Practical Aspects of Electric Load Forecasting

Panel Session at IEEE PES GM 2011
Chair: Dr. Tao Hong
Co-chair: Prof. Fran Li
Power System Planning & Implementation Committee

Introduction – Electric Load Forecasting

- Electric load forecasting
  - Established for over half a century
  - Wide applications in utility industry
    - » Generation / transmission / distribution
    - » Planning / O&M / market
  - New challenges
    - » Rate case
    - » DER – wind/solar generation forecasting
    - » EV – charging pattern
    - » Pricing
    - » DSM

Introduction – Motivation

- Gap between
  - Scientific research
    - » Algorithms
    - » Models
    - » Papers
  - Utility practical needs
    - » Understanding
    - » Communication
    - » Implementation
    - » Documentation
    - » Reproduction

Introduction – Panelists

- 6 invited panelists
- 4 countries
  - United States: NC, TX, WI
  - Canada
  - China
  - Australia
- 3 utilities, 2 universities, 1 consultant (vendor)

Agenda – Topics

- A Naive Multiple Linear Regression Benchmark for Short Term Load Forecasting
  - **Tao Hong**, SAS
- Comparative Study on Load Forecasting Technologies for Different Geographical Distributed Loads
  - **Wei-Jen Lee**, UT Arlington
- Short Term Load Forecasting using Regime-Switching GARCH Models
  - **Hao Chen**, Nanjing Power Supply Company, China
- Short-term Load Forecasting Using Semi-parametric Additive Models
  - **Shu Fan**, Monash University, Australia
- MGE Experience with INSITE Spatial Load Forecasting
  - **David Barger**, MGE
- Including a Combined Fuzzy and Probabilistic Load Model in Transmission Energy Loss Evaluation: Experience at BC Hydro
  - **Wenyuan Li**, BC Hydro

Agenda – Time

- 20 minutes presentation + 5 minutes Q&A per paper
- 20 minutes for panel discussion / concluding remarks

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A Naive MLR Benchmark for STLF

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Tao Hong

- Experience
  - Analytical Consultant, SAS Institute (07/2011 – present)
  - BKS Instructor, SAS Institute (12/2010 – present)
  - Principal Engineer, Quanta Tech. (01/2008 – 06/2011)
- Interest
  - Forecasting, optimization, price elasticity
  - Load / price forecasting, energy market
  - System planning, power engineering
- Education
  - Ph.D., E.E., O.R. NC State Univ., Raleigh
  - M.S., E.E., I.E., O.R., NC State Univ., Raleigh
  - B.Eng., Automation, Tsinghua Univ., Beijing

