Carnegie Mellon

Electric Energy EESG Systems Group

Electrical & Computer ENGINEERING

Multi-Scale Models for Decomposing Uncertainties in Load and Wind Power

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Motivation

- New operating and planning challenges in systems with intermittent resources and responsive
- Today's approach to operation and planning does not explicitly use wind predictive models; instead typical capacity factors.
- Necessary to represent uncertainties to different level of detail for operation and for planning
- Once adequate models are derived, it becomes necessary to integrate these into the decision making processes (short term dispatch, unit commitment, planning) .
- It is important to understand the effect of using better predictive models on locational prices, LMP's , profits and benefits, expected social welfare and investment risks. This could support design of policies and market rules for managing uncertainties-related risk at value.
- Illustrate qualitatively different predictive models.

Proposed Modeling Approaches for Representing Wind and Load Power

- ***Multi-Scale Decomposition-Based Models***
- ***Statistically – Based Linear Predictive Models characterization of uncertainty sources***
- ***Combined Multi-Scale Decomposition – and Markov Process Based Modeling.***
- ***Short term vs. long term decision trees for operations and planning of power systems***
  - ***Short – and Long-term Tree Representation***

Multi-Scale Decomposition –Based Modeling

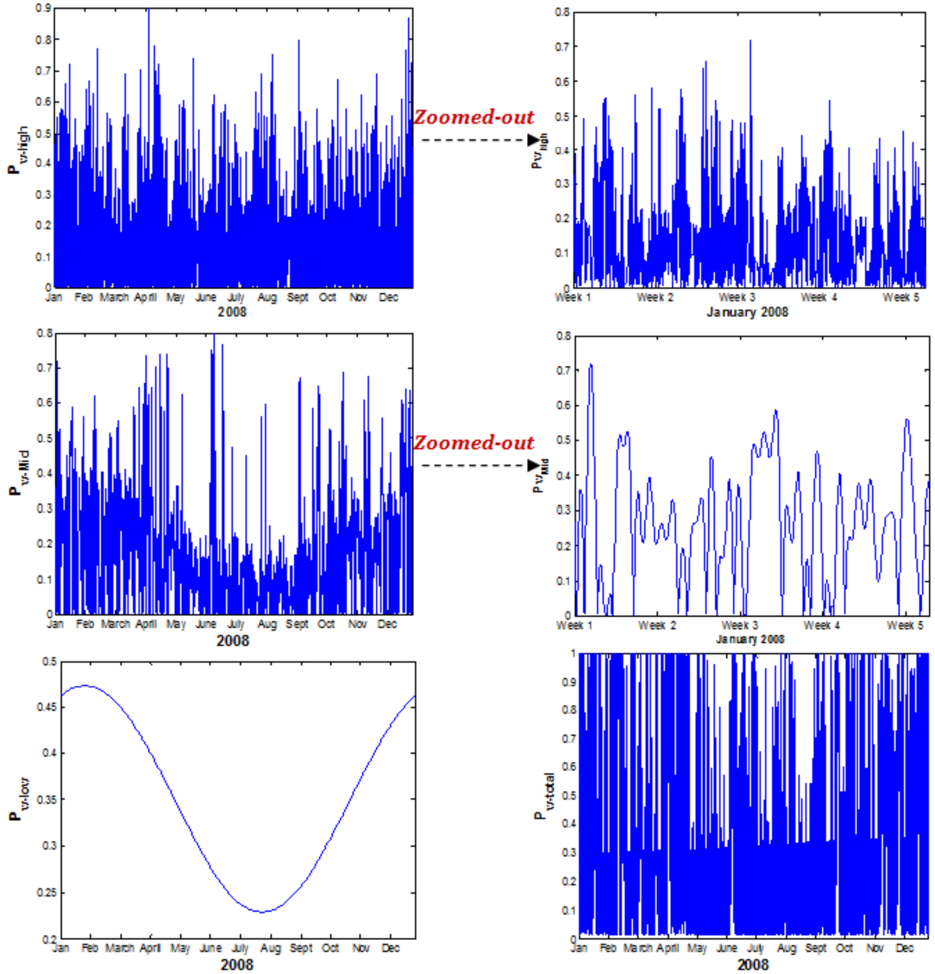


Figure 1 Low, medium and high frequency components of normalized wind power

The decomposition ranges from hourly (high frequency) up to yearly (low frequency), and are important in many power grid applications, [4].

