Power System Engineering, Inc.

Evaluating Distribution System Losses Utilizing Data from Deployed AMI and GIS Systems

IEEE Rural Electric Power Conference

Jeff M. Triplett, P.E.
triplettj@powersystem.org

May 18, 2010
Orlando, FL

System Energy Losses

System Losses = Energy purchased – Energy sold

As % of Energy purchased:

$$\frac{\textit{System losses}}{\textit{Energy purchased}}$$

*Measure of system efficiency and lost revenue

Sources of Losses

LOSS COMPONENT	FUNCTION OF	NOTES
Substation Power Transformers		
No-Load (core) losses	Voltage	Magnetizing transformer core. Contributes significantly to energy losses.
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. Contributes significantly to energy losses.
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. Contributes significantly to energy losses.
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.

Loss Evaluations

- Loss evaluations are very much dependent on the available data
- Historically, data has been limited
- Simple loss evaluation methods were employed
  - Calculate energy losses by simply subtracting system-wide sales from system-wide purchases
    - Difficulty aligning timeframes
    - Error introduced from self-read meters
  - Estimate peak demand losses with a basic engineering model
  - Estimate energy losses by system component using industry accepted approaches that rely heavily on assumptions and rules of thumb

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 = greater desire to know when and where losses are being incurred.

- More data available to use in loss evaluations
  - GIS systems
  - AMI systems
  - SCADA systems

GIS System – Data Ideally Available

- Detailed information for each piece of equipment and conductor installed across the system down to the customer meter
- Correct electrical connectivity
- Ability to extract data from the GIS database in a format that can be imported into a commercially available engineering analysis software package

AMI System

- Typically, meter readings are received at the central office once per day for the previous 24 hours of usage
- Ability to collect interval load data for each meter
  - Some hardware and software limitations may exist
  - Challenging to effectively store and manage data
  - Missing reads need to be addressed
  - Meter multipliers need to be correctly applied

Case Study

- Otsego Electric Cooperative – upstate NY
- Fully deployed Canon AMI system
- Deployed GIS system down to individual meters

Initial Efforts

- Tracking monthly distribution system losses by substation
  - Utilizing data from Canon AMI system to compare daily meter read for the last day of the wholesale power billing period to the daily meter read from the last day of the previous billing period
  - Integrated this process with their billing sytem
  - Alignment of purchases and sales time period achieved
- Discovered that their Richfield substation has a higher percentage of losses
  - Where are these losses coming from?
  - When are these losses the greatest?
  - What cost-effective measures can be implemented to reduce losses?

Innovative Look at Losses

- Leveraging of technology
  - Collected hourly interval load data from AMI system for every meter on Richfield substation
  - Database behind GIS system used to create a detailed engineering model of the Richfield area down to the individual meter level
- Applied load data to engineering model to calculate hourly losses by system component

Methodology Employed

Step 1

Data for each system component is collected from the GIS system

- ✓Secondary conductor size and length for each service
- ✓Transformer size for each service
- ✓Transformers/secondaries feeding multiple services
- ✓Detailed engineering model of distribution system

Step 2

Hourly load data is collected for each substation (purchases)

- ✓Can be obtained from wholesale power provider, transmission delivery company and/or SCADA
- ✓Location of metering (high-side vs. low-side) must be considered

Step 3

Hourly load data (sales) is collected for each meter from the AMI system

- ✓Estimates are made for missing data
- ✓Unmetered usage is determined

Step 4

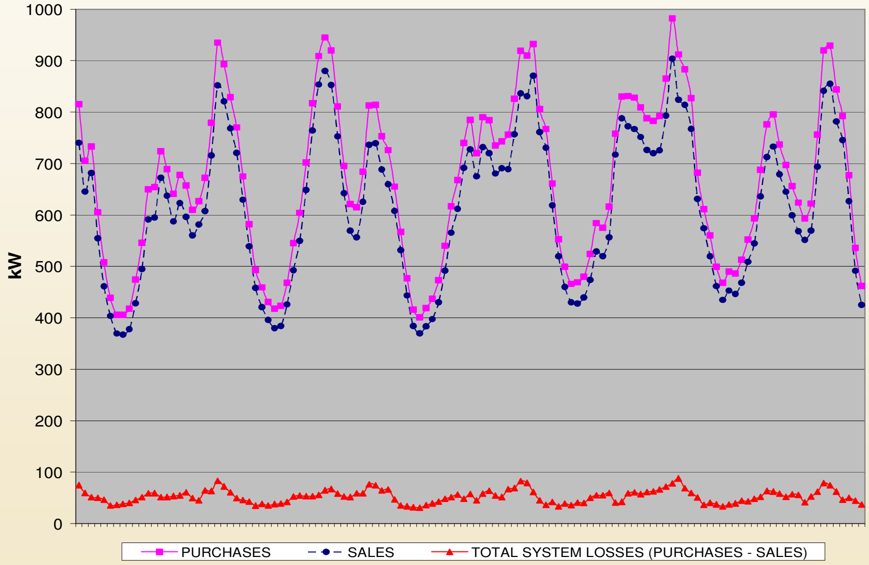
Total system losses are calculated

- ✓Hourly load data for each meter and any unmetered usage is aggregated to obtain total sales
- ✓Total system losses = purchases – total sales

