EE 590
Reliability (LOLE) Evaluation for Generation & Transmission Adequacy




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Generation & Transmission (G&T) Adequacy issues throughout history

- November 9, 1965
  - The largest blackout to this date in history occurred, as 30 million people lost power in the northeastern United States and southeastern Ontario, Canada.
- July 13-14, 1977
  - Blackout in New York City occurred. This led to the first federal legislation to propose voluntary reliability standards.
- August 14, 2003
  - North America experienced its worst blackout ever, as 50 million people lost power in the Northeastern and Midwestern U.S. and Ontario, Canada.

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LOLE Definition

- LOLE (Loss of Load Expectation)
  - LOLE is the measure of how long, on average, the available generation capacity is likely to fall short of the load demand
  - LOLE is used to asses Generation Adequacy
    - A product of Unit Availably
    - The "Perfect Storm"
  - LOLE is expressed as hours per year with the usual target criteria being (0.1 days/year) or 1 day in 10 years

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MARS LOLE Software Program

- MARS
  - Multi-Area Reliability Simulation program
  - A General Electric Company product
    - Originally developed for New York State
  - Uses a sequential Monte Carlo simulation
    - Steps through time chronologically and randomly drawing unit availability
    - Replicating simulation with different sets of random events until statistical convergence is obtained
  - Ability to analyze reliability of interconnected generation systems
    - Benefits of diversity
    - Tie-line effectiveness
  - Utilizes a flat file input format and multiple text file outputs
  - Most widely used LOLE software in the Power Systems Industry

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LOLE Model Inputs

- Some of the LOLE Model Inputs that are major drivers of the accumulation of loss of load events include:
  - Study System Zones/Areas & Pools
  - Generator Unit Forced Outage Rates
  - Zone to Zone Tie Limits
  - Load Forecast Uncertainty
  - Unit Maintenance Schedules

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Study System Zones/Areas & Pools

- LOLE models utilize an Equivilized Transportation Model as appose to a Detailed Transmission Model
- Detailed Transmission Model
  - Typical Load/Power Flow model used in transmission studies
  - Retains transmission system details with a system of voltage specific buses and voltage specific branches
  - Loads are modeled at bus level
- Equivilized Transportation LOLE Model
  - Retains individual generating unit details
  - System of interconnected zones/areas (pipelines)
  - Aggregated load at a zonal level model representation
  - Zones are grouped and pooled to represent electrical systems like the Midwest ISO and to help establish a priority of assistance

Study System Zones continued…

- Deciding how to equivilize and slice up the electrical system is the most important input into a LOLE study
- Past methods include defining zones using:
  - Electric Utilities
    - Control Areas & Balancing Authorities
  - States boundaries and other geographic regions
- A new method developed this year by the Midwest ISO includes: *(2009 MISO LOLE study currently in progress)*
  - Using system constraints to identify group of areas that are:
    - Import constrained (load at risk of not being served)
    - Export constrained (generation not fully deliverable to entire system)
  - Analyzing the magnitude and location of the Congestion Components that used in the calculation Location Marginal Prices (LMPs)
    - Finding where and where not the system acts like a “copper sheet”

