Impact of Heatwaves on Utility Systems

Eugene A. Feinberg

Department of Applied Mathematics and Statistics
Stony Brook University

Eugene.Feinberg@sunysb.edu

BNL, Upton NY

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Peak load forecasting

- Peak loads are determined by several factors. Weather is one of the most important factors. In geographic areas with summer peaks, peak loads usually happen during heatwaves.
- Important applications for peak load forecasting:
  - Planning and calculation of weather normalization factors that can be done for geographic areas.
  - Short-term load forecasts to control the system.

Major topics covered in the talk

- Long-term peak load forecasting:
  - Next year load pocket forecasting software that includes the computation of weather normalization factors
- Short-term hourly load forecasting:
  - System forecasting
  - Distribution substation load forecasting and transformer rating
  - Feeder load and overloading forecasting

Factors for accurate forecasts

- Weather factors:
  - Temperatures, Dew point, Humidity, Heatwave duration
  - Wind speed/wind direction
  - Sky coverage, Sunrise and sunset times
- Time factors:
  - Day of the week
  - Hour of the day
  - Holidays

Annual Peak Load Forecasting

- Annual peak load forecasting and Weather Normalization Factor (WNF) are important to planning since peak loads impact capacity requirements.
- In particular, load pocket peak forecasting is important for local area planning.
- The focus is to forecast the annual peak demand for distribution substations and feeders.

Model

A mixed additive-multiplicative model of the following form was developed

$$L(t)=L_0(d(t),h(t)) + L_1(d(t),h(t))\bullet f(w(t)) + u(t)$$

where:

- $L_0(d(t),h(t))$ is component independent of weather factors
- $L_1(d(t),h(t))$ is the weather normalized load factor
- $d(t)$ is day of the week, $h(t)$ is hour of the day
- $L(t)$ is the original load
- $f(w(t))$ is the weather factor
- $u(t)$ is the random error

Load Pocket Peak Forecasting Software

- For local areas, the software deals with two types of load peaks:

  (i) Peak load for the area

  (ii) Load for the area on the system peak date

- The software analyzes load and weather data for local areas.

Computation of Weather Normalized Factor (WNF)

- In particular, the software calculates Weather Normalization Factors

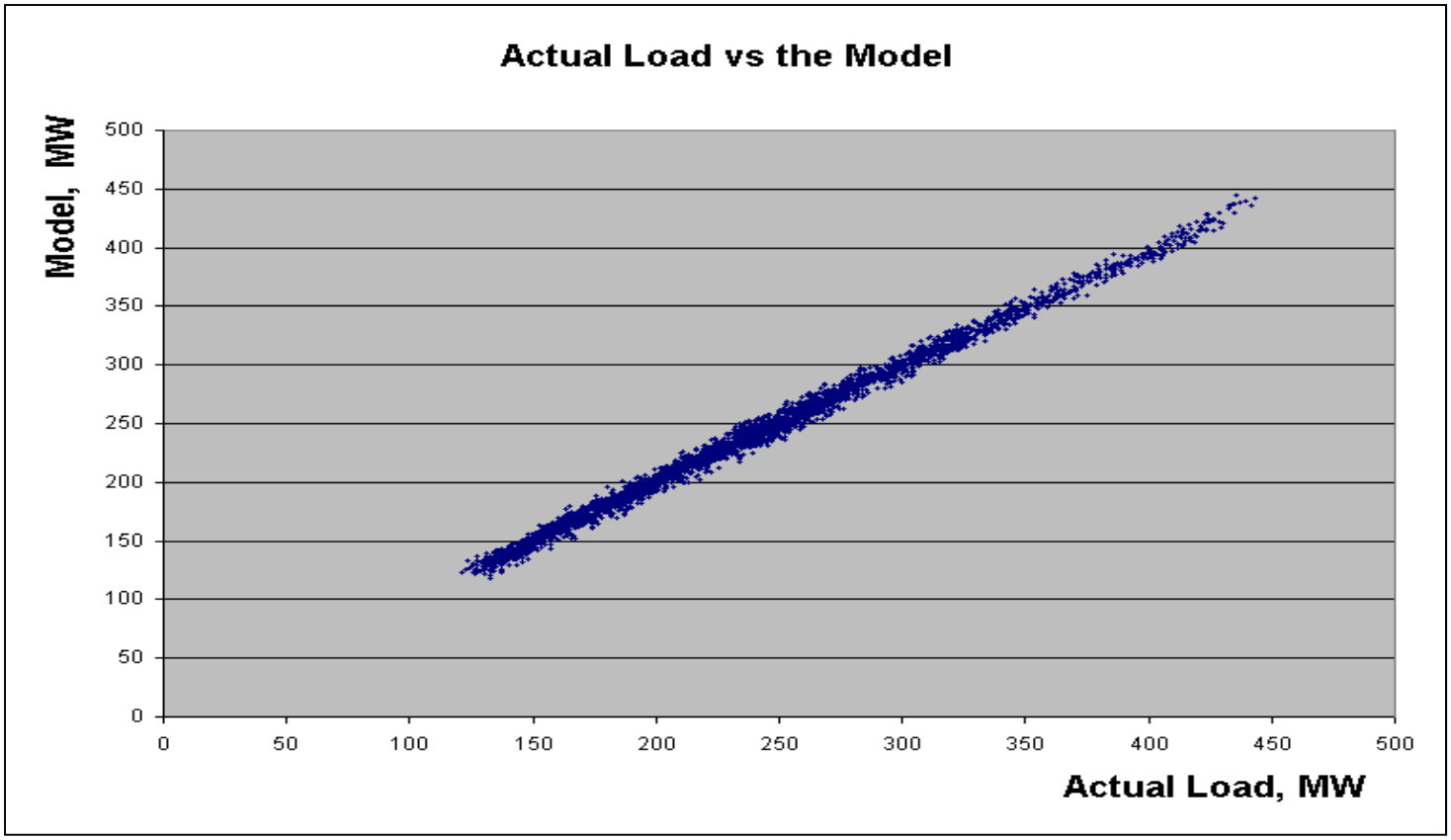
$$WNF = \frac{\text{Normal Load}}{\text{Peak Load}}$$

- It also provides the probability calculator for the next year peak load distributions.

