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To: ERCOT PARWG
Date: March 18, 2002
Subject: ERCOT Generation Adequacy Study

Please find attached ERCOT Generation Adequacy Study final report.

The report has the following sections:

Computer files are posted at http://k5gp.home.texas.net/relstudy.htm giving additional details for the four study phases in this report.

Please let me know if you have any questions concerning this study.

Sincerely,

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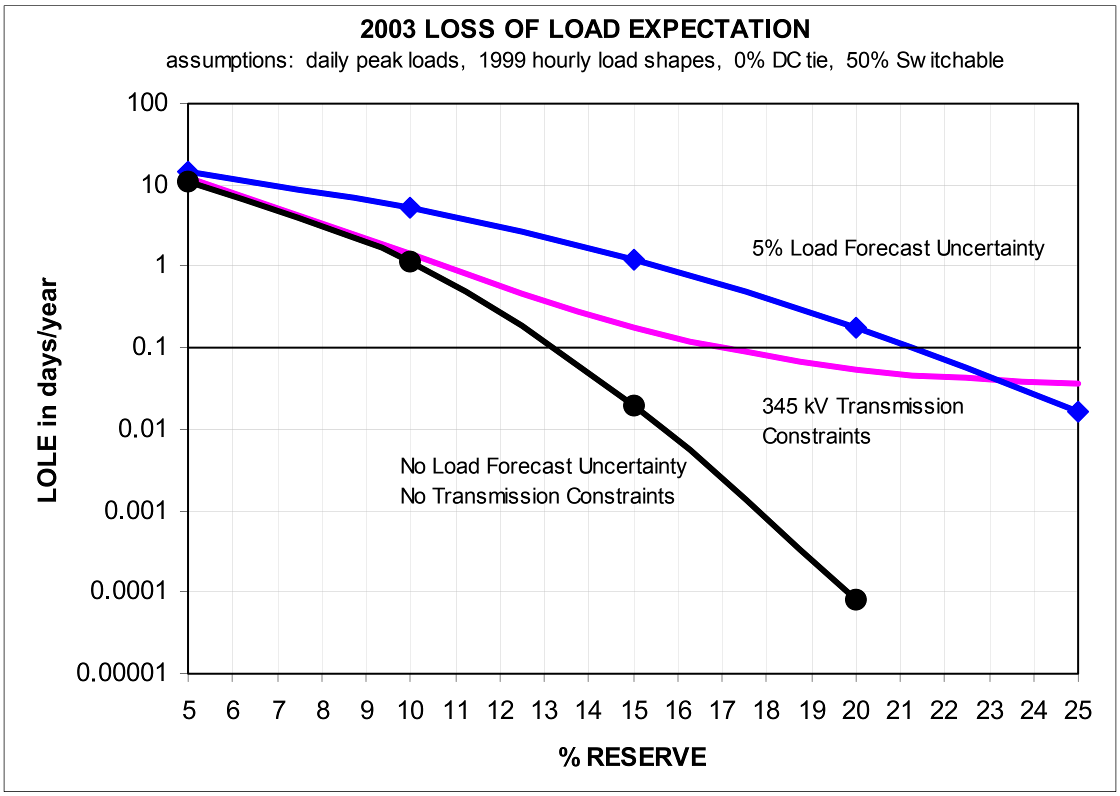
ERCOT Generation Adequacy Study

Summary of Findings:

The three curves below summarize the generation adequacy in ERCOT. The **black** curve shows the number of days per year in 2003 ERCOT generators will have insufficient installed capability to serve ERCOT load. The number of days per year is called the LOLE, which means Loss Of Load Expectation. An LOLE of 0.1 or less has been used by the industry to indicate that a system is reliable (adequate). Above 1.0 the system will experience shortages frequently. The region from 0.1 to 1.0 is a transition region between being reliable and unreliable.



The black curve assumes that the actual ERCOT demand is an accurate forecast for several years in advance. The **blue** curve takes load forecast error into account by introducing a 5% load forecast uncertainty above and below the forecasted hourly demands (the 5% is one standard deviation of a Normal distribution) . The blue curve shows that the LOLE is sensitive to load forecasting error.

The black line has also assumed no transmission constraints will limit generation. The **red** curve shows the increase in LOLE when 345 kV circuit constraints are considered (for single and multiple 345 kV circuit outages). The curve flattens to the right because loss of load for some load areas occurs due to loss of one or more critical circuits needed to serve those load areas. Also, a few generators are transmission constrained from being able to deliver power to the network, thus increasing LOLE.

ERCOT Generation Adequacy Study

Purpose:

To ensure the reliability and adequacy of the regional electrical system by ensuring that the generation planning reserve margin is adequate.

Phases:

Phase I

Provides a correlation between ERCOT reserve level and reliability indices for the year 2000 for no transmission constraints.

Phase II

Establishes the sensitivity of reliability indices with respect to future ERCOT generation additions through the year 2003 for no transmission constraints. Additional studies test the planning reserve margin from 5% to 25%.

Phase III

Examines the sensitivity of the year 2003 ERCOT reliability indices to transmission constraints.

Phase IV

Examines the sensitivity of the year 2003 ERCOT reliability indices to 0%, 50%, and 100% of the DC tie and switchable units being available to ERCOT.

Assumptions and Tasks:

Phases I and II

- Single area studies (several have been run since the 1960s)
- Random, independent outages/deratings of generating units (NERC GADS data)
- No unit maintenance (May - September)
- HVDC and switchable units fully available to ERCOT
- No transmission constraints
- Representative hourly load shape
- Service to firm load
- Load forecast uncertainty effects examined

Phase I

- Performed to provide a correlation between ERCOT reserve level and reliability indices
- Basic tasks
  - Develop FORs/DFORs
  - Calculate indices (5) for different reserve levels with and without load forecast uncertainty using 2000 generation
  - Present results graphically
- One sensitivity study comparing high FOR resources to low FOR resources

ERCOT Generation Adequacy Study

Phase II
- Performed to establish the sensitivity of reliability indices to future generation additions
- Basic tasks
  – Identify new generation planned for 2001 - 2003
  – Perform calculations similar to Phase I assuming different amounts of new generation
  – Examine with and without load forecast uncertainty

Phase III
- Performed to examine the sensitivity of reliability indices to transmission constraints
- Basic tasks
  – Develop transmission FORs
  – Repeat the 100% new generation calculations of Phase II incorporating all meaningful transmission outages
  – Present results graphically
- Two sensitivity studies
  – Effect of key transmission upgrades
  – 50% new generation calculation

Phase IV
- Performed to provide a correlation between ERCOT reserve level and reliability indices
- Basic tasks
  – Update hydro FORs
  – Calculate LOLE for reserve levels from 5% to 25% and for DC tie and switchable generation at 0%, 50%, and 100% of ratings
  – Present results graphically

ERCOT Generation Adequacy Study

Phase I Details:

The following tasks are performed in Phase I:

- Run nine single area 2000 studies using the 1998 hourly ERCOT loads for months May through September with reserve levels from 5% to 25%.
- Run nine additional studies using 1999 hourly loads for May – September.
- Reliability indices are calculated and graphed for the 18 studies.
- Load forecast uncertainty is calculated automatically by the computer program; therefore, the Phase II load uncertainty indices are also calculated and graphed.
- A sensitivity study that investigates the reliability value of wind generation relative to combined-cycle generation is performed.

