

Fundamentals of Transmission Operations

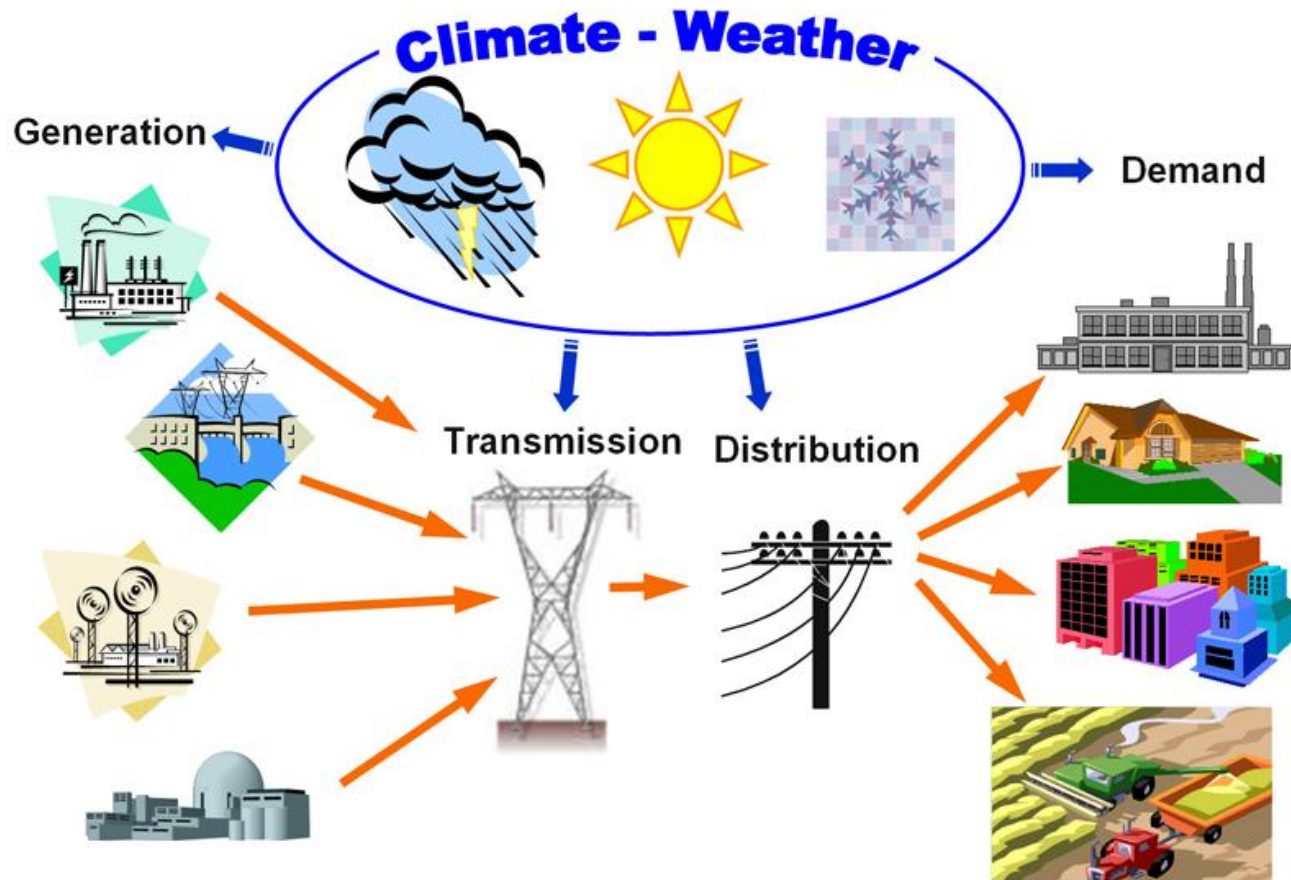
Load Forecasting and Weather

PJM State & Member Training Dept.

