Forecasting Prices and Congestion for Transmission Grid Operation

Project Team:
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Presentation Outline

- Project overview
- Short-term inferential forecasting: Combined ANN/TSM model for MISO day-ahead price forecasting
- Empirical data analysis and week-ahead price forecasting for RTE using standard TSM
- Development of electricity price forecasting tools for portfolio management by power market participants
- Conclusion

Project Overview

Project Goal: Design **nodal price and grid congestion forecasting tools** for **market operators** and **market Traders** which take careful account of **distinct purposes**, **data availability**, and **time horizons**.

Price forecasting for Market Operators (MOs)

- To identify potential congestive conditions
- To detect the exercise of market power
- To facilitate scenario-conditioned planning

Price forecasting for Market Participants (MPs)

- To manage short-term risk of portfolio
- To design trading strategies
- To assist long-term investment planning

Combined ANN/TSM model for MISO day-ahead price forecasting

Short-term inferential forecasting

- With publicly available market information, forecasting tools are typically restricted to ***statistical methods***.
- Artificial Neural Network (ANN) and Time Series Models (TSM) are the most often used statistical price forecasting tools.
- ANN training algorithm and performance do not guarantee the modeling requirement of white-noise residual terms.
- Standard TSM can be used to refine ANN residual terms, and to extract the necessary remaining information from price data.

Combined ANN/TSM model for MISO day-ahead price forecasting (Cont'd)

- Proposed combined ANN/TSM model: ANN is for ***coarse-tuning***, and TSM is for ***fine-tuning***.
- Model description: P_t = Price , ε_t, μ_t = Error Terms

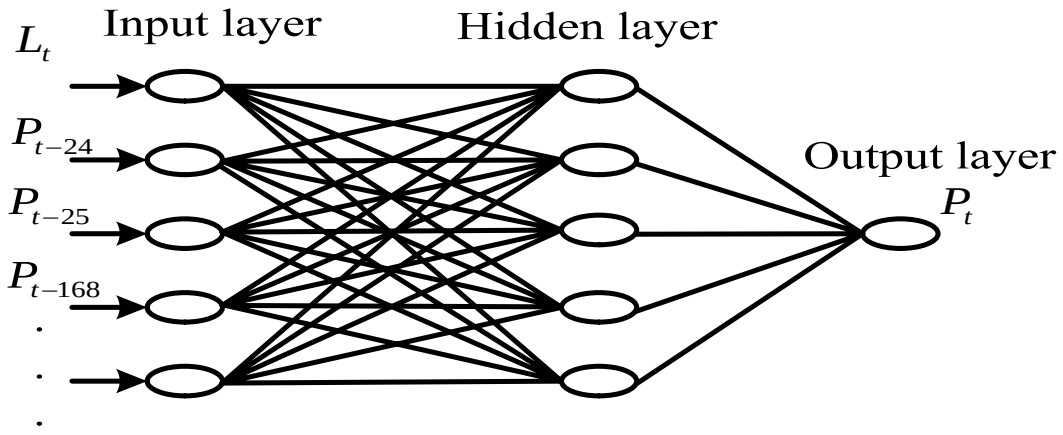
$$P_t = ANN(P_{t-24}, P_{t-25}, \ldots) + \mu_t$$

$$\mu_t = TSM(\mu_{t-24}, \mu_{t-25}, \ldots) + \varepsilon_t$$

$$\varepsilon_t \sim N(0, \sigma^2)$$

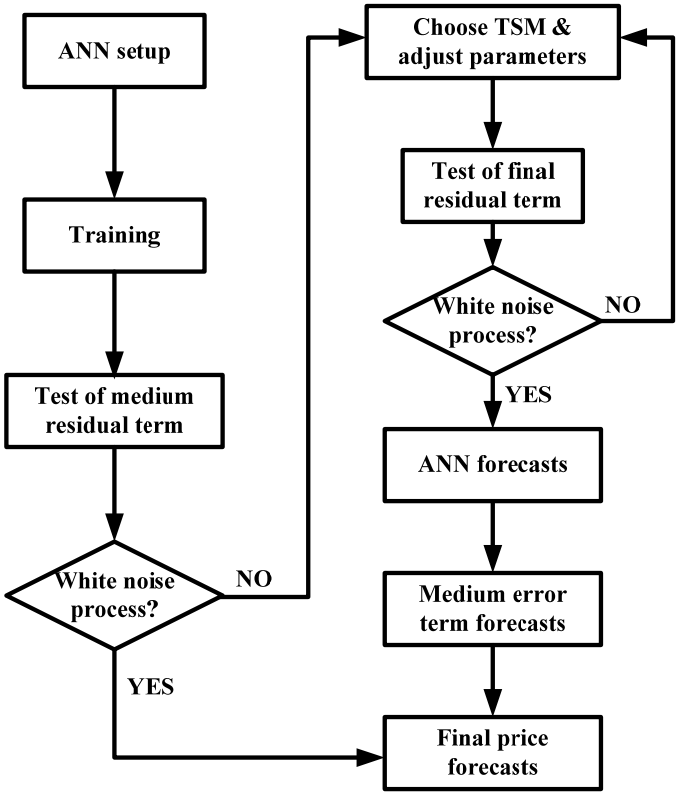
Combined ANN/TSM model for MISO day-ahead price forecasting (Cont'd)