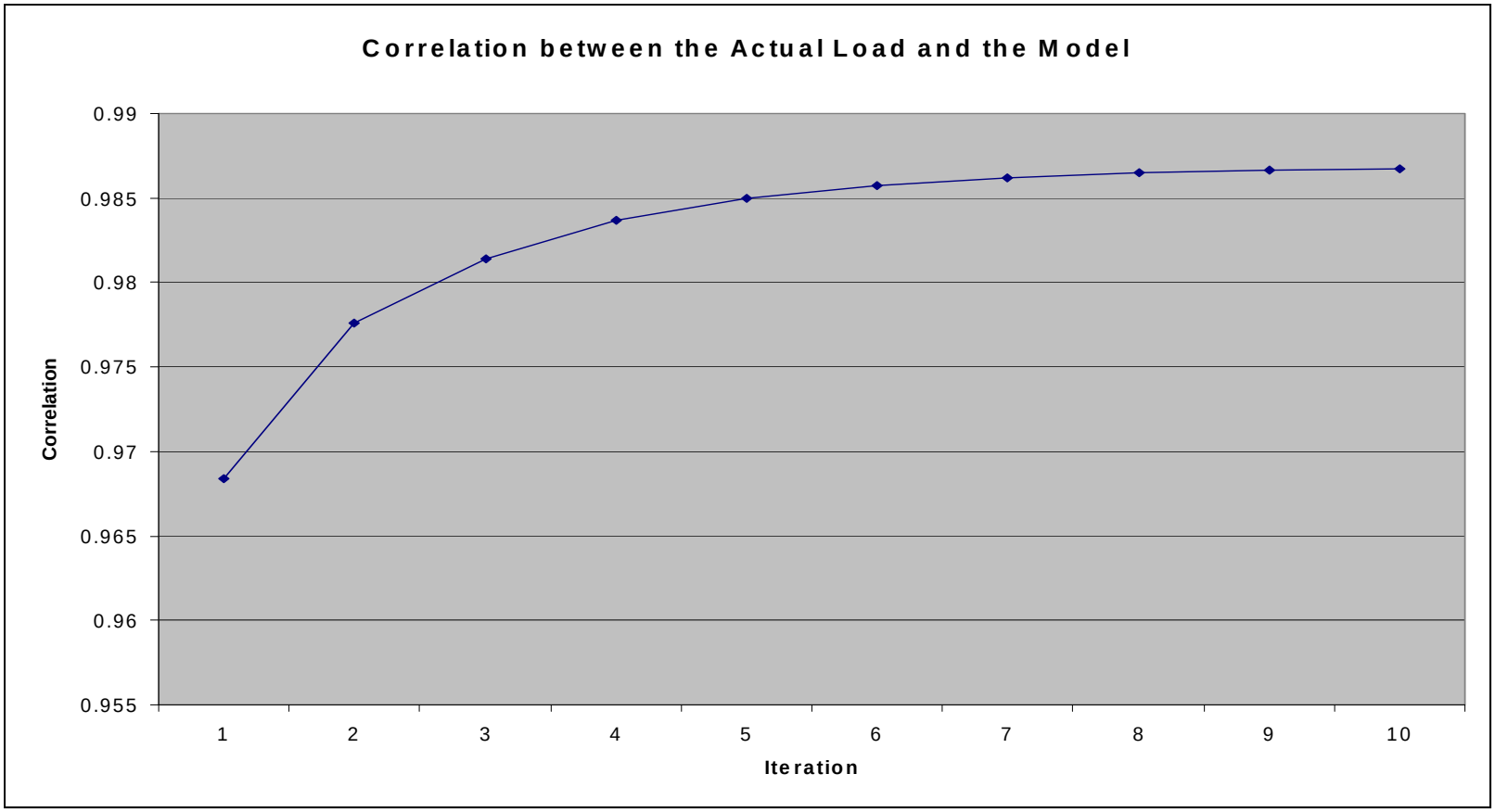
Outputs of Load Pocket Peak Forecasting Software

- Actual Load Shape by day of week and hour
- Weather Normalized Load Shape by day of week and hour
- Actual Load vs Model Load scatter plot
- Calculates Normalized Weather Parameters
- Calculates Weather Normalization Factors (WNFs)
- Calculates System and Pocket Peak Load Distributions

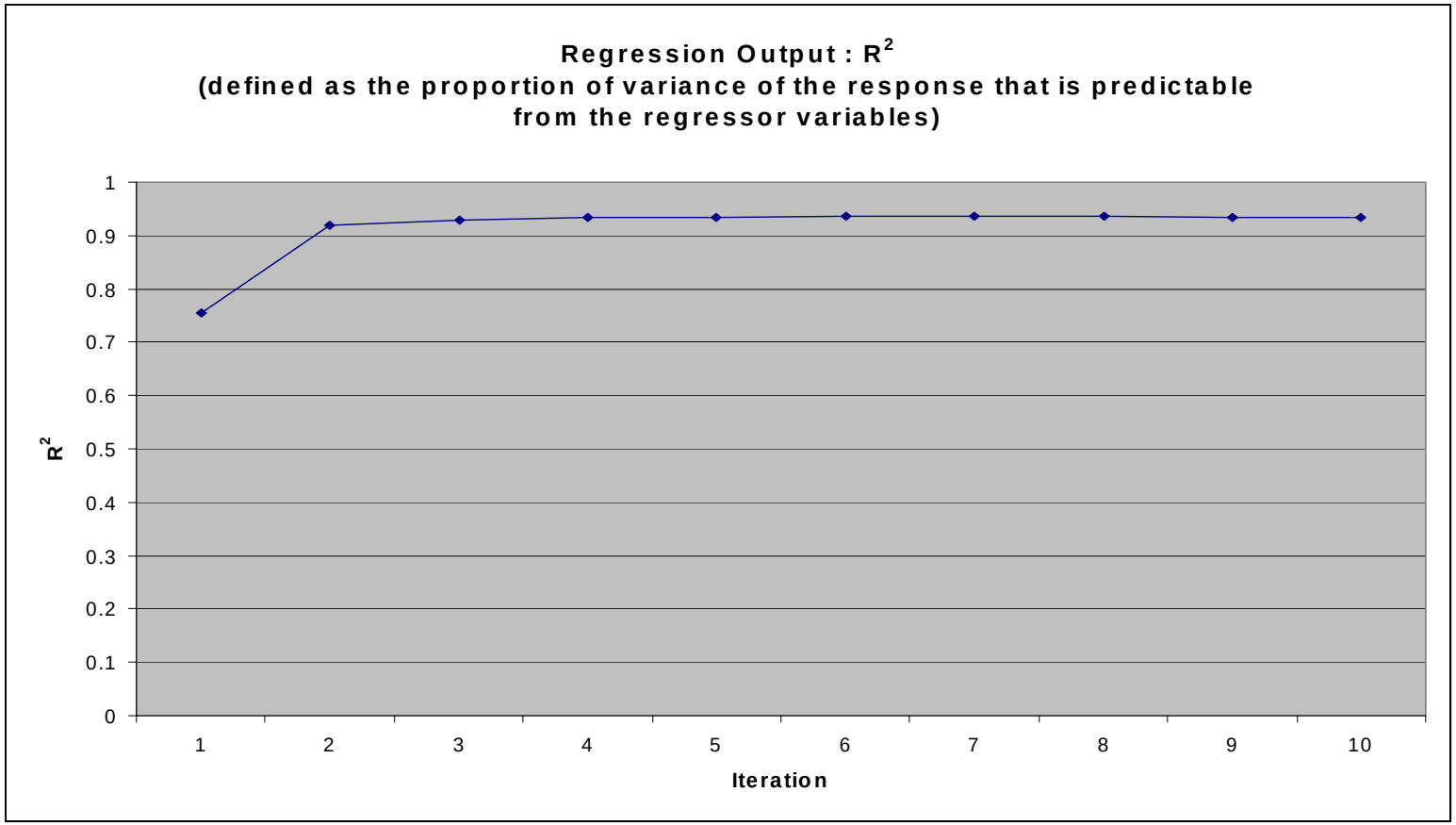
Scatter Plot of the Actual Load Vs the Model