The student will be able to:

- Identify the relationship between load and weather
- Describe the load pattern impacts based on the duration of the weather conditions
- Identify possible effects of human behavior on the load

Weather and Load



Weather and Load

- Weather conditions do interact and affect the loading of the transmission system of the RTO to include:
 - Temperature: Minimum/maximum
 - Humidity: Temperature Humidity Index (THI)
 - Wind: Direction/Speed/Wind Chill Index (WCI)
 - Storms: Lightning/Precipitation
 - Cloud cover
- For hot weather, temperature and humidity are most important factors
- For cold weather, temperature and wind speed are most important factors

Temperature

- Temperature:
 - Exceedingly hot or cold temperatures will cause the efficiency of system to decrease at or near maximum capacity
 - Significant temperature swings will increase system loading
 - Overloads on the transmission system
 - Unavailability or tripping of transmission facilities



Humidity

- Percentage of water vapor present in a given quantity of air compared to the amount it can hold at its temperature
 - Does not change the temperature
 - Does change how much energy is available for cooling
- Temperature Humidity Index (THI) reflects outdoor atmospheric conditions of temperature and humidity as a measure of comfort or discomfort during the warm season of the year
 - Effects of heat and moisture in the air

Temperature Humidity Index

		Relative Humidity									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Temperature (Fahrenheit)	80°	69	70	72	73	74	75	76	78	79	80
	81°	70	71	72	73	75	76	77	78	80	81
	82°	70	72	73	74	75	77	78	79	81	82
	83°	71	72	73	75	76	78	79	80	82	83
	84°	71	73	74	75	77	78	79	81	83	84
	85°	72	73	75	76	78	79	80	82	84	85
	86°	72	74	75	77	78	80	81	83	84	86
	87°	73	74	76	77	79	81	82	84	85	87
	88°	73	75	76	78	80	81	83	85	86	88
	89°	74	75	77	79	81	82	84	86	87	89
	90°	74	76	77	79	81	83	85	87	88	90
	91°	75	76	78	80	82	84	85	87	89	91
	92°	75	77	79	81	83	85	86	88	90	92
	93°	76	78	80	81	83	85	87	89	91	93
	94°	73	78	80	82	84	86	88	90	92	94
	95°	77	79	81	83	85	87	89	91	93	95
	96°	77	79	81	84	86	88	90	92	94	96
	97°	78	80	82	84	86	88	91	93	95	
	98°	78	80	83	85	87	89	91	94	96	
	99°	79	81	83	85	88	90	92	95		
	100°	79	82	84	86	89	91	93	95		
	101°	80	82	84	87	89	91	94	96		
	102°	80	83	85	88	90	92	95			
	103°	81	83	86	88	91	93	96			
	104°	81	84	86	89	91	94	96			
	105°	82	84	87	90	92	95				
	106°	82	85	87	90	93	96				
	107°	83	85	88	91	94	96				
	108°	83	86	89	92	95					
	109°	84	87	89	92	95					
	110°	84	87	90	93	96					

- Developed by National Weather Service
- Provides a single numerical value reflecting outdoor atmospheric conditions of temperature and humidity as a measure of comfort or discomfort during warm weather

 **Warning Zone**

 **Danger Zone**

THI ≤ 70 Relatively few people uncomfortable

THI @ 75 Half will be uncomfortable

THI @ 79 Almost all are uncomfortable

Electric use increases 1.5 to 2 days in a heat wave down from 3 days

Wind

- Brings the temperature from one weather system to replace the temperature of another weather system
- Can flatten afternoon valleys or increase peak loading
- Commonly associated with fronts and storms
- Direction and speed
 - Cool air is dense and heavy, circulating strongly over the earth's surface (Northern wind)
 - Warm air is lighter rising above cooler air coming down in an area with unstable air
- Wind Chill Index (WCI) reflects the “felt” air temperature on exposed skin due to the wind