- ANN Architecture



- Two TSMs are used:
  - Autoregressive Moving Average (ARMA) : constant mean and variance
  - Generalized Autoregressive Conditional Heteroskedasticity (GARCH): conditioned time-changing variance

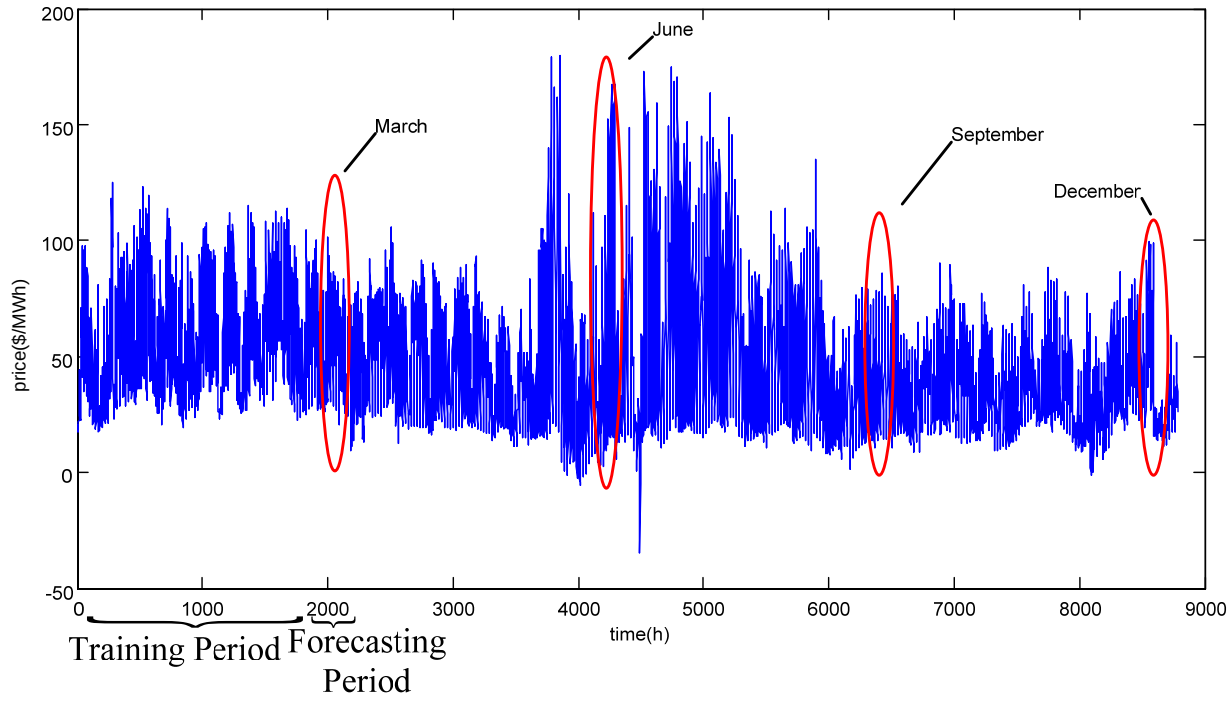
Combined ANN/TSM model for MISO day-ahead price forecasting (Cont'd)



Framework of the proposed approach

Combined ANN/TSM model for MISO day-ahead price forecasting (Cont'd)

- 2008 MISO data divided into training periods and forecasting periods for four different seasons.

