From Load Forecasting to Demand Response

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Guest Lecture at NC State University

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Tao Hong

- Education
  - B.Eng, Automation, Tsinghua University, Beijing
  - M.S. E.E., NC State University, Raleigh
  - M.S. O.R., I.E. NC State University, Raleigh
  - Ph.D. E.E., O.R., NC State University, Raleigh
- Experience
  - *Engineer, Sr. Engineer, Principal Engineer,* Quanta Technology, LLC.
  - *Business Knowledge Series Instructor,* SAS Institute, Inc.
- Interest
  - Load / price forecasting, energy market
  - System planning, power engineering

Objectives

- Improve the naïve MLR based benchmark
- Understand basic concepts of demand response
- Learn how to
  - use lagged regression to model recency effect
  - reduce autocorrelated errors
  - quantify energy savings due to demand response

Notes, data, and reading materials can be downloaded from the lecture webpage:
http://courses.DrHongTao.com/lfdr

Outline

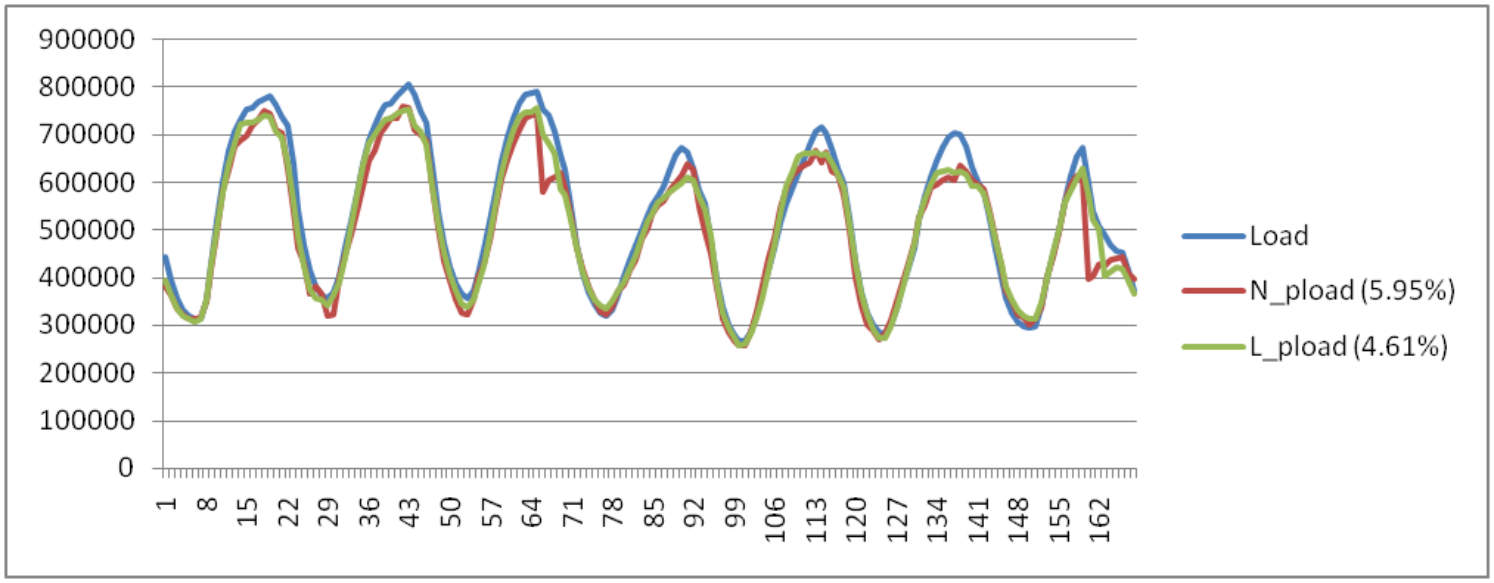
- Recency Effect and Lagged Regression
- Autocorrelated Errors
- Demand Response: What, Why, and How?
- Assessment of Energy Savings
- Demonstration (SAS)