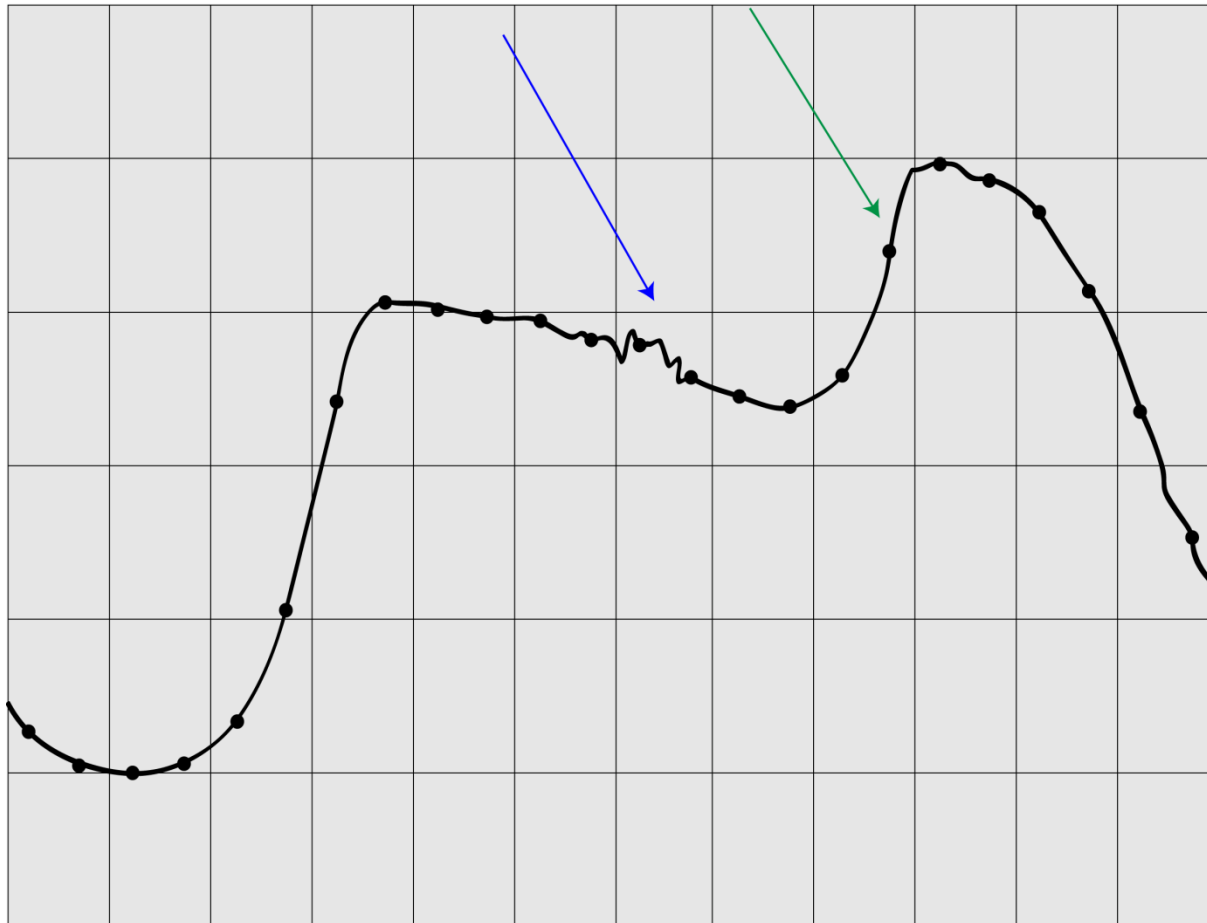
Wind

PJM EAST LOAD FORECAST

Effects of wind & dropping temperatures:

Limited drop off in valley

Large Evening Pick-up



Winter Load Curve

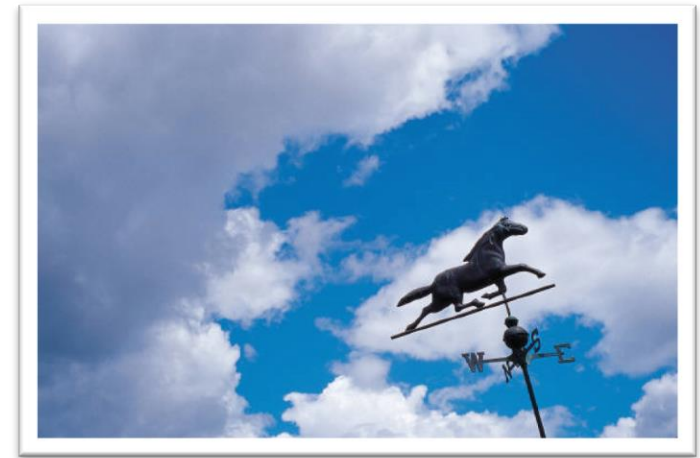
Storms

- Power outages and loss of customer demand
 - Thunderstorms cause wind and lightning damage
 - Lightning related outages cause the nation's utility industry over \$100 million annually in materials and labor costs
- Precipitation can decrease temperatures
 - Snow can decrease loading due to facility closings
 - Blizzards can increase loading on weekends

