Simulating the Potential Collapse of the U.S. Eastern Interconnection Due to a High-Intensity New Madrid Earthquake

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Outline of Presentation

I. Background, Objectives, and Overview

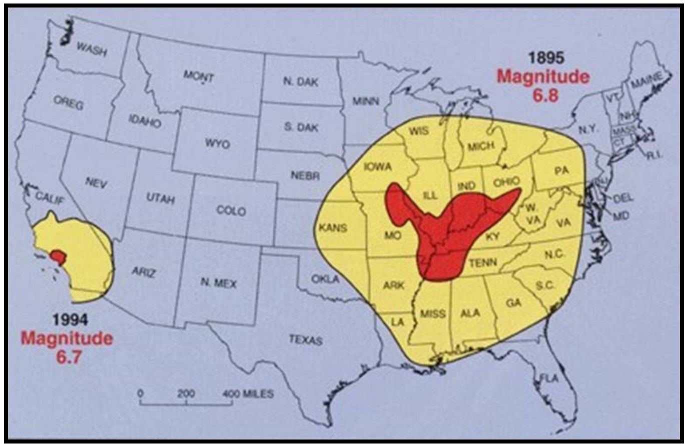
II. Methodology, Models, and Data

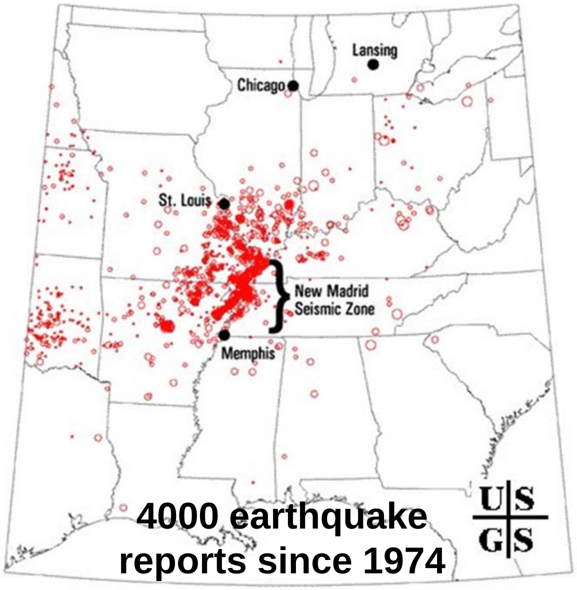
III. Simulation Results

IV. Question and Discussions

NEW MADRID SEISMIC EVENT – Background Material

- During winter of 1811-1812, central Mississippi Valley was struck by three of the most powerful earthquakes in U.S. history
  - *One of the quakes may have been as large as magnitude 8.0*
  - *Earthquakes were felt as far away as New York City and Boston, where church bells rang*
- Most seismically active area east of the Rockies
  - *Chance of having an earthquake similar to one of the 1811–12 sequence in the next 50 years is about 7% to 10% **
  - *Chance of having a magnitude 6 or larger earthquake in 50 years is 25% to 40% **
- Exercise based on New Madrid earthquake scenario set for May 2011
  - *Coordinated by Department of Homeland Security and the Federal Emergency Management Agency*
  - *First NLE to simulate a natural hazard*

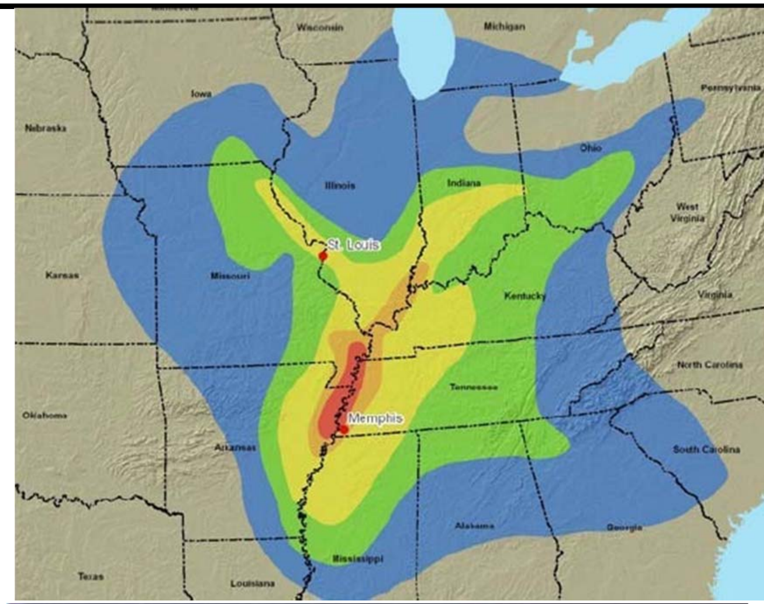




* URL: http://pubs.usgs.gov/fs/2009/3071/pdf/FS09-3071.pdf

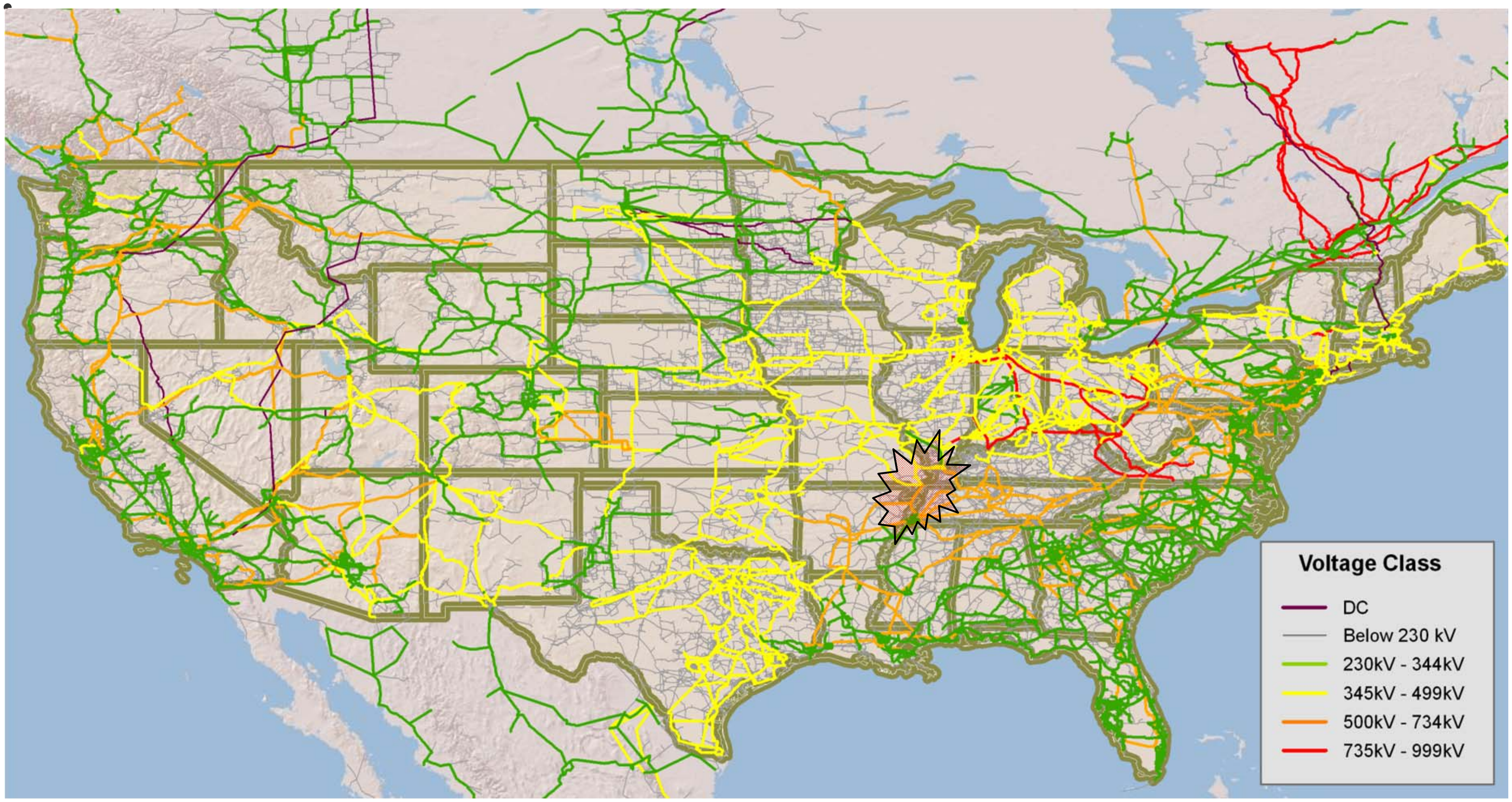
Primary Objectives of the DOE New Madrid Electric Transmission Study

- **Determine potential impacts of the seismic event on the regional grid.**
- **Determine extent of potential cascading failures and island grid formations.**
- **Identify electric transmission lines, substations, and power plants that are at risk for potential damage.**
- **Determine dispersal pattern of load losses; determine which areas would potentially experience the most losses/outage.**
- **Identify components needing long lead times for repair and restoration.**