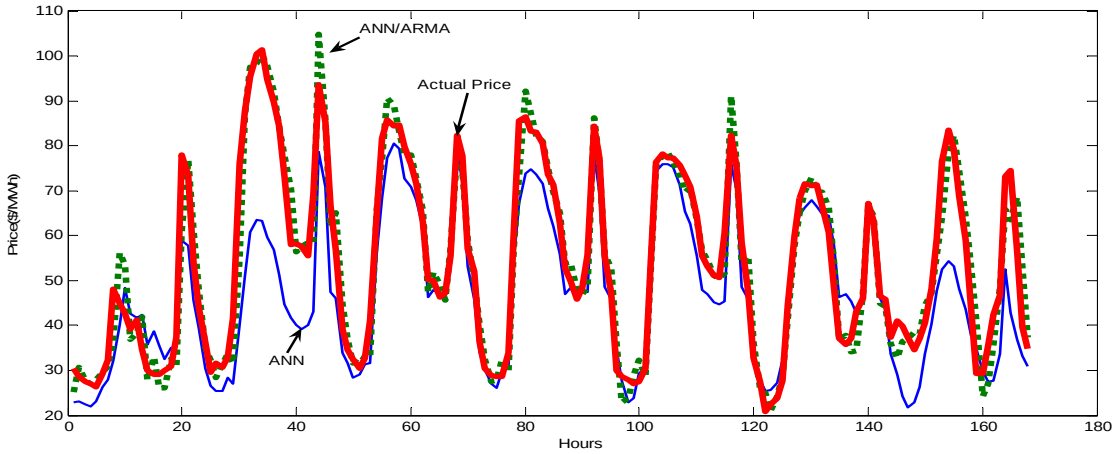


Combined ANN/TSM model for MISO day-ahead price forecasting (Cont'd)

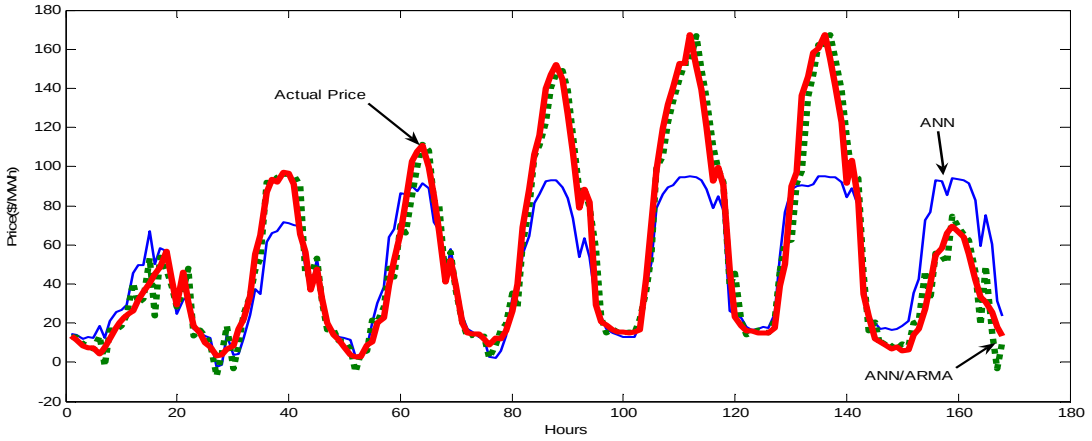
COMPARISON OF DAY-AHEAD FORECASTING PERFORMANCE USING ROOT MEAN SQUARE ERROR (RMSE) MEASUREMENT

RMSE	ARMA	ANN	**COMBINED ANN/ARMA**	**COMBINED ANN/GARCH**
Spring	13.17	12.24	5.20	5.26
Summer	30.66	22.41	9.91	11.06
Fall	15.12	5.88	4.31	5.41
Winter	14.17	11.96	6.58	6.63

Combined ANN/TSM model for MISO day-ahead price forecasting (Cont'd)



Forecasts in Spring



Forecasts in Summer

Additional Work in Progress

- To date, statistical methods (e.g. combined ANN/TSM) have been used to study price forecasting for power markets.
- Statistical methods cannot completely capture the Data Generating Mechanism (DGM) for electricity prices
- Structural models of power market operations could help improve forecasting performance.
- For structural modeling, use will be made of the ***AMES Wholesale Power Market Test Bed*** developed by Li, Sun, and Tesfatsion.