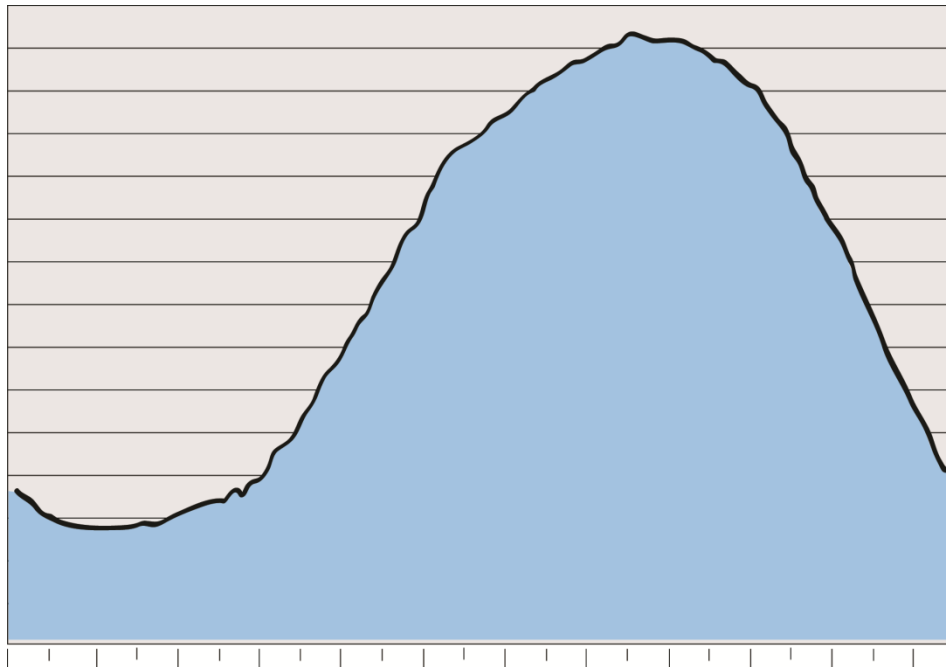


Cloud Cover

- Associated with fronts and storms
- Can flatten load curves
- Cause afternoon valleys to be shallow or non-existent
- Increase “lighting” load during the day or afternoon

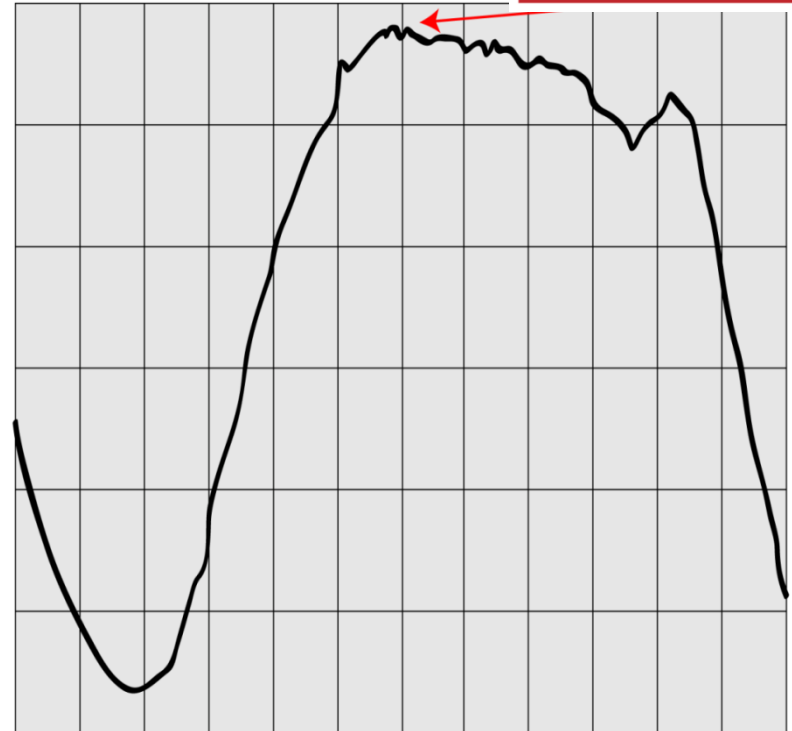


Cloud Cover



Typical Summer Load Curve

8/15/2005 - PJM LOAD



Flattened Peak resulting from heavy cloud cover in PHIL & DCA area in morning period

Summer Load Curve with Cloud Cover

Other Conditions & Behaviors

- Duration of Weather Conditions:
 - If a hot spell extends to three days or more, nighttime temperatures do not cool down, and the thermal mass in homes and buildings retain the heat from the previous days causing air conditioners to turn on earlier and stay on later in the day
 - During cold weather, portable heaters and strip heaters are among the highest sources of electrical demand