Recency Effect

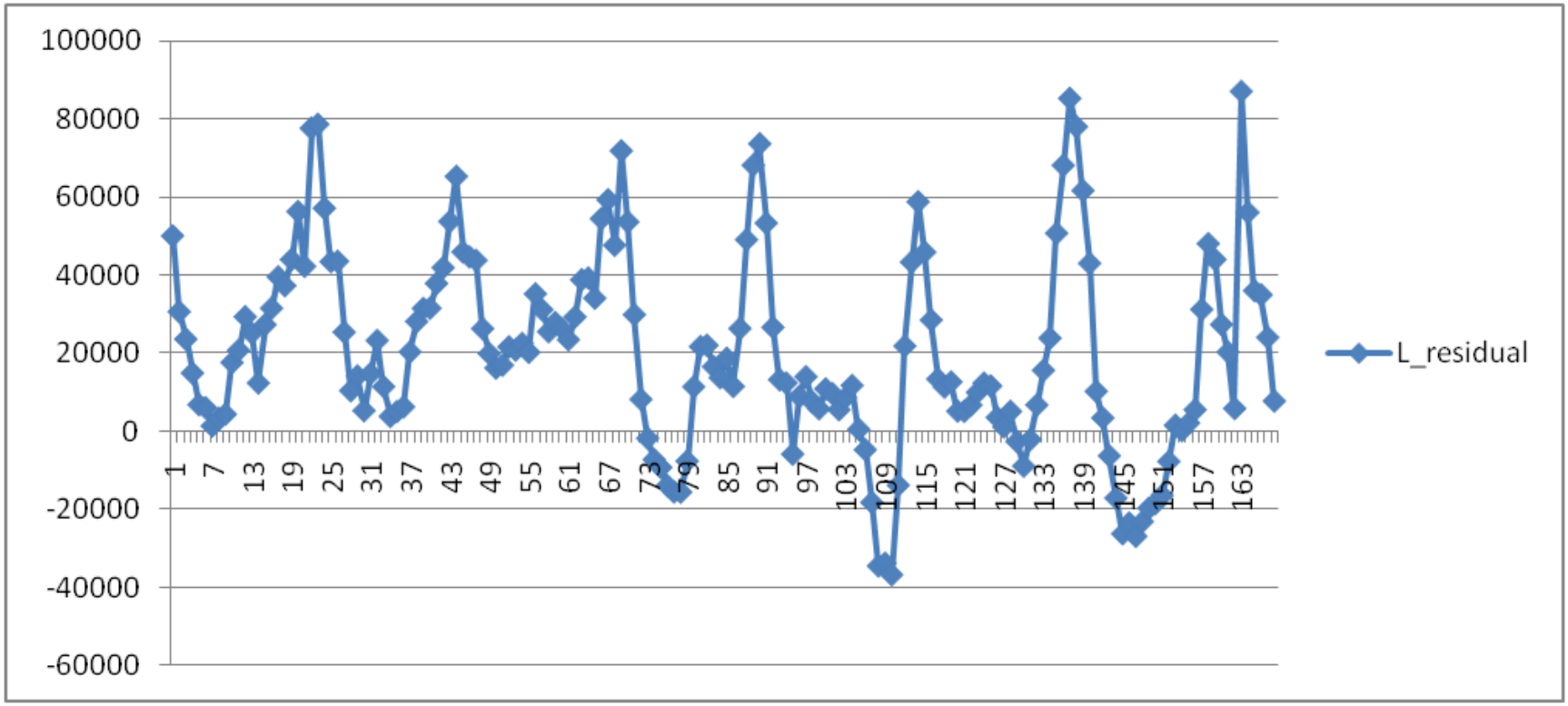
- The most recently presented items or experiences will most likely be remembered best. If you hear a long list of words, it is more likely that you will remember the words you heard last (at the end of the list) than words that occurred in the middle.

