Electric Grid Failure (Natural / Accidental)

Event Description

Electric Power Grid Failure: A significant regional power-grid failure that extends beyond the geographic area of the initiating incident, which is due to natural disaster/hazards, equipment failure, distribution/transmission failure/disruptions, or public appeals to reduce usage (brown-to blackouts).

Event Background

Electric Power Grid Failures are common. Significant ones are often associated with large-scale natural hazards, such as hurricanes, earthquakes, solar storms, and major winter storms. In addition to the natural physical effects of the events and the damage on the generation, transmission, and distribution equipment, the power grid is designed to fail "safely," which is to say, the control systems and operating protocols will intentionally shut down undamaged elements of the grid if sudden changes in supply and demand make the grid unstable. The Electric Power Grid Failure scenarios under evaluation are those that are attributable to the physical destruction of natural disasters, equipment failure, distribution/transmission disruptions and public appeals to reduce usage.

There is no single interconnected national grid for the U.S. Instead, the continental U.S. is served by four separate grids, which cannot be impacted by the failure of their neighbors, though it is feasible for events to impact more than one of the grids within the U.S.

The four separate networks are:

- The Western Interconnection, which serves those contiguous states west of the Rockies as well as their Canadian neighbors and portions of Northwestern Mexico;
- The Electric Reliability Council of Texas, which serves only the state of Texas,
- The Eastern Interconnection which serves all states (and Canadian Provinces) east of the Rockies and South of the Great Lakes and New York, and
- The Quebec Interconnection, which serves New York, New England, and Canadian provinces east of Manitoba.

The Eastern Interconnection is actually made up of four interconnected but separately managed grids, allowing some cascading failures within this large, heavily populated area.

No scenario exists for a national U.S. power grid failure, except apocalyptic events that may make power restoration issues seem minor.

A quantitative analysis of data provided by the National Protection and Programs Directorate (NPPD) regarding electric power grid outages from 2005 through 2014 was performed using those reported outages caused by 16 natural, equipment and public appeals for reduction of usage categories. Adversarial and Space Weather outages were not addressed in this analysis, but are covered elsewhere in the Strategic National Risk Assessment Summary; however, the resulting economic impacts may be comparable.

Over 10 years that cover the reported events, it is understood that more events occurred but only the reported events that resulted in outages were considered. These events led to significant

Megawatt (MW) Demand Loss to the electric power providers and significant economic loss to the customers. The overall average frequency of failure regardless of mechanism is 61.2 report events per year. The number of deaths that might be associated with power outages was not considered in this analysis for these reasons; 1) the information was not provided, 2) it is difficult to determine if a death is directly related to an outage, and 3) this analysis is not tracking deaths. This analysis looked at the economic impact that outages have in 2014 dollars using residential, small/medium businesses, and large businesses from 2012 and 2013 census data.

The following tables present the risk of grid failure to the Nation as a whole. The actual failure causative agents are localized in nature, and the failures do not affect the whole Nation at the time of the failure. The data does indicate these failures show the aggregate MW Demand Loss and economic impact that is incurred. Table 1 is a compilation of the 16 failure causes that occurred over the 10-year period outlining the resultant impact—in this case, on the MW Demand Loss that was incurred by the power industry providers and the numbers of customers affected by the outage.

