Long Run Impact of AMI on Load Research and Forecasting

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March, 2007
Overview

1. How load research and forecasting work today
2. Discussion of AMI technologies and functionality
3. What does not change with AMI
4. What does change with AMI
5. Impact on Load Research and Load Analysis
6. Impact on Forecasting
7. Conclusions
How LR&F Work Today

Standard Load Research Processes

- Some utilities have active samples. Some do not.
- Mass market samples are stratified and expanded using ratio or MPU methods. Samples are designed for 90/10.
- Large customers have interval meters and expansion is a census-based add up.
- LR gets validated interval data for large customers and unvalidated data for sample customers. Often data are received on a billing cycle basis.
- LR does the calculation to estimate class profiles, usually a monthly or annual process.
- Class profiles may be calibrated to the total system load net of estimated losses.
- Profile estimates are used for rates, forecasting, & marketing. In competitive markets, profiles are used for settlements.
How LR&F Work Today

Standard Financial Forecasting Processes

• Budget forecasts are developed once per year, usually in fall. Forecasts may be updated during the year.
  ➢ Sales models are estimated using billing data.
  ➢ Forecasts are for customers, sales, revenues, peaks.
  ➢ Base forecasts are with normal weather.
  ➢ Forecasts are for calendar month energy and peaks.
  ➢ Monthly forecasts may be disaggregated to daily/hourly.
  ➢ Scenarios for weather, economics,... may be included
• Monthly analysis of financial results may involve models.
  ➢ Weather normalization of monthly sales.
  ➢ Estimating calendar month results from cycle results.
  ➢ Estimating unbilled energy.
  ➢ Variance analysis of deviations from budget forecast.
How LR helps Forecasting

- Class profile data can be used to improve estimates of weather response, which strengthens models.
- Profile data or models of profile data can be used to estimate:
  - calendar month sales from cycle sales.
  - unbilled sales based on cycle or calendar sales.
- LR data can be used to help support revenue forecasts when rate structures change.

How Forecasting helps LR

- Calendar month sales by class can be used to strengthen ratio estimation.
- Forecasting models/methods can be used to weather normalize class profiles.
Sidebar on use of LR data in Forecasting

- Load profile data is very powerful for understanding weather relationships.
- There are 30 points per month, a strong advantage over monthly data.
- Load on a day and can be matched cleanly with weather for that day. Monthly sales data are matched approximately to days and weather based on cycle dates.
- There is more weather variation at the daily level. Billing month weather data is aggregated and weighted over the roughly 60 calendar days that impact sales in a billing cycle. The extremes are lost in both the X and Y directions.

2003 Load Research Data. Each point is one day.

2003 Billing Data. Each point is one month.
Sidebar on Use of Profile Data in Financial Closing

Profile data (or models of profile data) can be used to help translate billing data to calendar months and to compute unbilled energy.
AMI Defined

AMI is the use of smart meters, with advanced two-way communication technologies, that enables utilities to:

- Meet their business & operational needs for meter data collection
- Empower ALL their customers to participate in demand response and energy conservation
- Help move toward a smart grid
The AMR/AMI Continuum

- Support for Intelligent Grid
- Home Automation
- Demand Response
- RTP / CPP / Hourly Rates
- Remote Disconnect / Prepayment
- Smart Meter
- Mandatory Time Based Rates
- Voluntary Time Based Rates / Opt In
- Outage Reporting
- New Products & Services / Voluntary TOU
- Revenue Protection / Theft Detection
- Enterprise Meter Data Management
- Operational Improvements
- Revenue Cycle Improvements
- TOU / Demand / Net Metering
- Meter Reading Cost & Efficiency

Walk-by
Drive-by
Fixed Network-AMR
Open Protocols
2-Way
Functionality provided/enabled by AMI

1. Advanced meters $\leftrightarrow$ Communication network.
   - Two-way communication
   - Demand and meter event data in near real time
   - Data stored in MDM and provided to applications