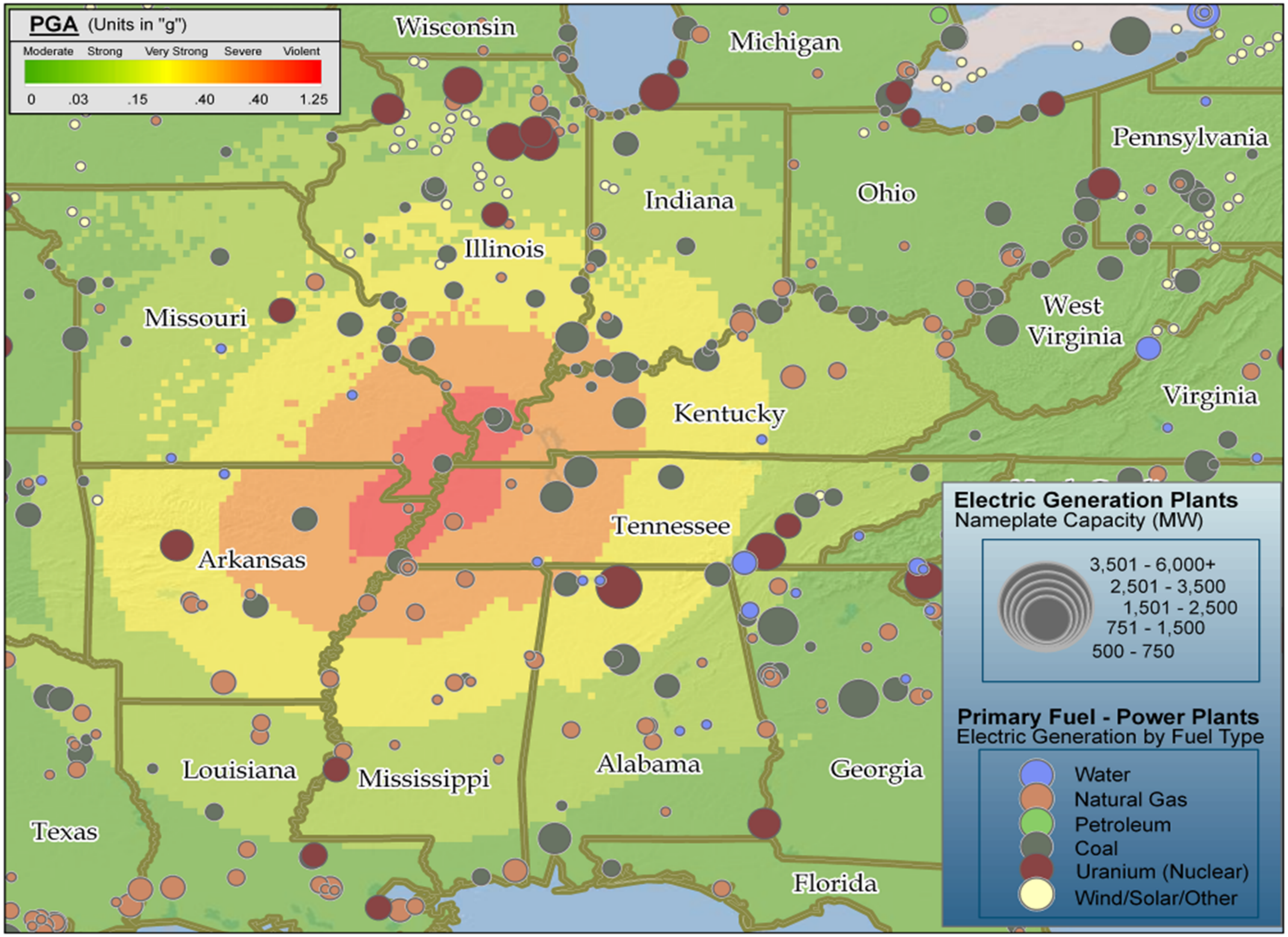


Overview of U.S. Power Grid

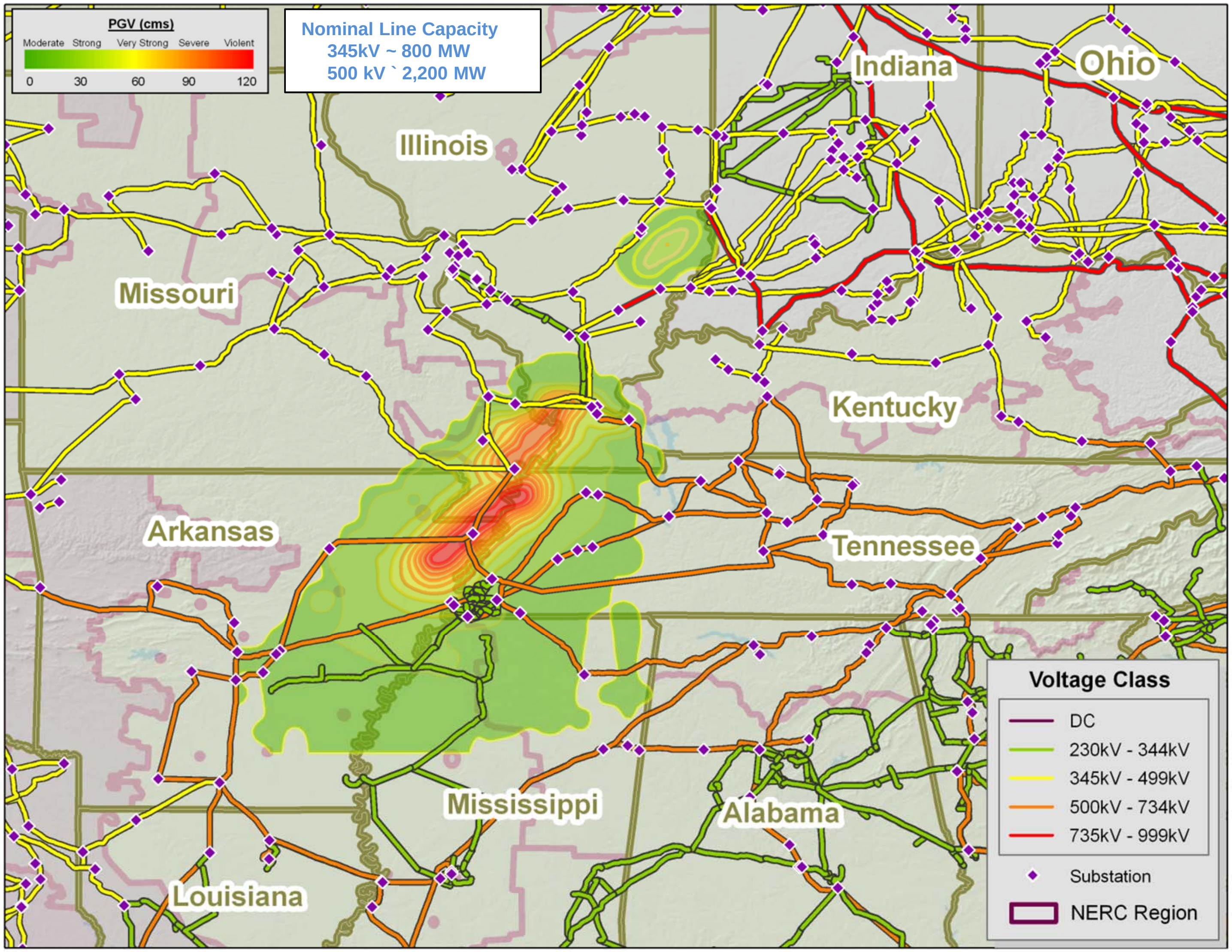
The U.S. power grid is a highly complex network of interconnected transmission lines, substations, and generation facilities.



Overview: Large Power Plants of Various Types in Within the NMSZ Shake Contours



Overview: High-voltage Transmission Lines and Substations in the NMSZ and WVSZ



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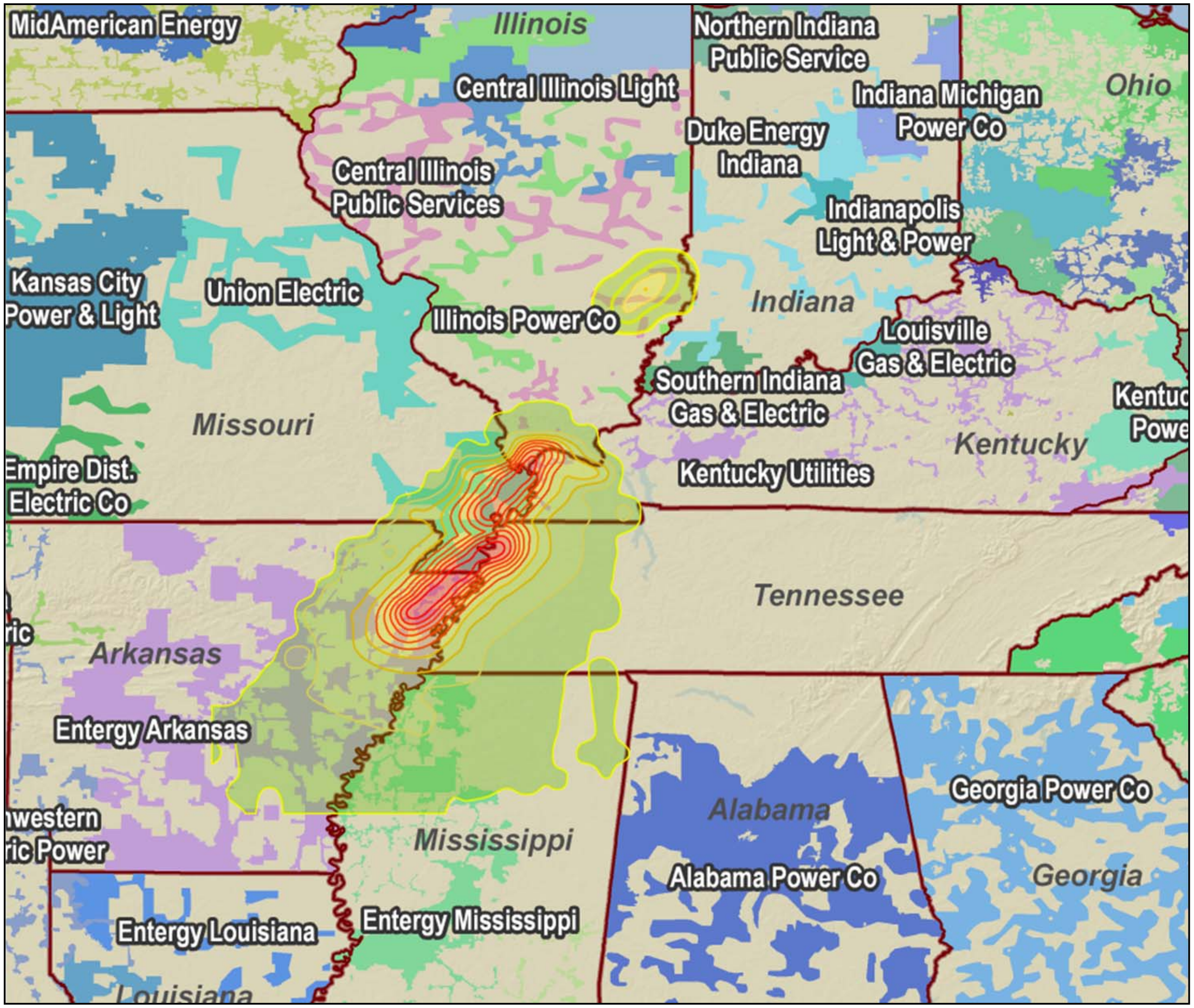
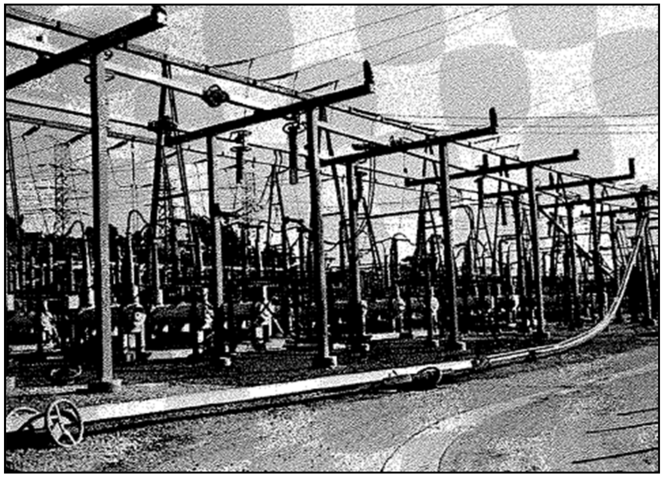
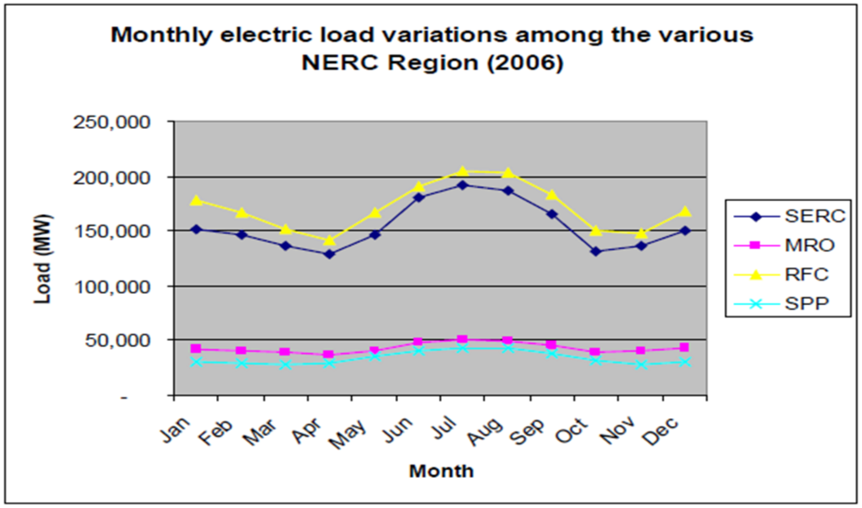
Overview: Investor-Owned Electric Distribution Companies in the NMSZ and WVSZ



