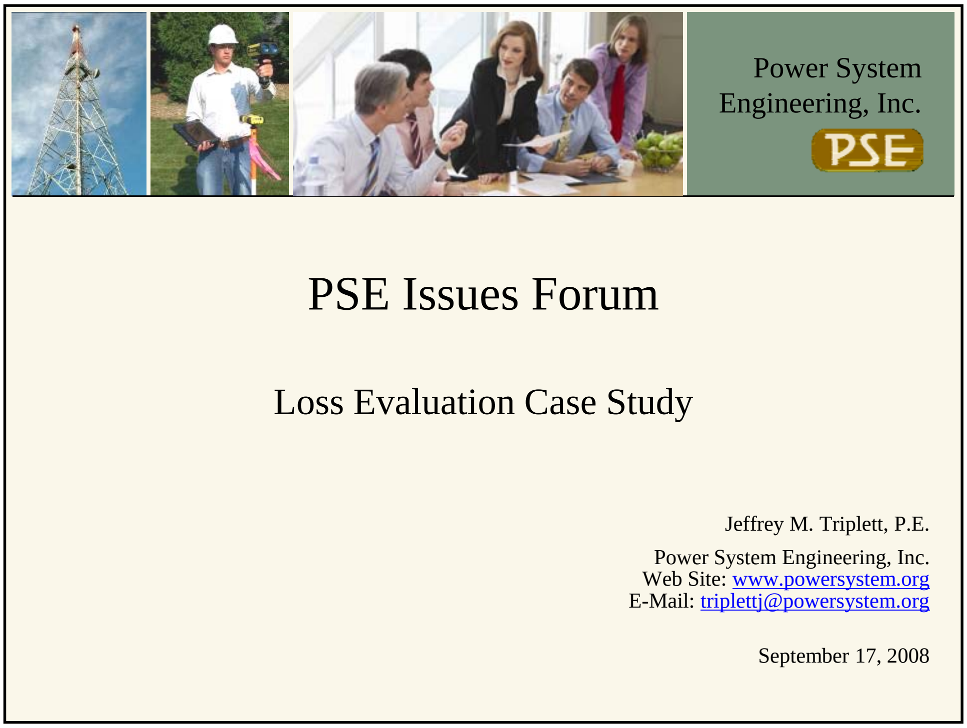

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PSE Issues Forum

Loss Evaluation Case Study

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September 17, 2008

Loss Evaluations

- Loss evaluations are very much dependent on the available data
- Historically, data has been limited
  - Annual data
  - Monthly billed kWh for each customer
  - Some non-coincident peak demand data for C&I customers
  - Basic system models
- Historically, demand losses were the primary concern
- Traditional loss evaluation methods were adequate
  - Estimate peak demand losses with an engineering model
  - Estimate energy losses using industry accepted approaches that rely heavily on assumptions and broad calculations

Loss Evaluations (cont.)

- Where we find ourselves today
  - High level of importance placed on energy efficiency
  - Hourly markets and transmission congestion charges
  - Myriad of different costing periods

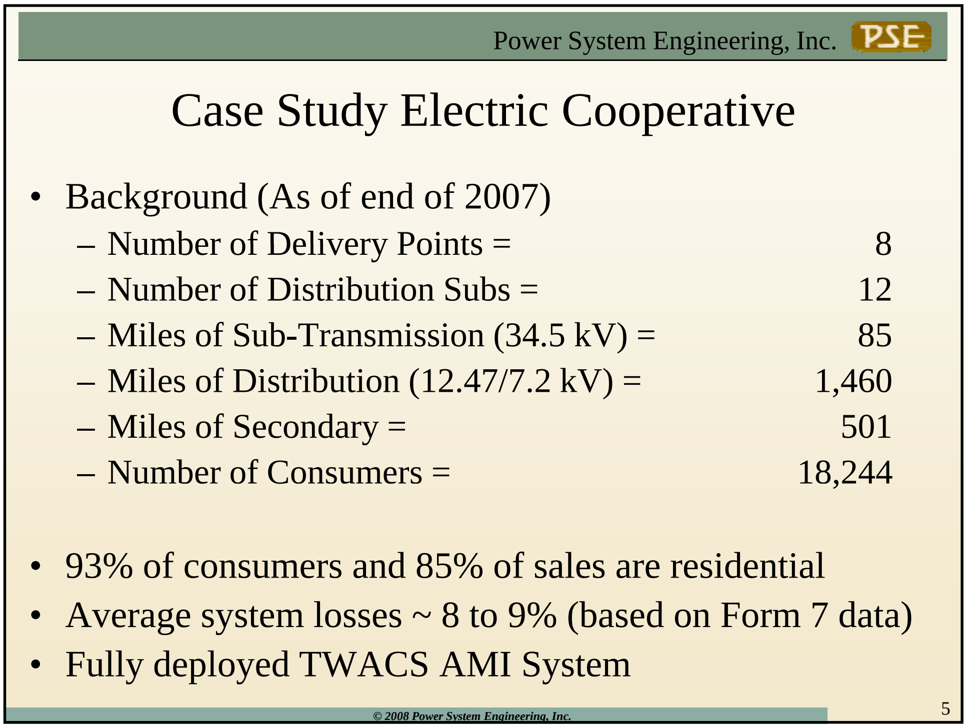
RESULT = energy losses are much more important today

- Better availability of data
  - ★ Interval load data from a deployed AMI system
  - Interval data from various locations across the system from a deployed SCADA system
  - ★ Very detailed electrical models

Goals of the Study

- Explore enhanced loss management evaluations that provide better understanding of the impact of both demand and energy losses using AMI interval load data and new approaches to estimate losses
- More accurately determine “when” and “where” losses are being incurred
- Develop recommendations to mitigate losses
  - Specific improvements to existing system
  - Recommendations relating to established policies and practices for new line extensions, transformer sizing, etc.