Other Conditions & Behaviors

- Effects of Human Behavior on Load:
 - Time of the year
 - Seasons
 - Day of the week
 - Load differences between weekends and weekdays
 - Load on different weekdays (Monday and Fridays are adjacent to weekends and have structurally different loads than Tuesday, Wednesday, and Thursday)
 - Sundays have the lowest demand followed by Saturday; the rest of the weekdays have small load variations
 - Holidays have decreased load demand based on the duration and length, and are more difficult to forecast due to infrequent occurrence



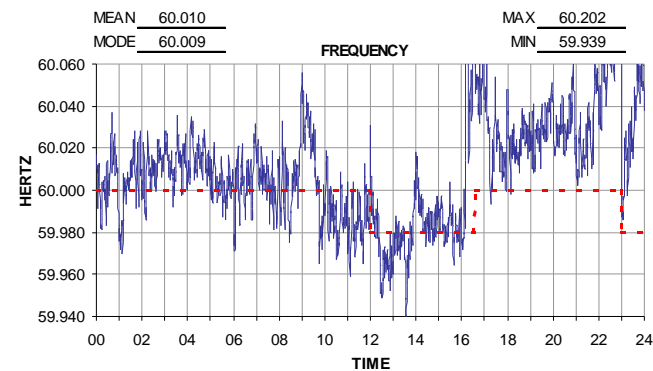
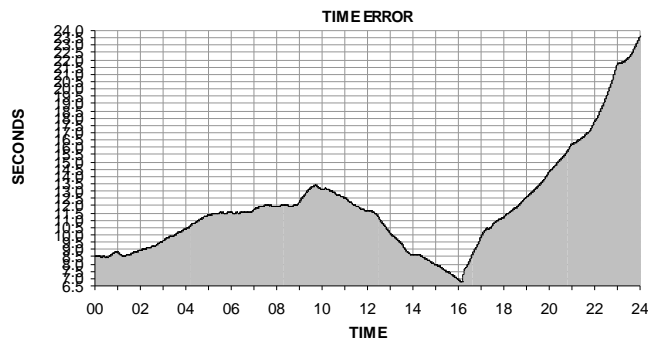
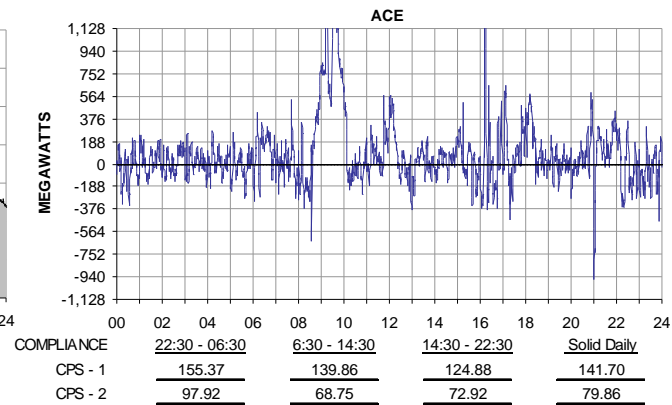
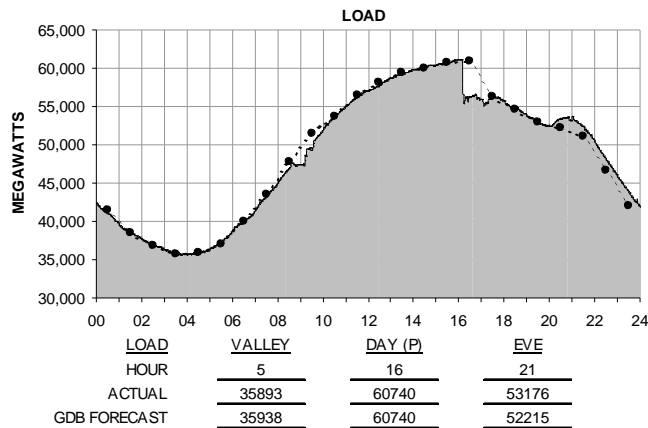
Other Conditions & Behaviors

- Effects of Human Behavior on Load:
 - Hour of the day
 - Load pattern follows the activities of the consumers
 - Demand steadily increases from 9 am to 12 noon with a small decrease during midday picking up again until 4 pm in the afternoon
 - Demand steadily decreases from 4 pm to 7 pm increasing again around 8 pm to 9 pm
 - After 9 pm, demand decreases gradually to the lowest load demand in the early morning
 - Events
 - Depending on the event, it can have either an increasing or decreasing effect on the overall load demand