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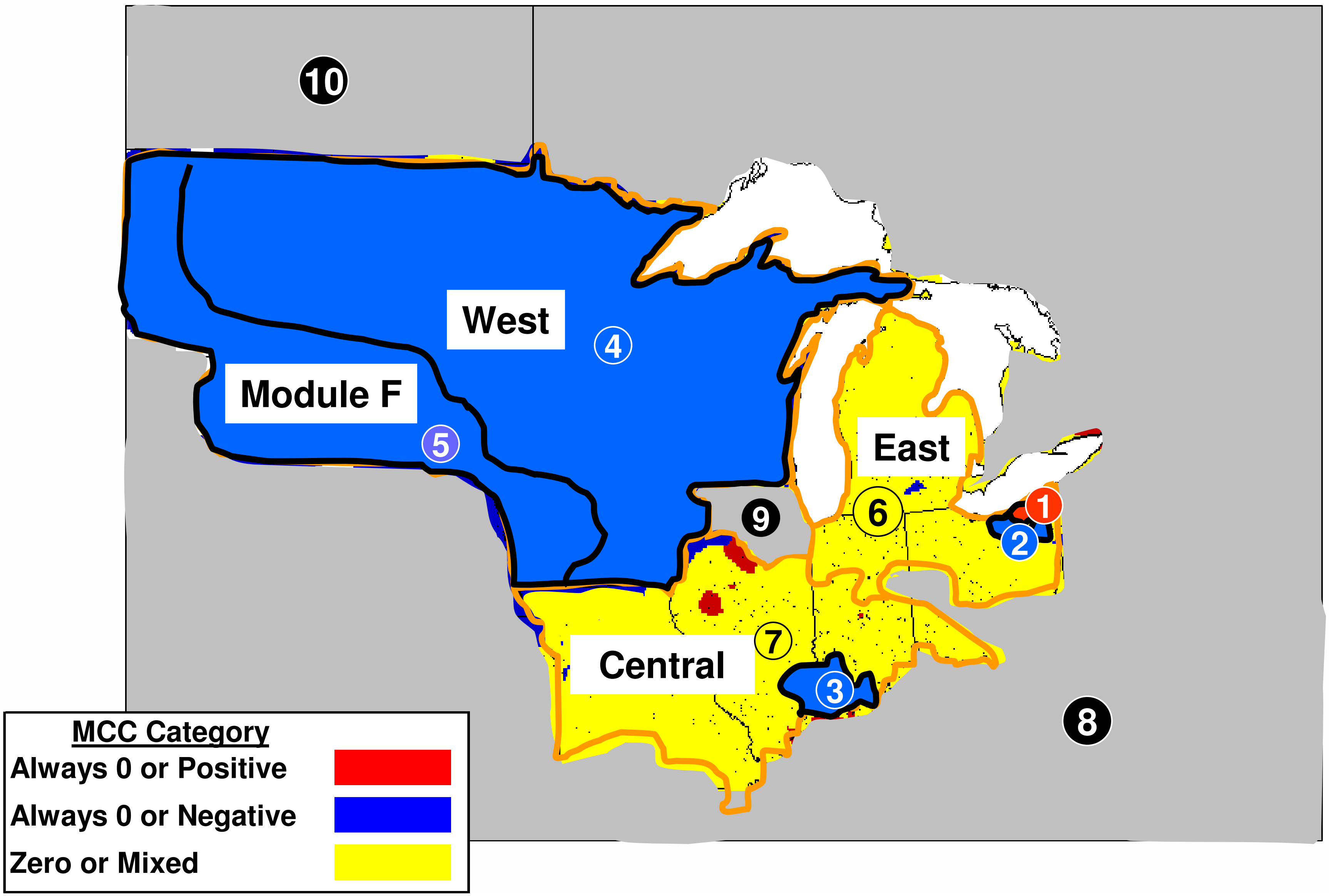