Develop repeatable process for application to other systems

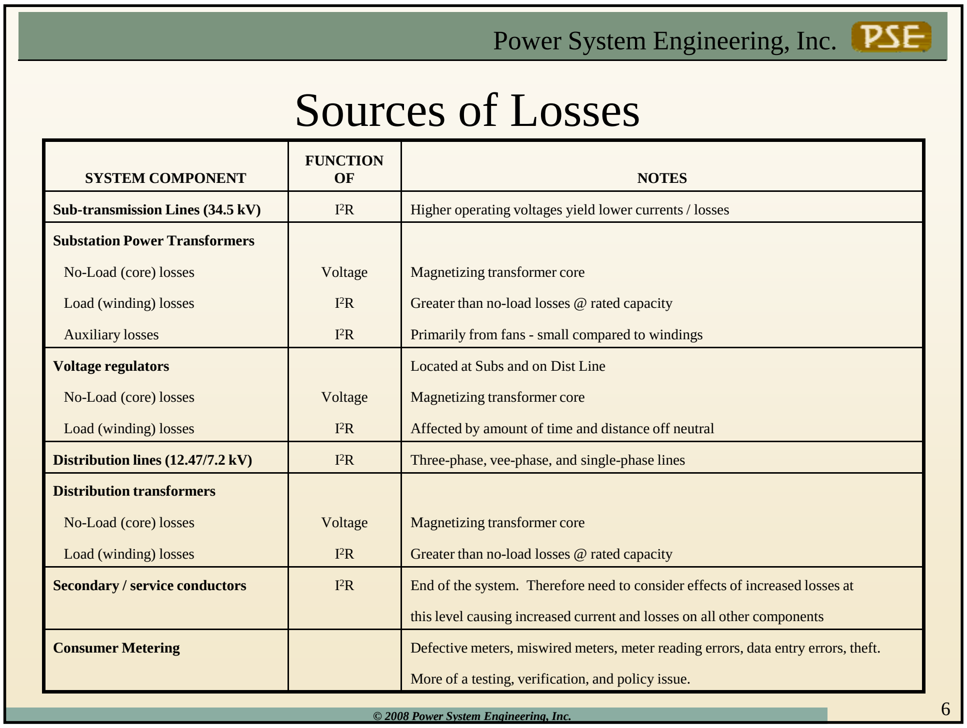


Case Study Electric Cooperative

- Background (As of end of 2007)

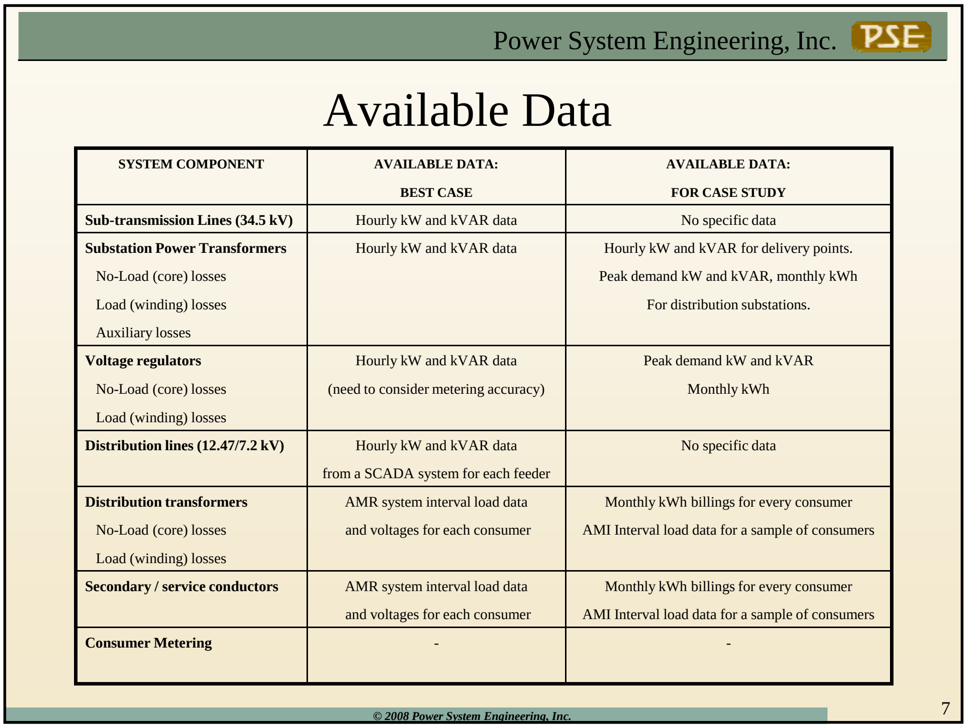
– Number of Delivery Points =	8
– Number of Distribution Subs =	12
– Miles of Sub-Transmission (34.5 kV) =	85
– Miles of Distribution (12.47/7.2 kV) =	1,460
– Miles of Secondary =	501
– Number of Consumers =	18,244

- 93% of consumers and 85% of sales are residential
- Average system losses ~ 8 to 9% (based on Form 7 data)
- Fully deployed TWACS AMI System



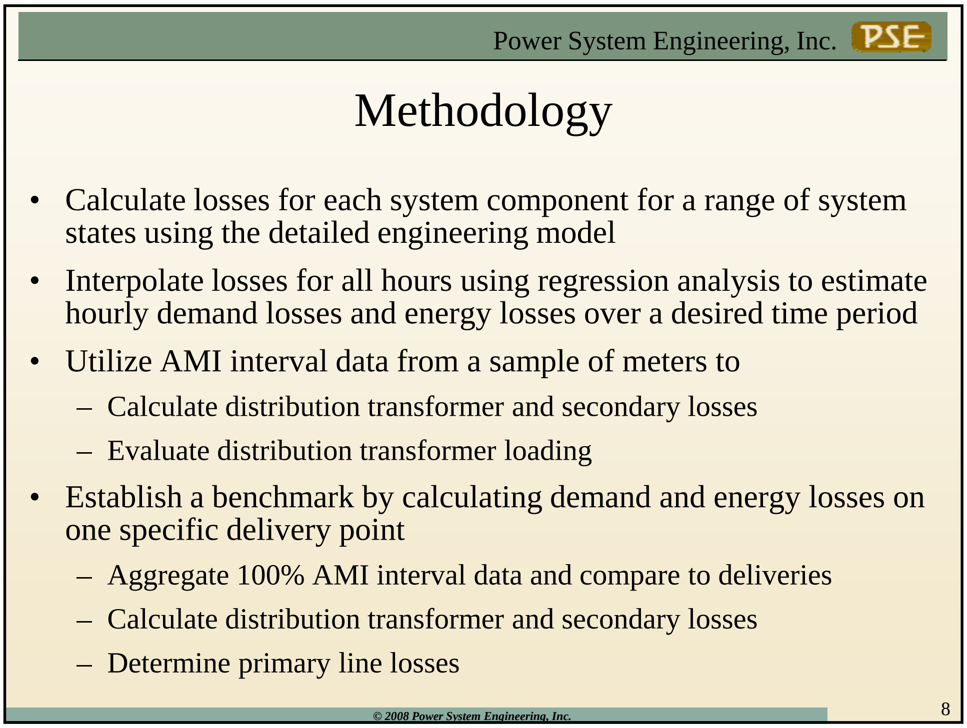
Sources of Losses

SYSTEM COMPONENT	FUNCTION OF	NOTES
Sub-transmission Lines (34.5 kV)	I^2R	Higher operating voltages yield lower currents / losses
Substation Power Transformers		
No-Load (core) losses	Voltage	Magnetizing transformer core
Load (winding) losses	I^2R	Greater than no-load losses @ rated capacity
Auxiliary losses	I^2R	Primarily from fans - small compared to windings
Voltage regulators		Located at Subs and on Dist Line
No-Load (core) losses	Voltage	Magnetizing transformer core
Load (winding) losses	I^2R	Affected by amount of time and distance off neutral
Distribution lines (12.47/7.2 kV)	I^2R	Three-phase, vee-phase, and single-phase lines
Distribution transformers		
No-Load (core) losses	Voltage	Magnetizing transformer core
Load (winding) losses	I^2R	Greater than no-load losses @ rated capacity
Secondary / service conductors	I^2R	End of the system. Therefore need to consider effects of increased losses at this level causing increased current and losses on all other components
Consumer Metering		Defective meters, miswired meters, meter reading errors, data entry errors, theft. More of a testing, verification, and policy issue.