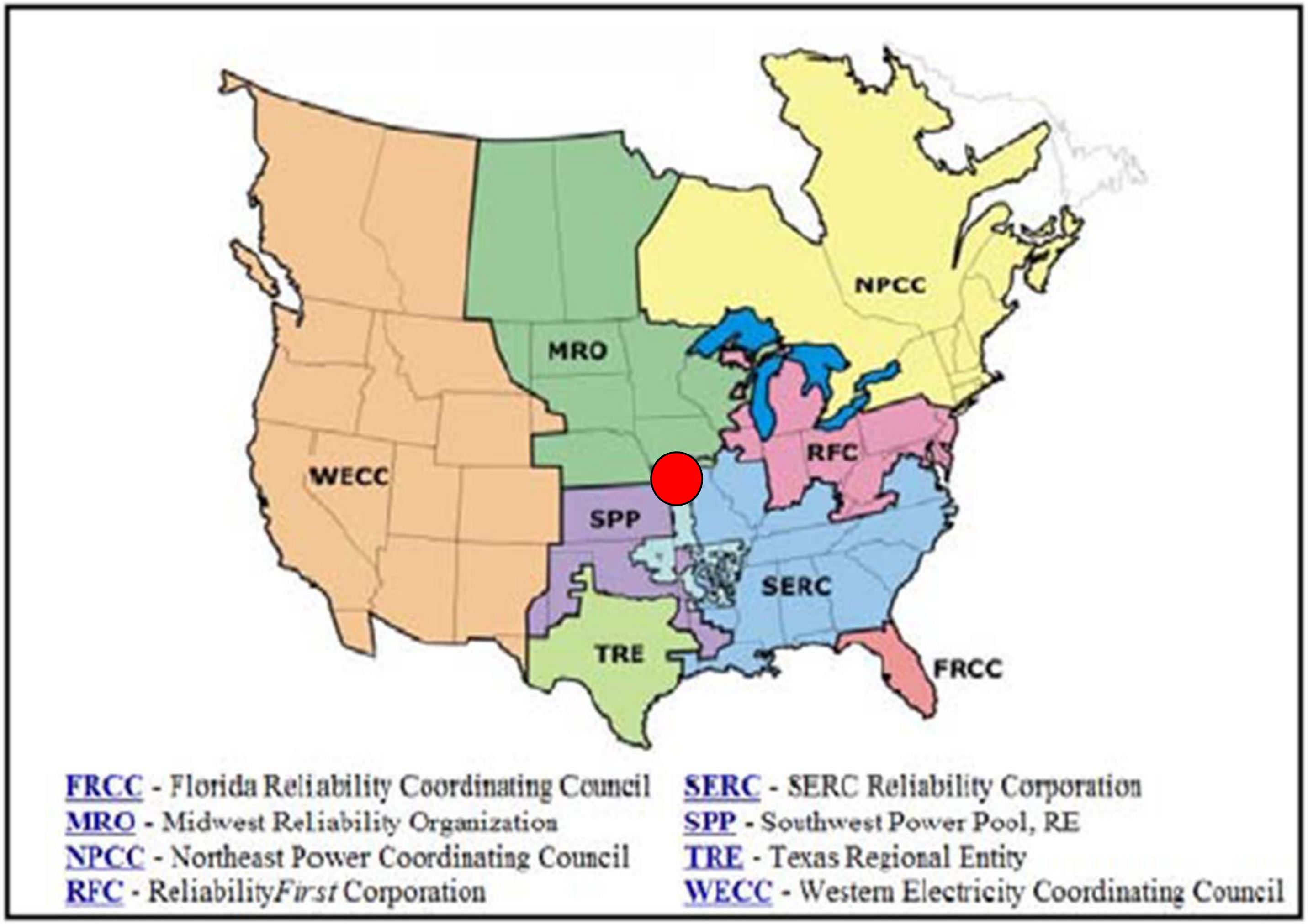
Scenario Description and Key Assumptions

- Simultaneous New Madrid and Wabash quakes with M 7.7 and 6.8, respectively.
- Events occurred on peak-day Summer months of July or August.
- Loading levels of transmission lines are at peak levels reaching up to 90% of line capacity for some lines.
- A failure of the substation would cause the associated transmission lines to de-energize and halt operations.

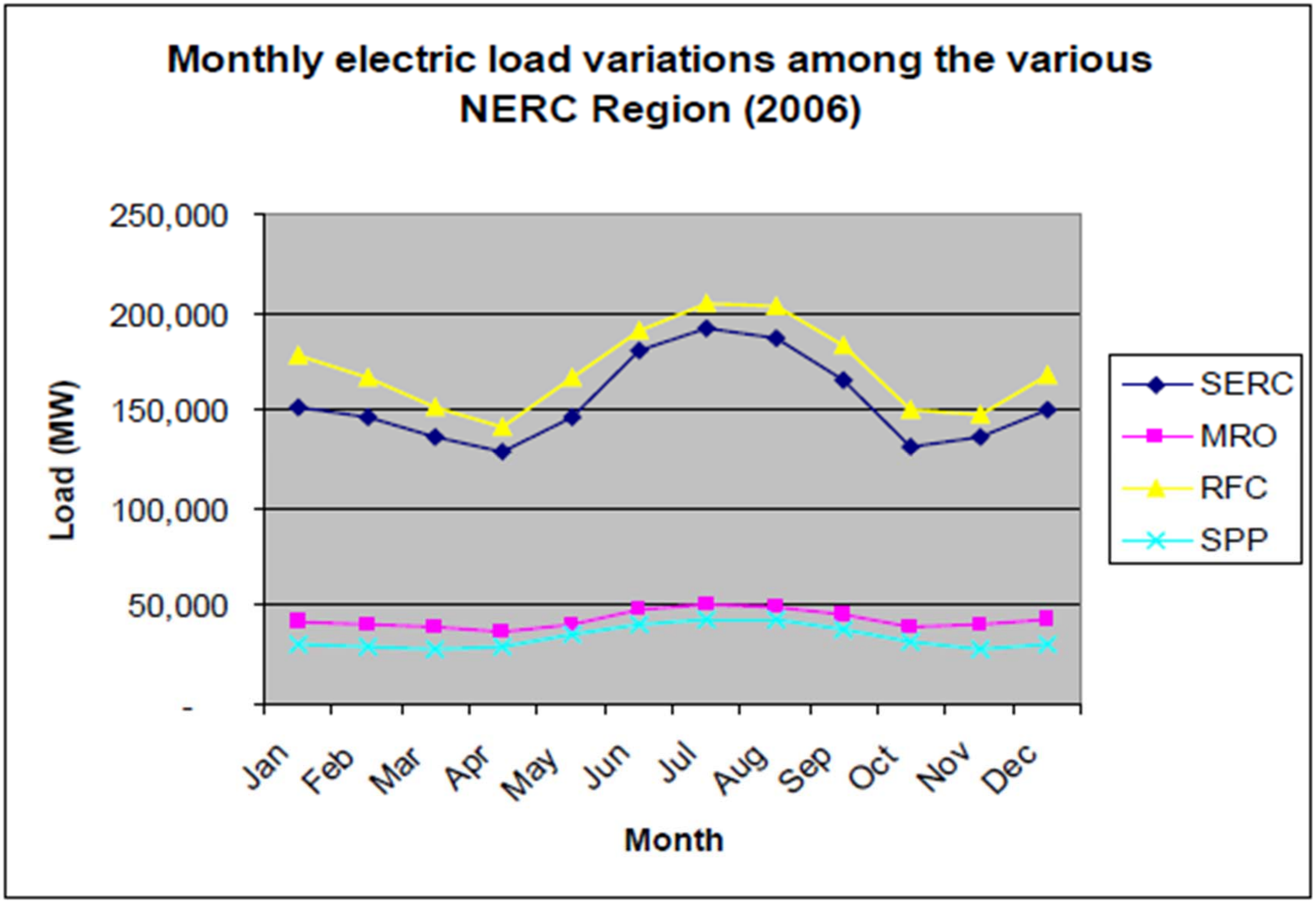




Overview: Affected NERC Regions



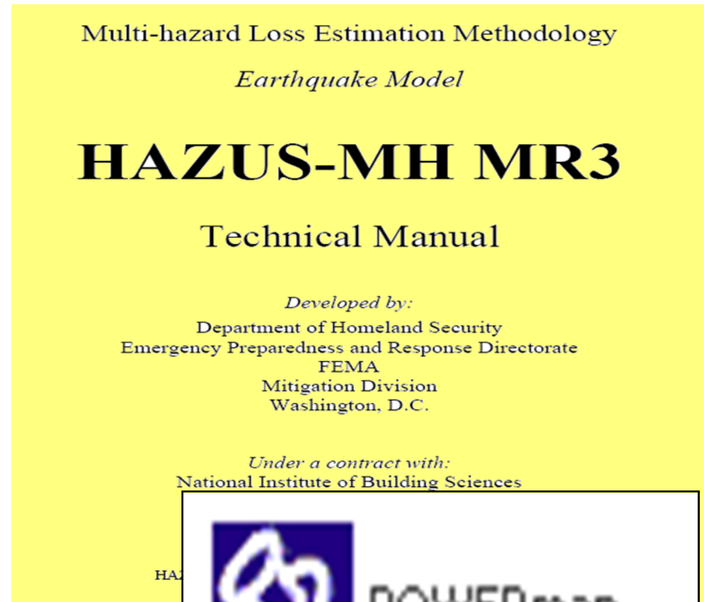
Overview: Electric Loading Levels Among Pertinent NERC Regions



Methodology and Sources of Data

A. Methodology

- Used HAZUS MH-MR3 for damage functions and fragility curves
- HAZUS used to identify electric components directly at risk by the seismic event
- Argonne's *EPfast* for downstream impact assessment
- Heuristics employed to account for potential effects of transients
- Used industry-based opinions for estimating component procurement times



B. Data Sources and Graphics

- **For Ground Motion: Used FEMA-provided shake maps (PGA, PGV, liquefaction)**
- **For transmission line and substation characterization and electric loads used:**
  - ERAG Summer 2010 Eastern Interconnection Model
  - EIA NERC monthly loading DBF
  - Platt's PowerMap for equipment inventory
- **For parts procurement: industry experts**

Damage Algorithms for Substations Based on *HAZUS* Formulation

Peak Ground Acceleration			
Classification	Damage State	Median (g)	Standard Deviation (β)
Low voltage	Slight/minor	0.15	0.70
	Moderate	0.29	0.55
	Extensive	0.45	0.45
	Complete	0.90	0.45
Medium voltage	Slight/minor	0.15	0.60
	Moderate	0.25	0.50
	Extensive	0.35	0.40
	Complete	0.70	0.40
High voltage	Slight/minor	0.11	0.50
	Moderate	0.15	0.45
	Extensive	0.20	0.35
	Complete	0.47	0.35

Note: ***Low voltage - 115-kV to 229-kV***
Medium Voltage- 230-kV to 499-kV
High Voltage - 500-kV and above

Definition of Different Damage States for Substations Based on *HAZUS* Formulation

- ***Slight/Minor Damage** is defined as the failure of **5%** of the disconnect switches (i.e., misalignment) or the failure of* 5% of the circuit breakers (i.e., circuit breaker phase sliding off its pad, circuit breaker tipping over, or interrupter-head falling to the ground) or by the building being in a state of minor damage.

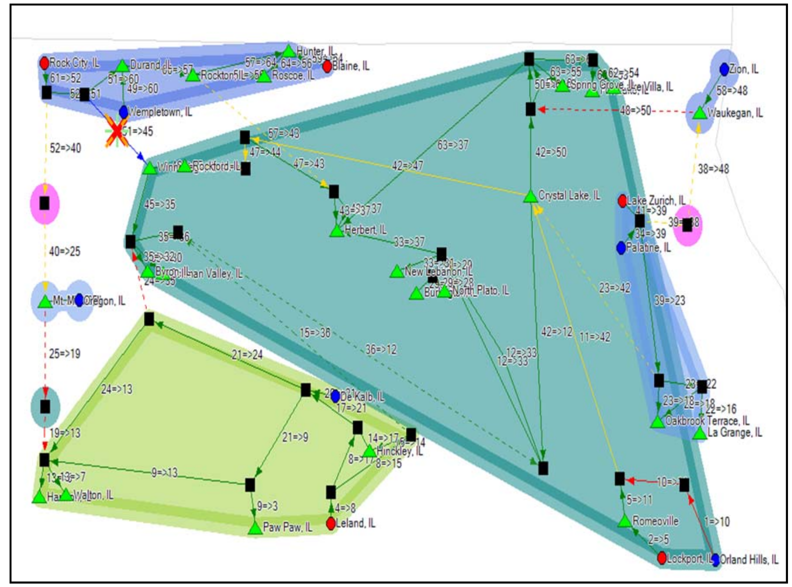
- ***Moderate Damage** is defined as the failure of **40%** of disconnect switches (e.g., misalignment) or 40% of circuit* breakers (e.g., circuit breaker phase sliding off its pad, circuit breaker tipping over, or interrupter-head falling to the ground) or the failure of 40% of current transformers (e.g., oil leaking from transformers, porcelain cracked) or by the building being in a state of moderate damage.