Lagged Regression

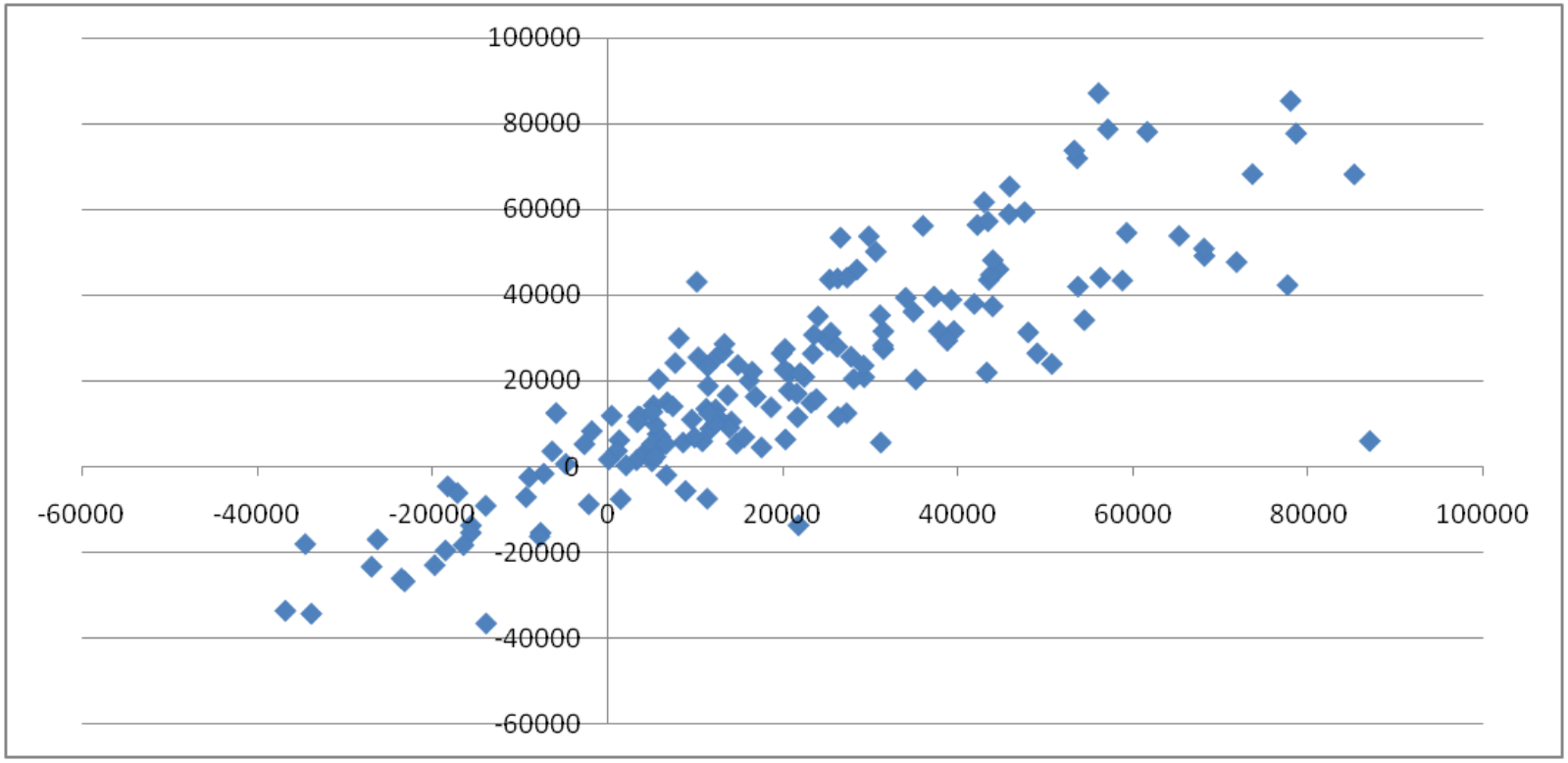
- Lagged regression models
  - To forecast an output series y_t, given a present and past of an input series x_t.
- Load(t+1) = f(T(t), T(t-1), T(t-2), …)



Residual Line Plot



Residual Scatter Plot



Time Series Methods

- Box-Jenkins approach
  - Autoregressive models (AR)
  - Moving average models (MA)
  - ARMA, ARIMA
- Reducing autoregressive errors
  - GLM, Box-Jenkins, add predicted residuals back
  - Time series regression: GLM, Box-Jenkins, transformed D.V.

Past Dependent Variables

- Load(t+1) = f(T(t), T(t-1), T(t-2), …, Load (t), …)
- Notice that during the forecasting stage
  - to forecast Load (t+20), we need Load(t+19), Load (t+18), Load(t+17)…
  - at time t, we don't have actual Load(t+19), Load(t+18), …
- There are several ways to deal with this
  - two stages: GLM first, then use predicted Load(t+1), Load(t+2), …
  - Predict Load(t+1), then use predicted Load(t+1) to predict Load(t+2), …
  - Don't use the most recent loads: Load(t+1) = f(Load(t-23), …)

What's Demand Response

- Demand response
  - Not Distributed Resources (DR)
  - Not Distributed Energy Resources (DER)
- Load control
- Demand side management (DSM)