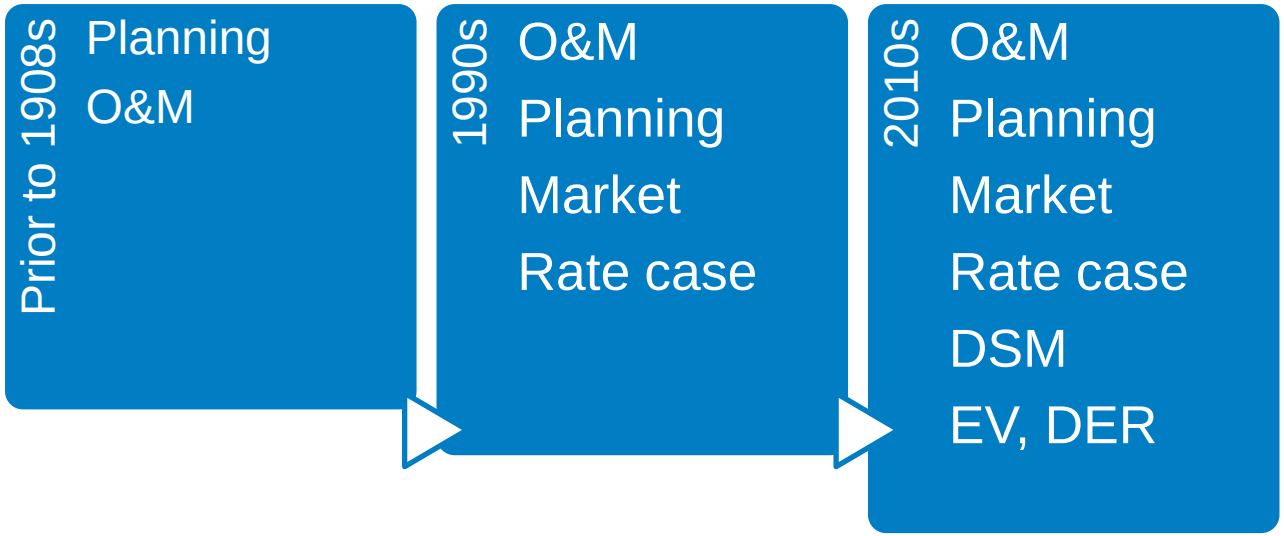
Outline

- Introduction
  - Business needs
  - Classification / terminology
- Literature review
  - What has been done?
  - What went wrong?
  - What to do next?
- Benchmarking process
  - Motivation
  - Requirements
  - Model
  - Results
- Work in progress

Introduction – Business Needs

- Generation
- Transmission
- Distribution

- Planning
- Operations & Maintenance
- Market related activities

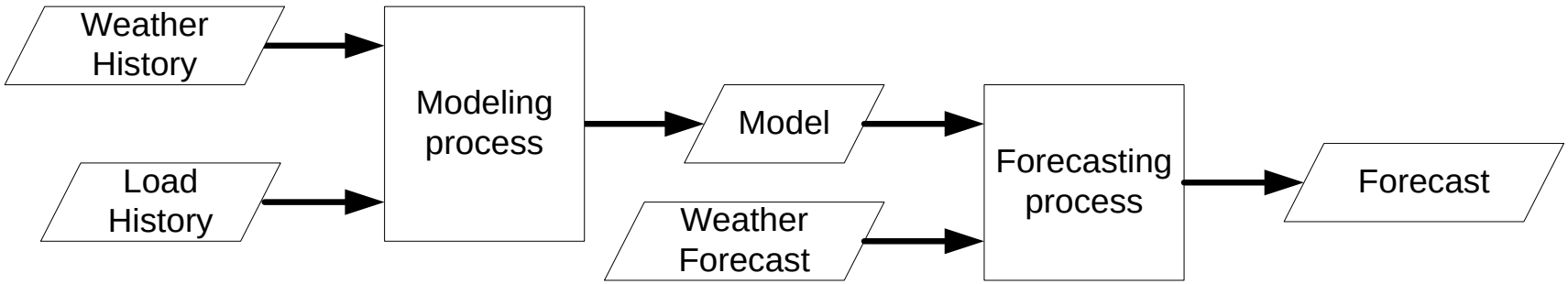


Introduction – Classification

- Classify by
  - Horizon – hour / day / week / month / year / 10 years / 30 years ahead
  - Resolution – 5 min / 30 min / hourly / daily / weekly / monthly / quarterly / annual
  - Engineering concepts – Load(kW, kVA, or Amp) / peak / valley / energy
  - Levels – System / nodal / T ss / D ss / feeder
- Terminology
  - Long term – 30 years, annual
  - Medium term – 3 years, monthly
  - Short term – 2 weeks, hourly
  - Very short term – 1 day, hourly or sub-hourly

Literature Review – What Has Been Done?

- A load forecasting process



- Modeling process
  - Statistics: linear regression, Box-Jenkins, nonparametric regression
  - A.I.: ANN, fuzzy logic, neuro-fuzzy system, SVM
  - Others: hybrid approach, multi-stage approach

Literature Review – What Went Wrong?