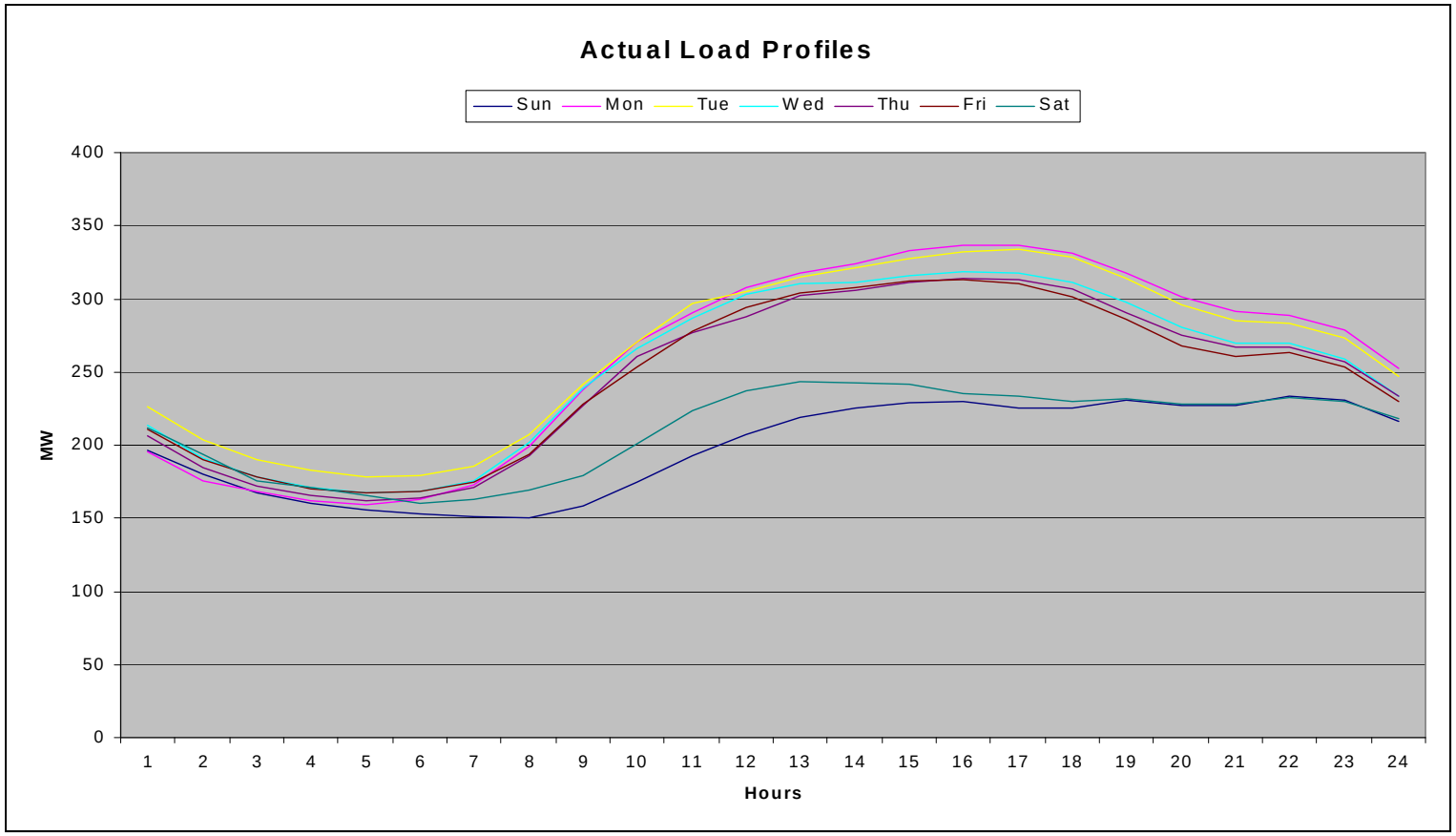
Correlation Between the Actual Load and the Model



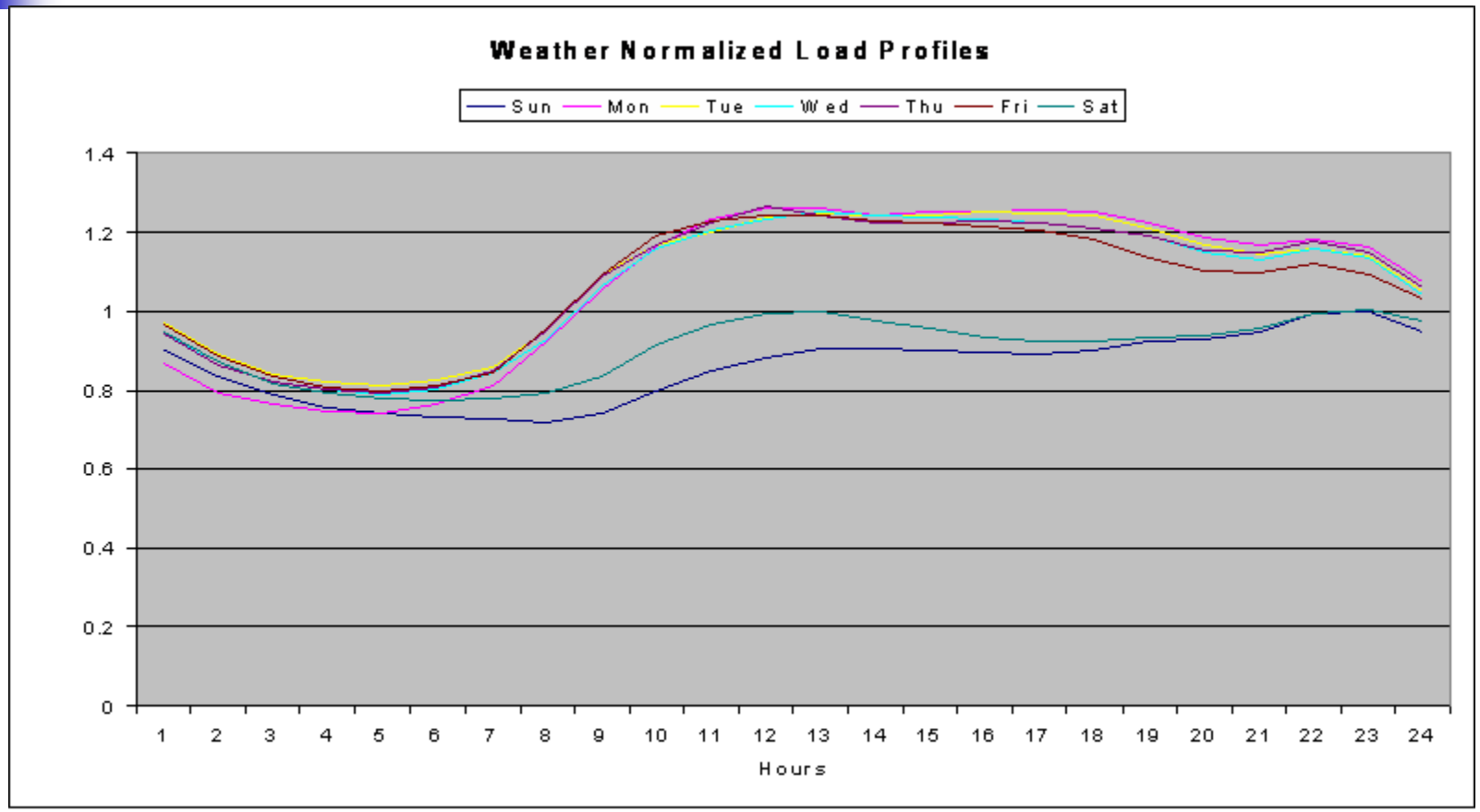
R-square Between the Actual Load and the Model



Actual Load Profiles



Weather Normalization Factors



System Peak Dates

Select Calendar

Babson - System Peak Dates
2013 Design Day (Salisbury)

HH	DATE	LOAD	STRING	TEMP	DP	THI	THI DAILYMAX	THI DAILYMAX TIME	THI_4	THI_24	TEMP DAILYMAX	TEMP DAILY TIME
19	9/4/73	223	3	70	71	76	80	13	78	76	88	
17	7/9/74	263	1	85	64	81	81	15	81	75	92	
17	8/1/75	285	1	89	75	82	83	15	83	77	93	
17	8/23/76	256	2	86	65	78	79	15	78	75	87	
16	7/21/77	305	5	89	75	82	83	12	82	77	90	
17	8/17/78	279	2	87	71	80	82	12	81	78	89	
16	8/1/79	278	2	85	75	80	81	15	80	77	86	
15	7/21/80	291	2	90	75	83	84	13	83	78	92	
17	7/9/81	299	2	94	69	83	84	15	84	78	95	
13	7/19/82		3	87	75	81	81	13	81	78	88	
15	9/7/83	275	2	89	64	80	80	14	80	77	90	
16	6/11/84	276	3	87	70	80	81	13	80	75	89	
17	8/15/85	278	2	86	71	80	83	12	81	78	88	
18	7/7/86	285	1	95	69	84	84	18	83	74	95	
17	8/17/87	264	1	83	75	79	81	14	80	77	86	
17	8/15/88	275	7	87	70	80	81	14	80	76	88	
16	8/4/89	270	1	89	72	81	82	13	79	75	91	