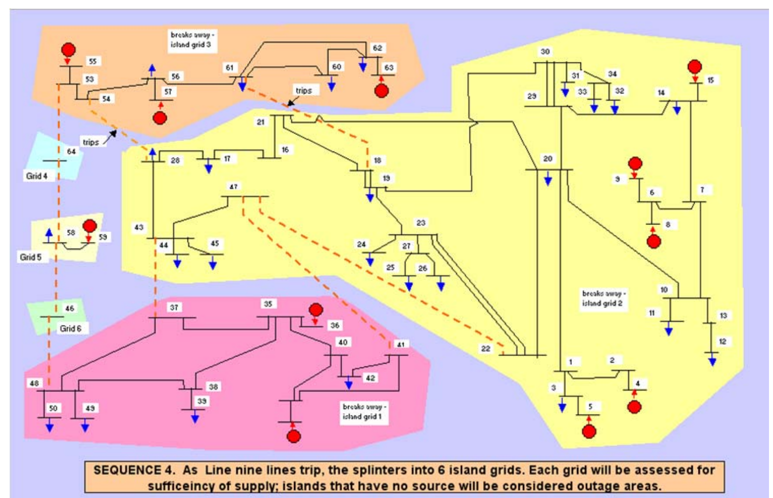
- ***Extensive Damage** is defined as the failure of **70%** of disconnect switches (e.g., misalignment), 70% of circuit* breakers, or 70% of current transformers (e.g., oil leaking from transformers, porcelain cracked), or by failure of 70% of transformers (e.g., leakage of transformer radiators) or by the building being in a state of extensive damage.

- ***Complete Damage** is defined as the failure of **all** disconnect switches, all circuit breakers, all transformers, or all current.*

EPFast: Model for Uncontrolled Islanding and Load Flow Analysis

- **Linear, steady-state model provides a quick estimate of impacts on the downstream substations due:**
  - Uncontrolled islanding
  - Single or multiple transmission line outages
  - Plant siting and line reinforcement studies
- **Can handle regional size networks:**
  ~ up to 100,000 nodes and 150,000 lines
- **User-friendly graphical user interface (GUI)**
- **Graphical and tabular HTML –formatted outputs**
- **Applications**
  - FEMA New Madrid Study
  - DOE New Madrid Study
  - General seismic and hurricane analysis
  - others as appropriate



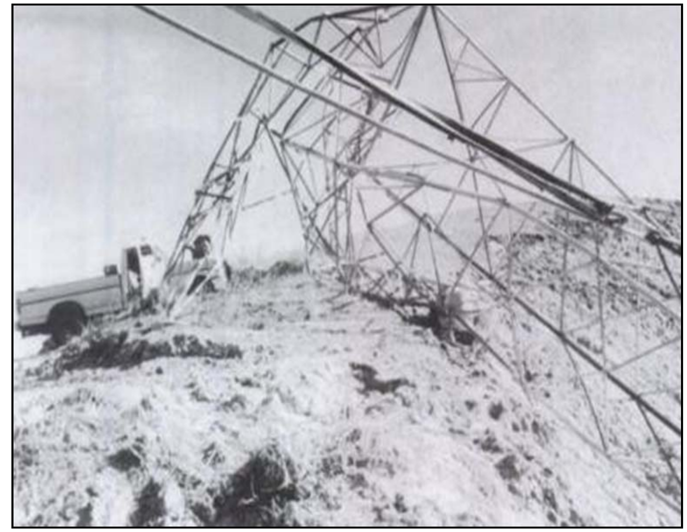


Steps in the Methodology

1. Define scenario and establish Base Case Load Flow.
2. Identify components likely to be damaged directly by the earthquake.
3. Run load flow assuming all damaged assets are out of service.
4. Identify overloaded lines of surviving network as a result of Item 3. Assume overloaded lines are outage. Run load flow again.
5. Check if the system splintered into island grids. If not, Stop and generate report (no islanding occurred). Otherwise, proceed to next step.
6. Balance supply with demand for each island grid formed. Perform load flow for each balanced island grid. Identify overloaded lines and assess losses.
7. Check if all island grids have been stabilized (i.e., balanced without line overloads). If not, trip all overloaded lines and see if more islands are formed and if so, repeat Step 6. Otherwise, end calculations and generate report.
8. Apply heuristics to enhance analysis, particularly, on the potential effects of transients.

Typical Component Damages to Towers and Distribution Systems Due to Seismic Events

- Buckling or collapse tower frame due to ground liquefaction, deformation and landslides.
- Insulator damages due to PGA ground motion.
- For distribution systems, there are two major types: burn-down of feeder and service lines and failure of concrete distribution poles.
- Downed lines can remain energized and cause fires. Assess, prioritize, and implement temporary quick work-around.
- Substations are more vulnerable to seismic shaking than transmission towers.
- In the U.S. wood poles are typically used for distribution and their performance in general has been very good.



FOUNDATION FAILURE

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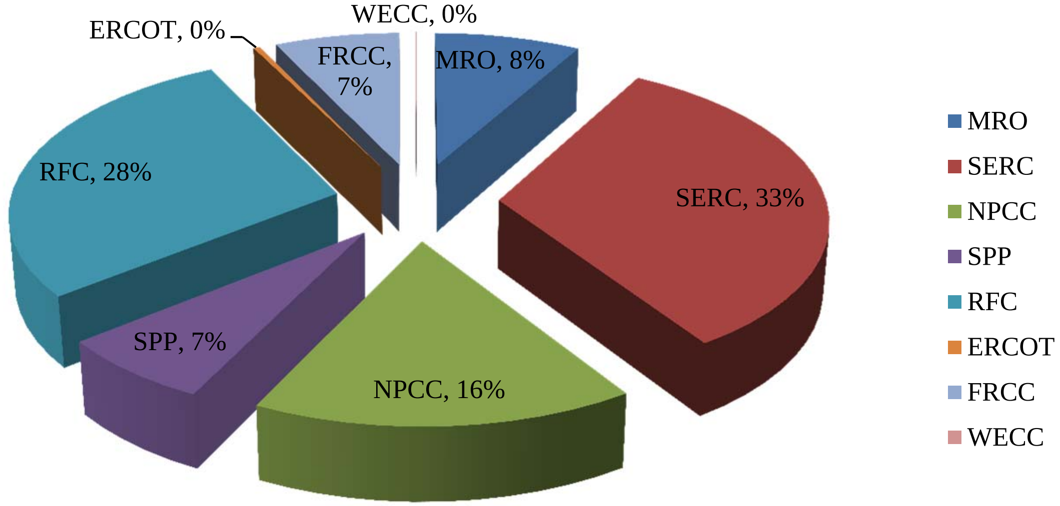
Description of Load Flow Data

Attributes	Description or Quantity
A. General	
NERC Regions Covered	RFC,SPP,MRO,SERC, NPCC, ERCOT,FRCC,WECC
Case Description	2010 Summer Peak
Source:	Eastern Reliability Assessment Group
B. Supply-demand (MW)	
Demand	663,241
Supply	663,241
DC Model Line Loss	0
C. No. of Buses	
Total	56,251
765-kV buses	33
500-kV buses	340
345-KV buses	1,976
230-kV buses	3,279
161-kV buses	2,674
138 kV buses	7,997
115-kV buses	9,766
69-kV buses	13,561
34.5 kV buses	2,143
all others	14,482
D. No. of Lines and Transformers	
Total lines and transforme	70,952
Total AC Lines	51,830
Total DC Lines	23
Total transformers	19,099

Model Load Dispersal (MW) Among Participating Regions

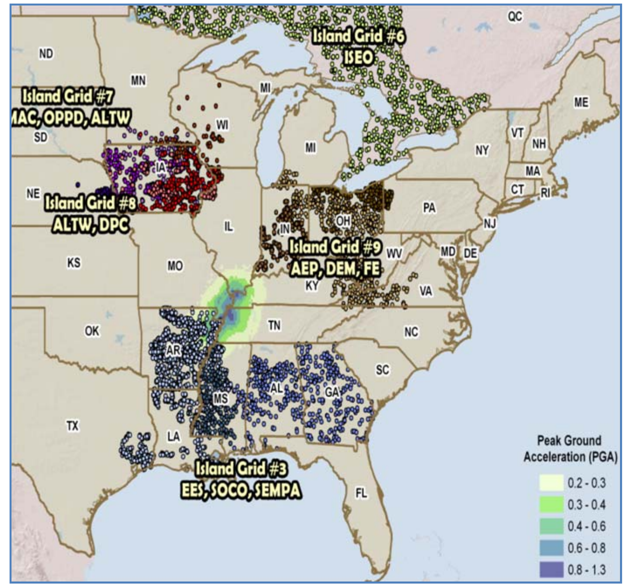


Total Load: 663, 240 MW

Result of Simulations

Caveats in Understanding the Results

- Data quality issues
  - Incomplete or lacking load data
  - Unavailability of per-bus geospatial information
  - Lacking some information on line rating
- Utilities or owners having widely dispersed properties or equipment presented problems in spatial depiction of islands grids.
- Spatial depiction of buses is approximate and is based on an in-housed developed automatic clustering algorithm anchored around the locational centroid of the owner utilities.
- The general layout and location island grids depicted here are based on the 3 or 4 core largest utilities comprising each island. Other utilities with smaller number of bus contributions are not included to save space.
- Utilities that appear far from the epicenter of the fault could experience severe load shedding due to its high stress level prior to the disturbance.
- A simple load shedding scheme is employed to balance supply and demand whenever an island is formed.



Initial Estimate of Number of Transmission Lines and Substations Likely to Experience Moderate to Extensive Damage (Based on Platt's *PowerMap* data)

Voltage Category (kV)	No. of Transmission Lines	No. of Substation
New Madrid Area		
230	40	37
345	20	18
500	28	19
Sub-total	**88**	**74**
Wabash Valley Area		
230	0	0
345	23	10
500	0	0
Sub-total	**23**	**10**
Grand Total	**111**	**84**

A much larger quantity was revealed when the ERAG-provided load flow data was considered, particularly, data that pertained to equipment with voltage ratings below 230 kV.

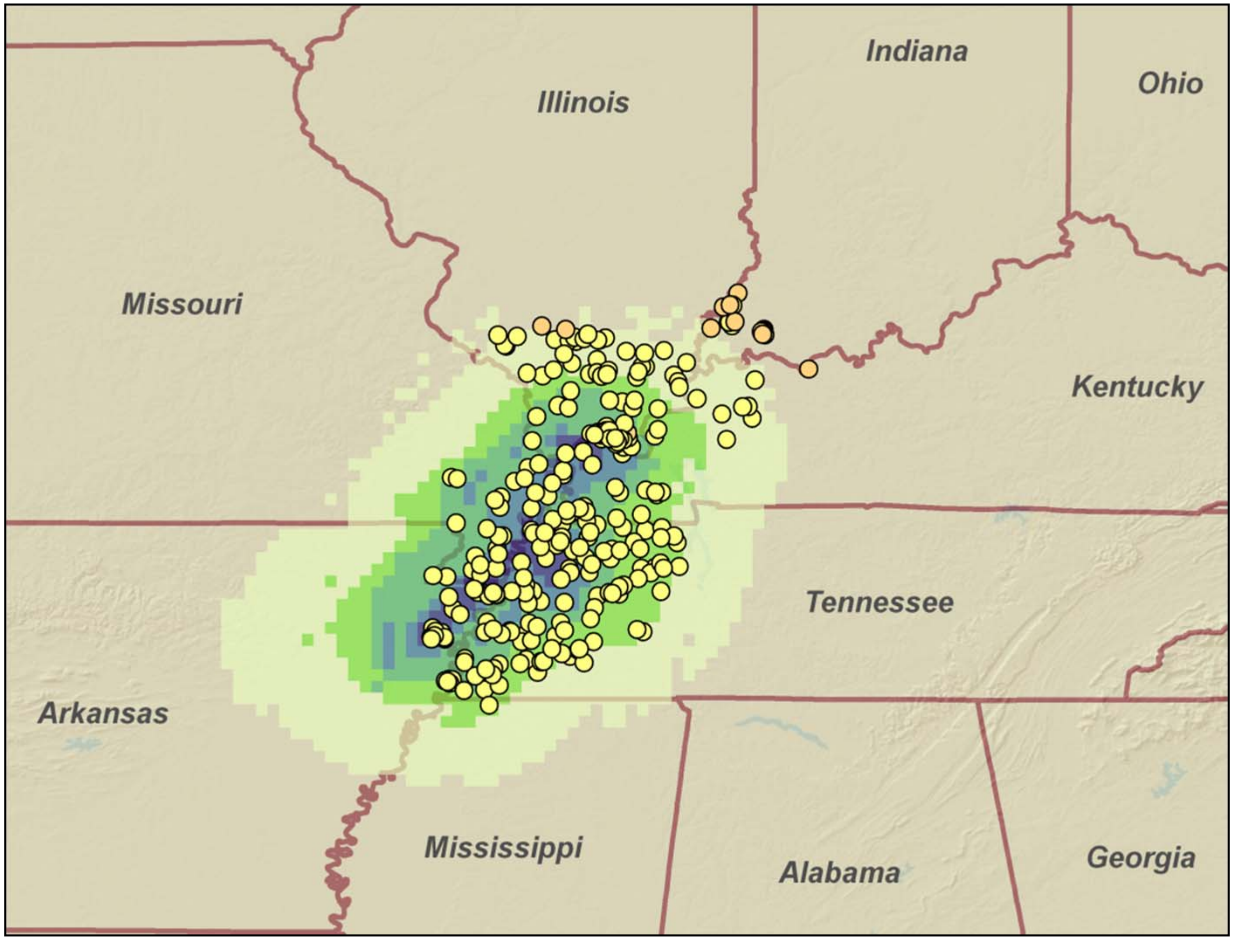
Initial Estimate of Installed MW likely to Experience Moderate to Extensive Damage (Based on Platt's *PowerMap* data)