The generator forced outage rates for various classes of generators that were derived from NERC GADS data and used in this study are:

FOR	DFOR	DER%	GENERATOR TYPE
.0001	.0	0.0	DC - DC TIE
.0422	.029	19.	ST - FOSSIL-STEAM (Western Coal and Lignite)
.067	.0	0.0	ST - FOSSIL-STEAM (Natural Gas)
.069	.023	5.5	NU - NUCLEAR
.10	.0	0.0	CT - COMBUSTION TURBINE
.12	.0	0.0	DI - DIESEL
.56	.0	0.0	HY - HYDRO
.64	.0	0.0	WI – WIND

FOR = per unit forced outage rate, i.e. the per unit amount of time the unit is in the down state
DFOR = p.u. derated outage rate, i.e. the per unit amount of time the unit is in the derated state
DER% = percent of the unit MW capability that is derated, i.e. the percent reduction in MW output

The wind FOR was estimated based on wind generator data from industry publications and transmission entities for the amount of wind energy produced during the study months without consideration for whether the wind generation is coincident or not coincident with ERCOT loads..

Hydro FOR is derived from NERC data based on the amount of energy that is produced from a large number of small hydro units scattered across the United States. Hydro generation is very reliable for short run periods. The high FOR of 56% for hydro that is used in this study accounts for the inability of hydro in Texas to supply energy for extended periods during summer months. (In Phase IV, the hydro FORs are updated.)

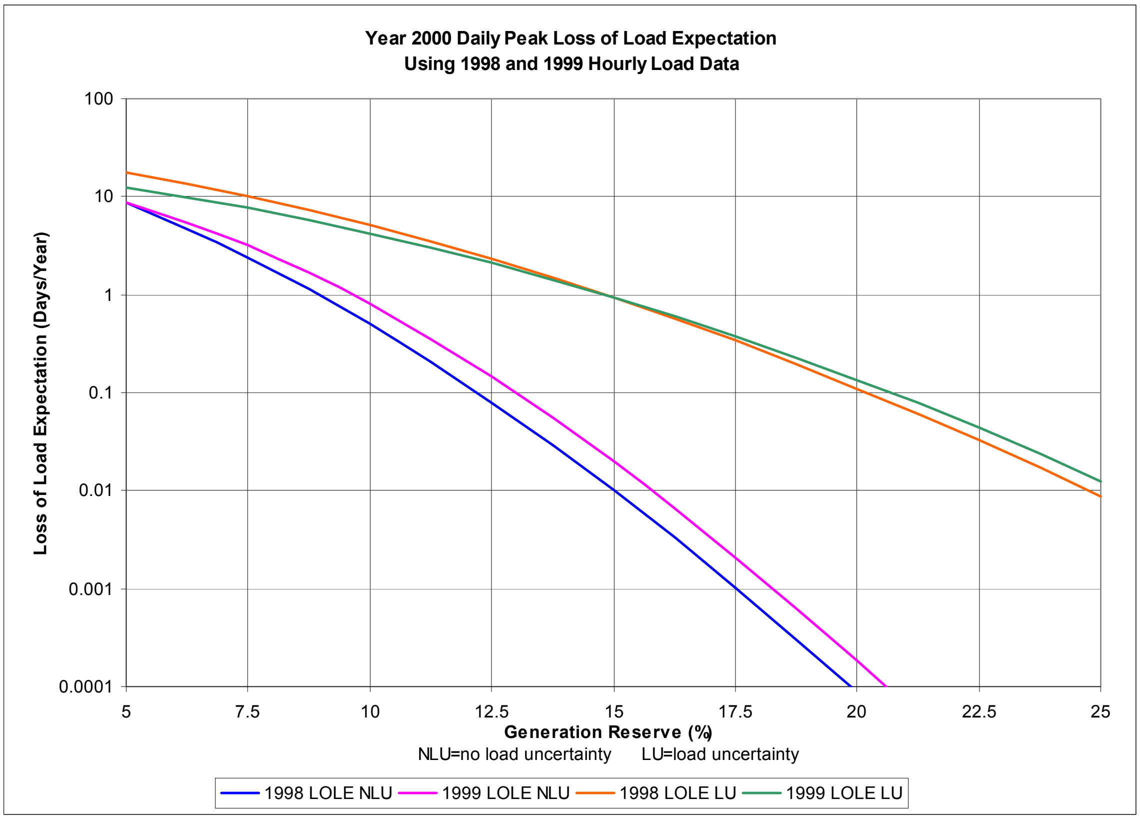
The Phase I study assumes no generator maintenance and no transmission constraints for the summer period months of May through September, a period of 3672 hours per year.

The load forecast uncertainty assumes a normal distribution with 5% of the forecast as one standard deviation. Load uncertainty is modeled as 101 steps from −4 to +6 standard deviations; i.e. −20% to +30% of the forecasted hourly loads.

ERCOT Generation Adequacy Study

Phase I Results:

Generation reliability studies performed for ERCOT in the 1970's (1970, 1974, and 1978) all calculated LOLE using daily peak loads. The graph below shows the LOLE results for this study for meeting daily peak loads with load forecast uncertainty (LU) and with no load forecast uncertainty (NLU) for 1998 and 1999 hourly load shapes.



The 1978 study established a benchmark acceptable LOLE of 0.121 days per year by calculating ERCOT's LOLE assuming a 15% installed reserve margin in 1974. This benchmark is very close to the standard of 0.10 days per year that has been used by the industry since the 1960s. In the above graph, ~13% reserve is needed to achieve an LOLE of 0.1 days per year for no load uncertainty.

The 1978 study also included a sensitivity study to examine the effect of a 5% load uncertainty which showed that a 22.5% reserve would have been needed in 1974 to achieve the same LOLE as a 15% reserve with no load uncertainty. The graph above shows that when a 5% load forecast uncertainty is added to this study, ~20% reserve is needed to achieve the .1 days per year LOLE. The addition of load uncertainty increased the planning reserve requirement by about 7% in both the 1978 study and this study.

ERCOT Generation Adequacy Study

Phase I Sensitivity Study:

A year 2000 sensitivity study has been performed in which the four 280 MW combined cycle Midlothian units (1120 MW) are increased in forced outage rate while the MW capability is also increased to hold reliability indices for ERCOT at a constant level. This allows us to identify the amount of additional capacity needed to overcome a high forced outage rate. Or, it can be used to derate high FOR units to a lower equivalent MW capability.

The base FOR for the four Midlothian units is 10%. Although the Midlothian units have been selected to be varied in FOR and MW, the actual intent here is to identify a derating factor that might possibly be used for high FOR wind generation.

The 15% generation reserve load level and 1998 hourly loads were used in this analysis. The 280 MW for each unit is increased to the following MW when the FOR is set to 64% (wind FOR):

1) 280 MW increased to 1426 MW to hold constant the .007692 annual probability for loss of load with no forecast uncertainty

2) 280 MW increased to 1630 MW to hold constant the .009316 LOLE for daily peak loads and no forecast uncertainty

3) 280 MW increased to 2000 MW to hold constant the .000679 LOLE for hourly loads and no forecast uncertainty

4) 280 MW increased to 800 MW to hold constant the .33210957 annual probability for loss of load with 5% load forecast uncertainty

5) 280 MW increased to 820 MW to hold constant the .919930 LOLE for daily peak loads and 5% load forecast uncertainty

6) 280 MW increased to 820 MW to hold constant the .111253 LOLE for hourly loads and 5% load forecast uncertainty

Using 2), the LOLE index reference with no load uncertainty, the effective capacity of wind is found to be 17% of the wind unit net capability. Expressed another way, the addition of 100 MW of wind generation or 17 MW of combined-cycle gas generation would have about the same inpact on ERCOT LOLE. This is based on the simplistic data used to model wind generation. More detailed time of day wind generation information, and its coincidence with ERCOT load patterns, could raise or lower this value.