Table 1: Electric Power Grid Reported Failure Loss – 2005–2014

Failure Cause	Number of Reported Events	Total Outage Hours	Average Outage Hours	Total MW Demand Loss	Average MW Demand Loss/Event	Average MW Demand Loss/Event Hour	Total Customers Affected[1]	Average Number of Customers[1] Affected/Event
Flooding	1	432.5	432.5	200	200	0.46	21000	21000.00
Earthquake	3	67.57	22.52	1375	458.33	20.35	420886	140295.33
Tornados	4	189.02	47.26	2335	583.75	12.35	363294	90823.50
Hurricanes/ Tropical Storms	18	2200.96	122.28	15106	839.22	6.86	4389780	243876.65
Brush/Wildfires	11	51.39	4.67	10412	946.55	202.69	3632732	330248.36
Ice Storms	23	2168.53	94.28	9709	422.13	4.48	3009934	130866.70
Severe Winter/ Winter Storms	40	2836.94	70.92	14649	366.23	5.16	9309160	232729.00
Wind	50	2482.73	49.65	11624	232.48	4.68	7024603	140492.06
Thunderstorms/ Lightning	94	3357.80	35.72	44959	478.29	13.39	16259599	172974.46
Storms/Severe Storms	81	4275.30	52.78	33250	410.49	7.78	16070627	198402.80
Electrical System Failures	100	561.44	5.61	66005	600.50	1176.56	5722055	57220.55
Equipment Fires	4	12.79	3.20	1081	270.25	84.45	128654	32163.50
Distribution/ Transmission/ Generator Failures	72	1980.71	27.51	32918	457.19	16.62	6755455	93825.76
Fuel Supply Disruption	24	3410.96	142.12	14760	615.00	4.33	140001	5833.38
Load Shedding/ Voltage Reduction	74	692.64	9.36	23435	316.69	33.83	6156567	83196.85
Public Appeals Reduction	13	375.10	28.85	18645	1434.23	49.71	4277859	329066.08
TOTAL	612	24096.38	39.37	300463	490.95	12.47	83682206	136765.63

[1] All customers affected – residential; small, medium, and large retail businesses and industry.

Table 2 provides the breakdown and total of the numbers of electricity customers/consumers for the Nation using the most recent census data. These numbers provided a baseline for the data presented in Table 3, Table 4, and Table 6.

Table 2: Electricity Consumers in the United States

Consumer Segment	Subtotal of Segment	Percent of Total	Census
Residential	132,802,859	95	2013
Small–Medium Business[2]	6,232,434	4	2012
Large Business[2]	1,199,374	1	2012
TOTAL ALL	140,234,667	100	

Table 3 addresses the impact to the Nation as a whole should the entire "national" grid suffer a catastrophic failure and the resultant significant economic impact regardless of the causative or aggregate failure agent(s).

Table 3: Power Outage Economic Impact to Consumers

Consumer Segment	Subtotal of Segment	Average Cost Factor per Hour[3] (2004 $)	Economic Impact per Outage Hour (2004 $)	Inflation Factor (2004 – 2014)[4]	Economic Impact per Outage Hour (2014$)
Residential	132,802,859	$3.00	$398,408,577	1.253	$499,205,947
Small–Medium Business	6,232,434	$1200.00	$7,478,920,800	1.253	$9,371,087,762
Large Business	1,199,374	$8200.00	$9,834,866,800	1.253	$12,323,088,100
NATIONAL TOTAL	140,234,667		$17,712,196,177	1.253	$22,195,381,809

[2] Small–Medium businesses are those that employ 0 to 499 employees. Large businesses are those that employ 500 or greater employees.
[3] Understanding the Cost of Power Interruptions to U.S. Electricity Consumers (2004), U.S. Department of Energy and Lawrence Berkeley National Laboratory
[4] U.S. Inflation Calculator, U.S. Bureau of Statistics

Table 4 presents the economic and social impact resulting from data in Table 6 which addresses the economic impact that resulted from the reported failures over the 10-year reporting period 2004 to 2014.

Table 4: Table of Findings

Category	Description	Metric	Low	Medium	High
	All Events	MW Demand Loss	200	490.95	66005
	All Events	Outage Hours	12.79	39.37	4275.30
Economic	Economic Residential	Dollars/Event	$75,012.00	$18,682,052.49	$58,079,287.63
Economic	Economic Small-Medium Business	Dollars/Event	$1,263,024.00	$314561410.50	$977,917,322.26
Economic	Economic Large Business	Dollars/Event	$2,157,666.00	$537,375,546.10	$1,670,608,759.85
Economic	Economic Residential	Average Dollars/Event Hour	$173.44	$896,866.89	$3,643,347
Economic	Economic Small-Medium Business	Average Dollars/Event Hour	$2,920.29	$15,101,108.81	$61,345,325.47
Economic	Economic Large Business	Average Dollars/Event Hour	$4,988.82	$25,797,728.22	$104,798,264.34
Social	All Events	Household Displacement	1,995.00	496,863.10	1,544,661.91

Table 5 shows the frequency or likelihood that a failure may occur each year associated with a particular failure cause. The table shows, as well, the total failures that may or likely occur each year regardless of the causative agent.