Type of Generation	At-risk Installed MW due Seismic Event
New Madrid	
Oil	90
NG	6,700
Coal	8,300
Nuclear	0
Hydro	400
Subtotal	**15,490**
Wabash Valley	
Oil	20
NG	2,200
Coal	7,400
Nuclear	0
Hydro	0
Subtotal	**9,620**
Grand Total	**25,110**

The actual operational level MW might be lower than shown above due to maintenance or unit commitment considerations.

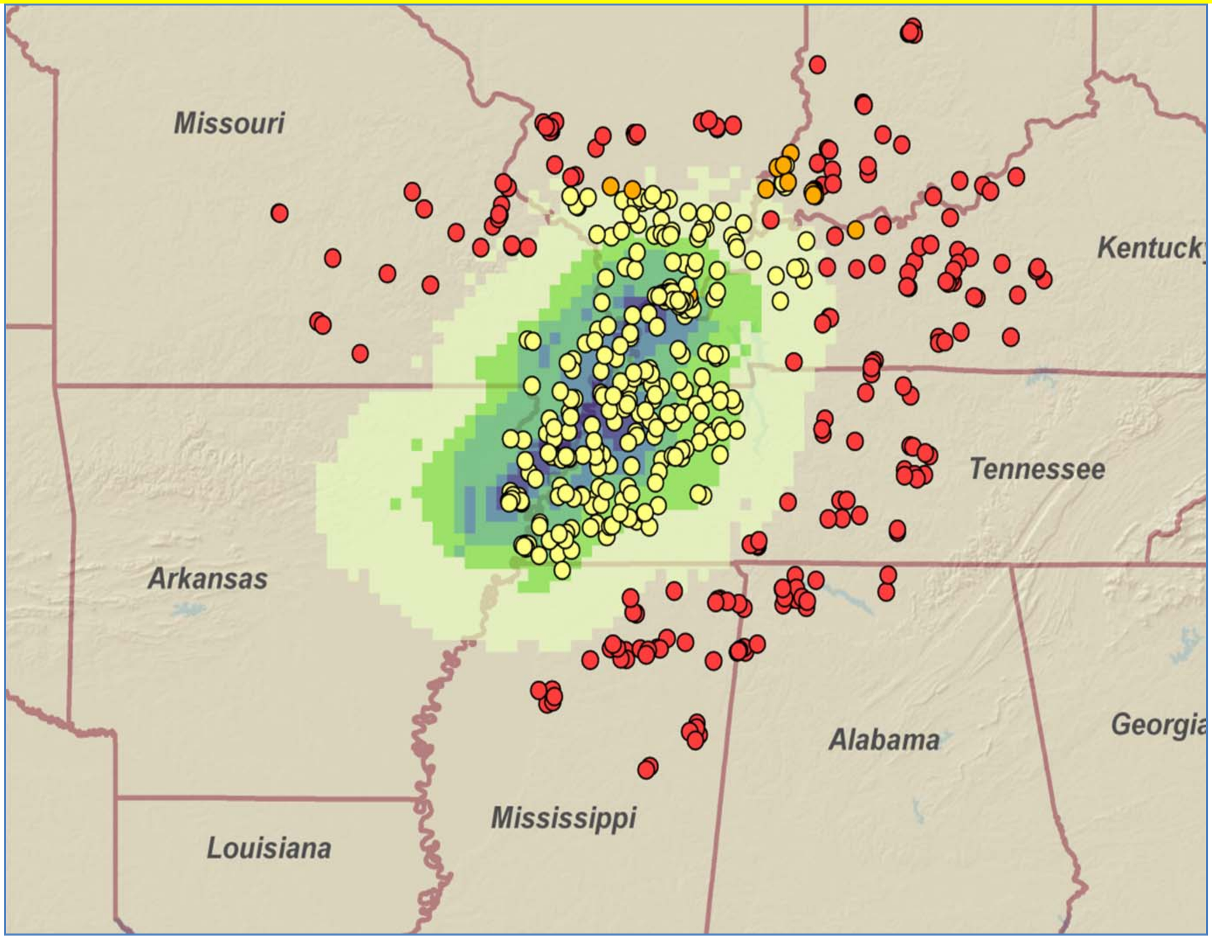
Dispersal of Damaged Substations at the Instant of the Earthquake (Based on ERAG Load Flow Data)

***About 310 buses, 750 lines and 11,300 MW of Generation would instantly be made non-operational by the earthquake*.**



Additional Buses Lost due to Line Overloads at the Second Iteration

Additional 200 buses and 110 lines would be lost due to ensuing line overloadings. About 108 island grids would be initially formed. Cascading effects due to overloaded lines would reach 22 iterations prior to finally settling to new stable operating point.



System State at End of Twenty Second Stage of Cascading Line Outages due to Successive Overloadings

The original 56,261 bus system splintered further into about 5,018 island grids.

Rank by Size	Island ID	No. of Buses	Load (MW)	Gen (MW)	Load Lost (MW)	Gen Lost (MW)	Total Original Load	% Load Reduction
1	3509	5,512	75,171	75,171	5,387	5,020		
2	3441	4,664	35,545	35,545	4,046	11,008		
3	3996	3,124	35,738	35,738	2,498	8,001		
4	4325	3,121	22,210	22,210	6,136	1,316		
5	4227	2,920	17,524	17,524	6,744	7,127		
6	3459	2,660	17,123	17,123	3,519	6,035		
7	4534	1,761	11,368	11,368	2,598	4,774		
8	4535	1,540	11,311	11,311	2,585	2,690		
9	4308	1,306	21,159	21,159	438	24,665		
10	3471	1,107	21,847	21,847	5,638	1,616		
11-5,018	N/A	1 to 973	106,899	106,899	247,757	215,094		
TOTAL		56,251	375,895	375,895	287,346	287,346	663,241	43%

The full extent of impact requires consideration of transient events such as frequency and voltage decays, generator-tripping power swings and mitigating schemes by utilities involved.

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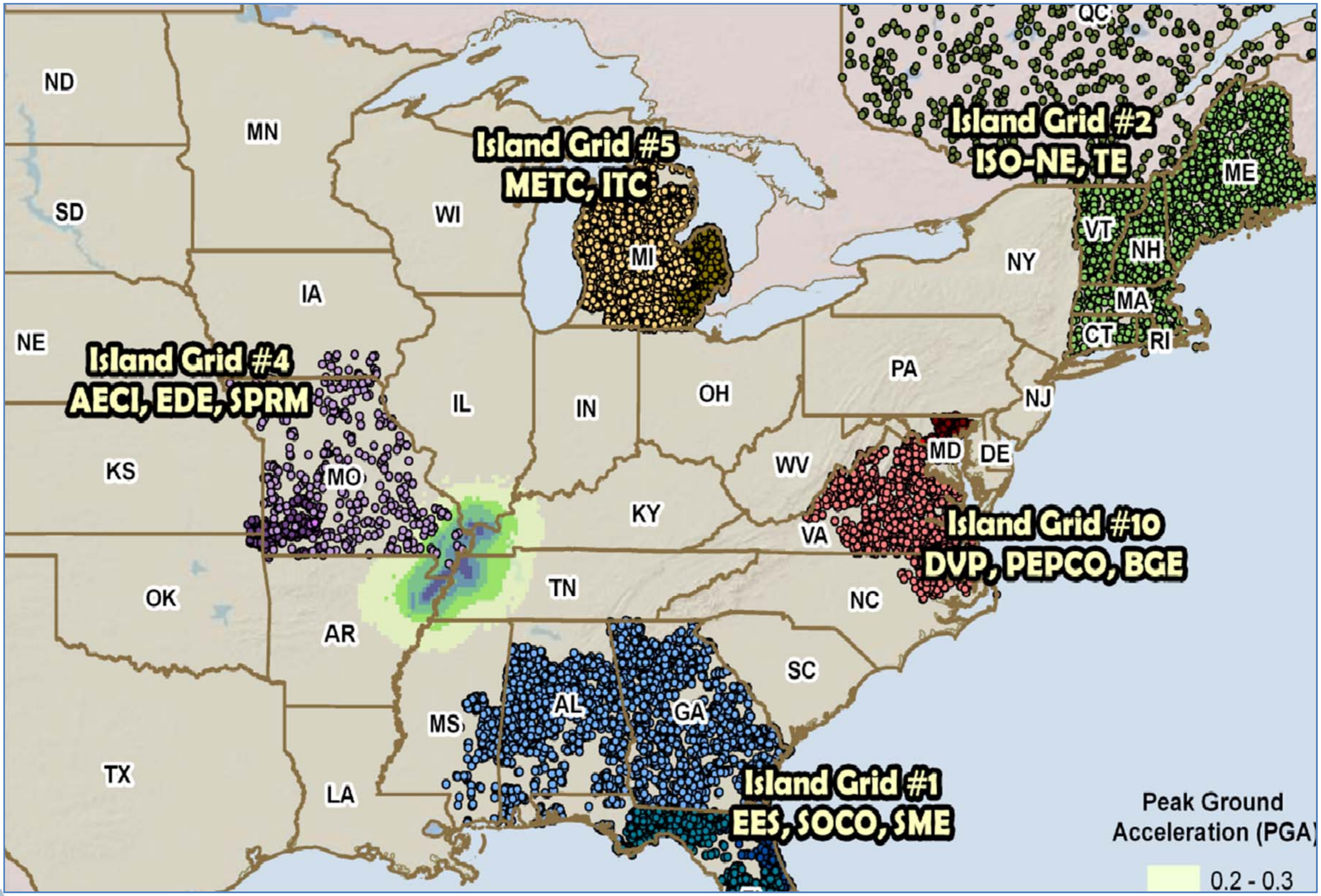
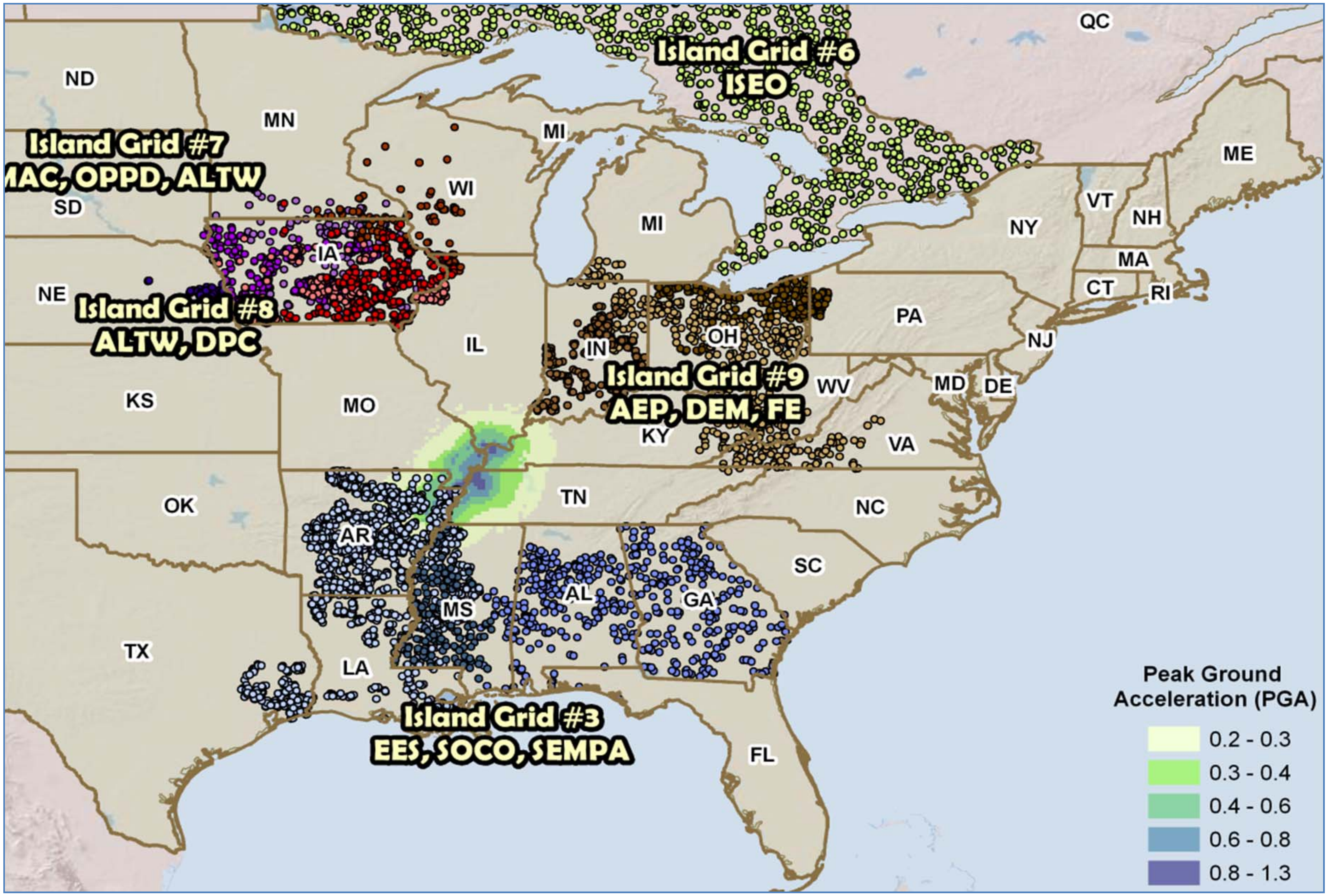
Locations of Five of the Ten Largest Island Grids in the U.S. Eastern Interconnection