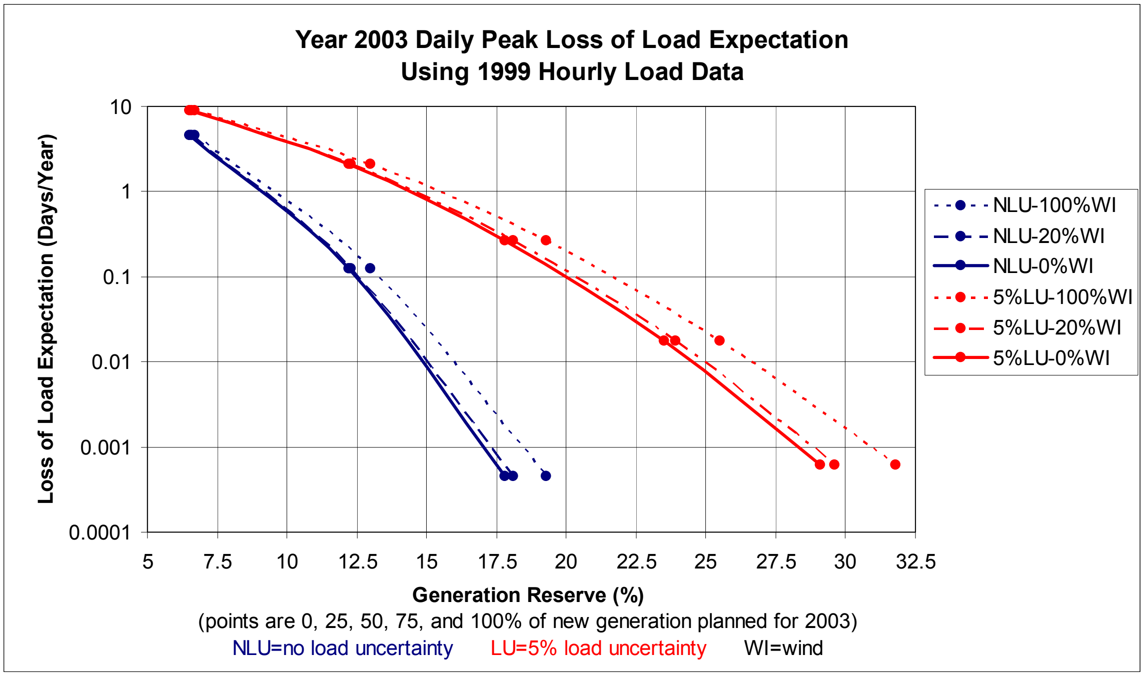
ERCOT Generation Adequacy Study

Phase II Details and Results:

The following tasks are performed in Phase II:

- Reliability indices are calculated for new generation added after 2000 in 25% steps. Phase II uses the 2003 firm load forecast of 63315 MW, 1999 hourly loads for May – September, forced outage rates as in Phase I, and no transmission constraints.
- Indices for a load forecast uncertainty of 5% are also calculated.

The graph below shows the LOLE results for Phase II for meeting the 2003 daily peak loads using the 1999 hourly load profile with and without load forecast uncertainty.



These results are very similar to Phase I. In the above graph, 12.5% reserve level has an LOLE of .1 days per year for no load uncertainty and 20% when a 5% load forecast uncertainty is included.

Assuming wind effective capacity is below 20% shows that the total wind generation of 1711 MW in the 2003 data has little effect on the ERCOT LOLE. The ERCOT CDR assumes zero MW effective wind capacity in the reserve calculation.

Phase III Details:

The following tasks are performed in Phase III:

- Reliability indices are calculated using the same set of 2003 generators as were used in the Phase II study. Transmission constraints are included in the Phase III study.
- Typical transmission forced outage rates are developed and used on all circuits.
- Limiting circuits, their associated contingencies, affected load areas, and affected generators are listed.
- Zones in the 2003 load flow data are clustered together to create logical load shedding areas in the load flow data. The process used to perform this clustering is described.
- Although load forecast uncertainty is not explicitly modeled, the LOLE reliability index is calculated and displayed for a wide range of annual peak demand forecasts.
- The methodology for calculating probabilistic circuit flows based on random generator and circuit outages and how load shedding is performed is described.

Phase III Transmission FOR Methodology:

Generic transmission FORs for all circuits are .0004 + .00002*L where L is the circuit length in miles. A circuit with a length of 100 miles would have an FOR of .0024 which is equivalent to about 8.8 hours/year for the summer study period used in this study. When applied to all the 345 kV circuits in ERCOT, this formula predicts approximately one 345 kV circuit will be out of service at any time. For parallel circuits on a common right of way, the common outages are assumed to be approximately 17% of the total number of outages of all the common circuit outages.

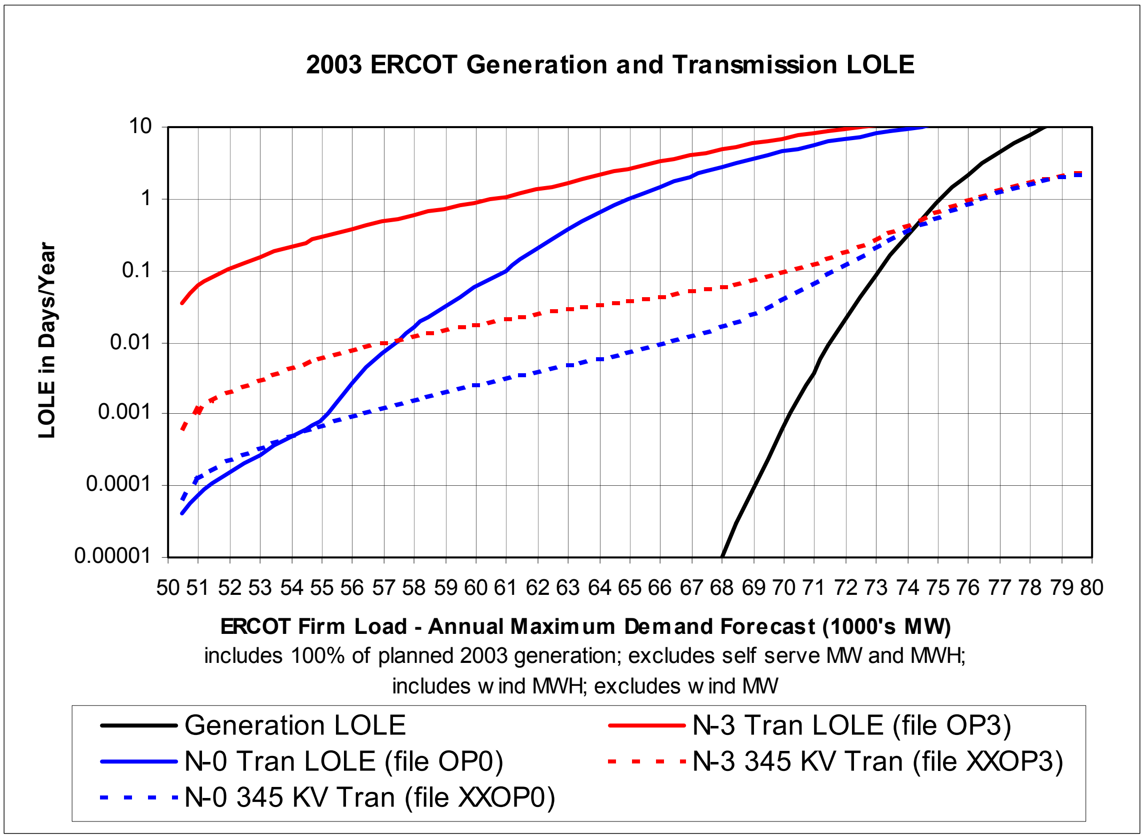
The 345/138 kV autotransformers are given an FOR of .02 which is equivalent to a 6 month outage time every 25 years or a 1 year outage time every 50 years. This is slightly better than the industry experience.