- Away from practice
- No benchmarking data
- No benchmarking model
- No benchmarking accuracy statistics
- Lack of comparisons
- Hard to reproduce the results
- Insufficient interpretability of some (black box) models
- Not fully utilize the power of the conventional techniques

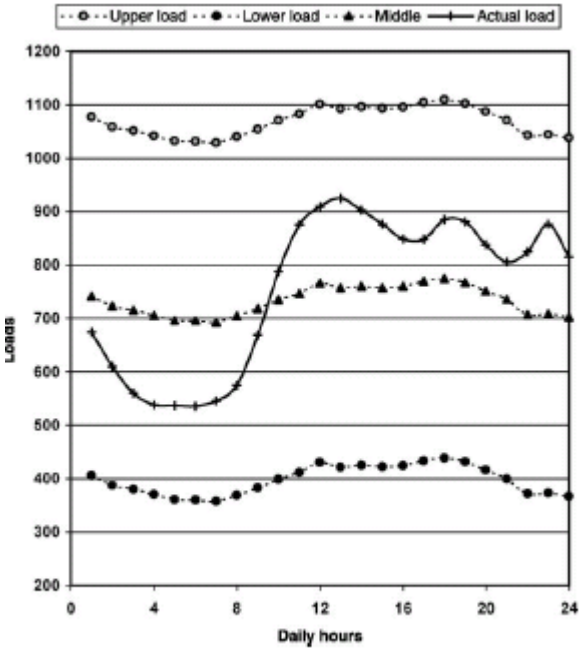


Fig. 1. Estimated load for a summer weekday, crisp load.

Literature Review – What To Do Next?

- Explore real-world business needs
  - Multi-region forecast
  - Probabilistic forecast / density forecast
  - Outlier detection / data cleansing
  - Incorporate system losses
- Quantify economic impact of forecasting accuracy
- Establish benchmarking data pool
- Regulate reporting format
- Develop benchmarking models
- Refresh the start-of-the-art of conventional techniques
- Increase interpretability of black-box approaches

Benchmarking Process – Motivation

- FAQ from utility engineers / managers
  - What data do we need?
  - How is our data quality?
  - Which weather station(s) shall we use?
  - Which software package or services shall we buy?
  - What skill sets shall we stuff?
  - Is my forecast accurate enough?
  - How does my forecast comparing to others?
  - Shall we spend more men/hours to improve our forecast?
  - How can we explain the forecasts to XXXX?
  - What if our load forecaster changes job?

Benchmarking Process – Requirements

- Simple
  - Easy to implement
- Creditable
  - Fairly accuracy and theoretically sound
- Widely applicable
  - Can be used by a wide range of utilities
- Interpretable
  - Can be understood by average electrical engineers, managers, etc.
- Reproducible
  - Can be reproduced based on documented procedures

Benchmarking Process – Model

- Multiple Linear Regression / Interaction Regression[1]

$$E(Load) = \beta_0 + \beta_1 \times Trend + \beta_2 \times Day \times Hour + \beta_3 \times Month + \beta_4 \times Month \times T + \beta_5 \times Month \times T^2 + \beta_6 \times Month \times T^3 + \beta_7 \times Hour \times T + \beta_8 \times Hour \times T^2 + \beta_9 \times Hour \times T^3$$

- ✓ Won an award from a largest data mining conference
- ✓ Listed as one of the customer success stories of SAS
- ✓ Adopted for weather normalization
- ✓ Applied in several medium and large utilities (700MW to 20GW+)
- ✓ Taught in NC State Univ.
- ✓ Reproduced by a group STAT/EE students in TAMU

[1] Tao Hong, "*Short Term Electric Load Forecasting*", PhD dissertation, NCSU

Benchmarking Process – Results (1)