Presentation Continued

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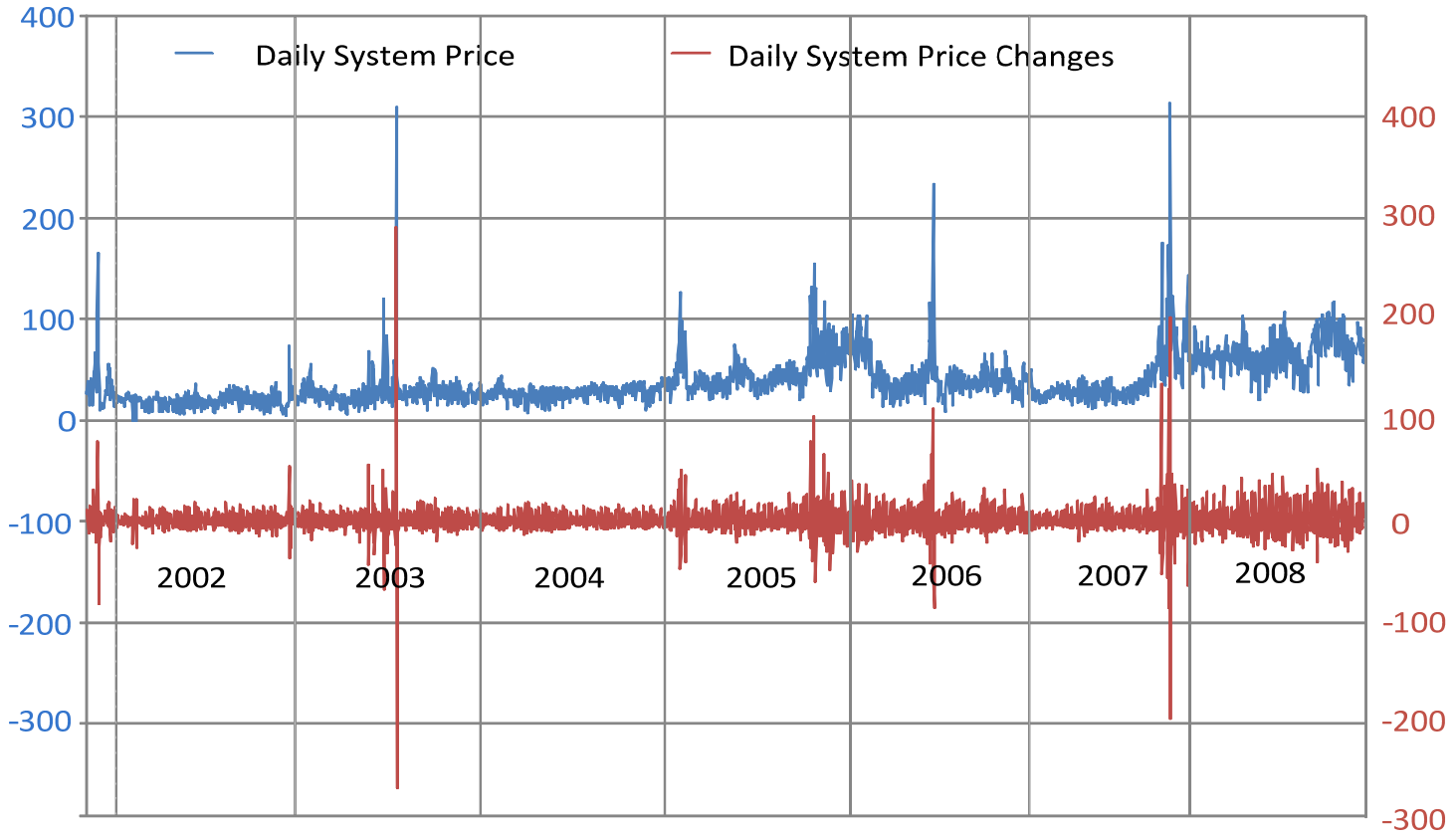
Daily system price and daily changes of system price for RTE (11-26-2001 to 12-10-2008)



Maximum Price: 314.27 Euro on November 15, 2007
Minimum Price: 0 Euro on February 27 and March 6, 2002
Mean Price: 40.48 Euro

Empirical data analysis and week-ahead price forecasting for RTE

Descriptive statistics for daily system price and other related times series

Series	Number of Observations	Mean	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis
P_t	2572	40.4775	33.0752	314.2692	0	24.3321	2.5432	18.5673
$P_t - P_{t-1}$	2571	0.0203	-1.0404	291.0325	-264.7862	15.9139	1.4100	101.4020
$\ln(P_t+10)$	2572	3.8306	3.7629	5.7816	2.3026	0.4129	0.4494	3.3808
$\ln(P_t+10) - \ln(P_{t-1}+10)$	2571	0.0003	-0.0236	2.3905	-1.7515	0.2369	0.9303	10.9030