Locations of the Next Five of the Ten Largest Island Grids in the U.S. Eastern Interconnection



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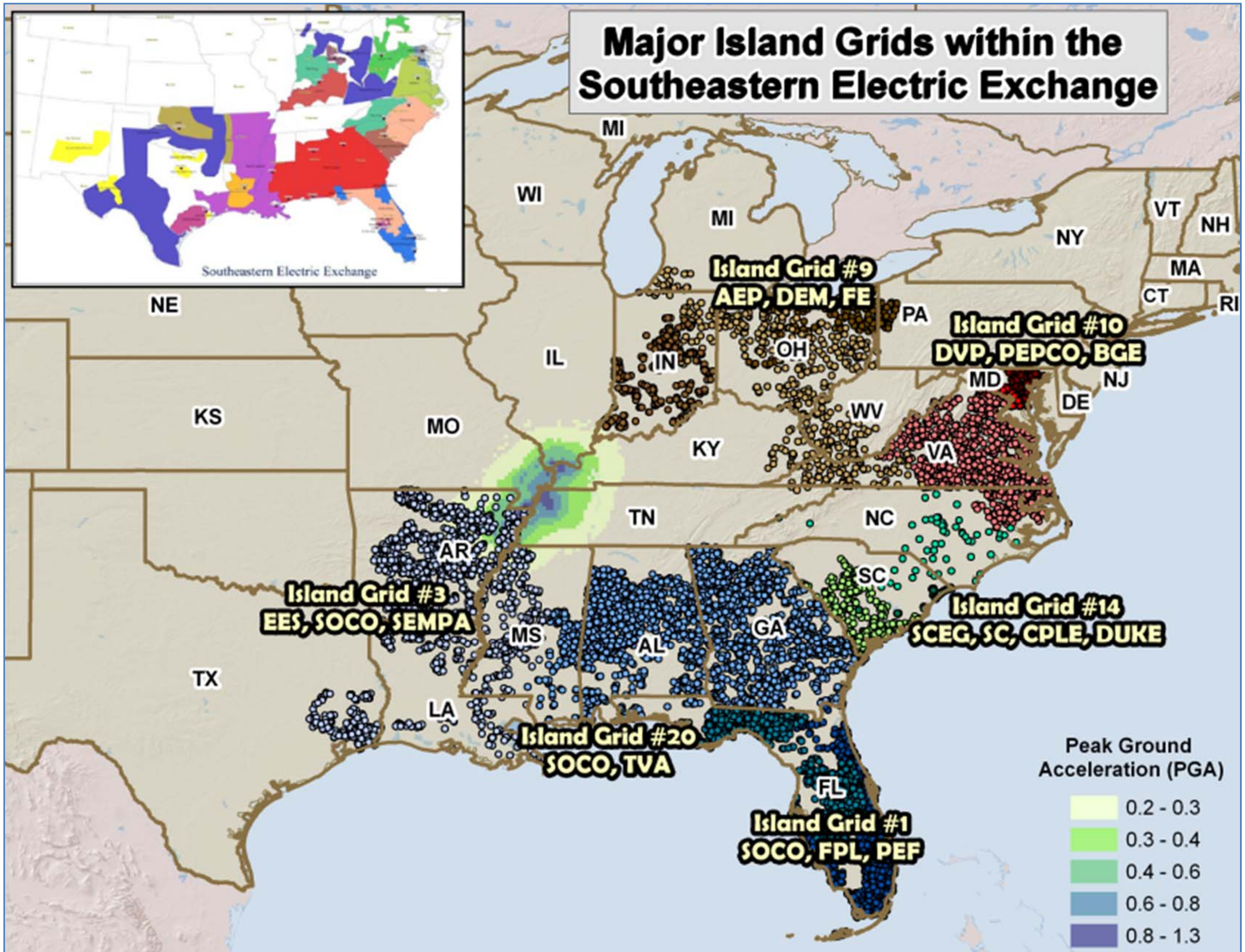
Locations of Major Island Grids Within S.E.E. Territory



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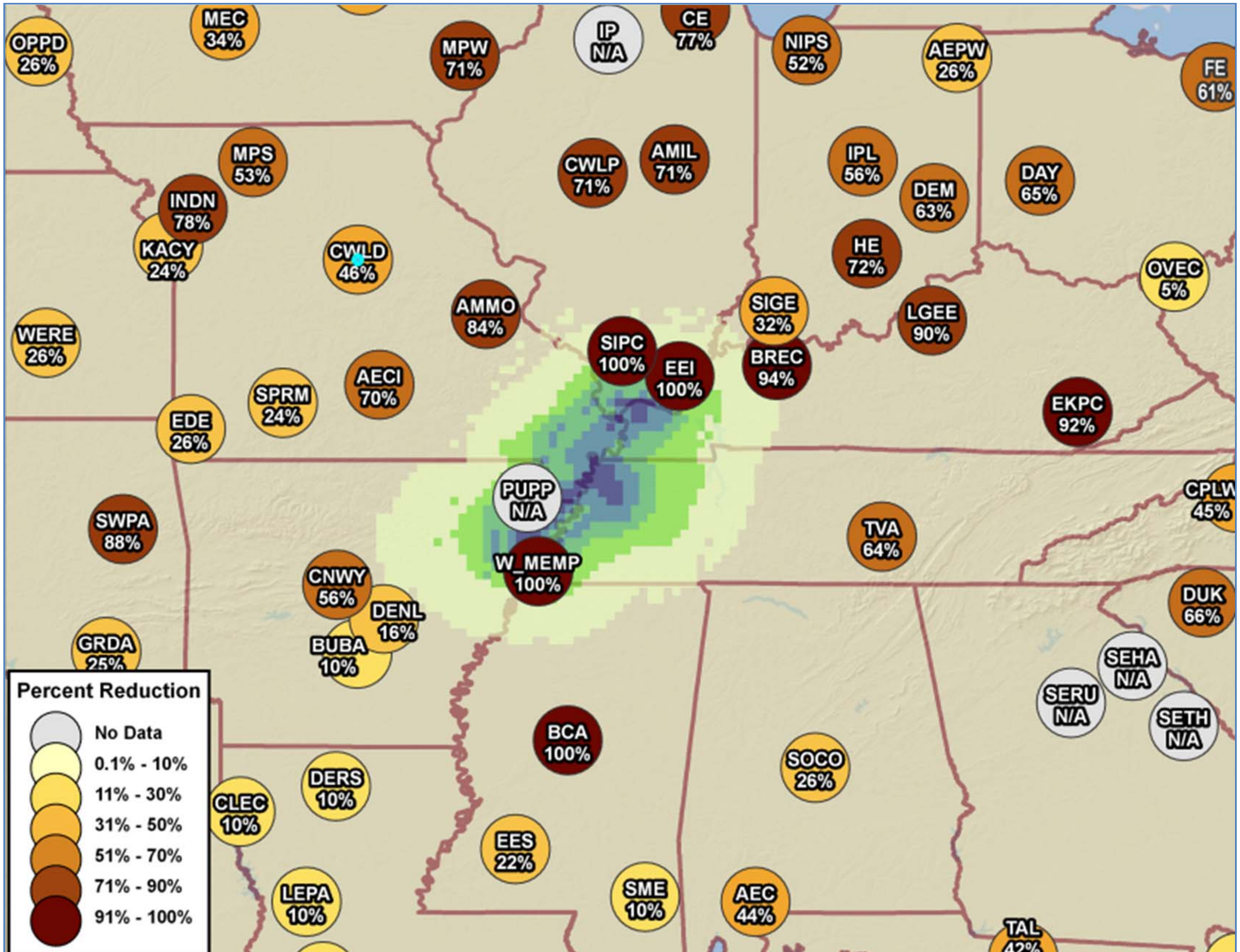
Summary of MW Loss Among Participating NERC Regions

NERC Region	Initial Load (MW)	Final Retained load (MW)	Total Load Lost (MW)	% Reduction in Load	% Share of Total Load Lost
RFC	187,936	78,884	109,051	58%	42%
SERC	216,497	113,810	102,687	47%	29%
NPCC	109,217	76,282	32,935	30%	13%
MRO	54,198	31,213	22,985	42%	9%
SPP	45,931	32,100	13,832	30%	5%
FRCC	46,518	41,371	5,147	11%	2%
ERCOT	2,431	1,822	609	25%	0%
WECC	513	413	100	20%	0%
Total	**663,241**	**375,895**	**287,346**	**43%**	**100%**