Table 5: Event Frequency of Occurrence

Failure Cause	Flooding	Earthquake	Tornados	Hurricanes/Tropical Storms	Brush/Wildfires	Ice Storms	Severe Winter/Winter Storms	Wind	Thunderstorms/ Lightning	Storms/Severe Storms	Electrical System Failures	Equipment Fires	Distribution/Transmission/ Generator Failures	Fuel Supply Disruption	Load Shedding/Voltage Reduction	Public Appeals Reduction	TOTAL
Report Events Frequency/ Year	0.1	0.3	0.4	1.8	1.1	2.3	4	5	9.4	8.1	10	0.4	7.2	2.4	7.4	1.3	61.2

Table 6 shows the overall economic impact each of the failure causes have on the economy broken down to residential, small–medium businesses, and large businesses along with, for planning purposes, the expected social displacement of households for shelter planning.

Summary

These tables present a wealth of information. The failure causes are isolated events that affect only a relatively small geographical area and rarely an entire region. As such, from a national risk assessment they may not necessarily be considered as risk. These failures and the resultant outages do have an economic impact, but it is isolated and is more a local nuisance than anything more. However, as we look at the aggregates of each failure cause then we begin to see that the economic impact begins to be significant, and the risk becomes nationally strategic. This becomes even more evident as we examine the result of all of the failures occurring at the same time or if the entire national grid and the four components that make up the national grid are affected at the same time catastrophically. Should this happen, the economic impact would be billions of dollars an hour (See Table 3), and if prolonged, would be economically unrecoverable. The social displacement from a catastrophic failure would be such that civilization as we currently know it would no longer exist because of the tremendous reliance the Nation's population has upon electric power. It is not unreasonable to expect that the social upheaval would be catastrophic as well. A prolonged catastrophic failure regardless of the causative agent(s) to society could lead to indeterminate collateral deaths, which could be in the tens to hundreds of million within the first year.