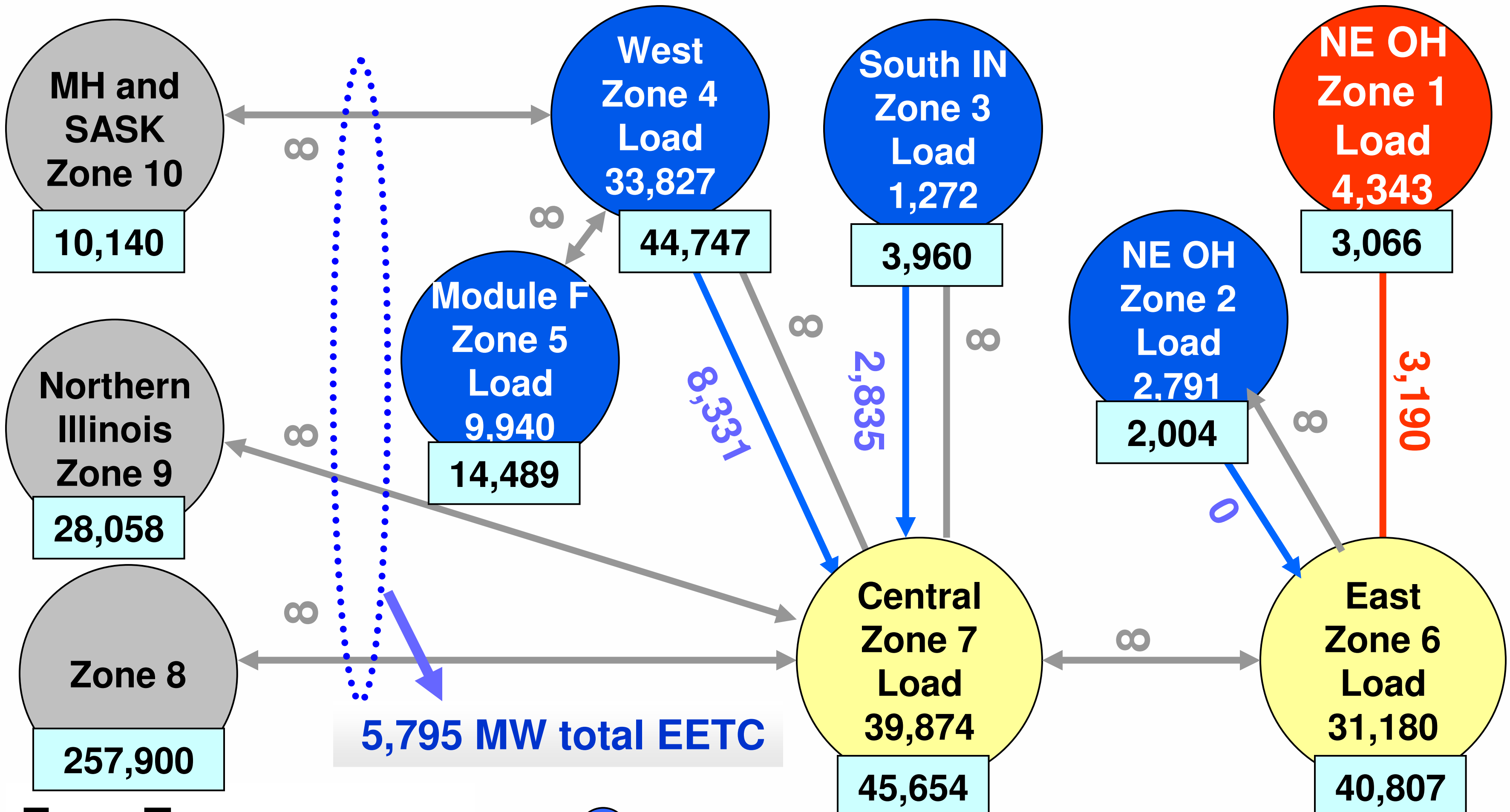
2009 Midwest ISO LOLE Congestion Based Zone Analysis