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Pocket Peak Dates

Select Calendar

Babson - Pocket Peak Dates
2013 Design Day (Salisbury)

HH	DATE	LOAD	STRING	TEMP	DP	THI	THI DAILYMAX	THI DAILYMAX TIME	THI_4	THI_24	TEMP DAILYMAX	TEMP DAILY TIME
15	8/28/73	296	1	93	73	84	85	14	84	77	95	
14	6/10/74	280	1	90	72	82	82	12	82	74	94	
15	8/1/75	290	1	93	72	83	83	15	83	77	93	
14	7/20/76	268	0	88	63	79	79	12	79	73	88	
16	7/21/77	305	5	89	75	82	83	12	82	77	90	
16	8/17/78	281	2	89	70	81	82	12	81	78	89	
16	8/2/79	284	3	84	78	80	80	14	80	78	84	
16	7/21/80	297	2	90	78	83	84	13	83	78	92	
16	7/9/81	299	2	95	70	84	84	15	84	78	95	
16	7/26/82	272	1	89	68	80	80	15	80	74	91	
16	9/6/83	282	1	89	72	81	81	15	81	76	89	
13	6/11/84	279	3	89	71	81	81	13	80	75	89	
16	8/15/85	287	2	87	75	81	83	12	81	78	88	
17	7/7/86	286	1	95	68	84	84	18	83	74	95	
15	7/10/87	280	2	90	75	83	83	15	81	77	90	
16	8/11/88	295	3	87	76	81	82	15	81	78	89	
15	7/26/89	279	1	90	71	82	82	10	81	76	92	

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Weather Normalization Factors Pocket WNFs

Babson: Pocket Peak Load

2013 Design Day (Salisbury)

TEMP	91
TEMP_DAILYMAX	92
TEMP_DAILYMAX_HOUR	14
STRING	2
THI	82
THI_DAILYMAX	83
THI_4	82
THI_24	77

Get Peak Distribution

Export

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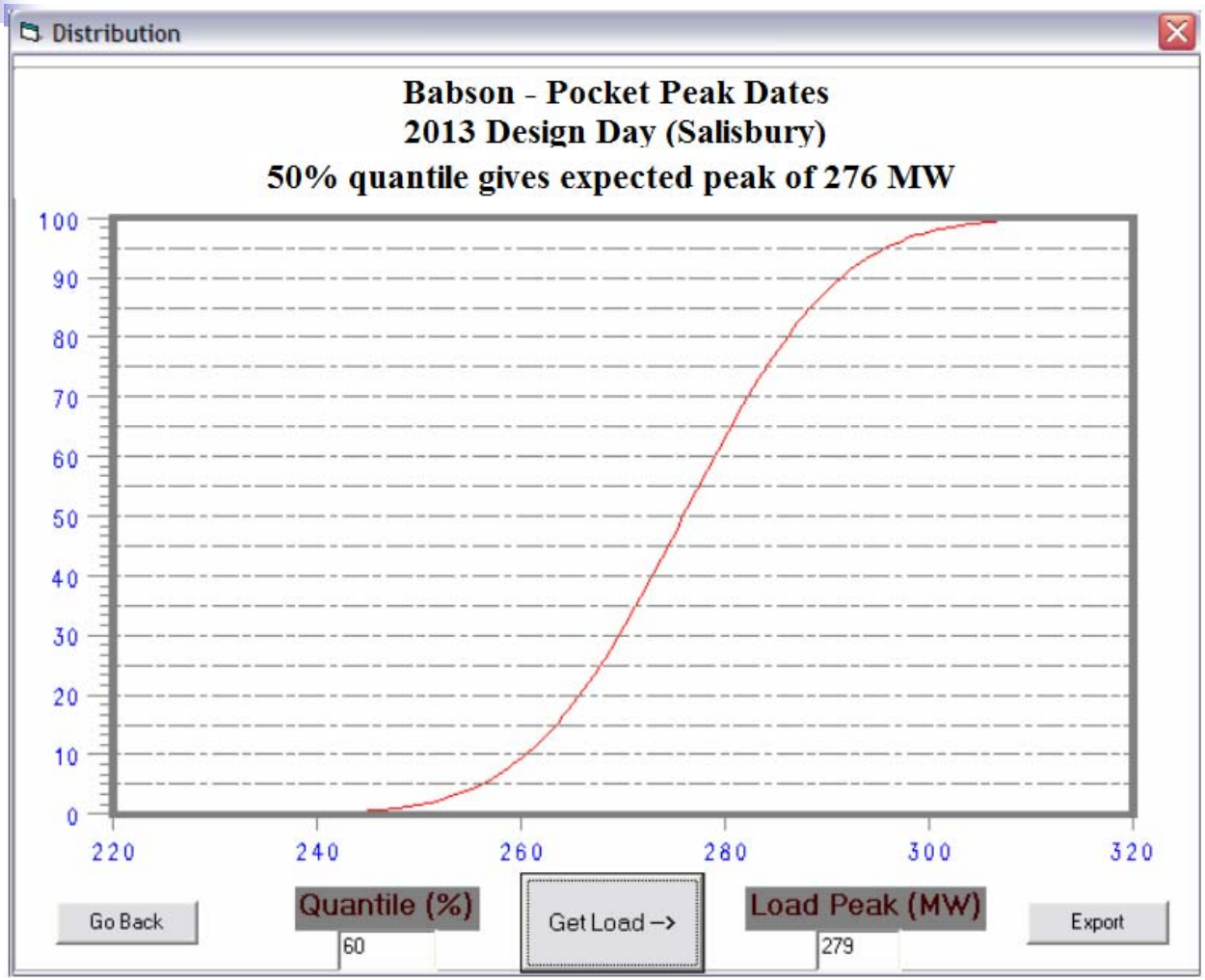
LOADS AND WNFS AT POCKET PEAK DAYS

YEAR	DESIGN DAY LOAD	PEAK LOAD	WNF	Date	Hour
2007	291	303.5	0.9588	7/22/2007	15
2008	308	324.5	0.9492	7/6/2008	16
2009	316	300.5	1.0516	8/7/2009	16
2010	330	345.3	0.9558	8/8/2010	16
2011	324	326.8	0.9913	7/29/2011	17
2012	347	341.8	1.0153	6/26/2012	17
2013	292.7	285.5	1.0251	8/8/2013	17