Blackout

Aug. 14, 2003

PJM RTO CONTROL DATA 8/14/2003



GENERATED AT: 8/15/2003 6:05

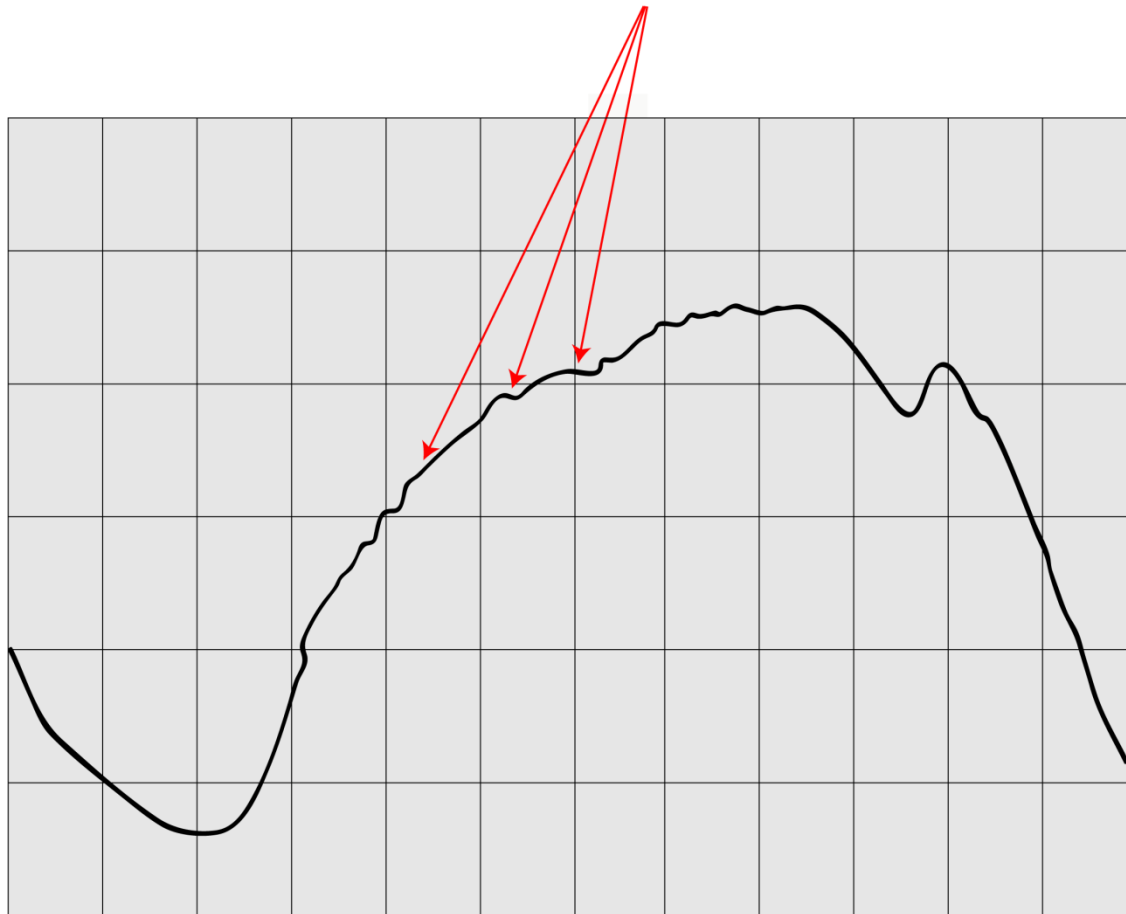
O.J. Simpson Trial

Example of erratic / unusual load shape during and after the televised announcement of the verdict in trial of O.J. Simpson – October 3, 1995