No 69 kV lines are outaged, no 138/69 kV transformers are outaged, and no generator stepup transformers are outaged in this study.

ERCOT Generation Adequacy Study

Phase III Results:

The graph below shows the 2003 ERCOT LOLE due to transmission constraints for 100% of the planned generation additions. The generation LOLE (black curve) includes 1711 MW wind generation, 920 MW of DC tie capacity, and 1712 MW of generation that is switchable in and out of ERCOT. The load flow data includes 860 MW of self serve generation and load that has been removed from the LOLE calculations.



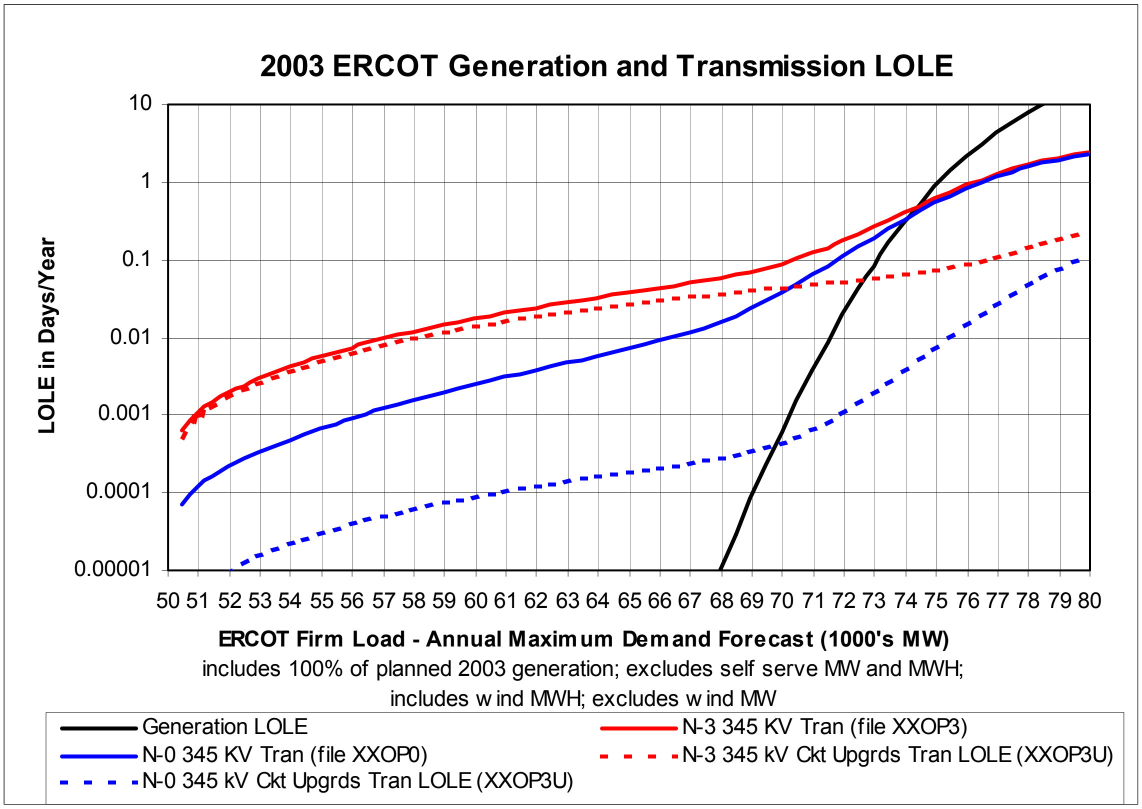
In the above graphs, the black line does not include the effects of transmission constraints. Conversely, the colored lines are only the LOLEs caused by transmission constraints. The solid colored lines include both 138 kV and 345 kV constraints. The dotted lines are only LOLEs caused by 345 kV constraints.

The blue lines are LOLEs caused by transmission constraints assuming all lines are in service. Note that random generator outages cause circuit and transformer overloads in the load flow data "base case" with all circuits in service (called N-0).

The red lines include single and multiple combinations of circuits and transformers being outaged simultaneously (called N-3). These outages have a much lower probability of occurrence; however, the electrical consequences are usually much more severe. This analysis does not include the loss of load due to islanding.

Effect on LOLE of Circuit Upgrades:

The graph below shows the 2003 ERCOT LOLE due to transmission constraints for 100% of the planned generation additions and ten 345 kV circuit upgrades. The circuits that are upgraded to 1631 MVA are listed as N-0 case overloads in file XXOP3 (search for "overload:" and "highest loaded" in XXOP3 to find these circuits).



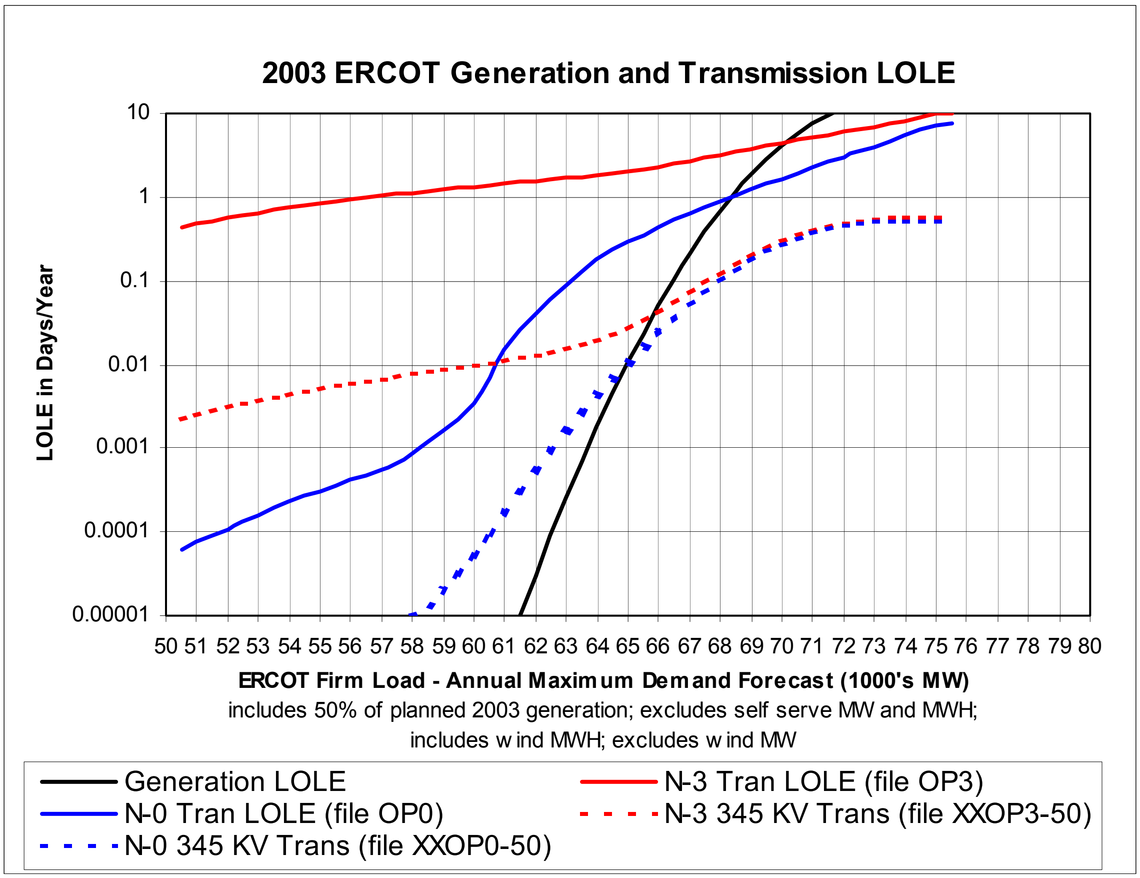
The upgraded circuits are:

1050	6235	ENRONIPP	345	ABMULCW7	345	1	717	MVA
1421	1436	WILLOWCK	345	PARKER	345	1	1072	MVA
1425	6100	FISHRDSS	345	OKLAEHV7	345	1	717	MVA
1436	1859	PARKER	345	EAGLE MT	345	1	1195	MVA
1695	5925	MOSES	345	DC-EAST	345	1	600	MVA
1876	1880	WLFHOL	345	ROCKY CK	345	1	1072	MVA
1907	1911	VENUS N	345	WEBB 1	345	1	1072	MVA
1911	1916	WEBB 1	345	LIG2 T	345	1	1072	MVA
2410	2420	NORWOODT	345	C HILL	345	1	1133	MVA
5915	44000	SO TEX 5	345	W_A_P_ 5	345	39	906	MVA

The upgrades show a dramatic improvement in the transmission N-0 case LOLE (the blue lines with no 345 kV circuits out of service) and little improvement for the N-3 transmission LOLE (red lines). This suggests that additional circuits are needed to improve reliability.

Phase III Effect of Decreasing New Generation 50%:

The graph below shows the 2003 ERCOT LOLE due to transmission constraints for 50% of the capacity of the planned generation additions. Comparing this graph with the one on page 10 shows that the new generation has a largest effect on the N-0 cases (blue lines). This indicates that the new generators are loading up the transmission constraining circuits to higher MW levels for longer periods of time and/or are creating new constraints.



Below are the top five limiting 345 kV circuits in the N-0 case from file XXOP0:

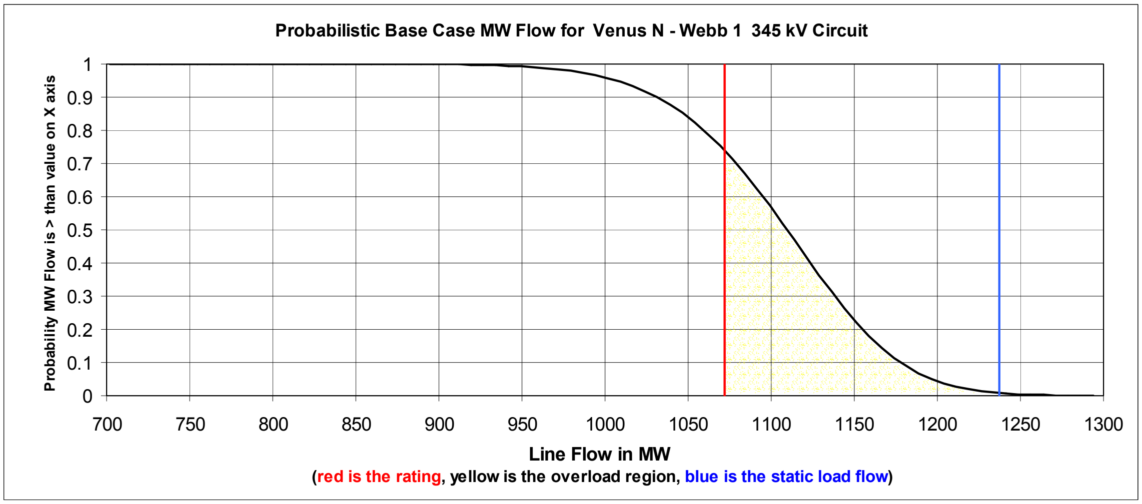
CIRCUIT-GENERATOR-AREA LOAD SHEDDING REPORT:

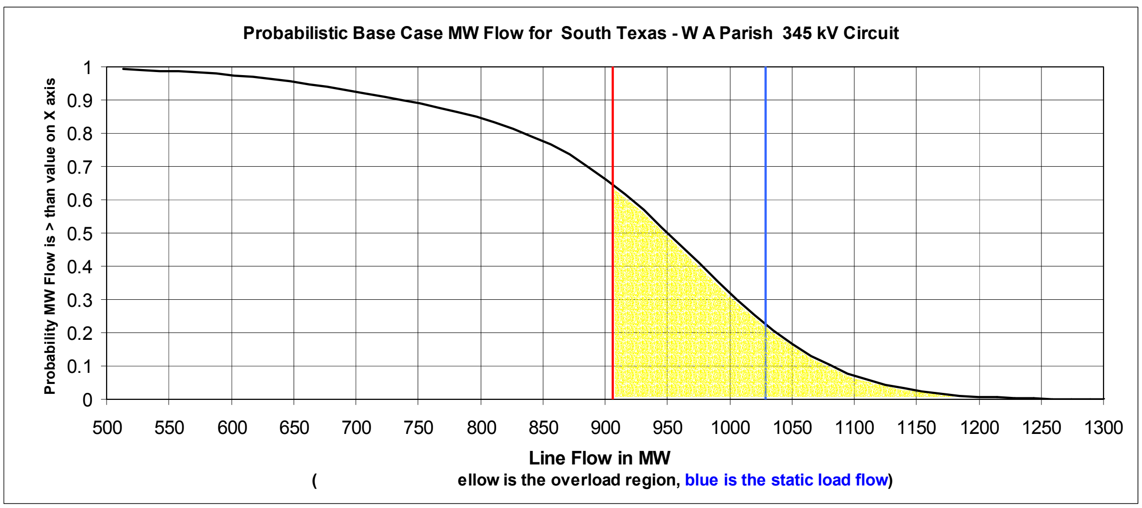
BUS#	BUS NAME		BUS#	BUS NAME	ID	MW	MWH	GENERATOR	> LOAD AREA	PDF
1907	VENUS N 345	-	1911	WEBB 1 345	1	280.	148.918091	MELP 3	DFW&NTX	0.23146
5915	SO TEX 5 345	-	44000	W_A_P_ 5 345	39	1311.	147.516998	STP1	HLP	0.27671
2436	TRICOR E 345	-	2437	FORNEY 345	1	189.	3.879349	CALFRE1G	DFW&NTX	0.13912
1421	WILLOWCK 345	-	1436	PARKER 345	1	268.	3.533287	WCPP 3 G	SYSTEM	0.69959
5915	SO TEX 5 345	-	42500	DOW345 5 345	18	1311.	3.425071	STP1	HLP	0.23691