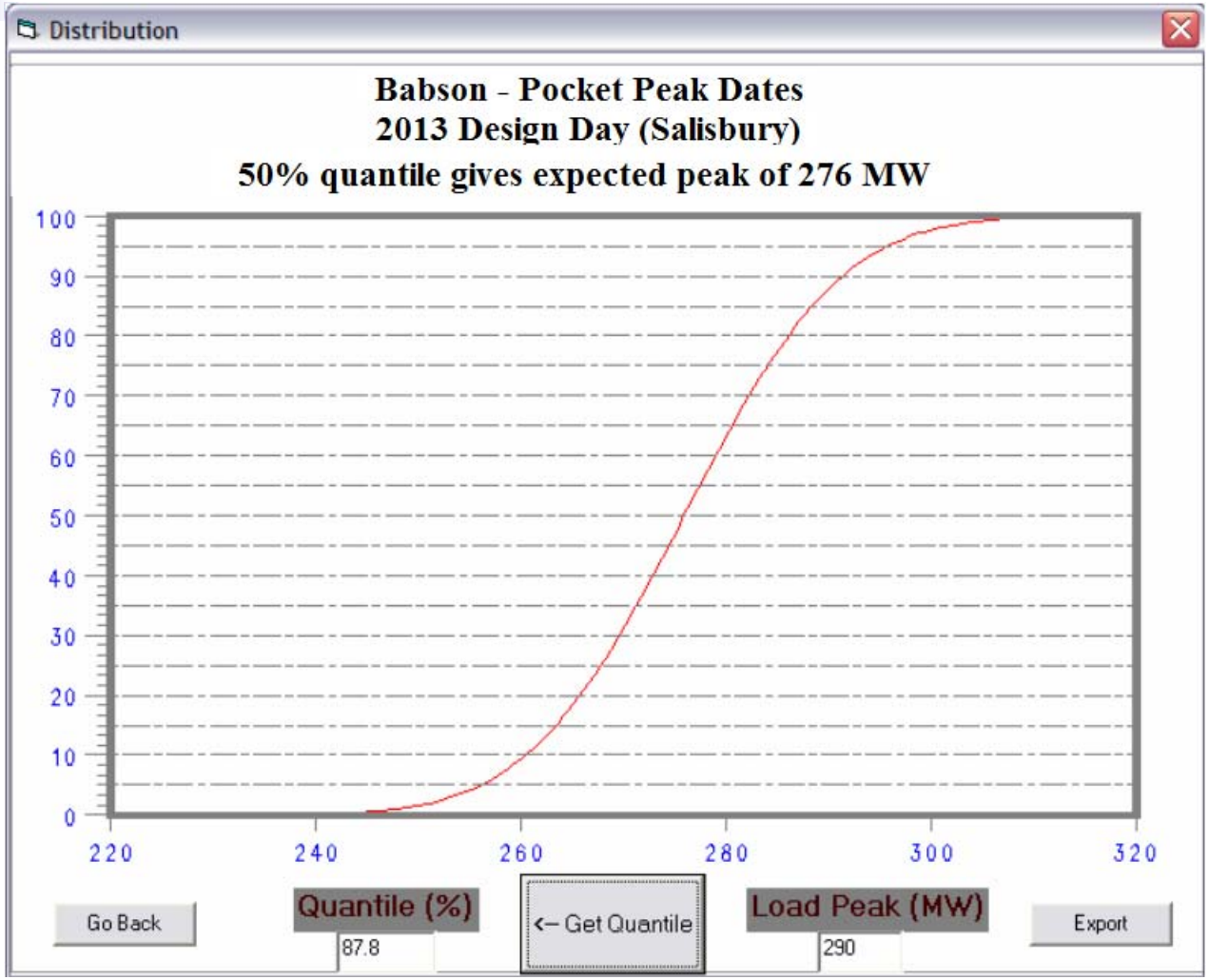
TRENDS

Year	Trend
2007-2008	1.0584
2008-2009	1.026
2009-2010	1.0443
2010-2011	0.9818
2011-2012	1.0615
2012-2013	0.9428
2013-2014	0.9428

Peak Distribution Calculator



Peak Distribution Calculator (Cont.)



Short-term Hourly Load Forecasting

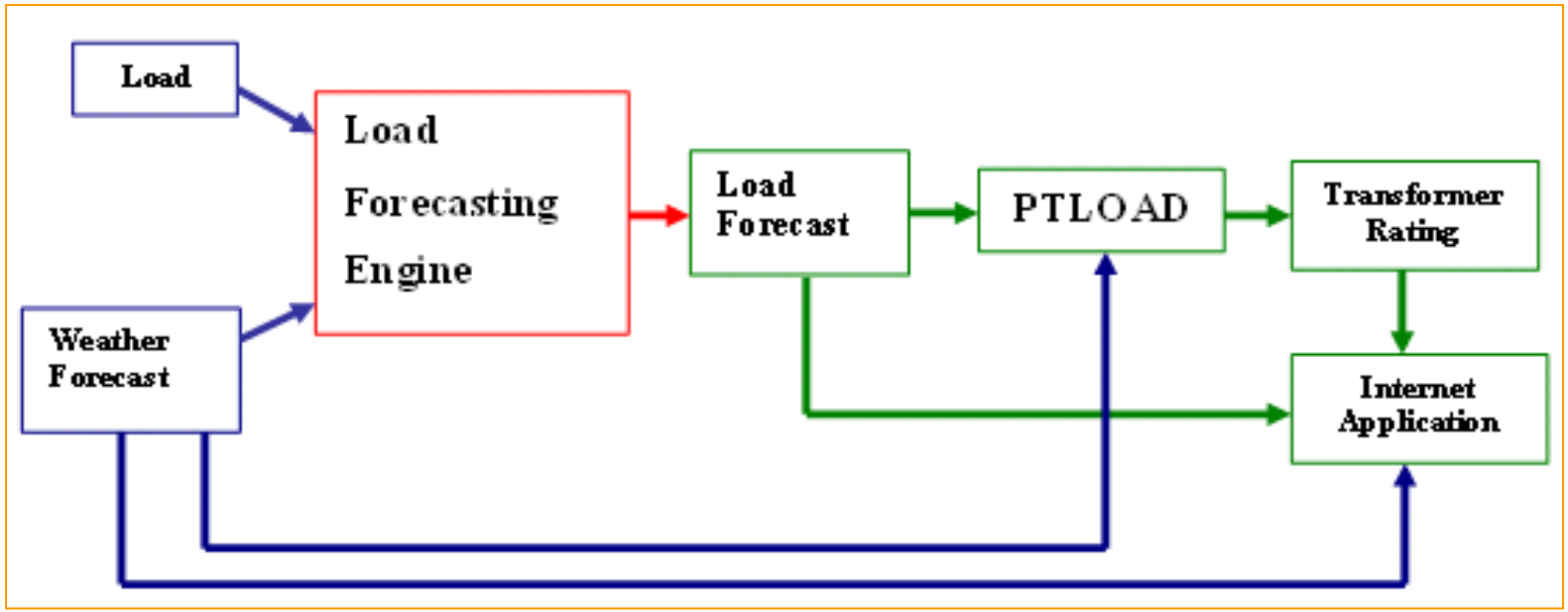
- The focus of short-term load forecasting was to provide hourly load forecasts (up to 168 hours ahead).

- We developed efficient algorithms and software implementation for short-term load forecasting, which can be used for calculation of daily peaks.

Short-term Load Forecasting at Different Levels

- System level: provide forecasts for the entire region as the whole
- Load pocket and transformer level: provide forecasts for a transformer or a set of transformers (defined as load pockets)
- Feeder level: provide forecasts for a particular feeder and predict feeder overloading events.

Short-term substation transformer load forecast and transformer rating



- After PTLOAD calculates the transformer ratings load forecasts as well as these transformer ratings are delivered to some internet based applications.
- For substation transformer level load forecasting, the accuracy of the one-day-ahead forecasts is around 4.5%.