2. Interval data collected for all customers.

3. Enables time sensitive pricing (e.g., TOU).

4. Enables demand management and real time pricing programs.

5. Meter events support outage detection and tamper detection.


7. Enables pre payment programs.

8. Enables calculation of facility (e.g., transformer) loads.
**AMI and Smart Grid**

**EPRI - Intelligrid Characteristics:**

- **Interactive** with consumers and markets
- **Self-Healing** and **Adaptive**
- **Optimized** to make best use of resources and equipment
- **Predictive** rather than reactive, to prevent emergencies
- **Accommodates** a variety of generation options
- **Integrated**, merging monitoring, control, protection, maintenance, EMS, DMS, marketing, and IT
- **More Secure**
Example of AMI Architecture

OpenWay™ CENTRON®

In-Home Display

Smart Appliances

Thermostat

Gas Meter

Wireless Switches and Keypads

Home Gateway

Communication Network

OpenWay™ Collection Engine

Meter Data Management

Electric / Gas / Water

Information collection, analysis, and application

Business Systems

Distribution Operations

OpenWay™ Collection Engine

Communication Network

In-Home Display

Smart Appliances

Thermostat

Gas Meter

Wireless Switches and Keypads

Home Gateway

OpenWay™ CENTRON®

Example of AMI Architecture

OpenWay™ Collection Engine

Communication Network

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Things that Do Not change

1. Energy still needs to be generated.
2. Environmental concerns remain important.
3. It still takes wires and pipes to deliver energy.
4. Bills are still calculated and delivered on cycles.
   - This is necessary to smooth workload in the billing process and the call center. This is the same reason that telecom and credit card companies bill on cycles.
   - Cycles are not necessarily "route" based.
5. Load profiles continue to be used in rate cases, forecasting, marketing, ....
6. Forecasting is still about the future...you can't meter the future.
7. Weather normalization and variance analysis remain counterfactual exercises that require analysis and modeling.
Things that Do change with AMI

1. Utilities are connected to their customers through smart meters.
2. Interval data (hourly or finer) are collected for all customers. Data is available on a nearly real-time basis.
3. Estimation of class profiles becomes a massive add up calculation. This can be done on a daily basis with a minor adjustment for completeness.
4. Estimation of calendar month usage by class becomes a massive add up calculation. This can be done soon after month end.
5. Estimation of unbilled energy by class becomes a massive add up calculation. This can be done soon after month end.
6. Estimation of distribution facility (e.g. transformer) loads becomes a detailed add up for each facility.
7. Loss estimation can be addressed directly (net system load minus the sum of loads at customer meters).
Profile Estimation before AMI

\[
y_{\text{Var}}_{c,s} = \frac{\left( \sum_{i=1}^{n_{c,s}} (y_i - y_{\text{Avg}}_{c,s})^2 \right)}{n_{c,s} - 1}
\]

\[
x_{\text{Var}}_{c,s} = \frac{\left( \sum_{i=1}^{n_{c,s}} (x_i - x_{\text{Avg}}_{c,s})^2 \right)}{n_{c,s} - 1}
\]

\[
M_{\text{Avg}}_{c} = \frac{N_{c,s}}{N_{c}} \times y_{\text{Avg}}_{c,s}
\]

\[
\text{Cov}_{c,s} = \frac{\sum_{i=1}^{n_{c,s}} (y_i - y_{\text{Avg}}_{c,s}) \times (y_i - y_{\text{Avg}}_{c,s})}{n_{c,s} - 1}
\]

\[
C_{\text{Avg}}_{c} = k \times \sum_{\text{sec}} \frac{N_{c,s}}{N_{c}} \times y_{\text{Avg}}_{c,s} = k \times M_{\text{Avg}}_{c}
\]

\[
k = \frac{\sum_{\text{sec}} \frac{N_{c,s}}{N_{c}} \times x_{\text{Avg}}_{c,s}}{\sum_{\text{sec}} \left( N_{c,s} \times y_{\text{Avg}}_{c,s} \right)}
\]

\[
S_{\text{Var}}_{Avg}_{c} = \sum_{\text{sec}} \frac{N_{c,s}}{N_{c}} \times \frac{S_{\text{Var}}_{c,s}}{n_{c,s}} \times \left( 1 - \frac{n_{c,s}}{N_{c,s}} \right)
\]