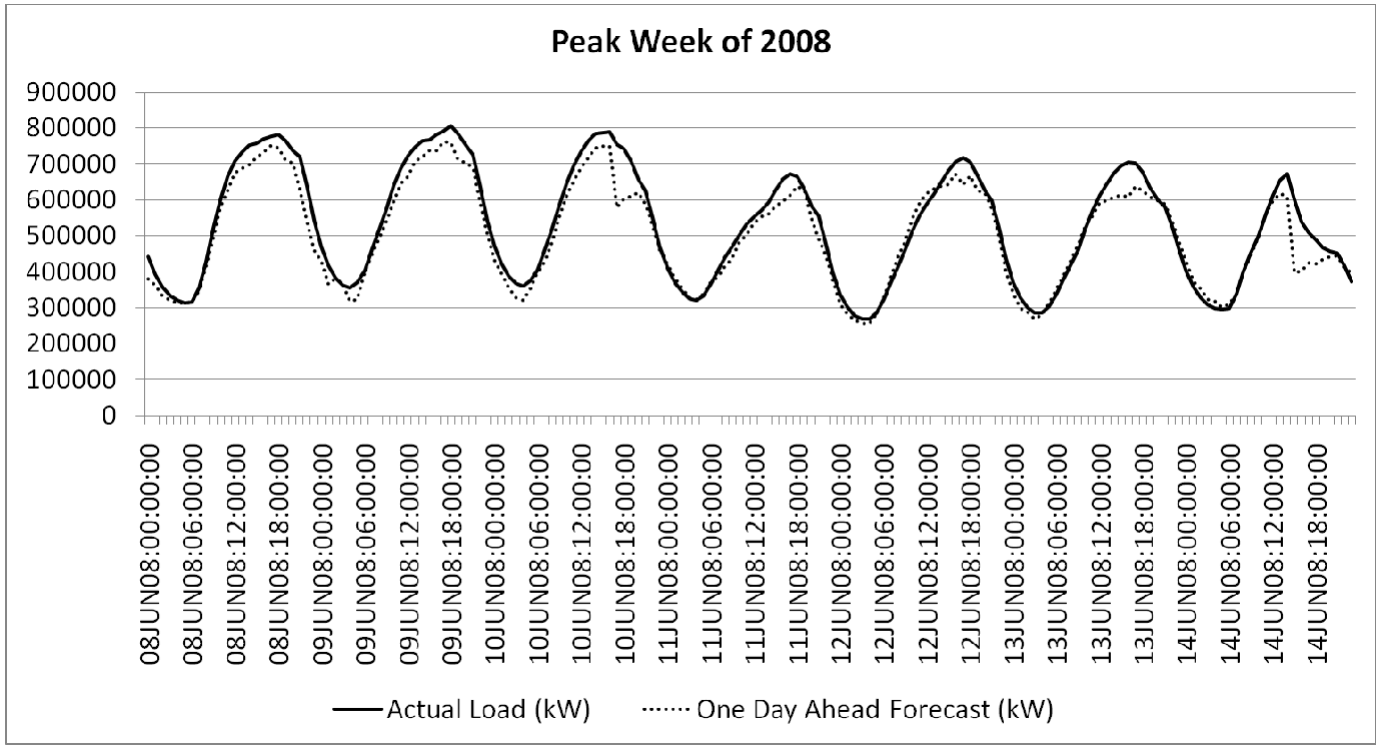
- Accuracy statistics
  - Naïve model
  - Weather station
  - Rapid growth

TABLE I
RESULTS (MAPE, %) OF THE NAÏVE MODEL

	Forecasting horizon (# of days)						
	1	2	3	4	5	6	7
Hourly load	4.98	5.00	5.01	5.01	5.02	5.03	5.04
Daily peak hour	4.27	4.29	4.29	4.29	4.30	4.30	4.30
Daily valley hour	5.44	5.46	5.47	5.49	5.50	5.50	5.52
Daily peak	3.94	3.96	3.97	3.97	3.98	3.99	3.99
Daily valley	4.93	4.95	4.96	4.98	4.99	5.00	5.02
Daily Energy	3.49	3.51	3.52	3.53	3.53	3.54	3.55

Benchmarking Process – Results (2)

- Line plots



Work in Progress

- Establishing data (load & weather) pool
  - Over 20 utilities
  - Over 300 zones/delivery points/substations/feeders
  - Over 30 weather stations
  - Partially available in several graduate level courses of NCSU
  - To be partially available in a SAS Business Knowledge Series course "*SAS for Electric Load Forecasting*"
- Benchmark forecasting accuracy
  - Hour/week/year ahead
  - Weather normalization for long range planning
- Develop benchmarking models using other approaches
  - ANN
  - Fuzzy regression

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