Short-term feeder load forecast and overloading prediction

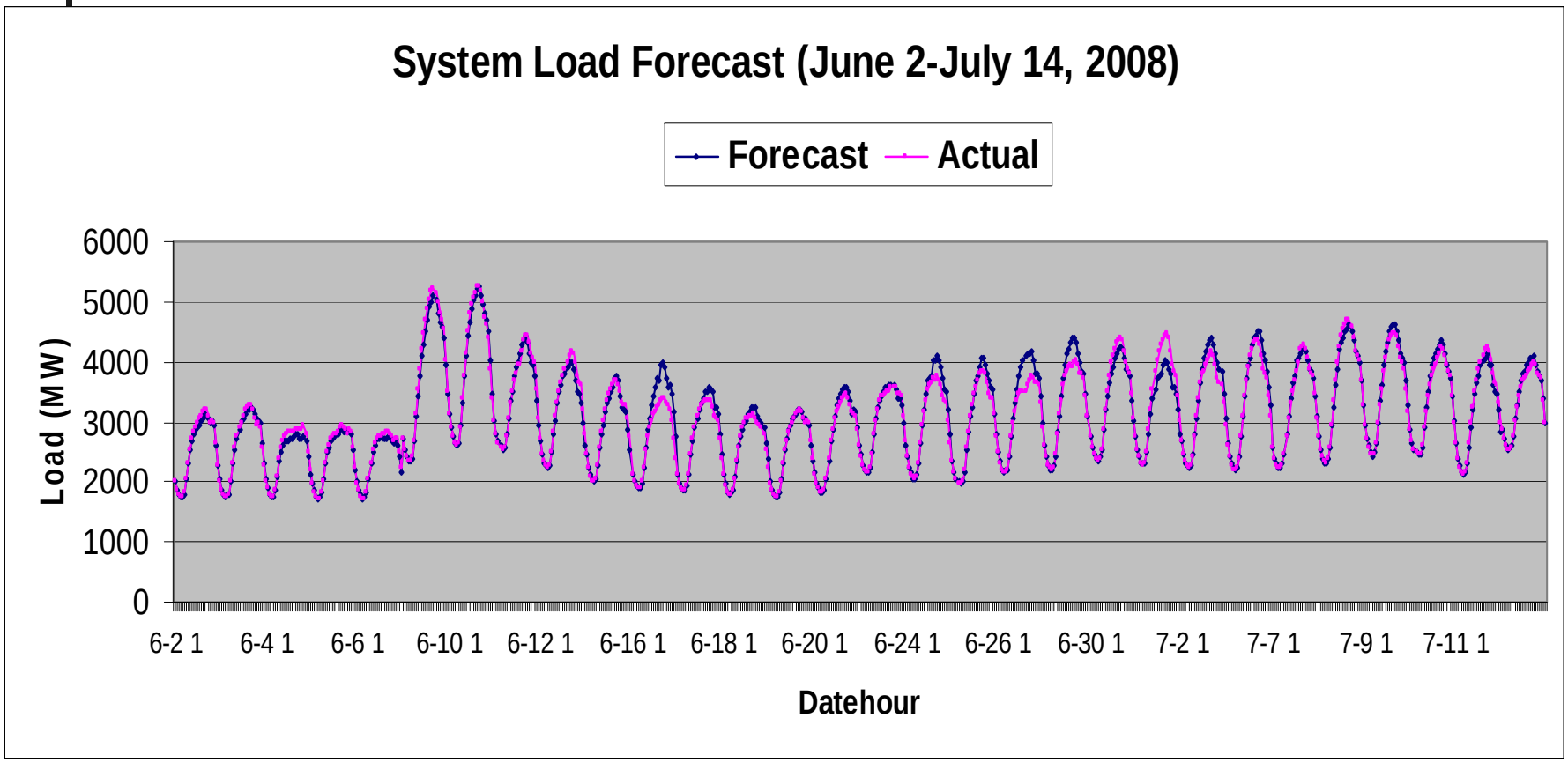
- Our model can be easily adapted to provide feeder level load forecasting.
- The Mean Absolute Percentage Error (MAPE) was around 6%.
- The model can also be adapted to predict overloading events during heatwaves.

Cross table of actual & predicted annual overloads (in hours)

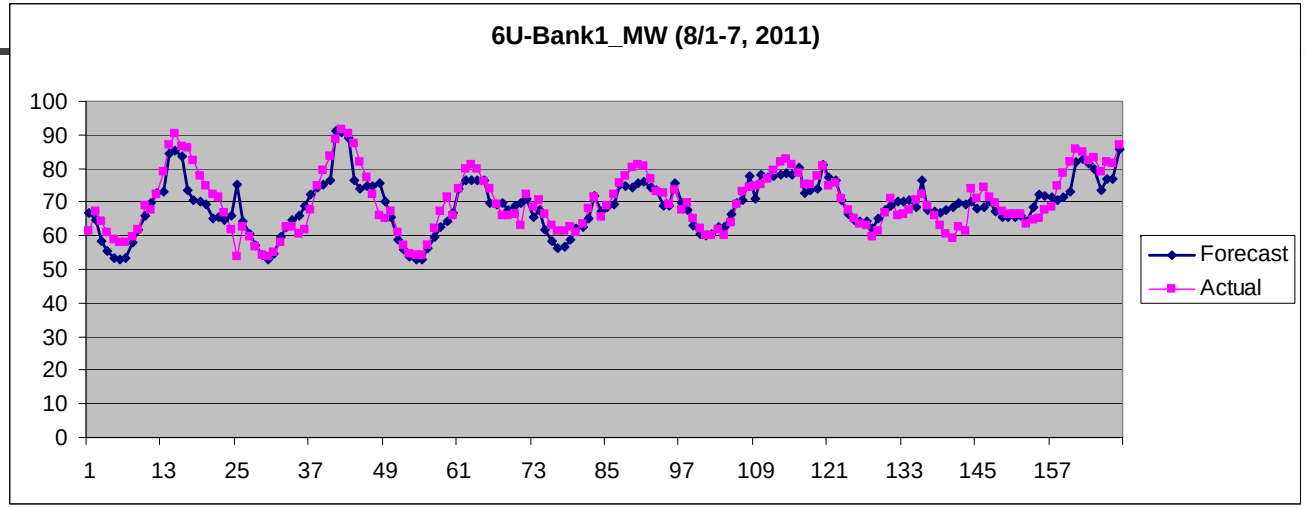
False alarms are rare.

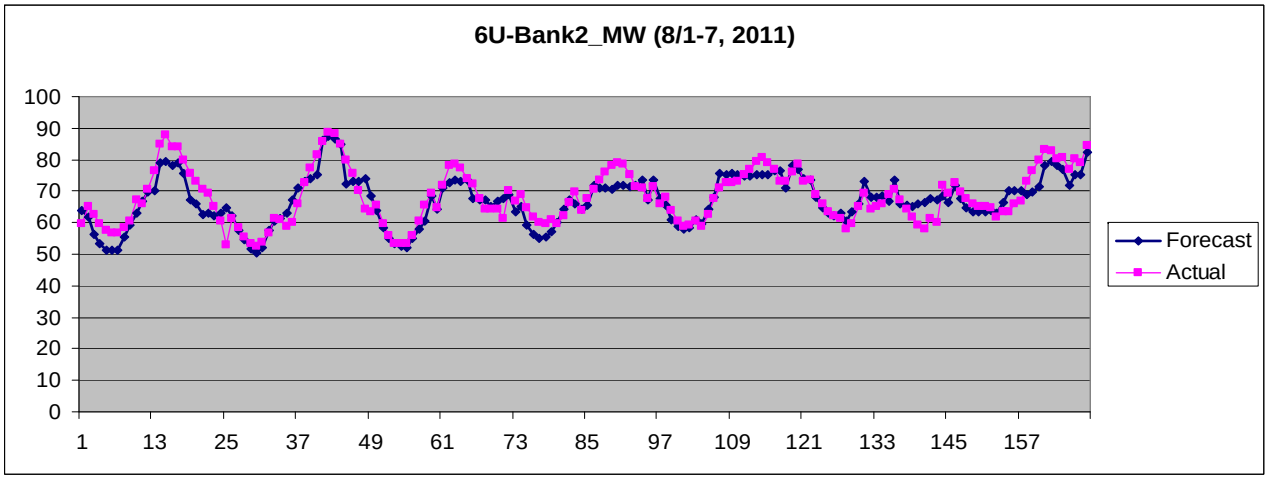
		Actual			
		> normal rating	95% to 100% normal rating	<95% normal rating	Total
Prediction	> normal rating	25	19	1	45
	95 to 100% normal rating	0	51	10	61
	<95% normal rating	0	0	181,657	181,657
	Total	25	70	181,668	181,764