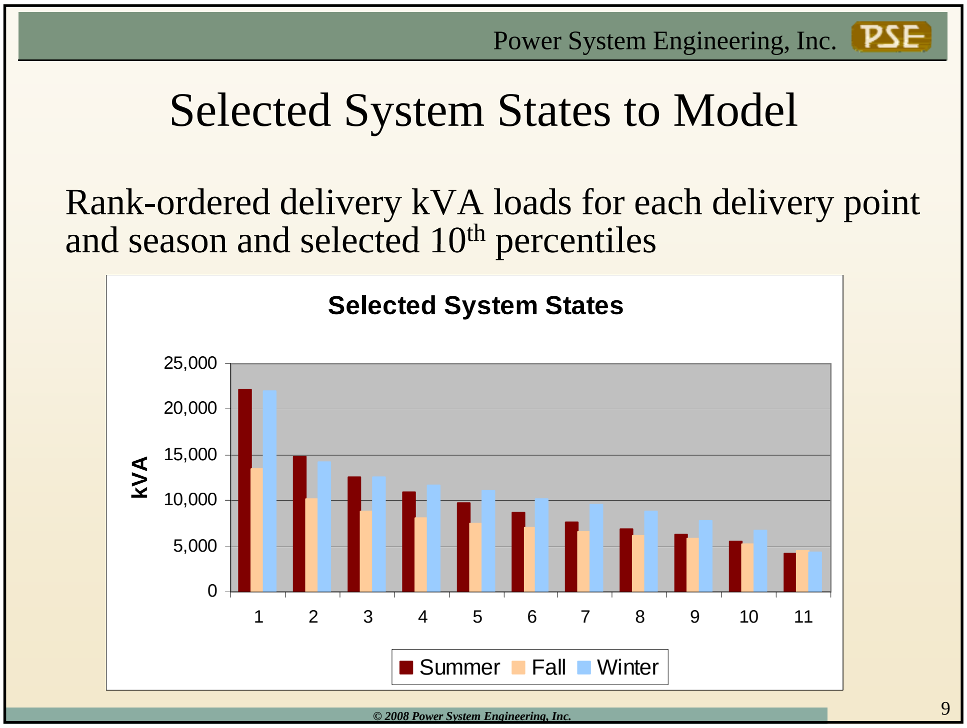
Available Data

SYSTEM COMPONENT	AVAILABLE DATA: BEST CASE	AVAILABLE DATA: FOR CASE STUDY
Sub-transmission Lines (34.5 kV)	Hourly kW and kVAR data	No specific data
Substation Power Transformers No-Load (core) losses Load (winding) losses Auxiliary losses	Hourly kW and kVAR data	Hourly kW and kVAR for delivery points. Peak demand kW and kVAR, monthly kWh For distribution substations.
Voltage regulators No-Load (core) losses Load (winding) losses	Hourly kW and kVAR data (need to consider metering accuracy)	Peak demand kW and kVAR Monthly kWh
Distribution lines (12.47/7.2 kV)	Hourly kW and kVAR data from a SCADA system for each feeder	No specific data
Distribution transformers No-Load (core) losses Load (winding) losses	AMR system interval load data and voltages for each consumer	Monthly kWh billings for every consumer AMI Interval load data for a sample of consumers
Secondary / service conductors	AMR system interval load data and voltages for each consumer	Monthly kWh billings for every consumer AMI Interval load data for a sample of consumers
Consumer Metering	-	-



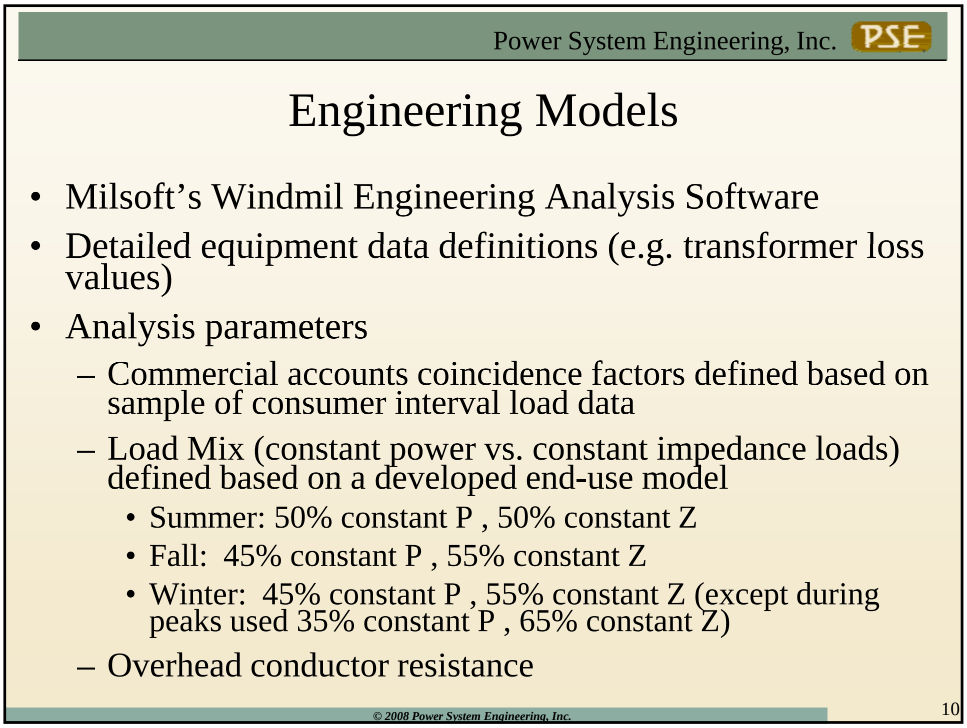
Methodology

- Calculate losses for each system component for a range of system states using the detailed engineering model
- Interpolate losses for all hours using regression analysis to estimate hourly demand losses and energy losses over a desired time period
- Utilize AMI interval data from a sample of meters to
  - Calculate distribution transformer and secondary losses
  - Evaluate distribution transformer loading
- Establish a benchmark by calculating demand and energy losses on one specific delivery point
  - Aggregate 100% AMI interval data and compare to deliveries
  - Calculate distribution transformer and secondary losses
  - Determine primary line losses