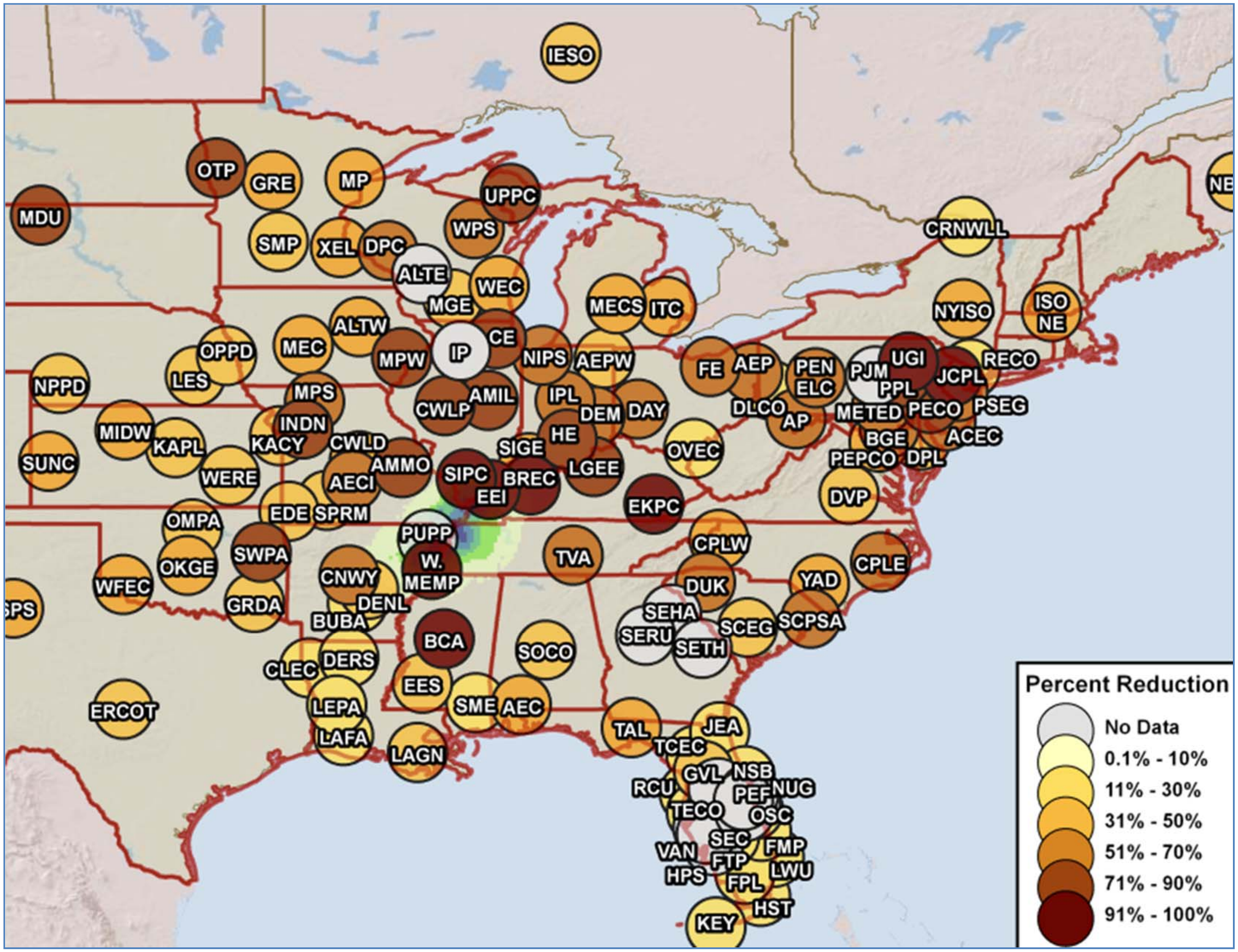
Top 25 Control Areas with the Largest Load Losses

AreaNo	Area Acronym	Area Full Name	NERC Region	Original Load (MW)	Total Load Lost (MW)	% Load Reduction
347	TVA	Tennessee Valley Authority	SERC	34,819.1	22,427.6	64%
222	CE	Commonwealth Edison	RFC	22,968.0	17,764.4	77%
342	DUKE	Duke Energy Carolinas	SERC	21,492.9	14,143.6	66%
102	NYISO	New York ISO	NPCC	29,586.7	13,705.2	46%
346	SOUTHERN	Southern Company	SERC	49,609.7	12,909.6	26%
205	AEP	American Electric Power	RFC	23,026.8	12,541.7	54%
101	ISO-NE	ISO New England	NPCC	30,142.2	10,322.6	34%
202	FE	FirstEnergy	RFC	14,081.6	8,729.2	62%
208	DEM	Duke Energy Midwest	RFC	12,875.3	8,076.6	63%
231	PSE&G	Public Service Electric & Gas Company	RFC	11,312.2	7,752.7	69%
230	PECO	PECO Energy Company	RFC	8,537.6	7,560.6	89%
356	AMMO	Ameren Missouri	SERC	8,888.0	7,478.0	84%
357	AMIL	Ameren Illinois	SERC	10,326.4	7,295.1	71%
363	LGEE	E.ON.US	SERC	7,922.9	7,115.0	90%
340	CPLE	Carolina Power & Light Company – East	SERC	12,845.8	6,981.7	54%
228	JCP&L	Jersey Central Power & Light Company	RFC	6,262.7	6,139.4	98%
345	DVP	Dominion Virginia Power	SERC	19,682.1	5,953.2	30%
351	EES	Entergy Electric System	SERC	26,297.9	5,783.1	22%
229	PPL	PPL Electric Utilities	RFC	7,223.3	5,582.1	77%
103	IESO	Independent Electric System Operator	NPCC	22,910.6	5,324.5	23%
232	BGE	Baltimore Gas & Electric Company	RFC	7,522.1	4,585.3	61%
201	AP	Allegheny Power	RFC	8,693.0	4,556.9	52%
219	ITCT	International Transmission Company	RFC	11,566.9	3,953.6	34%
600	XEL-MUNI-NMPA-CMMI	Xcel Energy North	MRO	11,297.0	3,878.0	34%

Control Areas near NMSZ with Estimated Percent Reduction in Load



Control Areas in the Eastern Interconnection with Estimated Percent Reduction in Load



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Applying Heuristics in the Analysis: Summary of Major Blackouts in the U.S.

Summary of Major Blackout Events in the U.S.

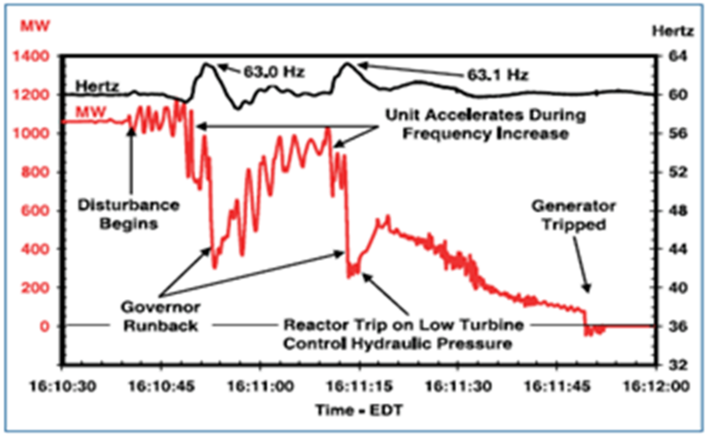
Event Name	MW lost	No. of People affected (Millions)
Aug 14, 2003 Northeast US-Canada Blackout	61,800	50
Aug 10, 1996 Blackout WSCC	30,500	23
Nov 9, 19965 Blackout Northeast US-Canada	37,080	30
July 2, 1996 WSCC Blackout	12,000	9
December 22, 1982 West coast blackout	12,350	5

The worst outage event in U.S. history (Aug. 14, 2003, blackout) was triggered by the failure of only two 345-kV lines (Stuart-Atlanta and Harding-Chamberlin lines) and the outage of a 597-MW power plant (Eastlake 5).

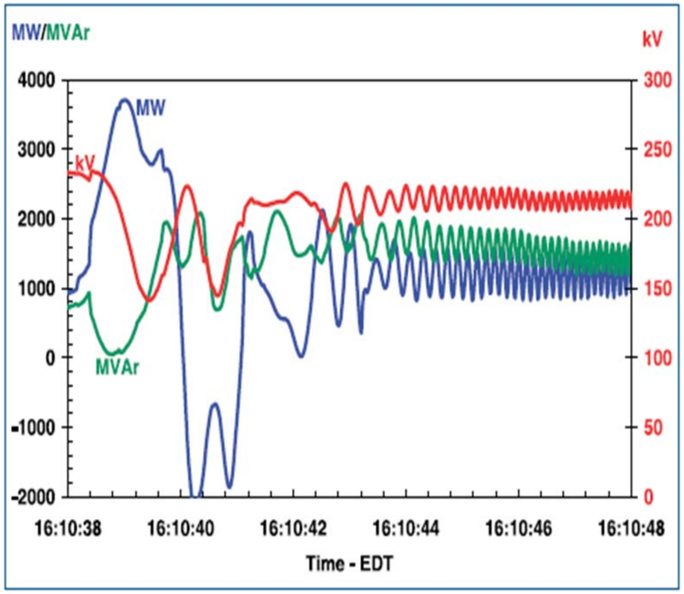
The effects of transient frequency decays (supply-demand imbalance) and voltage collapse (lack of reactive power), power swings (generator synchronization), and other transient instability problems can multiply the presented results so far by several factors, perhaps doubling the amount of load loss.

Summary of Heuristics Employed

- The level of reactive power directly affects the quality of voltage in the system. A sudden loss of a large amount of reactive power would most likely result in a large-scale systems collapse.
- An imbalance in supply and demand can cause a steep frequency decay or upsurge, thus causing frequency relays to trip loads as well as generators.
- Transient power swings due to sudden large disturbances (either loss of load or generation) can cause generators, especially those with lower electrical inertia, to step out of synchronism, thereby exacerbating the already imbalance system.



Events at one large generator during a cascade on August 14, 2003



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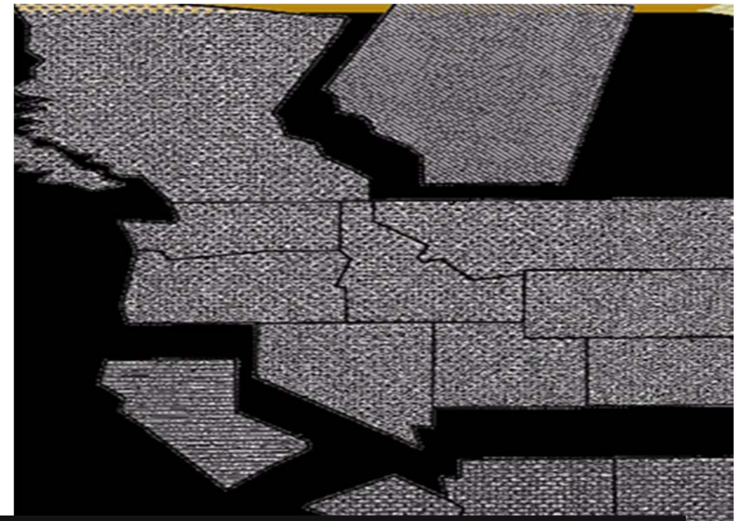
Estimated Downstream Impacts due to Cascading Failures

- **Far exceed impact of the August 14, 2003 Northeast U.S.- Canada blackout.**
- **Likely splinter a large portion of the national grid with potential load losses of 290,000 to 400,000 MW across large number of states.**
- **Eastern Interconnection would potentially break into numerous island grids and would likely collapse.**
- **Possibly affect 100 - 150 million people with the Northeast , Southeast, and Midwest regions likely to experience the brunt of the impacts.**
- **Many areas within the Eastern Interconnection will potentially have down times of at least 14 hrs to 5 days.**



SUMMARY AND CONCLUSIONS

- The combined New Madrid and Wabash events could instantly de-energize about 750 lines, 300 substations, and 11,300 MW of generation near epicenter.
- The combined events can put at risk for possible physical damage about 170-200 high voltage towers. Locations of these towers are most along or near the New Madrid fault lines.
- The combined events potentially could directly affect a large number of oil, natural gas, coal, and hydro plants with a total combined operating level of about 11,300 MW.
- Possibly affect 100-150 million people especially in states nearer to the epicenter with the Northeast, Southeast, and Midwest experiencing most of the outages.
- Eastern Interconnection would potentially break into numerous island grids and would likely collapse.
- Many areas within the Eastern Interconnection would potentially have down times of at least 14 hrs to 5 days.
- The equipment with the longest lead time is the transformer (8-12 months).
- In general, there are more approved suppliers for towers, switches, bushings, arresters and inductive reactors, implying shorter lead times (1-4 months).