Table 6: Electric Power Grid Economic Loss – 2005–2014

Event Cause	Report Events	Total Outage Hours	Average Outage Hours	Total Customers Affected (100%)	Average Number of Customers Affect/Event	Residential Customers Affected (95%)	Small-Medium Business Affected (4%)	Large Business Affect (1%)	Impact Cost Factor[5] Res.	Impact Cost Factor[5] S – M	Impact Cost Factor[5] Large	Econ Impact/ Event Res.	Econ Impact/ Event S – M	Econ Impact/ Event Large	Aver. Econ Impact/ Event Hour Res.	Aver. Econ Impact/ Event Hour S – M	Aver. Econ Impact/ Event Hour Large	Displaced Households[6]
Flooding	1	432.5	432.5	21000	21000.00	19950.00	840.00	210.00	$3.76	$1503.60	$10274.60	$75012.00	$1263024.00	$2157666.00	$173.44	$2920.29	$4988.82	1995.00
Earthquake	3	67.57	22.52	420886	140295.33	399841.70	16835.44	4208.86	$3.76	$1503.60	$10274.60	$1503404.79	$25313767.58	$43244352.96	$66758.65	$1124057.18	$1920264.34	39984.17
Tornados	4	189.02	47.26	363294	90823.50	345129.3	14531.76	3632.94	$3.76	$1503.60	$10274.60	$1297686.17	$21849954.34	$37327005.32	$27458.45	$462335.05	$789822.37	34512.93
Hurricanes/ Tropical Storms	18	2200.96	122.28	4389780	243876.65	4170291.00	175591.20	43897.8	$3.76	$1503.60	$10274.60	$15680294.16	$264018928.32	$451032335.85	$128232.70	$2159134.19	$3688520.90	417029.10
Brush/ Wildfires	11	51.39	4.67	3632732	330248.36	3451095.40	145309.28	36327.32	$3.76	$1503.60	$10274.60	$12976118.7	$218487003.41	$373248682.07	$2778612.14	$46785225.57	$79924771.32	345109.54
Ice Storms	23	2168.53	94.28	3009934	130866.70	2859437.30	120397.36	30099.34	$3.76	$1503.60	$10274.60	$10751484.25	$181029470.50	$309258678.76	$114037.80	$1920125.91	$3280215.09	285943.73
Severe Winter/ Winter Storms	40	2836.94	70.92	9309160	232729.00	8843702.00	372366.40	93091.60	$3.76	$1503.60	$10274.60	$33252319.52	$559890119.04	$956478953.36	$468870.83	$7894671.73	$13486730.87	884370.20
Wind	50	2482.73	49.65	7024603	140492.06	6673372.85	280984.12	70246.03	$3.76	$1503.60	$10274.60	$25091881.92	$422487722.83	$721749859.84	$505375.27	$8509319.69	$14536754.48	667337.29
Thunderstorms/Lightning	94	3357.80	35.72	16259599	172974.46	15446619.05	650383.96	162595.99	$3.76	$1503.60	$10274.60	$58079287.63	$977917322.26	$1670608759.85	$1625959.90	$27377304.65	$46769562.12	1544661.91
Storms/ Severe Storms	81	4275.30	52.78	16070627	198402.80	15267095.65	642825.08	160706.27	$3.76	$1503.60	$10274.60	$57404279.64	$966551790.29	$1651192641.74	$1087614.24	$18312841.80	$31284438.06	1526709.57
Electrical System Failures	100	561.44	5.61	5722055	57220.55	5435952.25	228882.20	57220.55	$3.76	$1503.60	$10274.60	$20439180.46	$344147275.92	$587918263.03	$3643347.68	$61345325.47	$104798264.34	543595.23
Equipment Fires	4	12.79	3.20	128654	32163.50	122221.30	5146.16	1286.54	$3.76	$1503.60	$10274.60	$459552.09	$7737766.18	$13218683.88	$143610.03	$2418051.93	$4130838.71	12222.13
Distribution/ Transmission/ Generator Failures	72	1980.71	27.51	6755455	93825.76	6417682.25	270218.20	67554.55	$3.76	$1503.60	$10274.60	$24130485.26	$406300085.52	$694095979.43	$877153.25	$14769177.95	$25230679.00	641768.23
Fuel Supply Disruption	24	3410.96	142.12	140001	5833.38	133000.95	5600.04	1400.01	$3.76	$1503.60	$10274.60	$500083.57	$8420220.14	$14384542.75	$3518.74	$59247.26	$101214.06	13300.10
Load Shedding/ Voltage Reduction	74	692.64	9.36	6156567	83196.85	5848738.65	246262.68	61565.67	$3.76	$1503.60	$10274.60	$21991257.32	$370280565.65	$632562632.98	$2349493.30	$39559889.49	$67581477.82	584873.87
Public Appeals Reduction	13	375.10	28.85	4277859	329066.08	4063966.05	171114.63	42778.59	$3.76	$1503.60	$10274.60	$15280512.35	$257287551.70	$439532900.81	$529653.81	$8918112.71	$15235109.21	406396.61
TOTAL	612	24096.38	39.37	83682206	136765.63	79498095.70	3347288.24	836822.06	$3.76	$1503.60	$10274.60	$298912839.83	$5032982597.66	$8598011937.68	$7592401.32	$127838013.66	$218389940.00	7949809.57

[5] *Understanding the Cost of Power Interruptions to U.S. Electricity Consumers* (2004), U.S. Department of Energy and Lawrence Berkeley Laboratory. (2004 Residential: $3/hr., Small/Medium Business: $1200/hr., Large Business: $8200/hr. These values were multiplied by the inflation factor rise of 1.253 (25.3%) from 2004 to 2014 (U.S. Inflation Calculator, U.S. Bureau of Statistics).

[6] Displaced Household values derived from using the planning metric of 10% of evacuated residents will seek shelter. Displacement values are for planning purposes only. Actual displacement of residents is dependent upon a number of variables. Not all event causes will necessitate a displacement.