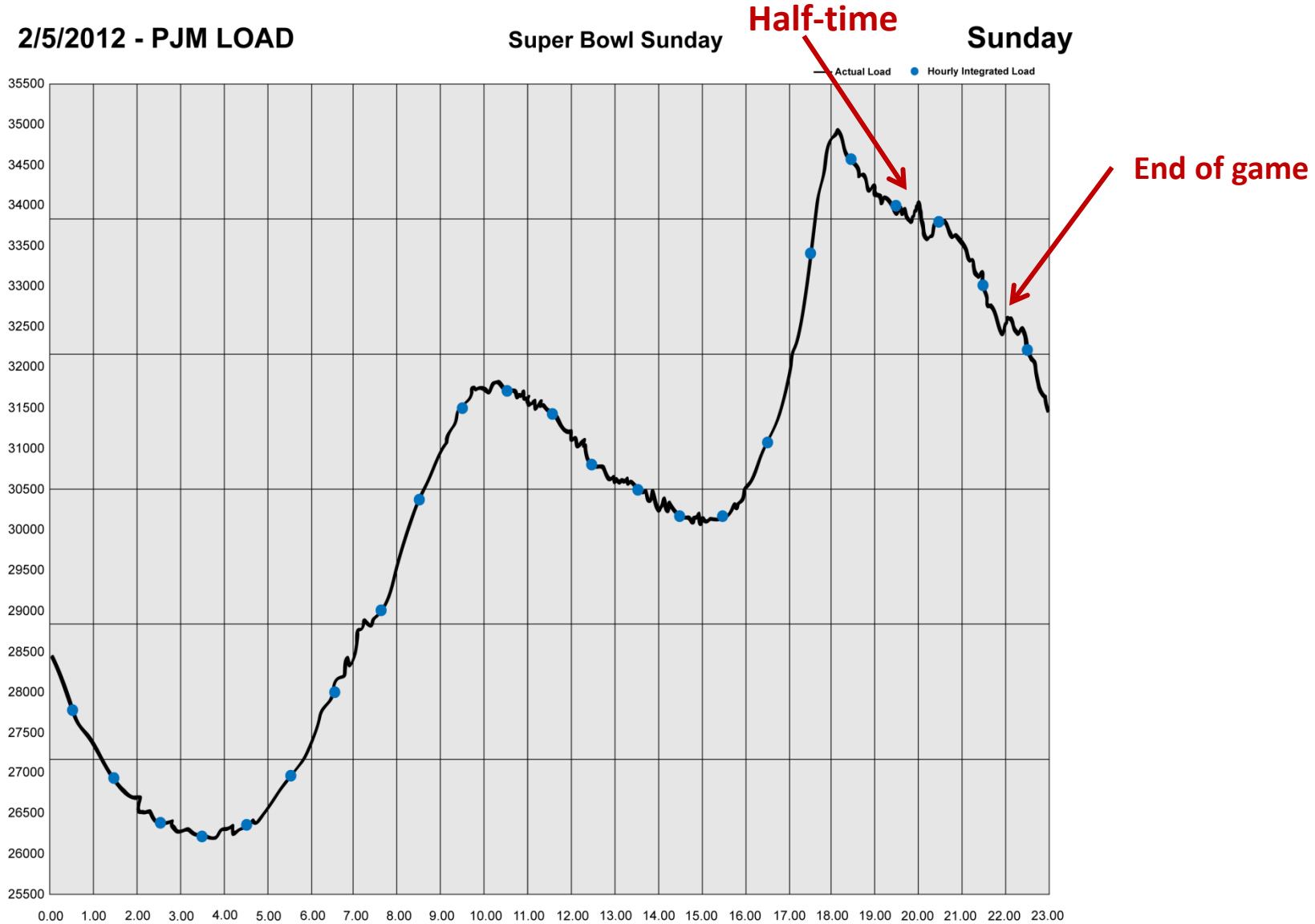


9/11/01

Effects of the attacks on the World Trade Center and Pentagon

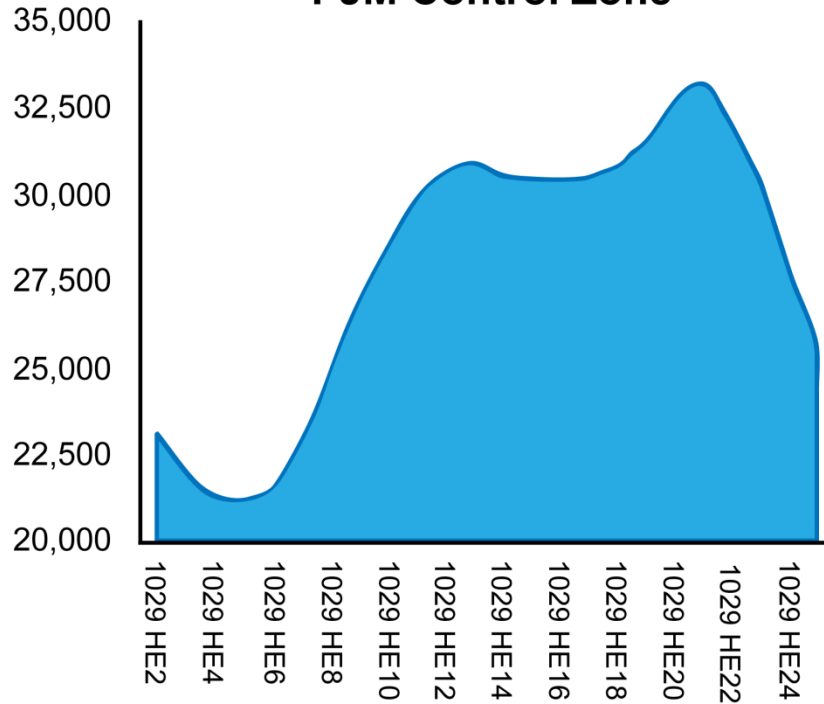


Superbowl 2012



Hurricane Sandy 2012

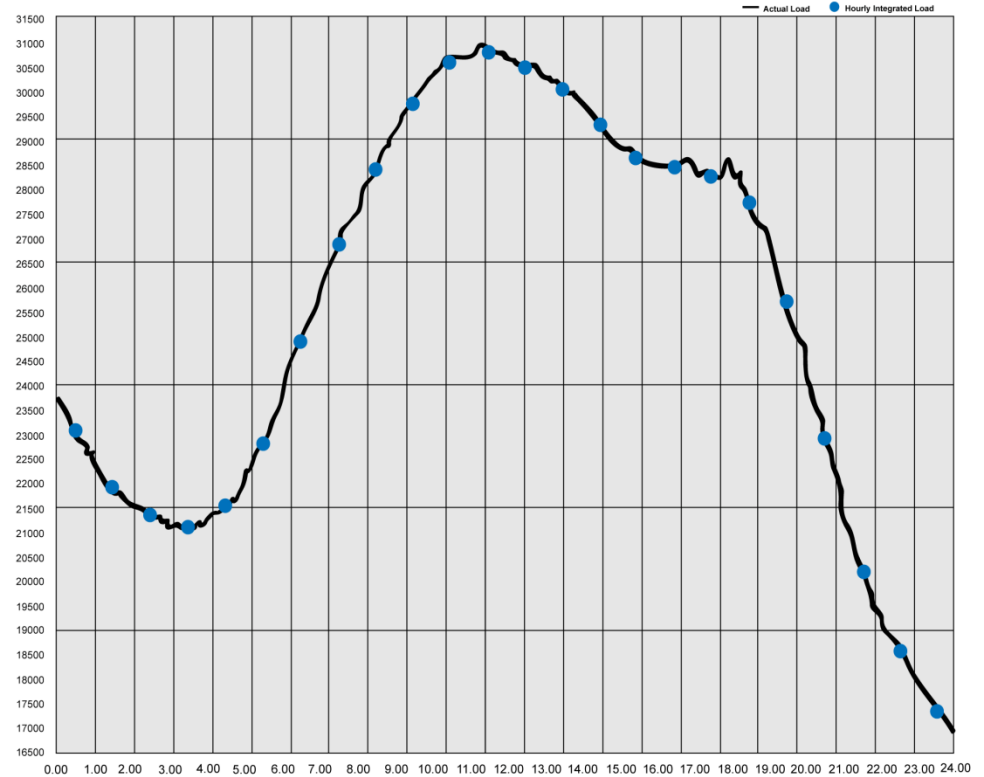
PJM Control Zone



10/29/2012 PJM LOAD

Hurricane Sandy

Monday



Summary

- Weather brings a variety of changes to load demand
 - Direct weather impacts (wind, lightning, etc)
 - Human reactions to weather changes (or lack of weather changes)
 - Human Behaviors
- Hot Weather
 - Temperature
 - Humidity
- Cold Weather
 - Temperature
 - Wind
- Storms & Cloud Coverage

Resources and References

- “Climate Change Impacts on the Electric Power System in the Western United States,” Decision and Information Sciences,
www.dis.anl.gov/index.html
- “The Estimated Impact of Weather on Daily Electric Utility Operations,”
Ronald N. Keener, Jr.,
sciencepolicy.colorado.edu/socasp/weather1/keener.html
- “Load Forecasting,” Eugene A. Feinberg,
Eugene.Feinberg@sunysb.edu

Disclaimer:

PJM has made all efforts possible to accurately document all information in this presentation. The information seen here does not supersede the PJM Operating Agreement or the PJM Tariff both of which can be found by accessing:

<http://www.pjm.com/documents/agreements/pjm-agreements.aspx>

For additional detailed information on any of the topics discussed, please refer to the appropriate PJM manual which can be found by accessing:

<http://www.pjm.com/documents/manuals.aspx>