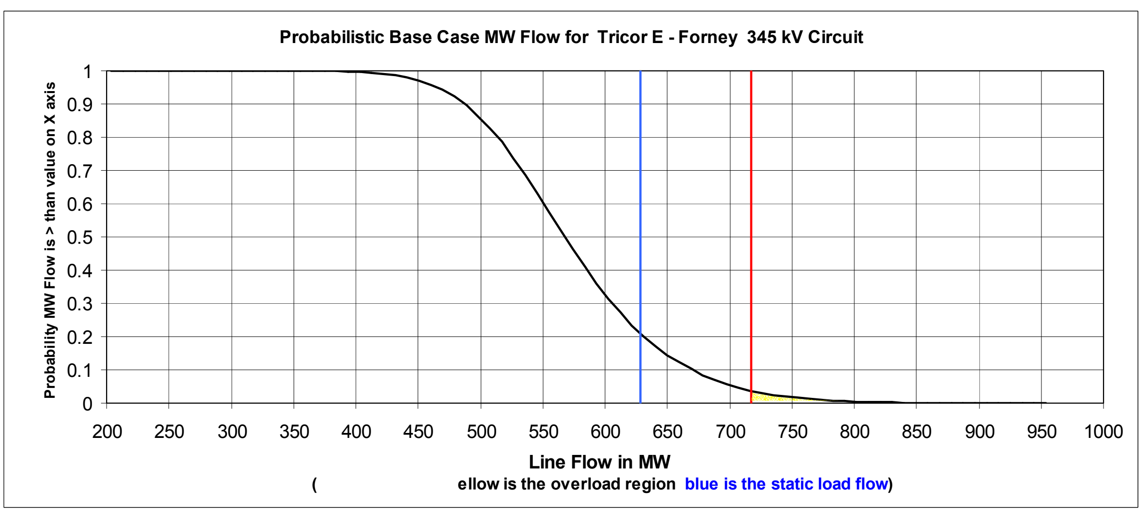
Venus-Webb is loaded to 123.9% in the initial load flow, SoTex-WAP to 111.9%, and Tricor-Forney to 92.7%. The above circuits cause loss of load in the no circuits out case (base case) for high ERCOT load levels. Random generator outages can cause higher probabilistic overloads on circuits. Graphs of the probabilistic circuit flows for these three circuits are shown on the next page. The circuit overload regions are shown in yellow.

ERCOT Generation Adequacy Study

Limiting 345 kV circuits in the N-0 base case from file XXOP0:







ERCOT Generation Adequacy Study

The following is a list of all the limiting 345 kV circuits in file XXOP3 (N-3 analysis):

BUS#	BUS NAME			BUS#	BUS NAME		ID	MW	MWH	GENERATOR >	LOAD AREA	PDF
1907	VENUS N	345	-	1911	WEBB 1	345	1	280.	154.168915	MELP 3	DFW&NTX	0.23146
5915	SO TEX 5	345	-	44000	W_A_P_ 5	345	39	1311.	149.923859	STP1	HLP	0.27671
2436	TRICOR E	345	-	2437	FORNEY	345	1	189.	4.469209	CALFRE1G	DFW&NTX	0.13912
1421	WILLOWCK	345	-	1436	PARKER	345	1	268.	3.798968	WCPP 3 G	SYSTEM	0.69959
5915	SO TEX 5	345	-	42500	DOW345 5	345	18	1311.	3.477435	STP1	HLP	0.23691
1425	FISHRDSS	345	-	6100	OKLAEHV7	345	1	615.	2.043899	OKLAUN1G	W FALLS	0.65948
2410	NORWOODT	345	-	2420	C HILL	345	1	818.	1.608480	THSE 2 G	DFW&NTX	0.10150
1876	WLFHOL	345	-	1880	ROCKY CK	345	1	468.	0.326960	WLFHOL2G	SYSTEM	0.30760
1885	EVER 1BT	345	-	1933	KENNDLE2	345	1	818.	0.319578	DEC 1 G	DFW&NTX	0.14292
1436	PARKER	345	-	1859	EAGLE MT	345	1	268.	0.274721	WCPP 3 G	DFW&NTX	0.28738
1050	ENRONIPP	345	-	6235	ABMULCW7	345	1	400.	0.253744	ENRONIPP	ABILENE	0.59963
1873	BENBRK	345	-	1890	DECORDVA	345	1	615.	0.156089	DEC 1 G	W FALLS	0.39665
1911	WEBB 1	345	-	1916	LIG2 T	345	1	280.	0.155807	MELP 3	DFW&NTX	0.22870
3429	SANDOW	345	-	7040	AUSTRO34	345	1	167.	0.089803	LOSTPN 3	WACO-CTX	0.27977
1430	GRAHAM	345	-	1436	PARKER	345	1	399.	0.034238	GRAM 2 G	SYSTEM	0.40562
1690	VALLEY	345	-	1692	PARIS SS	345	1	341.	0.033445	LPP 6 G	SYSTEM	0.49176
1906	VENUS S	345	-	2420	C HILL	345	1	280.	0.028497	MELP 2	DFW&NTX	0.36147
5915	SO TEX 5	345	-	42500	DOW345 5	345	27	1311.	0.024837	STP1	HLP	0.23691
3429	SANDOW	345	-	7040	AUSTRO34	345	2	167.	0.020055	LOSTPN 3	WACO-CTX	0.27977
1026	ODES EHV	345	-	1028	ODEHV 1T	345	1	180.	0.019726	TIE ST2G	SYSTEM	0.61476
1917	SHERRY T	345	-	2420	C HILL	345	1	227.	0.014767	DEC 1 G	PALESTIN	0.20326
42000	P_H_R_ 5	345	-	42500	DOW345 5	345	99	986.	0.009747	DOW1	HLP	0.29258
5371	SKYLINE	345	-	7044	MARION34	345	1	155.	0.008193	GUALUP 4	CPS	0.43579
2427	WATMILLW	345	-	2436	TRICOR E	345	1	510.	0.008053	STRYK 2G	VENUS	0.23582
1025	FS COGEN	345	-	1030	MRGN CRK	345	1	70.	0.006933	CALENG2G	SYSTEM	0.85737
3124	TRINDAD2	345	-	3134	RICHLND2	345	1	189.	0.005379	CALFRE6G	DFW&NTX	0.32182
2436	TRICOR E	345	-	3123	TRINDAD1	345	1	189.	0.005338	CALFRE1G	DFW&NTX	0.20812
1436	PARKER	345	-	1869	BENB A T	345	1	268.	0.004348	WCPP 3 G	SYSTEM	0.42769
2432	TRICORN	345	-	2433	SGVL SS	345	1	417.	0.003940	GATEWY4G	DFW&NTX	0.11606
1880	ROCKY CK	345	-	1886	EV EAST	345	1	304.	0.003722	WLFHOL2G	SYSTEM	0.29079
1695	MOSES	345	-	1697	SULSP SS	345	1	227.	0.003654	MOSES2 G	SYSTEM	0.38880
967	GIBCRK B	345	-	44500	OBRIEN 5	345	1	462.	0.003012	GIBCRK	HLP	0.31563
1430	GRAHAM	345	-	6230	ABMULCE7	345	1	615.	0.002795	OKLAUN1G	W FALLS	0.38452
44000	W_A_P_ 5	345	-	44650	SMTHRS 5	345	50	636.	0.002491	WAP6	HLP	0.31607
1886	EV EAST	345	-	1932	KENNDLE1	345	1	818.	0.002259	DEC 1 G	DFW&NTX	0.17213
1685	FARM SW	345	-	2461	ROYSE	345	2	227.	0.002135	VAL 3 G	SYSTEM	0.42974
1030	MRGN CRK	345	-	1430	GRAHAM	345	1	80.	0.002076	ENCOGN4G	SYSTEM	0.36931
1420	ENCOGEN	345	-	1430	GRAHAM	345	1	80.	0.001900	ENCOGN4G	SYSTEM	0.42856
3391	JEWETT N	345	-	46500	TOMBAL 5	345	1	744.	0.001471	LIM1	HLP	0.20994
1430	GRAHAM	345	-	1873	BENBRK	345	1	399.	0.000915	GRAM 2 G	SYSTEM	0.30891
7042	ZORN 34	345	-	7044	MARION34	345	1	155.	0.000820	GUALUP 2	AustEngy	0.62191
1882	EV WEST	345	-	1906	VENUS S	345	1	280.	0.000706	MELP 2	MINERL W	0.67575
3414	TEMP SS	345	-	3429	SANDOW	345	1	167.	0.000677	LOSTPN 3	WACO-CTX	0.44183
3123	TRINDAD1	345	-	3133	RICHLND1	345	1	189.	0.000415	CALFRE1G	DFW&NTX	0.30064
1918	SHERRY	345	-	1930	CENTURY3	345	1	818.	0.000345	DEC 1 G	DFW&NTX	0.16406
1870	BENB B T	345	-	1873	BENBRK	345	1	399.	0.000339	GRAM 2 G	SYSTEM	0.24992
2437	FORNEY	345	-	2474	ROYSE T	345	1	189.	0.000260	CALFRE1G	DFW&NTX	0.09959
7044	MARION34	345	-	7045	ZORN 34	345	1	155.	0.000184	GUALUP 2	AustEngy	0.57640
1887	EVER 2BT	345	-	1888	DEC T	345	1	327.	0.000181	DEC 1 G	SYSTEM	0.32035
1855	ALLIANCE	345	-	1859	EAGLE MT	345	1	379.	0.000177	EGMT 3 G	DFW&NTX	0.24269
2437	FORNEY	345	-	2453	CNVIL	345	1	727.	0.000140	MTNLK 3G	DFW&NTX	0.08787
3413	TEMPSSLT	345	-	3429	SANDOW	345	1	167.	0.000120	LOSTPN 3	WACO-CTX	0.44149
5211	HILL CTY	345	-	7044	MARION34	345	1	155.	0.000111	GUALUP 4	CPS	0.54848
1931	COURTLND	345	-	1933	KENNDLE2	345	1	818.	0.000107	DEC 1 G	DFW&NTX	0.14843
1886	EV EAST	345	-	1907	VENUS N	345	1	280.	0.000105	MELP 3	MINERL W	0.36282
3405	T HOUSE	345	-	3409	LAKE CRK	345	2	578.	0.000087	THSE 1 G	RND ROCK	0.68799
1902	JOHN SS	345	-	1907	VENUS N	345	1	200.	0.000061	TENASKA	SYSTEM	0.36242
1917	SHERRY T	345	-	1931	COURTLND	345	1	818.	0.000051	DEC 1 G	DFW&NTX	0.18340
2428	WATMILLE	345	-	2432	TRICORN	345	1	291.	0.000048	GATEWY4G	SYSTEM	0.22943
44650	SMTHRS 5	345	-	47000	BELAIR 5	345	50	636.	0.000047	WAP6	HLP	0.30981
5400	SPRUCE	345	-	5725	PAWNESW6	345	1	159.	0.000046	LAP #6	CPS	0.44980
3409	LAKE CRK	345	-	3414	TEMP SS	345	1	578.	0.000044	THSE 1 G	RND ROCK	0.51778
45500	T_H_W_ 5	345	-	45600	ADICKS 5	345	71	85.	0.000041	THW GT51	BPUB	0.30028
3390	JEWETT S	345	-	45500	T_H_W_ 5	345	1	356.	0.000030	NLK 3 G	HLP	0.20516
1906	VENUS S	345	-	3405	T HOUSE	345	1	818.	0.000027	THSE 2 G	DFW&NTX	0.26162
7042	ZORN 34	345	-	9074	LYTTON	345	1	253.	0.000027	HAYSN 3	RND ROCK	0.55832
3405	T HOUSE	345	-	3414	TEMP SS	345	1	578.	0.000019	THSE 1 G	RND ROCK	0.49990
3380	BIGBRN	345	-	3390	JEWETT S	345	1	327.	0.000016	BBRN 2 G	LIMESTON	0.49812
40255	CHAMBR 5	345	-	40900	KING 5	345	97	210.	0.000011	BTE ST4	LIMESTON	0.53200
5371	SKYLINE	345	-	5400	SPRUCE	345	1	426.	0.000005	JKS1	CPS	0.80675
1422	BOWMAN	345	-	1425	FISHRDSS	345	1	389.	0.000003	OKLAUN1G	SYSTEM	0.54954
2420	C HILL	345	-	2431	DESOTOSW	345	1	213.	0.000003	TRACEN1G	MINERL W	0.24902
5211	HILL CTY	345	-	5371	SKYLINE	345	1	155.	0.000003	GUALUP 1	CPS	0.30424
1029	ODEHV 2T	345	-	1030	MRGN CRK	345	1	180.	0.000002	TIE ST2G	SYSTEM	0.50242
1028	ODEHV 1T	345	-	1030	MRGN CRK	345	1	180.	0.000001	TIE ST2G	SYSTEM	0.47112
3134	RICHLND2	345	-	3380	BIGBRN	345	1	543.	0.000001	BBRN 2 G	DFW&NTX	0.29147
7048	GARFIE34	345	-	9074	LYTTON	345	1	167.	0.000001	LOSTPN 3	RND ROCK	0.35680