Sample autocorrelation function for the system price

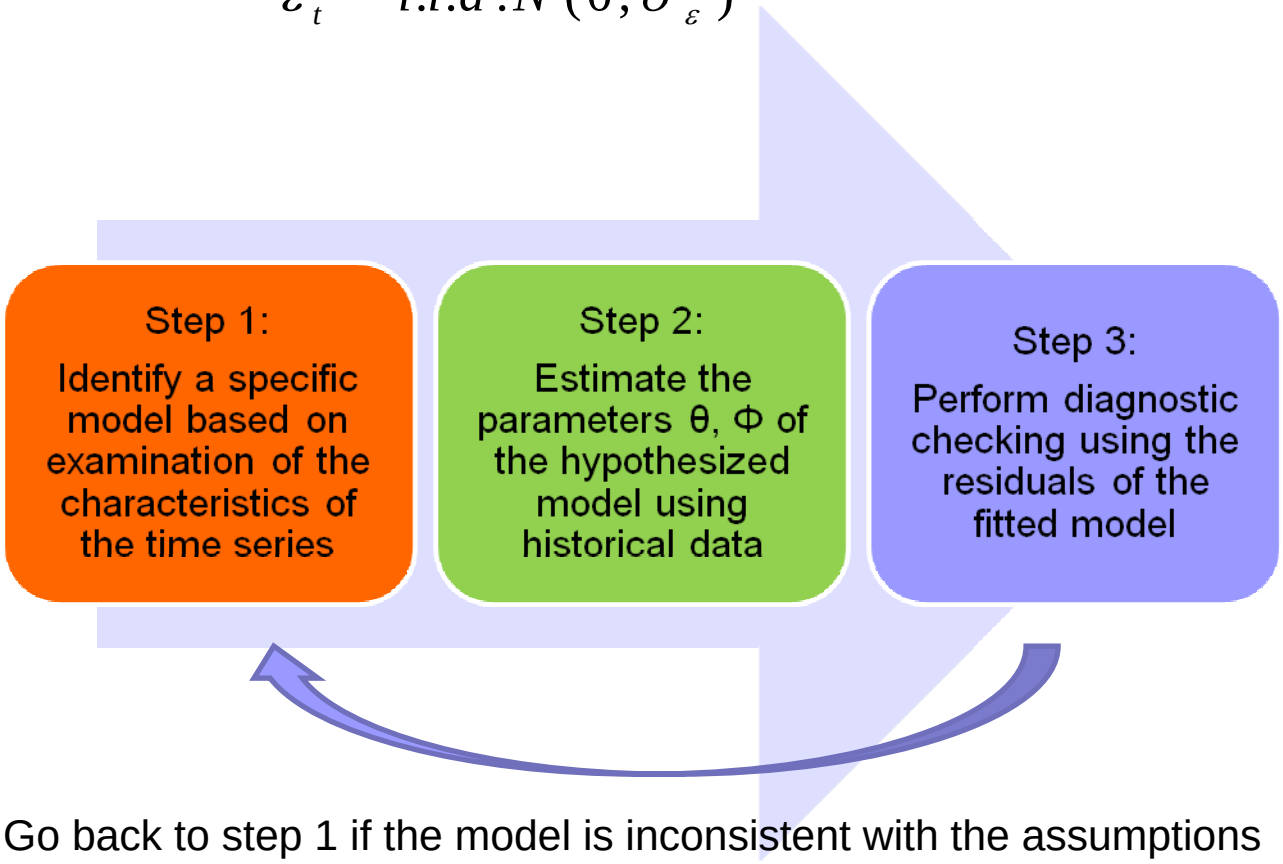
Series	Sample Autocorrelation of Lag							
	1	2	3	7	14	21	28	35
P_t	0.786	0.668	0.629	0.710	0.623	0.617	0.597	0.570
$P_t - P_{t-1}$	-0.226	-0.184	-0.014	0.28536	0.277	0.267	0.265	0.234
$\ln(P_t+10)$	0.835	0.722	0.680	0.812	0.739	0.733	0.717	0.696
$\ln(P_t+10) - \ln(P_{t-1}+10)$	-0.158	-0.214	-0.071	0.512	0.496	0.483	0.480	0.465

Week-Ahead Daily Average Price Forecasting

The system log price is modeled by an ARIMA model

$$(1-\phi_1 B-\cdots\phi_p B^p)(1-B)(1-B^7)P_t=(1-\theta_1 B-\cdots\theta_q B^q)\varepsilon_t$$

$$\varepsilon_t \sim i.i.d.N(0,\sigma_\varepsilon^2)$$



Go back to step 1 if the model is inconsistent with the assumptions

Forecast Performance Evaluation

Two indices are used to evaluate the price forecast:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{P}_i - P_i)^2} \qquad MAPE = \frac{100}{N}\sum_{i=1}^{N}\frac{\left|\hat{P}_i - P_i\right|}{P_i}$$