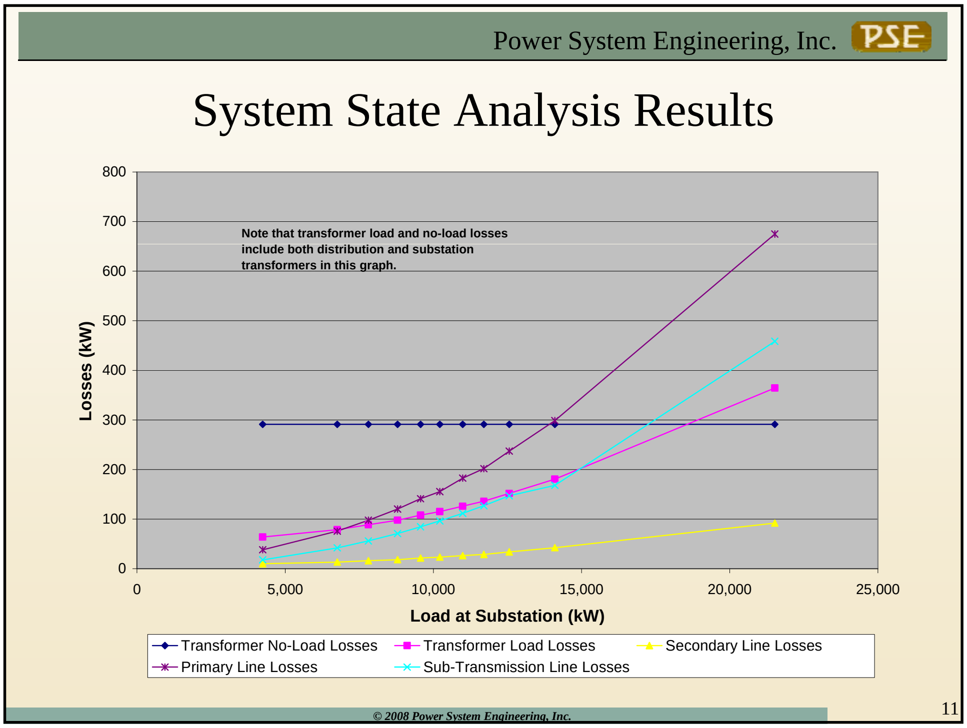
Selected System States to Model

Rank-ordered delivery kVA loads for each delivery point and season and selected 10th percentiles



Engineering Models

- Milsoft's Windmil Engineering Analysis Software
- Detailed equipment data definitions (e.g. transformer loss values)
- Analysis parameters
  - Commercial accounts coincidence factors defined based on sample of consumer interval load data
  - Load Mix (constant power vs. constant impedance loads) defined based on a developed end-use model
    - Summer: 50% constant P , 50% constant Z
    - Fall: 45% constant P , 55% constant Z
    - Winter: 45% constant P , 55% constant Z (except during peaks used 35% constant P , 65% constant Z)
  - Overhead conductor resistance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System State Analysis Results

Note that transformer load and no-load losses include both distribution and substation transformers in this graph.

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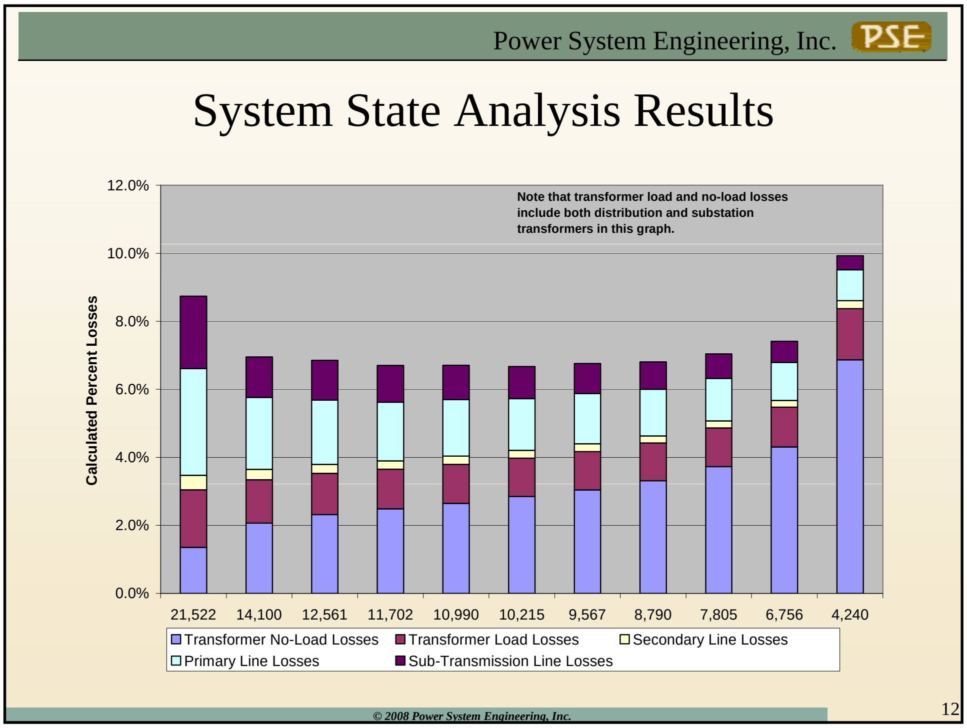
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System State Analysis Results

Note that transformer load and no-load losses include both distribution and substation transformers in this graph.