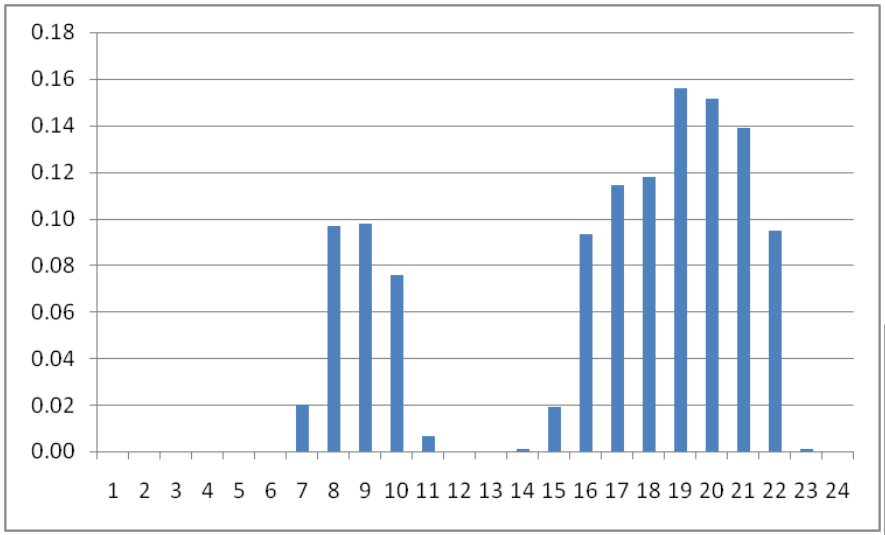
Why Demand Response Programs?

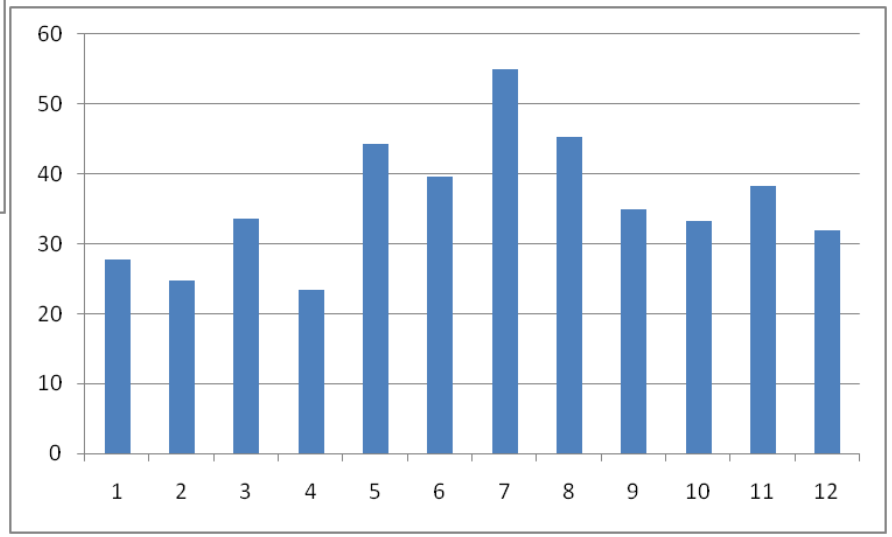
- Cut peak
  - Save kW
- Response to the energy market
  - Save $$$
- Energy conservation
  - Save kWh

How to Implement Demand Response?

- Programs
- Technologies
- Services infrastructures
- Dynamic pricing tariffs
- And more…

How to Implement Demand Response?