Fitting Period: From five weeks ahead to one week ahead

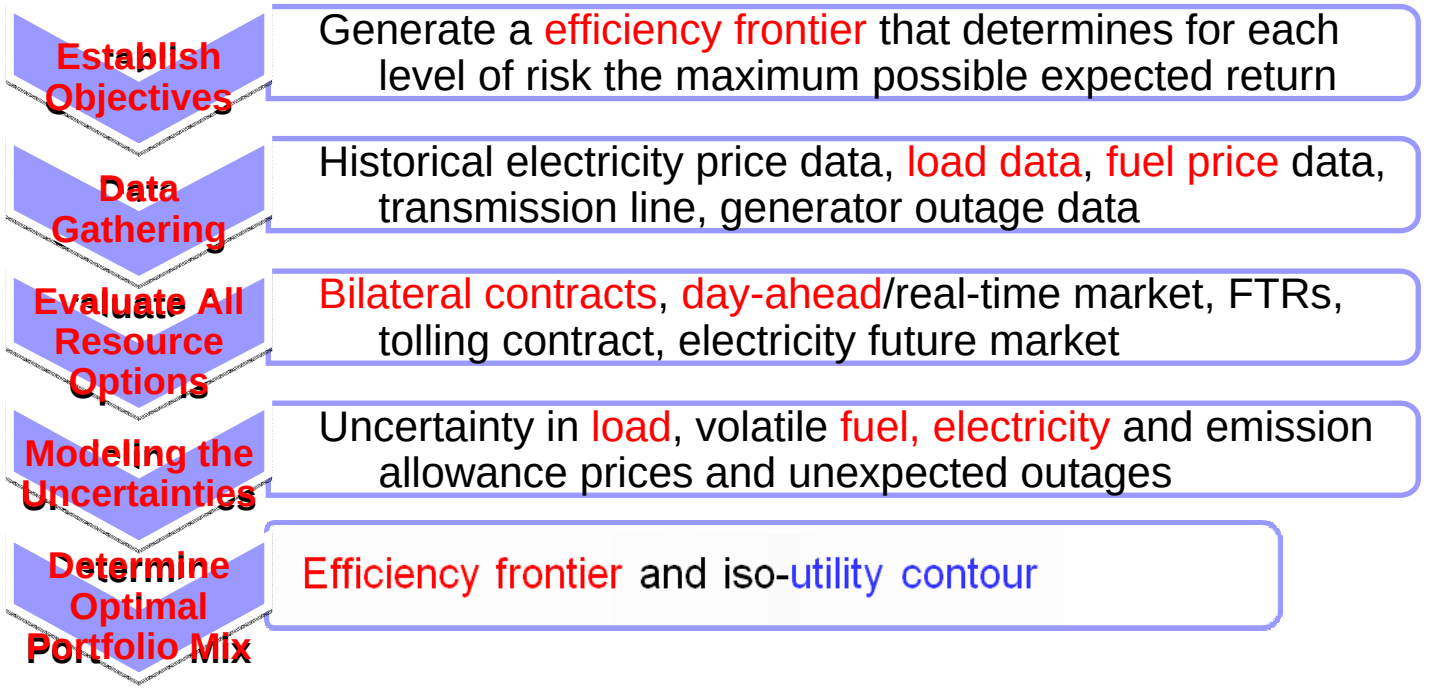
Forecast Period	RMSE	MAPE
1-25-2002 – 1-31-2002	2.070808	6.399645
3-26-2002 – 4-01-2002	6.553692	27.6827
5-25-2002 – 5-31-2002	2.263012	17.01064

- Historical price itself does not contain sufficient information for forecasting (This can be illustrated by the unpredictable price spikes in the price series)
- Other critical information (load and fuel price data) could improve the forecasting performance
- Therefore, in the next part of the project we will investigate combined structural/TSM forecasting tools for RTE

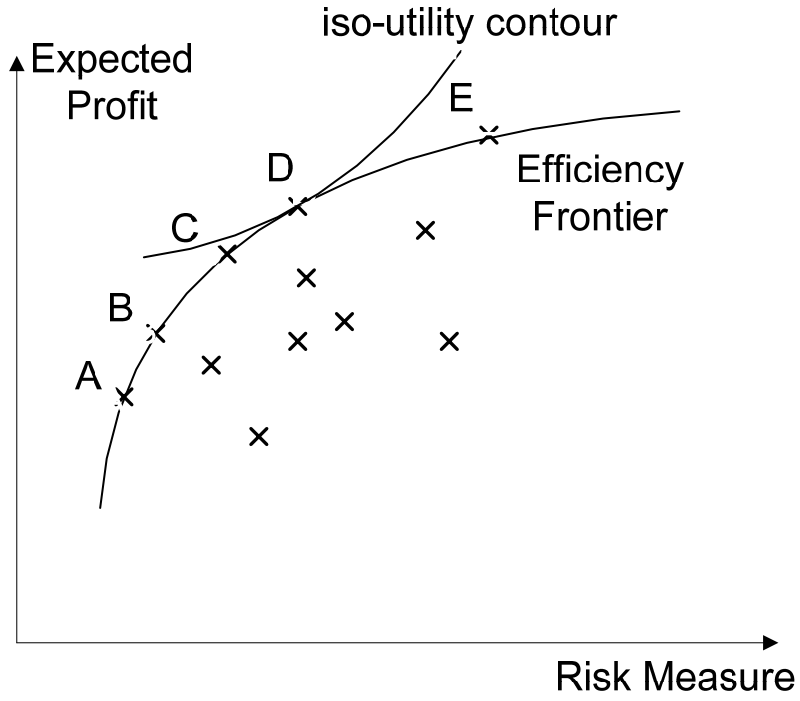
Developing electricity price forecasting tools for portfolio management

The basic idea of portfolio management is to diversify a portfolio so that risk is minimized for each given expected profit or net earnings level.