Sample system level load forecast

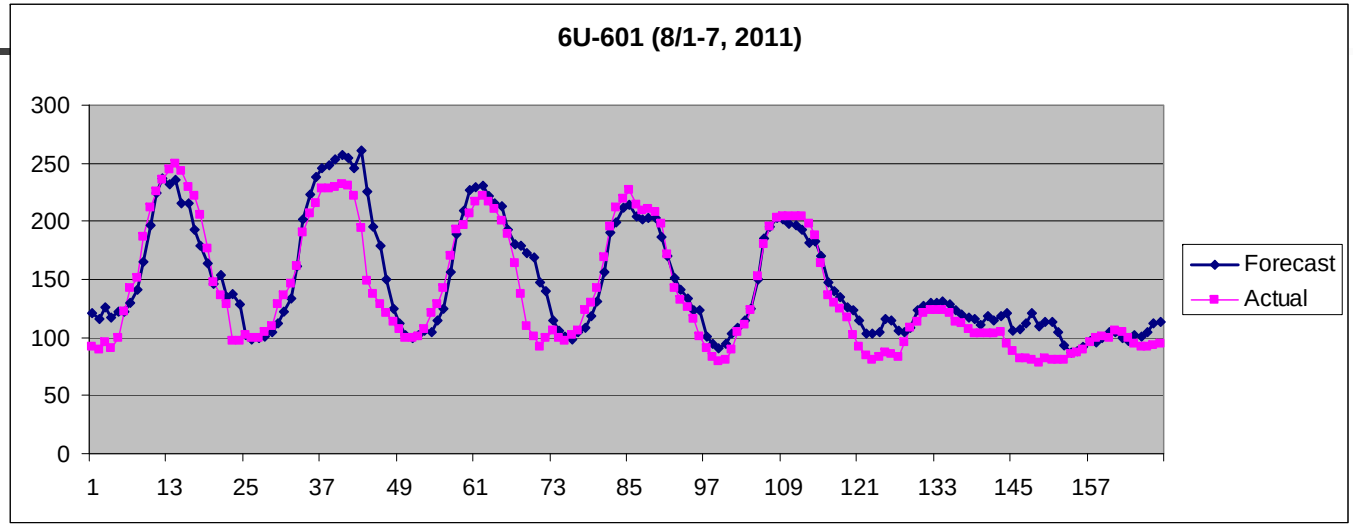


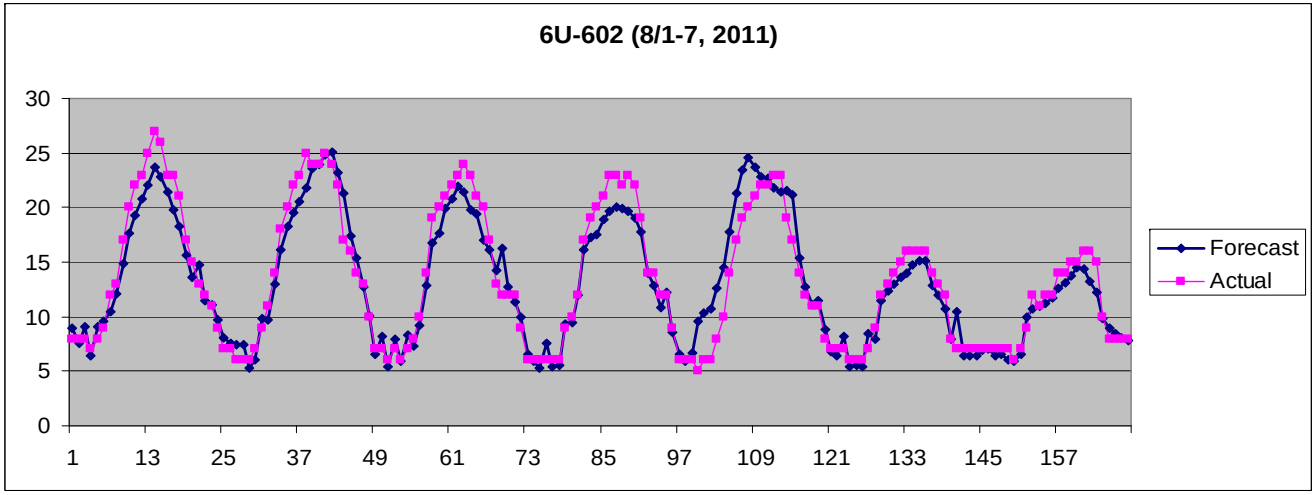
Sample substation transformer load forecasts