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U.S. DEPARTMENT OF ENERGY

Load Losses Among Utilities within FRCC

Item No.	NERCRegion	AreaFullName	AreaNo	AreaAcronym	Original Load MW	Load Lost MW	% Load Reduction
1	ERCOT	Electric Reliability Council of Texas, Inc.	998	ERCOT	2,431.3	608.8	25%
2	FRCC	Calpine at Recker (TECO)	428	CALPINE	0.0	0.0	0%
3	FRCC	City of Homestead	405	HST	92.4	9.1	10%
4	FRCC	City of Key West	407	KEY	129.6	12.7	10%
5	FRCC	City of Lake Worth Utility	409	LWU	90.9	8.9	10%
6	FRCC	City of Tallahassee	415	TAL	598.6	252.2	42%
7	FRCC	Desoto Generation IPP at Whidden (FPL)	436	DESOTOGEN	0.0	0.0	0%
8	FRCC	Florida Municipal Power Pool	411	FMPP	2,282.7	224.5	10%
9	FRCC	Florida Power & Light	401	FPL	22,683.5	2,231.0	10%
10	FRCC	FMPA / City of Vero Beach	417	FMP	164.6	16.2	10%
11	FRCC	Fort Pierce Utility Authority	403	FTP	109.2	10.7	10%
12	FRCC	Gainesville Regional Utility	404	GVL	534.9	52.6	10%
13	FRCC	Hardee Power Station (TECO)	433	HPS	0.0	0.0	0%
14	FRCC	IPS Avon Park at Vandolah (PEF)	431	VAN	0.0	0.0	0%
15	FRCC	Jacksonville Electric Authority	406	JEA	3,031.6	298.2	10%
16	FRCC	Non-Utility Generators	418	NUG	0.0	0.0	0%
17	FRCC	Oleander IPP at Brevard (FPL)	427	OLEANDER	0.0	0.0	0%
18	FRCC	Osceola at Holopaw (PEF)	426	OSC	0.0	0.0	0%
19	FRCC	Progress Energy Florida	402	PEF	11,954.9	1,554.1	13%
20	FRCC	Reedy Creek Energy Services, INC.	419	RCU	190.1	18.7	10%
21	FRCC	Reliant at Indian River (FMPP)	438	IPP-REL	0.0	0.0	0%
22	FRCC	Seminole Electric Cooperative	412	SEC	282.5	27.8	10%
23	FRCC	Tampa Electric Company	416	TECO	4,277.7	420.7	10%
24	FRCC	Treasure Coast Energy Center	421	TCEC	0.0	0.0	0%
25	FRCC	Utilities Commission of New Smyrna Beach	410	NSB	94.4	9.3	10%

Load Losses Among Utilities within MRO

Item No.	NERCRegion	AreaFullName	AreaNo	AreaAcronym	Original Load MW	Load Lost MW	% Load Reduction
26	MRO	Alliant Energy East (ATC)	694	ALTE	3,032.8	0.0	0%
27	MRO	Alliant Energy West	627	ALTW	4,696.8	2,299.9	49%
28	MRO	Dairyland Power Cooperative-Wisconsin Public pwr	680	DPC-WPPI	897.8	616.3	69%
29	MRO	Great River Energy	615	GRE	1,686.3	631.5	37%
30	MRO	Lincoln Electric System, NE	650	LES	807.3	172.3	21%
31	MRO	Madison Gas and Electric Company (ATC)	697	MGE	818.2	99.0	12%
32	MRO	Manitoba Hydro	667	MHEB	3,334.6	2,698.6	81%
33	MRO	MidAmerican Energy	635	MEC-CBPC-RPGI-IAMU-MMEC	6,156.5	2,119.7	34%
34	MRO	Minnesota Power & Light	608	MP	1,999.8	744.3	37%
35	MRO	Montana-Dakota Utilities Co.	661	MDU	620.8	439.7	71%
36	MRO	Muscatine Power & Water	633	MPW	165.2	117.3	71%
37	MRO	Nebraska Public Power District	640	NPPD	3,684.1	809.1	22%
38	MRO	Omaha Public Power District	645	OPPD	2,996.0	769.7	26%
39	MRO	Otter Tail Power Company	620	OTP	2,185.8	1,817.2	83%
40	MRO	Saskatchewan Power Co.	672	SPC	3,217.8	1,540.2	48%
41	MRO	Southern Minnesota Municipal Power Association	613	SMMPA	388.1	91.6	24%
42	MRO	Upper Peninsula Power Company (ATC)	698	UPPC	216.9	157.5	73%
43	MRO	Western Area Power Administration, et al	652	WAPA-MPC-BEPC-NWPS-MRES	3,350.1	1,155.9	35%
44	MRO	Wisconsin Public Service Corporation (ATC)	696	WPS-CWP-MEWD-MPU	2,646.0	1,404.6	53%
45	MRO	Xcel Energy North	600	XEL-MUNI-NMPA-CMMPA	11,297.0	3,878.0	34%

Load Losses Among Utilities within RFC

Item No.	NERCRegion	AreaFullName	AreaNo	AreaAcronym	Original Load MW	Load Lost MW	% Load Reduction
53	RFC	Allegheny Power	201	AP	8,693.0	4,556.9	52%
54	RFC	American Electric Power	205	AEP	23,026.8	12,541.7	54%
55	RFC	Atlantic Electric	234	AE	2,815.6	1,686.2	60%
56	RFC	Baltimore Gas & Electric Company	232	BGE	7,522.1	4,585.3	61%
57	RFC	Commonwealth Edison	222	CE	22,968.0	17,764.4	77%
58	RFC	Dayton Power & Light Company	209	DAY	3,400.2	2,199.0	65%
59	RFC	Delmarva Power & Light Company	235	DP&L	4,107.4	699.4	17%
60	RFC	Duke Energy Midwest	208	DEM	12,875.3	8,076.6	63%
61	RFC	Duquesne Light Company	215	DLCO	3,036.4	161.9	5%
62	RFC	FirstEnergy	202	FE	14,081.6	8,729.2	62%
63	RFC	Hoosier Energy Rural Electric Cooperative, Inc.	207	HE	845.3	606.3	72%
64	RFC	Illinois Power- Riverside Plant	220	IPRV	0.0	0.0	0%
65	RFC	Indianapolis Power & Light Company	216	IPL	3,323.3	1,858.9	56%
66	RFC	International Transmission Company	219	ITCT	11,566.9	3,953.6	34%
67	RFC	Jersey Central Power & Light Company	228	JCP&L	6,262.7	6,139.4	98%
68	RFC	Metropolitan Edison Company	227	METED	2,890.4	1,967.0	68%
69	RFC	Michigan Electric Transmission Co., LLC	218	METC	10,177.7	3,581.3	35%
70	RFC	Northern Indiana Public Service Company	217	NIPS	3,549.7	1,862.6	52%
71	RFC	Ohio Valley Electric Corporation	206	OVEC	35.9	1.9	5%
72	RFC	PECO Energy Company	230	PECO	8,537.6	7,560.6	89%
73	RFC	Pennsylvania Electric Company	226	PENELEC	2,722.3	1,778.9	65%
74	RFC	PJM 500 kV System	225	PJM	0.0	0.0	0%
75	RFC	Potomac Electric Power Company	233	PEPCO	7,121.7	2,369.2	33%
76	RFC	PPL Electric Utilities	229	PPL	7,223.3	5,582.1	77%
77	RFC	Public Service Electric & Gas Company	231	PSE&G	11,312.2	7,752.7	69%
78	RFC	Rockland Electric Company	237	RECO	488.6	20.2	4%
79	RFC	Southern Indiana Gas & Electric Company	210	SIGE	1,966.4	638.8	32%
80	RFC	UGI Utilities, Inc.	236	UGI	196.0	181.5	93%
81	RFC	Wisconsin Electric Power Company - Edison Sault	295	WEC-ESE	7,189.4	2,195.7	31%

Load Losses Among Utilities within SERC

Item No.	NERCRegion	AreaFullName	AreaNo	AreaAcronym	Original Load MW	Load Lost MW	% Load Reduction
82	SERC	Alabama Electric Cooperative	350	AEC	1,095.5	484.4	44%
83	SERC	Ameren Illinois	357	AMIL	10,326.4	7,295.1	71%
84	SERC	Ameren Missouri	356	AMMO	8,888.0	7,478.0	84%
85	SERC	APGI – Yadkin Division	352	YAD	4.1	1.9	45%
86	SERC	Associated Electric Cooperative Inc.	330	AECI	4,187.4	2,944.1	70%
87	SERC	Batesville	331	BCA	14.4	14.4	100%
88	SERC	Benton Utilities Balancing Authority	336	BUBA	87.0	8.4	10%
89	SERC	Big Rivers Electric Corporation	314	BREC	1,719.7	1,620.6	94%
90	SERC	Carolina Power & Light Company – East	340	CPLE	12,845.8	6,981.7	54%
91	SERC	Carolina Power & Light Company – West	341	CPLW	872.1	396.7	45%
92	SERC	City of North Little Rock	339	DENL	307.3	48.1	16%
93	SERC	City of Ruston	338	DERS	73.9	7.2	10%
94	SERC	City of Springfield (IL) Water Light & Power	360	CWLP	491.6	348.1	71%
95	SERC	Columbia, MO Water and Light	333	CWLD	328.4	152.7	46%
96	SERC	Conway	335	CONWAY	219.6	122.0	56%
97	SERC	Dominion Virginia Power	345	DVP	19,682.1	5,953.2	30%
98	SERC	Duke Energy Carolinas	342	DUKE	21,492.9	14,143.6	66%
99	SERC	E.ON.US	363	LGEE	7,922.9	7,115.0	90%
100	SERC	East Kentucky Power Cooperative	320	EKPC	2,262.3	2,077.8	92%
101	SERC	Electric Energy Incorporated	362	EEI	79.7	79.7	100%
102	SERC	Entergy Electric System	351	EES	26,297.9	5,783.1	22%
103	SERC	Louisiana Generating Company	332	LAGN	1,344.4	152.3	11%
104	SERC	South Carolina Electric & Gas Company	343	SCEG	5,488.4	1,167.5	21%
105	SERC	South Carolina Public Service Authority	344	SCPSA	4,787.7	2,442.9	51%
106	SERC	South Mississippi Electric Power Association	349	SMEPA	793.6	76.9	10%
107	SERC	Southern Company	346	SOUTHERN	49,609.7	12,909.6	26%
108	SERC	Southern Illinois Power Cooperative	361	SIPC	327.4	327.4	100%
109	SERC	Tennessee Valley Authority	347	TVA	34,819.1	22,427.6	64%
110	SERC	West Memphis	334	WESTMEMP	127.1	127.1	100%

Load Losses Among Utilities within SPP

Item No.	NERCRegion	AreaFullName	AreaNo	AreaAcronym	Original Load MW	Load Lost MW	% Load Reduction
111	SPP	American Electric Power	520	AEPW	10,374.5	2,645.7	26%
112	SPP	Board of Public Utilities	542	KACY	565.5	137.4	24%
113	SPP	Central Louisiana Electric Company	502	CELE	2,516.8	243.8	10%
114	SPP	City of Independence	545	INDN	325.8	253.8	78%
115	SPP	City Utilities of Springfield	546	SPRM	789.0	191.6	24%
116	SPP	Empire District Electric Company	544	EMDE	1,189.2	304.3	26%
117	SPP	Grand River Dam Authority	523	GRDA	1,039.5	258.9	25%
118	SPP	Kansas City Power and Light Company	541	KAPL	3,615.3	1,068.8	30%
119	SPP	Lafayette Utilities	503	LAFA	492.2	47.7	10%
120	SPP	Louisiana Energy and Power Authority	504	LEPA	230.9	22.4	10%
121	SPP	Midwest Energy	531	MIDW	385.9	140.7	36%
122	SPP	Missouri Public Service Company	540	MIPU	2,096.7	1,116.4	53%
123	SPP	Oklahoma Gas and Electric Company	524	OKGE	6,308.7	2,171.7	34%
124	SPP	Oklahoma Municipal Power Authority	527	OMPA	674.1	166.3	25%
125	SPP	Southwestern Power Administration	515	SWPA	902.2	791.6	88%
126	SPP	Southwestern Public Service	526	SPS	5,844.4	1,795.3	31%
127	SPP	Sunflower Electric Cooperative	534	SUNC	452.7	159.9	35%
128	SPP	Westar	536	WERE	6,073.0	1,553.0	26%
129	SPP	Western Farmers Electric Cooperative	525	WFEC	1,372.0	493.8	36%
130	SPP	Westplains Energy	539	WEPL	682.8	268.4	39%
131	WECC	Western Electricity Coordinating Council	999	WECC	513.2	100.4	20%