Five basic steps



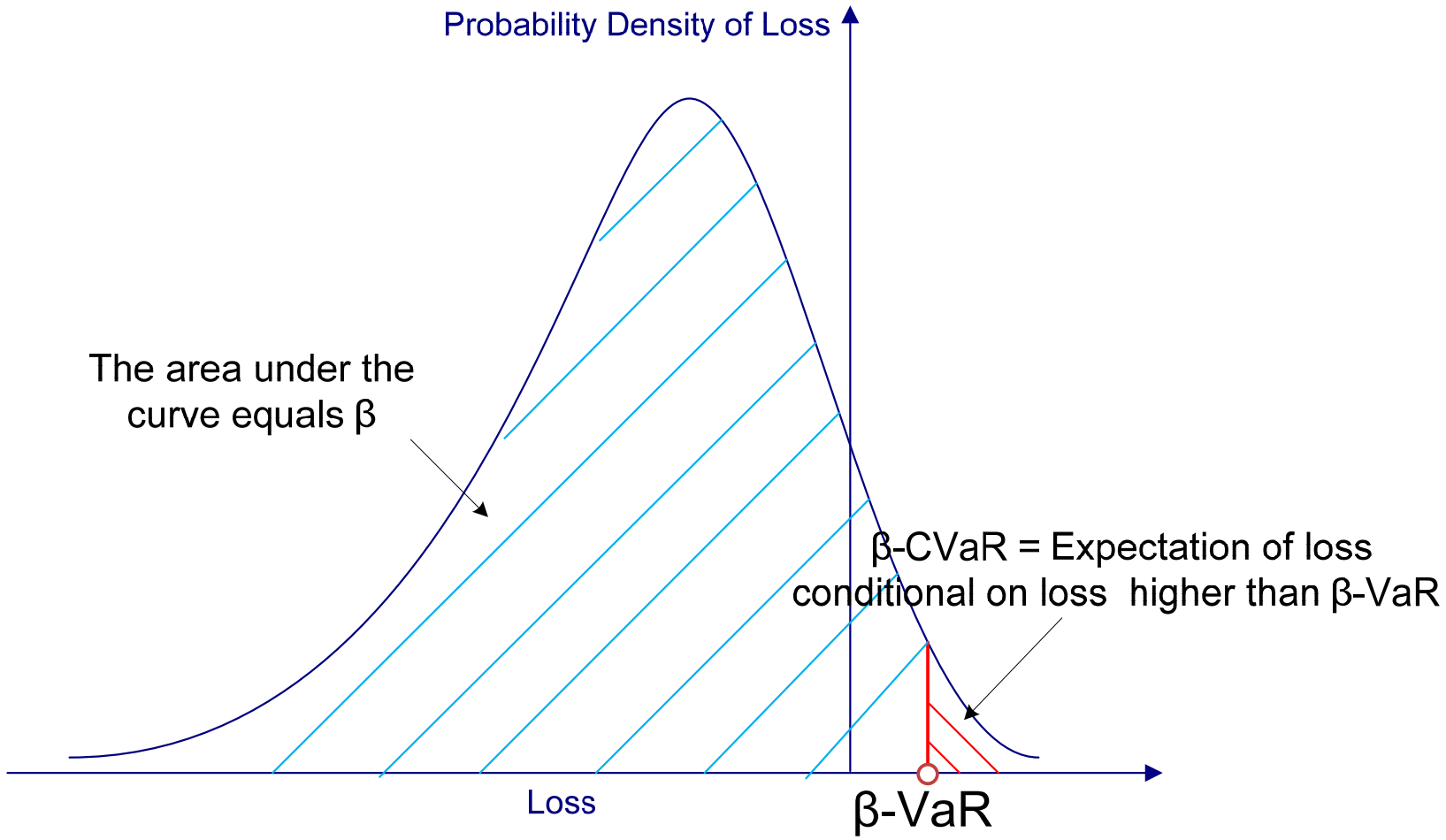
Determine the optimal portfolio mix



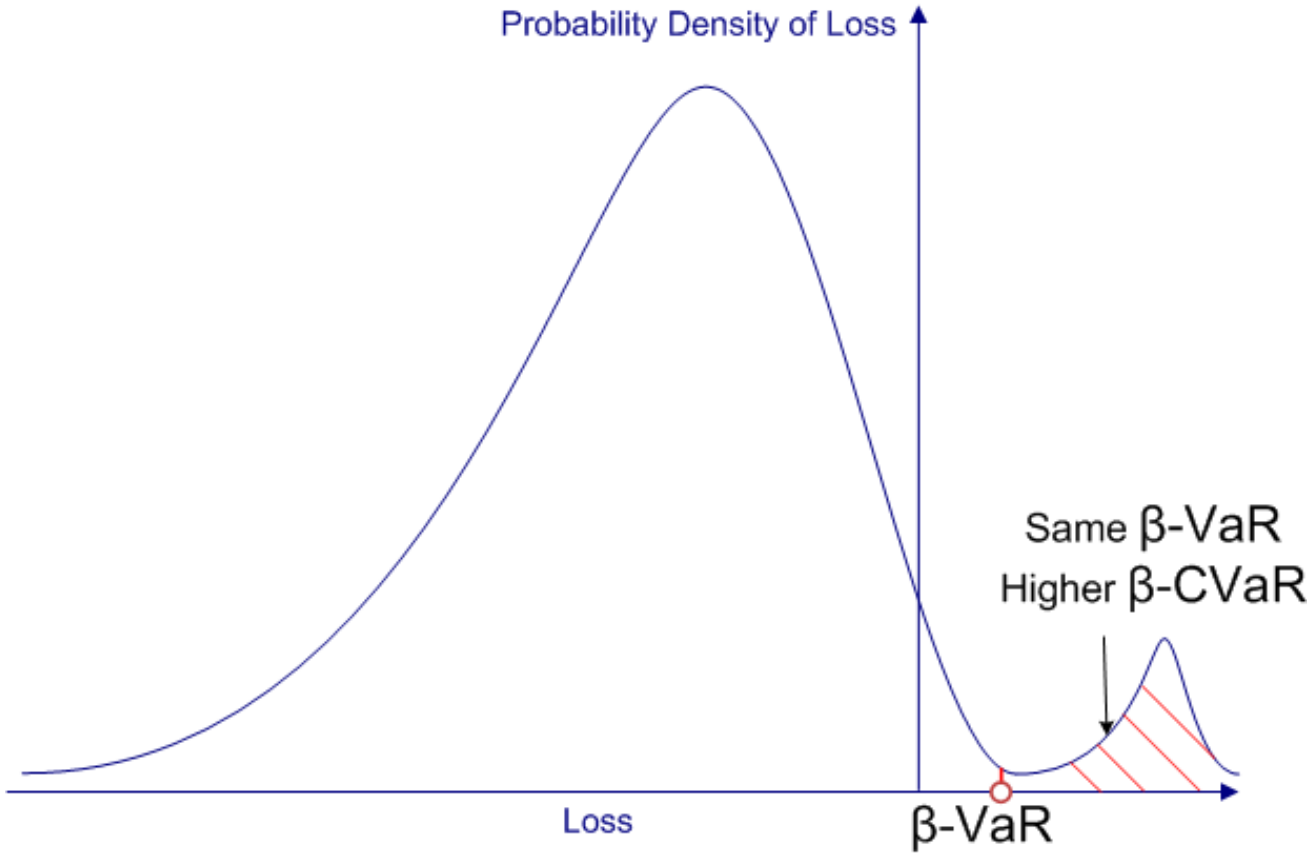
Two different risk measures are being investigated in this project for portfolio management:

- Value at risk (β -VaR) "How bad can things get"
- Conditional value at risk (β -CVaR) "If things do get bad, how much can we expect to lose"

Calculation of VaR and CVaR from the probability density function of loss



Alternative situation to the previous figure



- β-VaR is the same, but β-CVaR is larger

Proposed Structural Model of a GenCo's Portfolio Optimization

(1) Collect historical load data

(2) Build load model

(3) Decide how to represent rival bidding behaviors

(4) Determine own supply offer and portfolio mix

(5) Submit supply offer to ISO (Solve with AMES)

(6) Get net earning outcome, update database

(7) Update load/rival models

(8) Adjust supply offer and portfolio mix

(9) Go back to step 5

Conclusions

- Price forecasting is critical for both market traders and market operators in restructured wholesale power markets.
- The combined ANN/TSM approach incorporates the advantages of both ANN and TSM methods.
- In this project, ANN and TSM methods have been used to generate price forecasts for both MISO and RTE data.
- The evidence suggests that the inclusion of structural power market aspects could improve forecasting performance for both MISO & RTE.
- The AMES Structural power market test bed is being extended to permit the study of forecasting tools both by GenCos facing portfolio management problems and by market operators.
- MISO and RTE data will be used as the two principal case studies for this test bed work.

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