LOLE 2009 Model Zone Input Values



Zone Types:

Resource MW Nameplate

- Export Limited
- Import Limited
- Neutral
- External

External load set to match with generation At 1 day in 10 level of reliability

August Transfer Level Limit Shown:
Average flow at daily peak load hours from forced dispatch case (monthly values are used in LOLE run)

Generator Unit Forced Outage Rates

- NERC - GADS
  (North American Electric Reliability Corporation - Generator Availability Data System)
  – Industry Rules and Guidelines of collecting Generator Outage and Performance Statistics
- EFORd
  (Equivalent Demand Forced Outage Rate)
  – A measure of the probability that a generating unit will not be available due to forced outages or forced deratings when there is demand on the unit to generate

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EFORd - Equation

The equivalent forced outage rate demand calculation is based on the equation defined in the IEEE Standard No. 762 *"Definitions for Use in Reporting Electric Generating Unit Reliability, Availability and Productivity."* This equation is shown below.

$$EFOR_d = \frac{FOH_d + EFDH_d}{FOH_d + SH} \quad x \quad 100\,\%$$

where:

FOHd = ff x FOH

EFDHd = (fp x EFDH) if no reserve shutdown events reported.

ff = full forced outage factor = (1/r + 1/ T)/(1/r + 1/T +1/D)

r = average forced outage duration = (FOH)/(# of FO occurrences)

D = average demand time = (SH + Synch Hours)/(# of unit actual starts)

T = average reserve shutdown time = (RSH)/(# of unit attempted starts)

FOH = full forced outage hours

SH = service hours

Synch Hours = synchronous hours

RSH = reserve shutdown hours

EFDH = equivalent forced de-rated hours

EFDHRS = equivalent forced de-rated hours during reserve shutdowns

fp = partial forced outage factor = (SH + Synch Hours/AH)

AH = available hours

2002-2006 NERC Pooled Class Average EFORd

Fossil Steam Turbine

All Fuel Types		
Nameplate	# of Units	EFORd
All Sizes	1488	7.01
1-99	360	7.95
100-199	396	7.14
200-299	173	7.82
300-399	136	5.72
400-599	252	6.72
600-799	122	6.74
800-999	36	3.63
1000 Plus	13	9.05

Coal - Primary		
Nameplate	# of Units	EFORd
All Sizes	905	6.48
1-99	160	6.96
100-199	243	6.32
200-299	120	5.93
300-399	83	6.09
400-599	168	7.28
600-799	94	6.42
800-999	25	3.85
1000 Plus	12	9.05

Oil - Primary		
Nameplate	# of Units	EFORd
All Sizes	150	15.93
1-99	48	19.19
100-199	36	18.29
200-299	11	40.41
300-399	16	4.77
400-599	19	5.12
600-799	10	8.84
800-999	9	1.63

Gas - Primary		
Nameplate	# of Units	EFORd
All Sizes	443	7.19
1-99	137	8.39
100-199	132	8.12
200-299	43	7.04
300-399	41	5.45
400-599	67	6.28
600-799	13	9.39

Nuclear Units

All Nuclear Types		
Nameplate	# of Units	EFORd
All Sizes	112	4.21
400-799	22	7.37
800-999	39	4.15
1000 Plus	51	3.14

PWR		
Nameplate	# of Units	EFORd
All Sizes	67	2.9
400-799	10	1.7
800-999	23	3.41
1000 Plus	34	2.87

BWR		
Nameplate	# of Units	EFORd
All Sizes	34	3.45
400-799	5	1.65
800-999	12	3.6
1000 Plus	17	3.66

CANDU		
Nameplate	# of Units	EFORd
All Sizes	11	15.47

Jet Engine		
Nameplate	# of Units	EFORd
All Sizes	370	10.48
1-19	52	25.26
20 Plus	318	9.94

Gas Turbine		
Nameplate	# of Units	EFORd
All Sizes	1010	9.94
1-19	202	25.79
20-49	220	11.16
50 Plus	588	6.8

Combined Cycle		
Nameplate	# of Units	EFORd
All Sizes	116	6.17

Diesel Engine		
Nameplate	# of Units	EFORd
All Sizes	131	10.3

Hydro		
Nameplate	# of Units	EFORd
All Sizes	1187	3.89
1-29	515	4.62
30 Plus	672	3.13

Pumped Storage		
Nameplate	# of Units	EFORd
All Sizes	115	2.57

Data Source: 2002-2006 Generating Unit Statistical Brochure from website: www.nerc.com

Zone to Zone Tie Limits

- Zones of a LOLE model are inter-connected to each other with ties
- Ties are the pipelines in which zones can share a reserve surplus with other zones
- Ties are used to represent the limited capabilities of the transmission system