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Regression Equations

```
Dependent Variable: PRIMARY
Method: Least Squares
Date: 04/01/08   Time: 11:41
Sample: 1 11
Included observations: 11

                Coefficient   Std. Error    t-Statistic     Prob.

C                  15.3801     1.723819      8.922111          0
KVA_WIN^2   0.00000137     9.44E-09      144.6913          0

R-squared          0.99957    Mean dependent var       202.1356
Adjusted R-s      0.999523    S.D. dependent var       173.4351
S.E. of regre     3.789669    Akaike info criterion      5.6654
Sum squarec       129.2543    Schwarz criterion        5.737745
Log likelihoo     -29.1597    Hannan-Quinn criter.     5.619797
F-statistic       20935.56    Durbin-Watson stat         1.8262
Prob(F-statis            0
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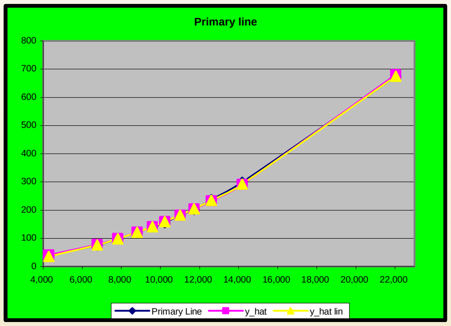


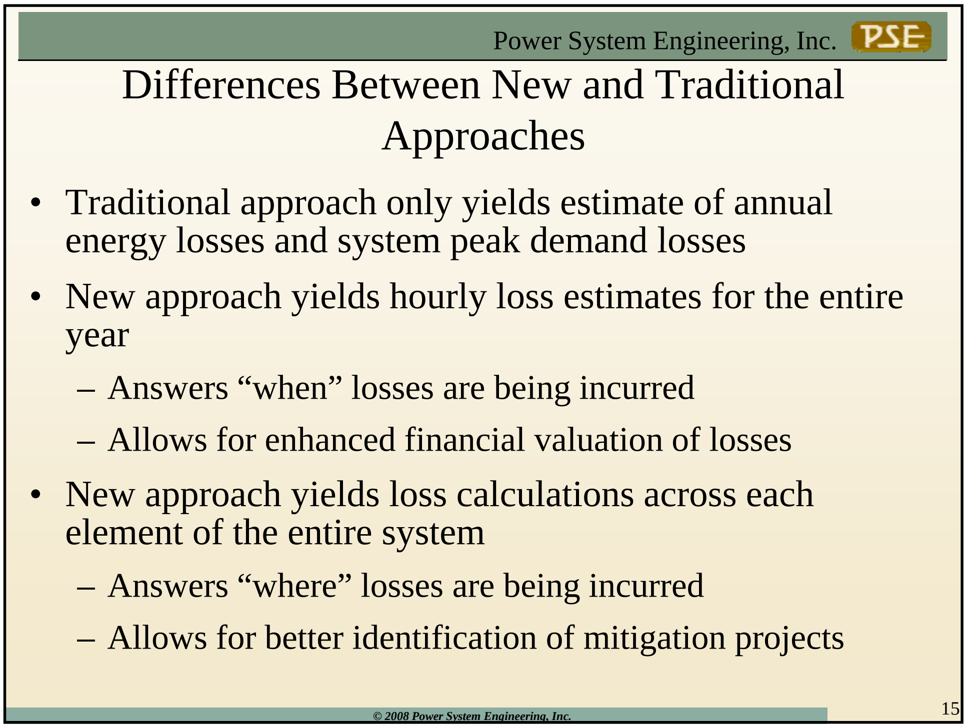
Since line and winding losses are directly related to I^2, fitted equations are quadratic in nature based on kVA^2

New and Traditional Approaches Comparison

Calendar Year 2007	Sub-Transm. Losses	Sub Xfrmr No-Load Losses	Sub Xfrmr Load Losses	Primary Losses
Traditional Loss Analysis				
kWh	1,830,745	1,377,930	803,388	4,574,573
Percent Loss	0.66%	0.50%	0.29%	1.65%
New Approach				
kWh	1,529,257	1,377,948	734,985	4,551,145
Percent Loss	0.55%	0.50%	0.26%	1.64%
Difference				
kWh	-301,489	18	-68,404	-23,428
Percent Loss	-0.11%	0.00%	-0.02%	-0.01%

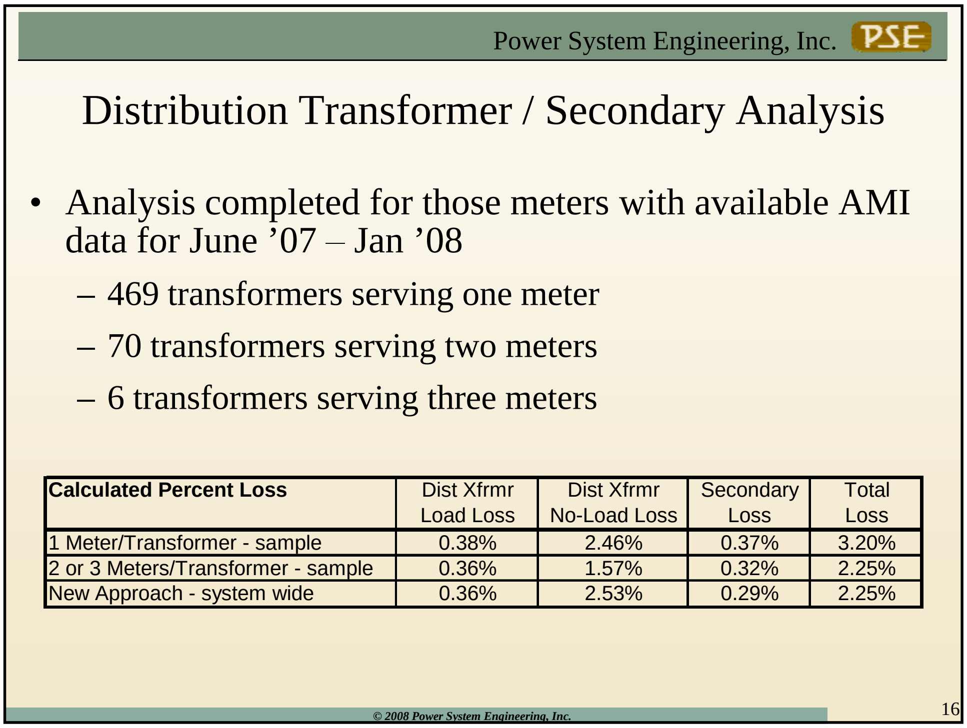
Calendar Year 2007	Dist Xfrmr No-Load Losses	Dist Xfrmr Load Losses	Secondary Losses*	Total Loss Estimate
Traditional Loss Analysis				
kWh	7,025,170	883,789	1,533,650	18,029,246
Percent Loss	2.53%	0.32%	0.55%	6.49%
New Approach				
kWh	7,032,129	986,422	817,932	17,029,818
Percent Loss	2.53%	0.36%	0.29%	6.13%
Difference				
kWh	6,959	102,633	-715,718	-999,428
Percent Loss	0.00%	0.04%	-0.26%	-0.36%

***Note: Windmil model appears to have calculated ~ 1/2 of expected secondary losses**



Differences Between New and Traditional Approaches

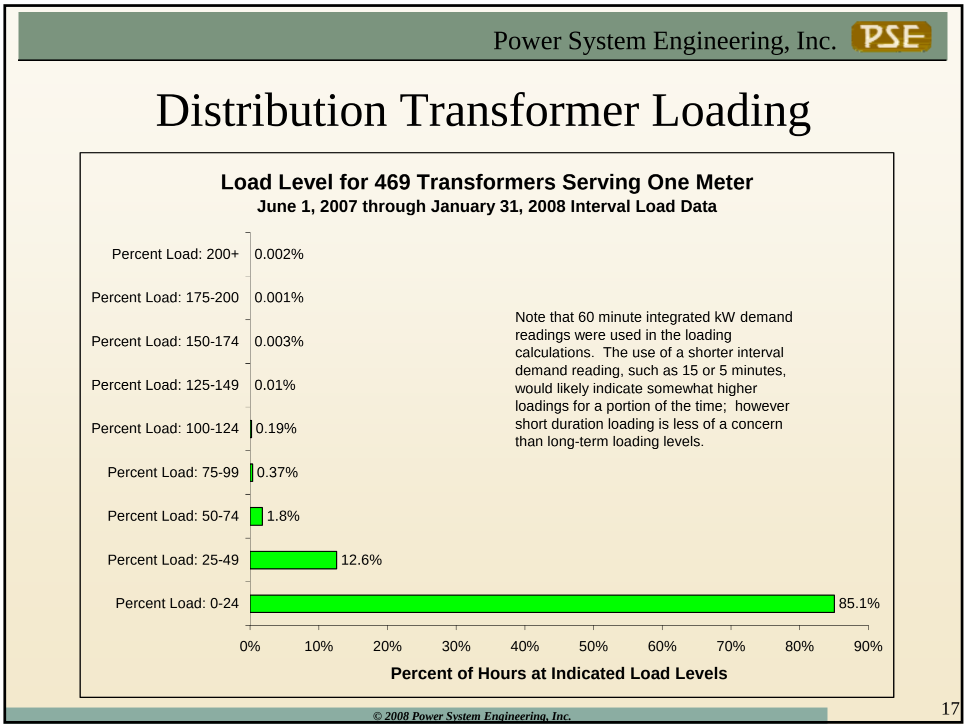
- Traditional approach only yields estimate of annual energy losses and system peak demand losses
- New approach yields hourly loss estimates for the entire year
  - Answers “when” losses are being incurred
  - Allows for enhanced financial valuation of losses
- New approach yields loss calculations across each element of the entire system
  - Answers “where” losses are being incurred
  - Allows for better identification of mitigation projects



Distribution Transformer / Secondary Analysis

- Analysis completed for those meters with available AMI data for June ’07 – Jan ’08
  - 469 transformers serving one meter
  - 70 transformers serving two meters