❑we aim to decompose them into three components of different frequencies,

1) Low Frequency range: for economic development such as long term adaptation and generation investment (time horizon: many years),

2) Medium Frequency range: for seasonal weather variations and annual generation maintenance (time horizon: weeks but not beyond a year),

3) High frequency range: for Intra-day and Intra-week variations for regular generation dispatches and generation forced outage (time horizon: hours but within a week).

Statistically –Based Linear Predictive Model

a) Linear Prediction Coding Model: Auto- Regressive: More than 50 thousands of data samples.
b) Two phases, one we called a training phase and the other is the prediction phase. The data points in the training phase are used to determine the actual and estimated signals and hence the estimated error. In the prediction phase, the estimated error from the training phase is used to predict the next time stamp data point

L = 1: → Point estimator case.
L = ∞: →Time series case, i.e., no estimation at all, [1] and [5].

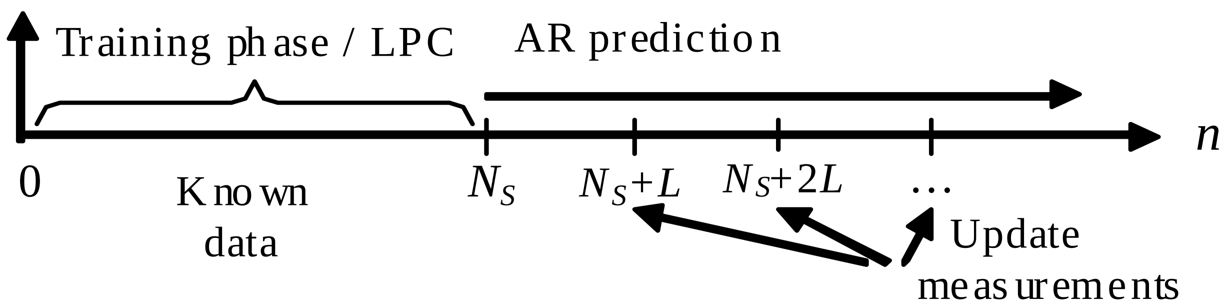
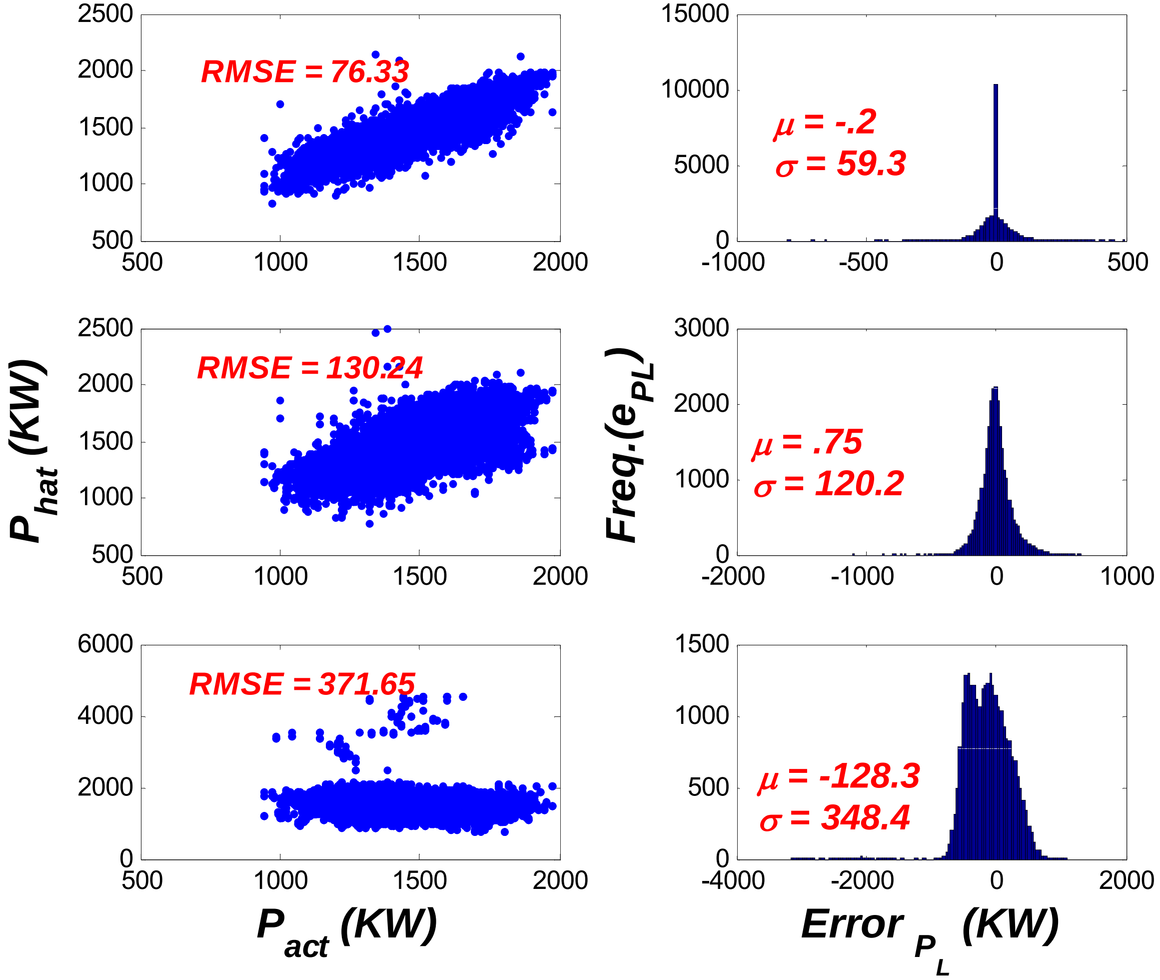