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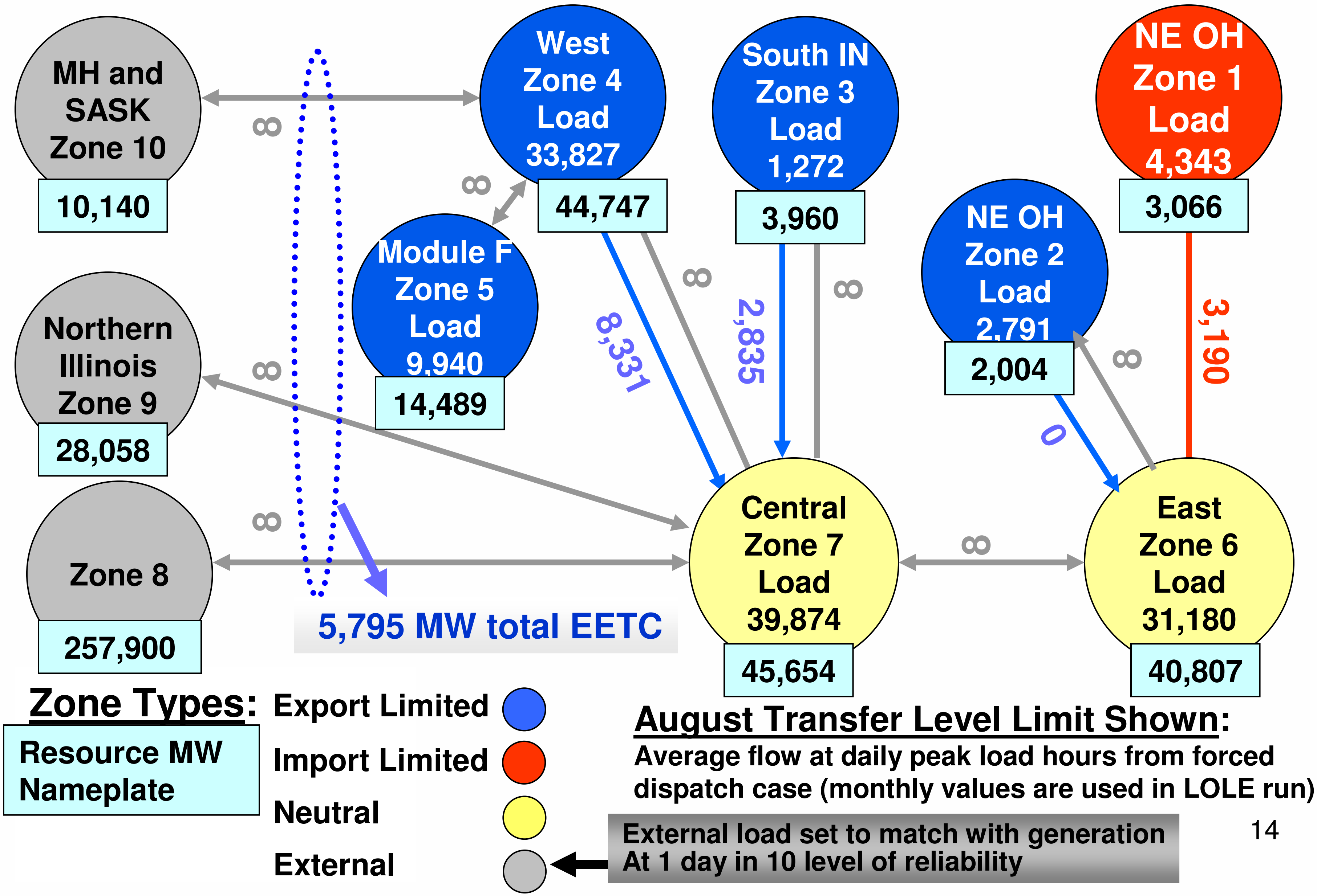
LOLE 2009 Model Zone Tie Values



LOLE Model Inputs continued…

- Load Forecast Uncertainty
  – Accounts for variations from a 50/50 load forecast
  – Which could be due to changes in weather and economic factors that effect forecasted load levels
- Unit Maintenance Schedules
  – Accounts for the seasonal & routine planned maintenance schedules of generating units
  – Usually planned maintenance doesn't accumulate loss of load events because it is scheduled during low risk (low load) periods like the Fall and Spring seasons

What are LOLE indices used for?

- Evaluating Load Deliverability
  - 2006 Midwest ISO Transmission Expansion Plan (MTEP) Load Deliverability Study
- Establishing Planning Reserve Margins
  - Midwest Planning Reserve Sharing Group (PRSG) Study
- Generation and Transmission Planning
  - Targeted 765kV ITC-AEP Project - LOLE Study

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Questions ?

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