  - 6 transformers serving three meters

Calculated Percent Loss	Dist Xfrmr Load Loss	Dist Xfrmr No-Load Loss	Secondary Loss	Total Loss
1 Meter/Transformer - sample	0.38%	2.46%	0.37%	3.20%
2 or 3 Meters/Transformer - sample	0.36%	1.57%	0.32%	2.25%
New Approach - system wide	0.36%	2.53%	0.29%	2.25%



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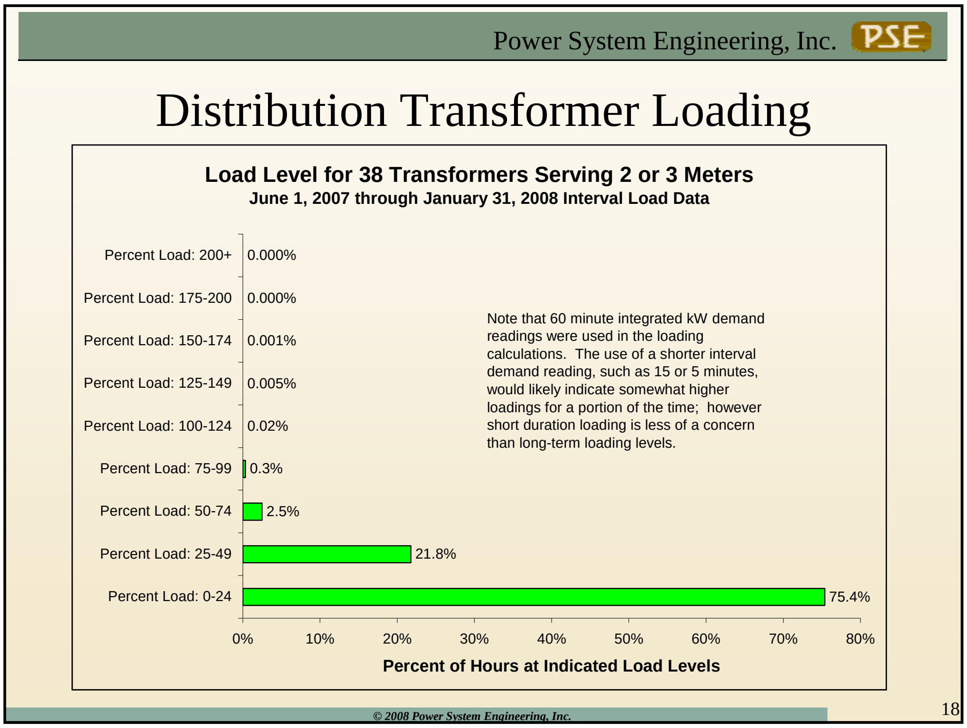
Distribution Transformer Loading

Load Level for 469 Transformers Serving One Meter
June 1, 2007 through January 31, 2008 Interval Load Data

Note that 60 minute integrated kW demand readings were used in the loading calculations. The use of a shorter interval demand reading, such as 15 or 5 minutes, would likely indicate somewhat higher loadings for a portion of the time; however short duration loading is less of a concern than long-term loading levels.



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Distribution Transformer Loading

Load Level for 38 Transformers Serving 2 or 3 Meters
June 1, 2007 through January 31, 2008 Interval Load Data

Note that 60 minute integrated kW demand readings were used in the loading calculations. The use of a shorter interval demand reading, such as 15 or 5 minutes, would likely indicate somewhat higher loadings for a portion of the time; however short duration loading is less of a concern than long-term loading levels.

Distribution Transformer Loading

- The majority of distribution transformers analyzed are being under utilized from a capacity loading standpoint
- Maximum transformer efficiency occurs at the load level where the winding and core losses are equal (for the loss data provided, this is in the range of 50% loading)
- An analysis was completed to determine the impact on loading and operating efficiency for a smaller transformer size

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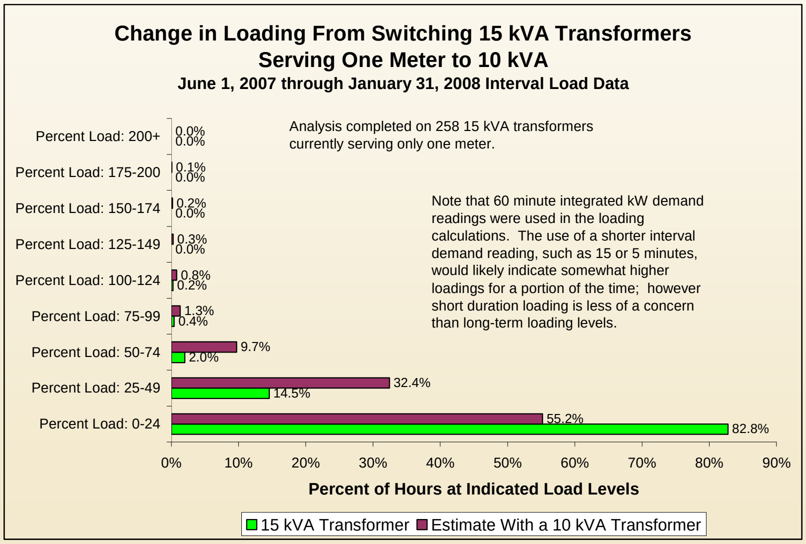
Distribution Transformer Loading

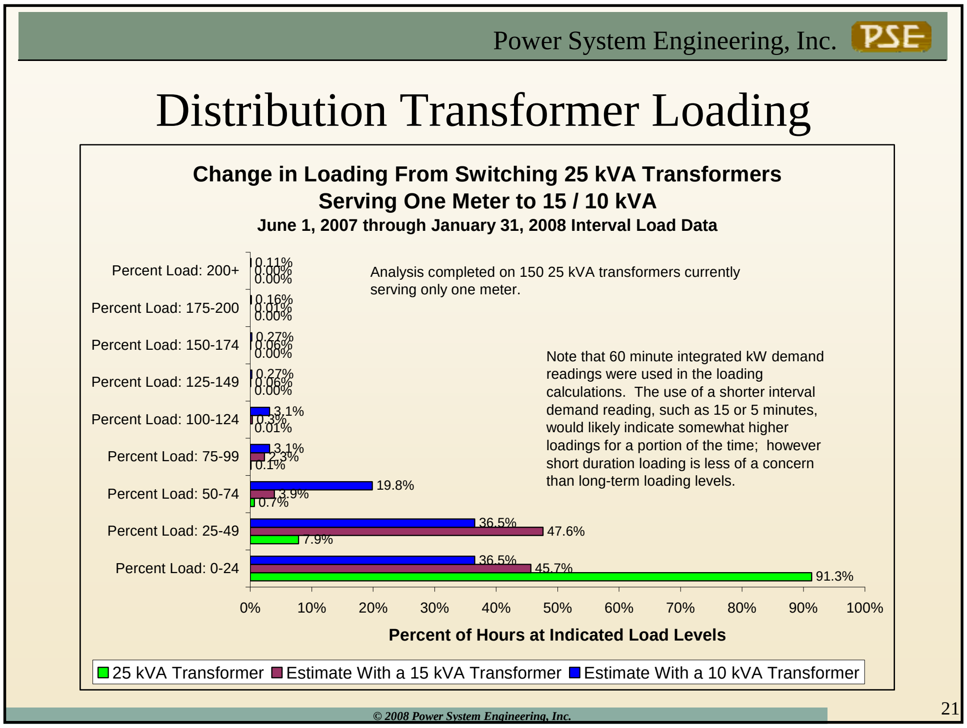


Change in Loading From Switching 15 kVA Transformers Serving One Meter to 10 kVA

June 1, 2007 through January 31, 2008 Interval Load Data

Analysis completed on 258 15 kVA transformers currently serving only one meter.

Note that 60 minute integrated kW demand readings were used in the loading calculations. The use of a shorter interval demand reading, such as 15 or 5 minutes, would likely indicate somewhat higher loadings for a portion of the time; however short duration loading is less of a concern than long-term loading levels.



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Distribution Transformer Loading

Change in Loading From Switching 25 kVA Transformers Serving One Meter to 15 / 10 kVA

June 1, 2007 through January 31, 2008 Interval Load Data

Analysis completed on 150 25 kVA transformers currently serving only one meter.