\[
M_{\text{VarTot dom}} = \sum_{c, \text{domscope}} \left( N_{c,s}^2 \times \frac{z_{\text{Var}}_{c,s}}{n_{c,s}} \times \left( 1 - \frac{n_{c,s}}{N_{c,s}} \right) \right)
\]

\[
z_{\text{Var}}_{c,s} = \frac{\sum_{i=1}^{n_{c,s}} \left( z_i - \frac{z_{\text{Sum}}_{c,s}}{n_{c,s}} \right)^2}{n_{c,s} - 1} = \frac{\sum_{i=1}^{n_{c,s}} Z_i^2 + \sum_{i \in \text{domcess}} \left( \sum_{i \in \text{domcess}} Z_i \right)^2}{n_{c,s} - 1}
\]

\[
C_{\text{VarAvg}}_{c} = \sum_{\text{sec}} \frac{N_{c,s}}{N_{c}} \times \frac{C_{\text{Var}}_{c,s}}{n_{c,s}} \times \left( 1 - \frac{n_{c,s}}{N_{c,s}} \right)
\]

\[
S_{\text{Avg}}_{c} = \frac{1}{N_{c}} \times \sum_{\text{sec}} \sum_{i=1}^{n_{c,s}} y_i
\]

\[
M_{\text{Avg}}_{dom} = \frac{1}{N_{c}} \times \sum_{c, \text{domscope}} \left( x_{c,s} \times z_{\text{Sum}}_{c,s} \right) \times \sum_{\text{sec}} \frac{N_{c,s} \times x_{\text{Avg}}_{c,s}}{N_c}
\]
Profile Estimation after AMI

\[ KWh_{\text{class, hour}} = \sum_{\text{cust} \in \text{class}} KWh_{\text{cust, hour}} \]

1. Validation is an issue.
2. Small scaling for completeness (<1%).
3. MDMs will need to perform or support this calculation.
One of the benefits of AMI – Improved Clarity

With AMI, there will be improved clarity about retail customer hourly loads. Instead of estimating class loads with +/- accuracy, they will be calculated.
What this means for Load Research

1. Standard load research processes will continue to be used through transition periods. This may be many years in some places.

2. Once AMI meters are in place and interval data collection processes are running smoothly, MDMs will be configured to provide the data required for add-up processes.

3. Once add-up processes are implemented, there will be no need for the load research expansion formulas for estimating class loads. These formulas will still be used in special studies.

4. In competitive markets, there is no further need for profile backcasting. All customers have interval data for settlements.

5. Special studies (e.g., end-use metering, program design, and program evaluation) will continue to require specialized samples.

6. Load research departments will morph into data analysis and special study departments.
What this means for Forecasting

1. The role of forecasting in estimation of calendar month energy by class will go away. This will be a direct calculation.

2. The role of forecasting in estimation of unbilled energy by class will go away. This will be a direct calculation, providing improved financial clarity.

3. Budget forecasting needs will remain the same, but the models will eventually be estimated using calendar month data instead of cycle data. Forecasts of daily energy by class will be based on models of daily data.

4. Weather normalization processes will continue. These processes will be applied at the daily level (tracking weather normalized daily energy by class against budget forecasts), providing improved clarity and visibility.

5. Monthly variance analysis processes will continue. But the variance calculations by class will be based on actual calendar month loads instead of estimated calendar month loads.
What this means for IT & MDM

1. IT systems will need to be scaled for large quantities of data. 15 minute data for 1 million customers implies about 40 billion intervals per year.

2. MDM systems will need to support analysis systems for a variety of calculations:
   -- Billing determinants by customer for the billing system.
   -- Class profiles for rate analysis, forecasting ,...
   -- Facility level profiles for distribution system management.
   -- Calendar month add ups for financial closing.
   -- Unbilled add ups for financial closing.
   -- Load management calculations for program analysis.

3. The role of IT departments in the utility will increase.
Discussion

1. Everything I said may be wrong.