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The following is a list of the limiting 345 kV circuits in file XXOP0 (N-0 analysis) sorted in decreasing order of the MWH column. The MWH column is the integral of the circuit flow from the circuit rating to infinity (previously shown as the yellow areas):

BUS#	BUS NAME			BUS#	BUS NAME		ID	MW	MWH	GENERATOR >	LOAD AREA	PDF
1907	VENUS N	345	-	1911	WEBB 1	345	1	280.	148.918091	MELP 3	DFW&NTX	0.23146
5915	SO TEX 5	345	-	44000	W_A_P_ 5	345	39	1311.	147.516998	STP1	HLP	0.27671
2436	TRICOR E	345	-	2437	FORNEY	345	1	189.	3.879349	CALFRE1G	DFW&NTX	0.13912
1421	WILLOWCK	345	-	1436	PARKER	345	1	268.	3.533287	WCPP 3 G	SYSTEM	0.69959
5915	SO TEX 5	345	-	42500	DOW345 5	345	18	1311.	3.425071	STP1	HLP	0.23691
1425	FISHRDSS	345	-	6100	OKLAEHV7	345	1	231.	1.411878	OKLAUN1G	W FALLS	0.65948
1911	WEBB 1	345	-	1916	LIG2 T	345	1	280.	0.068846	MELP 3	DFW&NTX	0.22870
1050	ENRONIPP	345	-	6235	ABMULCW7	345	1	400.	0.066162	ENRONIPP	ABILENE	0.59963
3429	SANDOW	345	-	7040	AUSTRO34	345	1	167.	0.049763	LOSTPN 3	WACO-CTX	0.27977
5915	SO TEX 5	345	-	42500	DOW345 5	345	27	1311.	0.011399	STP1	HLP	0.23691
2410	NORWOODT	345	-	2420	C HILL	345	1	280.	0.008009	MELP 2	DFW&NTX	0.16631
5371	SKYLINE	345	-	7044	MARION34	345	1	155.	0.000755	GUALUP 4	CPS	0.43579
967	GIBCRK B	345	-	44500	OBRIEN 5	345	1	462.	0.000714	GIBCRK	HLP	0.31563
3429	SANDOW	345	-	7040	AUSTRO34	345	2	167.	0.000529	LOSTPN 3	WACO-CTX	0.27977
1876	WLFHOL	345	-	1880	ROCKY CK	345	1	304.	0.000372	WLFHOL2G	SYSTEM	0.30760
3123	TRINDAD1	345	-	3133	RICHLND1	345	1	189.	0.000248	CALFRE1G	DFW&NTX	0.30064
42000	P_H_R_ 5	345	-	42500	DOW345 5	345	99	917.	0.000079	DOW2	HLP	0.29258
45500	T_H_W_ 5	345	-	45600	ADICKS 5	345	71	85.	0.000032	THW GT51	BPUB	0.30028
3390	JEWETT S	345	-	45500	T_H_W_ 5	345	1	356.	0.000012	NLK 3 G	HLP	0.20516
1906	VENUS S	345	-	2420	C HILL	345	1	280.	0.000006	MELP 2	DFW&NTX	0.36147
2432	TRICORN	345	-	2433	SGVL SS	345	1	189.	0.000002	CALFRE6G	DFW&NTX	0.13135