Importance of Accounting for all Usage

- Assume that 100 meters are installed along a particular feeder.
- For a given time period, it is known that 110 kWh were delivered from data collected from a SCADA system with revenue-grade accuracy.
- If each meter used 1 kWh for the same time period, the calculated losses on a percent basis are (110 kWh – 100 kWh) ÷ 110 kWh = 9.1%.
- For every meter that data is missing and not accounted for, the calculated losses would be increased by 1 kWh, or 0.9% (1 ÷ 110)

Hourly Purchases, Sales and Losses



Step 5

Secondary losses are calculated

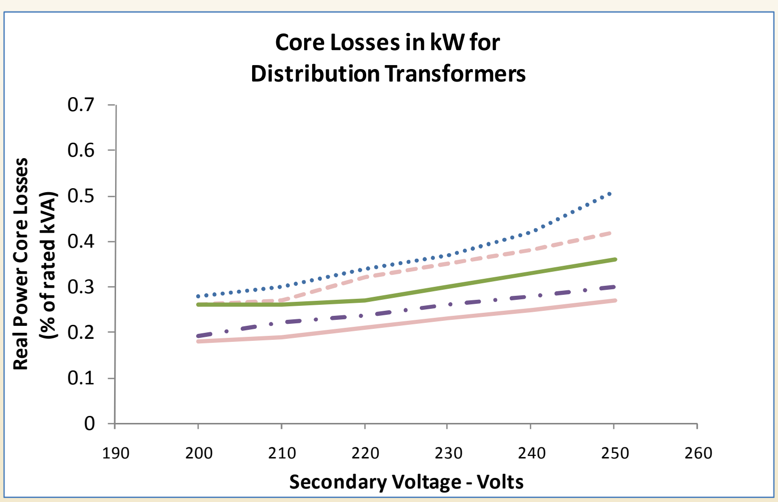
- ✓Load data for each secondary service is used to calculate I^2R losses
- ✓120V load imbalance on center tapped transformers and power factor should be considered. (*A sensitivity analysis was performed to determine how much effect each of these variables had on the calculated results. For this analysis, the impact was determined to be minor*.)

Step 6

Distribution transformer losses are calculated

- ✓No-load (core) losses typically considered to be a constant. (These losses may vary with the applied voltage depending on the transformer design.)
- ✓Load data used to calculate load (winding) losses

Transformer No-Load (Core) Losses



Transformer Load (Winding) Losses

$$Transformer\ Load\ Loss = \left[\frac{kVA\ Load}{Rated\ Transformer\ kVA}\right]^2 \times Rated\ Load\ Loss$$

- Overloading transformers significantly increases winding losses
- Conversely, underloading transformers significantly decreases winding losses

Maximum transformer efficiency achieved at load level where core losses = winding losses

Step 7

Substation transformer / regulator losses are calculated

✓No-load (core) losses typically considered to be a constant. (These losses may vary with the applied voltage depending on the transformer design.)

✓Load data used to calculate load (winding) losses

✓ Amount of time and distance off neutral must be considered with regulator load loss calculations

Step 8

Primary distribution system losses are calculated

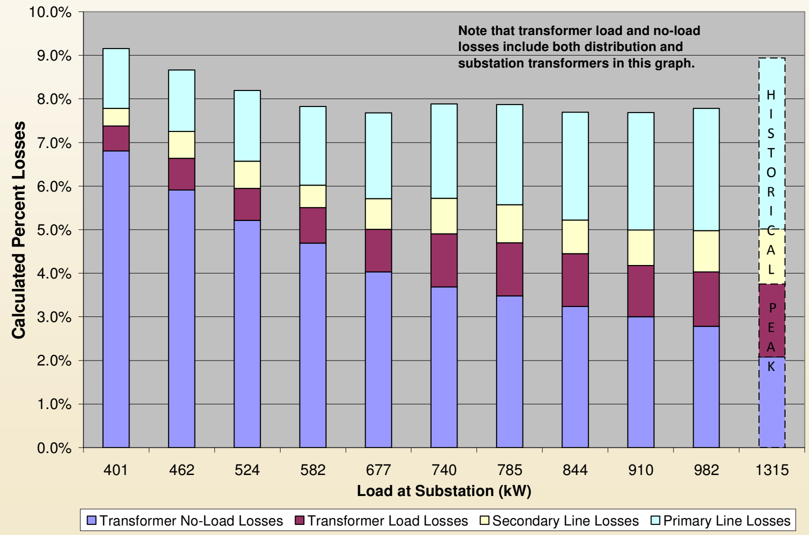
✓Assuming no metering/billing/theft losses, primary distribution system losses = total system losses – (secondary losses + distribution transformer losses + substation losses)

✓Engineering model can be used to calculate losses across the system and better determine where the losses are being incurred

Engineering Model Analysis

- Calculate primary distribution system losses for a range of system states using the detailed engineering model
  - 10^{th} percentiles found to typically be adequate
- Interpolate losses for all hours using regression analysis to estimate hourly demand losses and energy losses over desired time period
  - Since line losses are directly related to I^2, fitted equations are quadratic in nature based on kVA^2

Summary of Results



Conclusions

- Traditional loss methods may be appropriate for quick look at total annual energy losses and peak demand losses
- Aggregating 100% AMI data to calculate losses not without its challenges
- New loss evaluation method was successfully applied using AMI and GIS data to estimate hourly losses by system component
  - Significant gains in determining “when” and “where” losses are being incurred
  - Potential for enhanced financial valuation of losses

Questions?

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