Note that 60 minute integrated kW demand readings were used in the loading calculations. The use of a shorter interval demand reading, such as 15 or 5 minutes, would likely indicate somewhat higher loadings for a portion of the time; however short duration loading is less of a concern than long-term loading levels.

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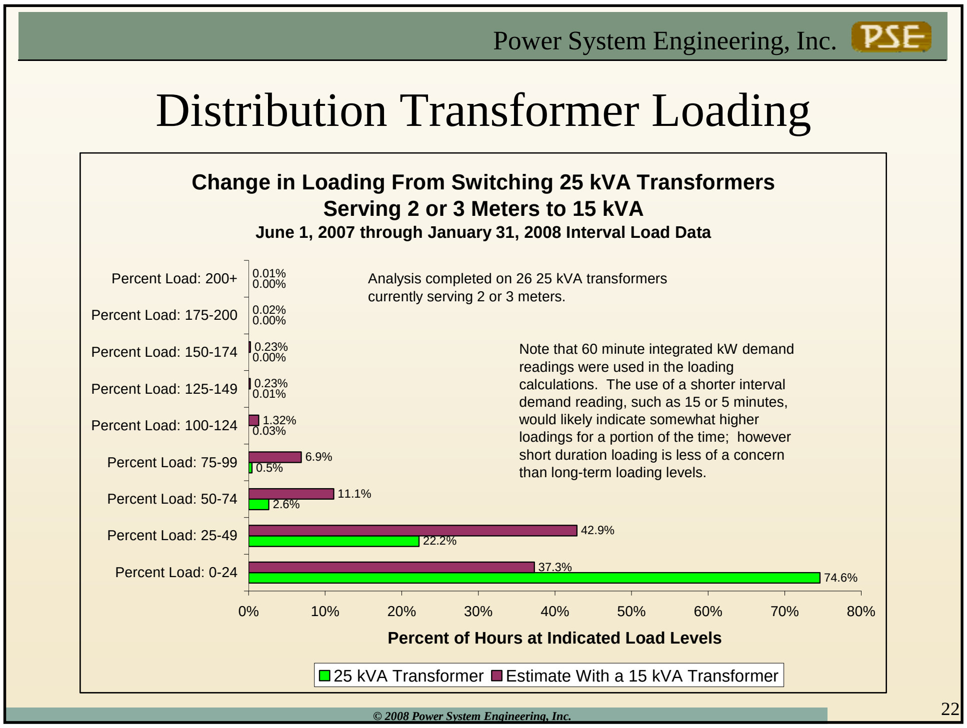

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Distribution Transformer Loading

Change in Loading From Switching 25 kVA Transformers Serving 2 or 3 Meters to 15 kVA

June 1, 2007 through January 31, 2008 Interval Load Data

Analysis completed on 26 25 kVA transformers currently serving 2 or 3 meters.

Note that 60 minute integrated kW demand readings were used in the loading calculations. The use of a shorter interval demand reading, such as 15 or 5 minutes, would likely indicate somewhat higher loadings for a portion of the time; however short duration loading is less of a concern than long-term loading levels.

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Distribution Transformer Selection

Energy Losses June '07 - Jan '08 545 Meters	Existing Installations	Reduced Transformer Size	Difference	
			kWh	%
Transformer No-Load Losses	148,473	117,326	(31,148)	-21.0%
Transformer Load Losses	23,786	40,737	16,952	71.3%
Secondary Losses	22,779	22,779	0	0.0%
Total Losses	195,038	180,842	(14,196)	-7.3%

1. Selecting smaller transformers will reduce overall energy losses, but will increase peak demand losses.
2. Economics do not generally justify changing out existing transformers based on loss savings.

Distribution Transformer Selection

- In general a 10 kVA transformer appears to be the most efficient transformer for installations serving one customer on the case study system
- In general a 15 kVA transformer appears to be the most efficient transformer for installations serving two or even three customers on the case study system
- Final transformer selection needs to also consider
  - Voltage drop and flicker from motor starts
  - Effects of transformer loading on life expectancy
  - Growth on existing services and potential for additional services connecting to the same transformer

Additional Thoughts Relating to Distribution Transformers

- DOE published rule creating higher efficiency levels for all new distribution transformers starting 2010
- Existing transformer designs will need to be evaluated to determine compliance
- Opportunity to develop new transformer designs with energy and demand losses in mind
  - Compliance based on total transformer efficiency at defined temperatures and 50% transformer loading
  - No-load and load losses can be designed to maximize loss savings