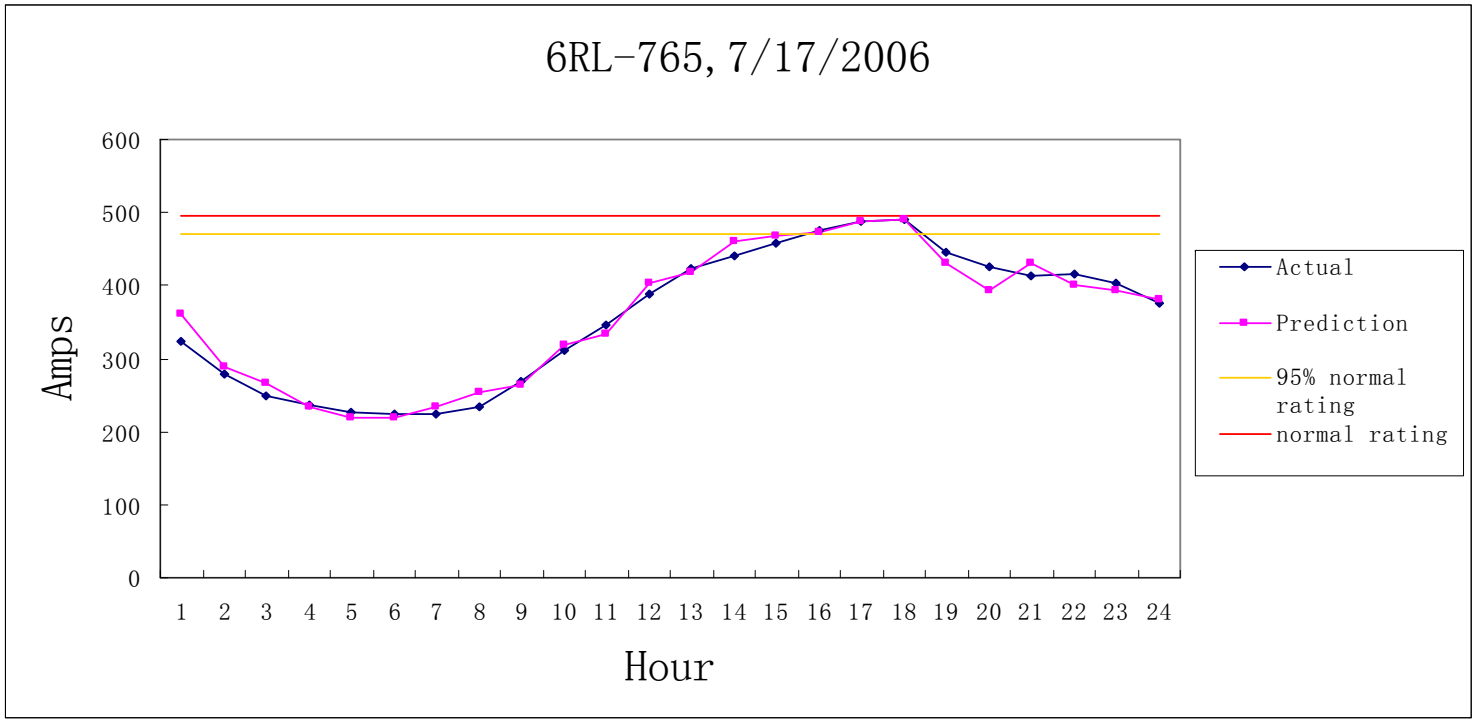


Sample feeder level load forecast

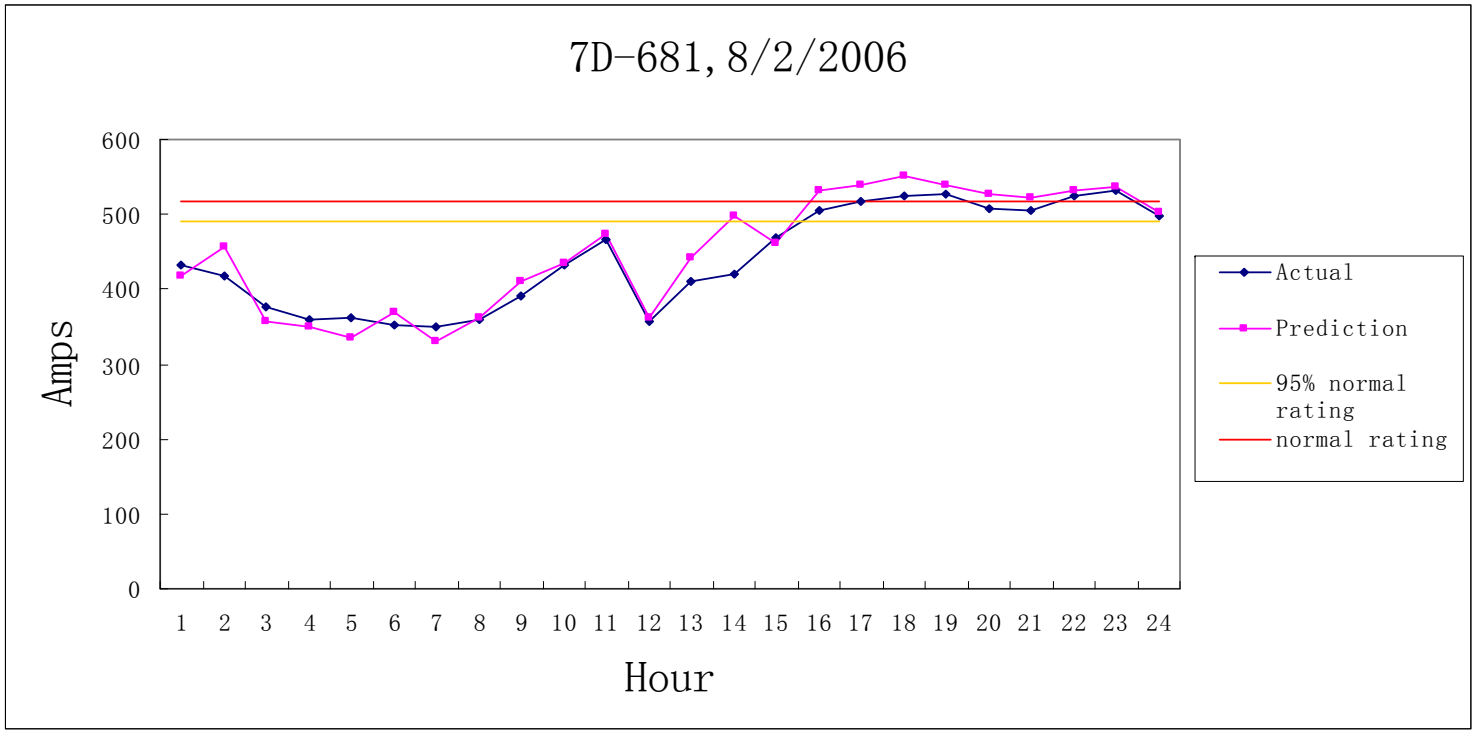




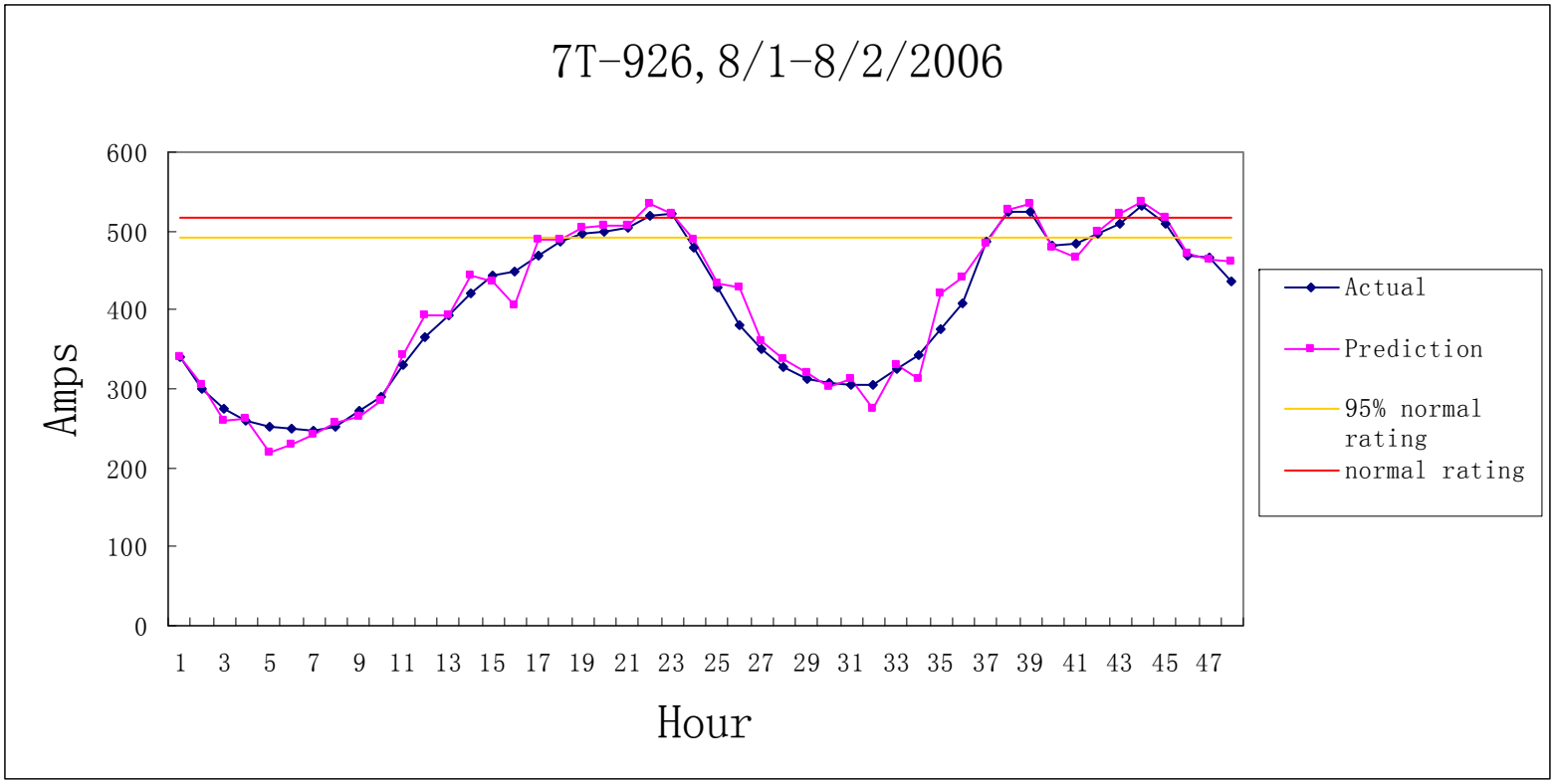
Sample Overloading Event 1



Sample Overloading Event 2



Sample Overloading Event 3



Software Operation

- The software is scheduled to run on the daily basis at 8 AM from May 15 to September 30.
  - First, it received and processed the 7-day weather forecasts and actual weather and load information on the previous day.
  - Second, it computed the 7-day load forecasts and identified potential overloading.
  - Third, it sent out load forecasts, previous day error summary, and overloading alerts via email to the designated personnel.

Future Directions

- Integrate load transfers, contingency events, new feeders, and other configuration changes into the software
- Provide the capability to produce load forecasts on demand (e.g., address rapidly changing weather forecasts)