Figure 2

Statistically –Based Linear Predictive Model Results



Error distributions for longer look ahead time forecast show more disturbance from normal distribution and longer tails. This is expected without updating forecasting signal to include new available measured values

Figure 3. **Scatter plot of load power predicted vs. actual on the LHS and error distribution plots on the RHS for a) 10 minute (top), b) 1 hours (middle), and c) 24 hours (last)**

Combined Multi-Scale Decomposition – and Markov Process Based Modeling

Short –and Long –term Tree Representation of Uncertainties, [7]

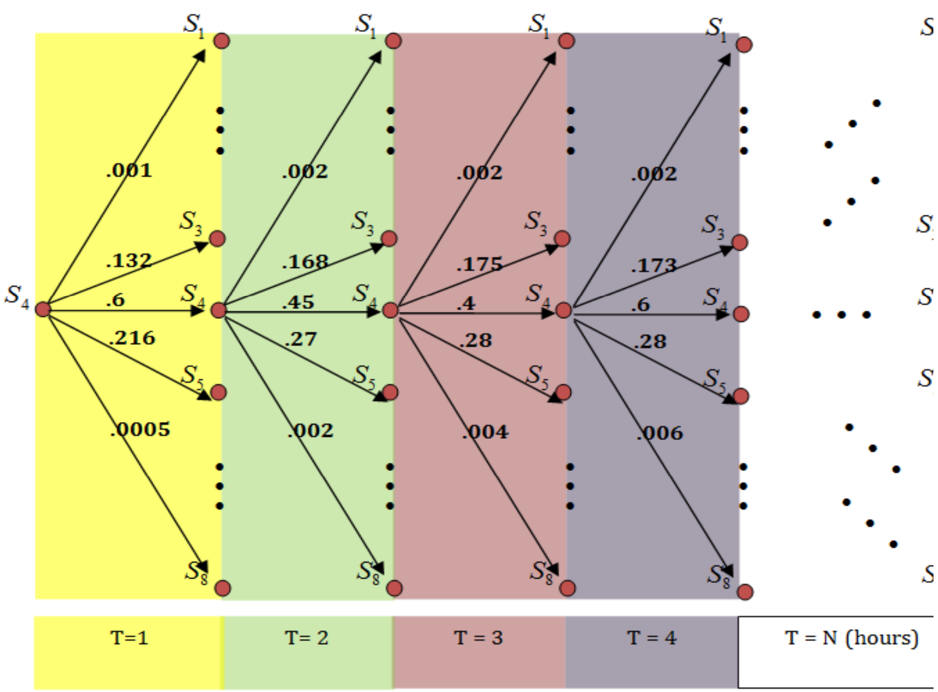


Figure 4 Load power short-term Uncertainty/decision tree.

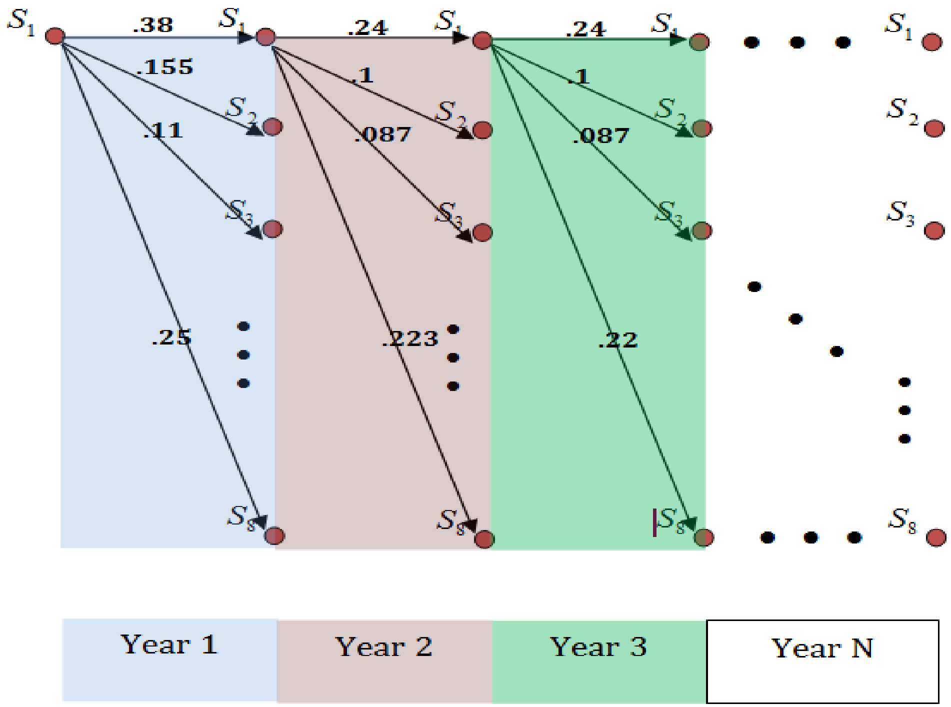


Figure 5 Load power long-term Uncertainty/decision tree.

Conclusions

- Several approaches used to derive predictive models of uncertain wind and load power
- High frequency models can be used for short term economic dispatch
  - Instead of assuming capacity factor, on-line forecast of wind and load power
- Low frequency models can be used for planning under uncertainties, [6]

References

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[5] Flores book Noha Abdel-Karim and Marija Ilic, a Chapter entitled "***Multi-temporal Models for Decomposing Uncertainties in Load and Wind Power***", in Springer Monograph on "Engineering IT – Enabled Electricity Services: The Case of Low-Cost Green Island", (Editors Marija Ilic and Le Xie).

[6] Flores book Audun Botterud, Noha Abdel-Karim, Marija Ilic, a chapter entitled "***Generation Planning under Uncertainty with Variable Resources",*** in Springer Monograph on "Engineering IT – Enabled Electricity Services: The Case of Low-Cost Green Island", (Editors Marija Ilic and Le Xie).

[7] Noha Abdel-Karim, Marija Ilic , "***Modeling Key Uncertainties in Future Electric Energy Systems***," Accepted Paper to the IEEE General Meeting Conf. 2012,