    - For example, if larger transformers are needed because of flicker concerns, transformer designs should minimize no-load losses to the extent practical and not worry as much about load loss component
- Important to continue evaluating transformer purchases based on “Total Ownership Cost” approach

Specific Delivery Point Analysis to Establish a Benchmark

- AMI interval load data collected for all meters during January 2008 for one delivery point
  - Challenges with some missing data
  - Holes due to communication issues filled
- Unmetered kWh sales estimated (i.e security lights)
- Aggregated hourly sales and compared to hourly purchases to calculate losses in each hour
- Specific evaluation of each distribution transformer and secondary service using AMI interval load data

Specific Delivery Point Analysis: Results

	Detailed Calcs For Every Cust (kWh)	New Loss Method (kWh)	Difference
Transformer No-Load Losses	13,361	13,318	-0.3%
Transformer Load Losses	2,228	2,000	-10.2%
Secondary Losses [1]	2,987	1,518	-49.2%
Sub-Total	18,576	16,836	-9.4%
Total Calculated Losses	35,317	20,385	-42.3%
Primary Line Losses [2]	16,741	3,549	-78.8%

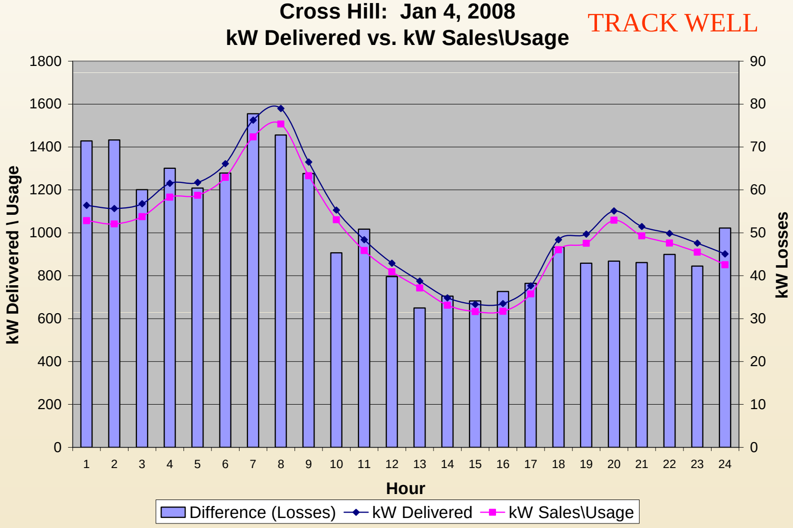
Notes:

[1] Windmil model appears to be calculating ~ 1/2 of total secondary losses.

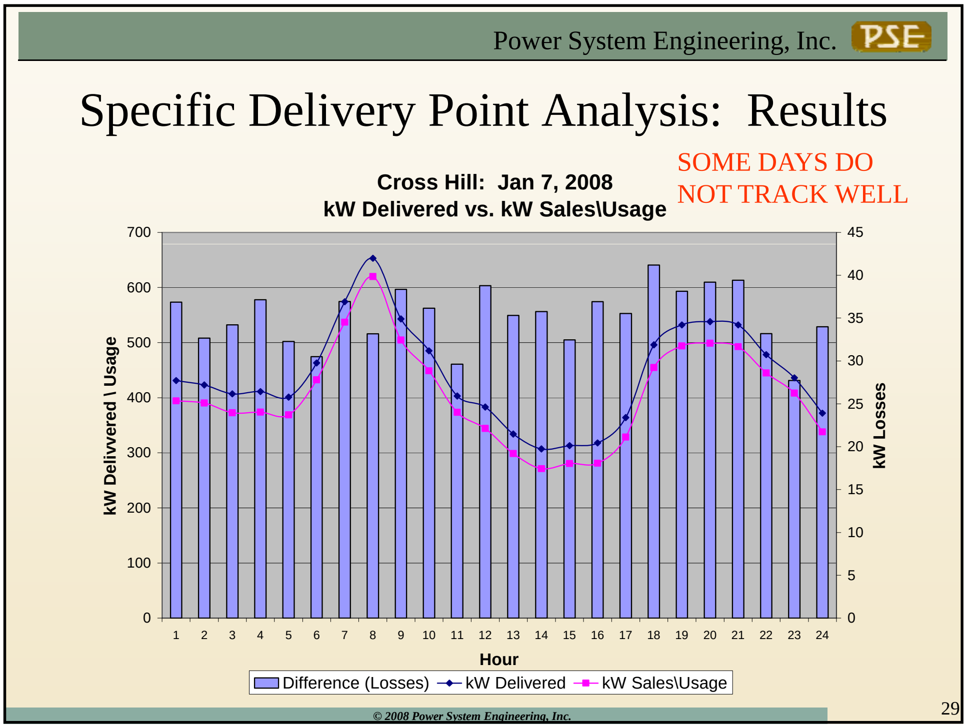
[2] Primary line losses in column 1 are estimated by subtracting the total calculated losses from calculated transformer and secondary losses.

Losses in the first column are likely being overstated due to missing kWh sales/usage (in particular unmetered usage) and/or error introduced from statistically estimating missing hourly data.

Specific Delivery Point Analysis: Results



SOME DAYS TRACK WELL



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Specific Delivery Point Analysis: Results

SOME DAYS DO NOT TRACK WELL

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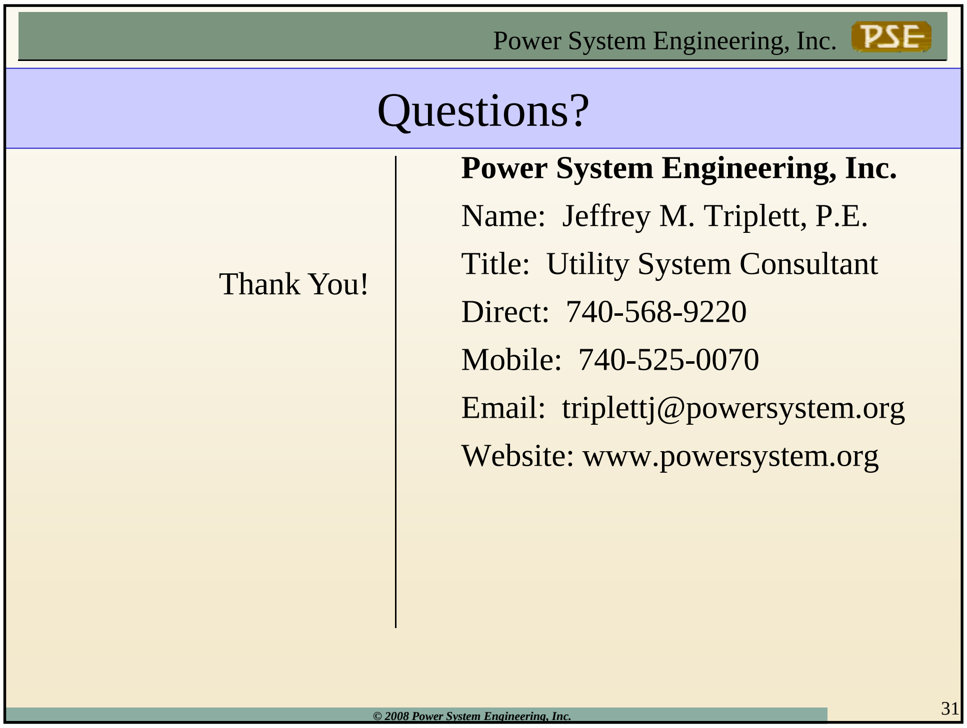
Conclusions

- Traditional loss methods appropriate for quick look at total annual energy losses and peak demand losses
- New loss method has been successfully developed to estimate hourly losses, yielding significant gains in determining “when” and “where” losses are being incurred and allowing for enhanced financial valuation of losses
- Availability of AMI interval load data has significant benefits in evaluating existing practices relating to transformer sizing and new line extensions
- Aggregating 100% AMI data to calculate losses not without its challenges
- Potential projects to mitigate losses can be developed and evaluated using the improved loss estimates
- Loss mitigation may play an important role in attaining specific efficiency goals/requirements



Questions?

Thank You!

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