Three Challenges

- Irreproducible
- Irregular activities
- Limited samples

Two Methods

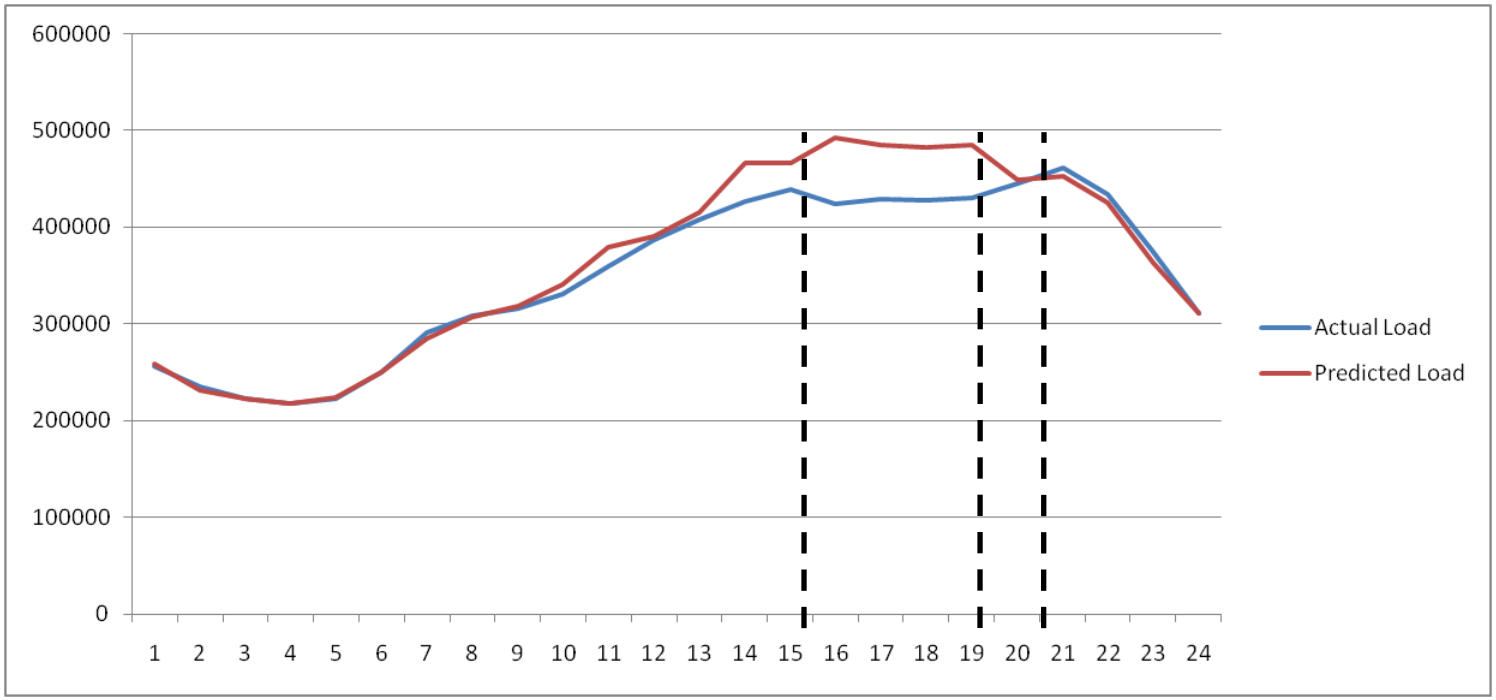
- Partition the data
  - Use the loads of the unaffected hours to "predict" or "restore" the loads of the affected hours
  - But be very careful…
- Use accurate VSTLF models (most likely tied to Box-Jenkins)
  - Forecast the loads of the affected hours recursively
    - use the loads of the recent 168 hours to forecast the 169th hourly load
    - add the predicted 169th hourly load to the history to forecast the 170th hourly load
    - add the predicted 170th hourly load to the history to forecast the 171st hourly load
    - …

One Example

- Assumption
  - Load picks-up within one hour after load control
- A medium sized utility: Medium State Electric
  - 800MW annual peak
  - 460MW average load
- In 3 years
  - Total hours: 26280
  - LC hours: 1300 Average cut: 3.7MWh/hr
  - LC periods: 300 Average pick-up: 11MWh/hr
  - Total energy savings in 3 years: 3.7x1300 – 11x300 = 1510MWh

One Example

- Load control
  - 15:00 to 19:00



Demonstration

- Lagged regression
- Data partition
- Assessment of Energy savings

References

- Tao Hong, "*Short term electric load forecasting,*" PhD dissertation, North Carolina State Univ., 2010
- Kutner, Nachtsheim, Neter, and Li, "*Applied Linear Statistical Models, 5 ed*"

Takeaways

- Use lagged regression to model recency effect
- Use past dependent variables to reduce autocorrelated errors
- Use accurate load forecasting models to restore load profile
- Quantify energy savings due to load control

Homework

- Data: http://courses.drhongtao.com/dahlf
- *Requirements*:
  - To forecast the loads of a given day, you can only use the loads up to two days prior to the given day. For instance, to forecast the loads of 2007/8/3, you can use the loads up to the last hour of 2007/8/1.
  - You will use the loads starting from the first hour of 2004/1/1 for the first two problems.
  - The load of the first hour of Day Light Saving (DST) time of each year may be shown as zero, while the last hour may show the sum of the loads of two hours. You don't need to make any adjustment when doing the first two problems. If you make adjustment for the 3rd problem, please indicate your adjustment strategy.

Homework

- Problems
  - Using the naive MLR benchmarking model to forecast the loads of 2007/8/3, and 2007/11/22, report the MAPE and MAE for each day. (30')
  - Using the lagged regression model to forecast the loads of 2007/8/3, and 2007/11/22, report the MAPE and MAE for each day. (40')
  - Can you further improve the forecasting accuracy of 2007/11/22? Report the methodology you used and the best MAPE and MAE you can get. (30')

Your grade of Problem #3 will be based on your rank among your peers.

Fractional ranking method (1, 2.5, 2.5, 4) will be used.

Your grade of Problem #3 = max{30-2r, 0} where r is your rank.

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  http://www.sas.com/events/analytics/us/poster.html

Thank You

- Questions / comments?

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