The listing below shows contingencies causing additional overloading for three of the circuits listed above. The severity of each overload below is ranked as the product of MW overload and outage hours of each contingency. All 345 kV contingencies and 345 kV circuit overloads are given in file XXOP3 (search for **overload:** to locate the listing):

```
OVERLOAD:       ----FROM----  -----TO----- ID BASE   N-1  >N-1
  1907   1911   VENUS N  345  WEBB 1   345 1  1072  1072  1072
 OUTAGES:                                     RATG  RUN#  %OVLD  HOURS  MW*HRS
  BASE CASE                                            1   124 3672.00 936804.

  2428  46020   WATMILLE 345  LIMEST 5 345 1  1631   124   127    8.06   2324.

  2435  46020   WATMLLDB 345  LIMEST 5 345 2  1631   129   127    8.06   2323.

  1906   3405   VENUS S  345  T HOUSE  345 1   956    87   126    5.93   1673.

  1436   1900   PARKER   345  COM PEAK 345 1  1434    44   129    4.52   1405.

  2410   2420   NORWOODT 345  C HILL   345 1  1133   116   154    2.38   1373.


OVERLOAD:       ----FROM----  -----TO----- ID BASE   N-1  >N-1
  5915  44000   SO TEX 5 345  W_A_P_ 5 345 39  906  1088  1088
 OUTAGES:                                     RATG  RUN#  %OVLD  HOURS  MW*HRS
  BASE CASE                                            1   113 3672.00 425688.

  5915  42500   SO TEX 5 345  DOW345 5 345 18  906   325   154    1.67    976.
  5915  42500   SO TEX 5 345  DOW345 5 345 27  906

 42500  44001   DOW345 5 345  WAP_C710 345 99  906   242   113    5.55    766.

 42000  42500   P_H_R_ 5 345  DOW345 5 345 99  906   340   132    2.05    709.
 42500  44001   DOW345 5 345  WAP_C710 345 99  906

 44001  47000   WAP_C710 345  BELAIR 5 345 98  906   249   113    3.33    456.

  5915  42500   SO TEX 5 345  DOW345 5 345 18  906   192   106    4.80    291.


OVERLOAD:       ----FROM----  -----TO----- ID BASE   N-1  >N-1
  2436   2437   TRICOR E 345  FORNEY   345 1   717   717   717
 OUTAGES:                                     RATG  RUN#  %OVLD  HOURS  MW*HRS
  2461   3103   ROYSE    345  SHAMBRGR 345 1  1072   137   115    7.41    775.

  2432   2433   TRICORN  345  SGVL SS  345 1  1072   125   142    2.16    658.

  2427   2436   WATMILLW 345  TRICOR E 345 1   956   120   139    2.31    645.

  3100   3103   MARTINLK 345  SHAMBRGR 345 1  1195   139   112    4.66    399.

  2396   2428   W LEVP2  345  WATMILLE 345 1  1632   113   121    1.83    275.
```

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Differencing the N-3 and N-0 tables on pages 11 and 12 shows the following 345 kV circuits have probabilistic overloads only when there are other transmission contingencies:

BUS#	BUS NAME	BUS#	BUS NAME	ID	MW	MWH	GENERATOR	> LOAD AREA	PDF
1885	EVER 1BT 345 -	1933	KENNDLE2 345	1	818.	0.319578	DEC 1 G	DFW&NTX	0.14292
1436	PARKER 345 -	1859	EAGLE MT 345	1	268.	0.274721	WCPP 3 G	DFW&NTX	0.28738
1873	BENBRK 345 -	1890	DECORDVA 345	1	615.	0.156089	DEC 1 G	W FALLS	0.39665
1430	GRAHAM 345 -	1436	PARKER 345	1	399.	0.034238	GRAM 2 G	SYSTEM	0.40562
1690	VALLEY 345 -	1692	PARIS SS 345	1	341.	0.033445	LPP 6 G	SYSTEM	0.49176
1026	ODES EHV 345 -	1028	ODEHV 1T 345	1	180.	0.019726	TIE ST2G	SYSTEM	0.61476
1917	SHERRY T 345 -	2420	C HILL 345	1	227.	0.014767	DEC 1 G	PALESTIN	0.20326
2427	WATMILLW 345 -	2436	TRICOR E 345	1	510.	0.008053	STRYK 2G	VENUS	0.23582
1025	FS COGEN 345 -	1030	MRGN CRK 345	1	70.	0.006933	CALENG2G	SYSTEM	0.85737
3124	TRINDAD2 345 -	3134	RICHLND2 345	1	189.	0.005379	CALFRE6G	DFW&NTX	0.32182
2436	TRICOR E 345 -	3123	TRINDAD1 345	1	189.	0.005338	CALFRE1G	DFW&NTX	0.20812
1436	PARKER 345 -	1869	BENB A T 345	1	268.	0.004348	WCPP 3 G	SYSTEM	0.42769
1880	ROCKY CK 345 -	1886	EV EAST 345	1	304.	0.003722	WLFHOL2G	SYSTEM	0.29079
1695	MOSES 345 -	1697	SULSP SS 345	1	227.	0.003654	MOSES2 G	SYSTEM	0.38880
1430	GRAHAM 345 -	6230	ABMULCE7 345	1	615.	0.002795	OKLAUN1G	W FALLS	0.38452
44000	W_A_P_ 5 345 -	44650	SMTHRS 5 345	50	636.	0.002491	WAP6	HLP	0.31607
1886	EV EAST 345 -	1932	KENNDLE1 345	1	818.	0.002259	DEC 1 G	DFW&NTX	0.17213
1685	FARM SW 345 -	2461	ROYSE 345	2	227.	0.002135	VAL 3 G	SYSTEM	0.42974
1030	MRGN CRK 345 -	1430	GRAHAM 345	1	80.	0.002076	ENCOGN4G	SYSTEM	0.36931
1420	ENCOGEN 345 -	1430	GRAHAM 345	1	80.	0.001900	ENCOGN4G	SYSTEM	0.42856
3391	JEWETT N 345 -	46500	TOMBAL 5 345	1	744.	0.001471	LIM1	HLP	0.20994
1430	GRAHAM 345 -	1873	BENBRK 345	1	399.	0.000915	GRAM 2 G	SYSTEM	0.30891
7042	ZORN 34 345 -	7044	MARION34 345	1	155.	0.000820	GUALUP 2	AustEngy	0.62191
1882	EV WEST 345 -	1906	VENUS S 345	1	280.	0.000706	MELP 2	MINERL W	0.67575
3414	TEMP SS 345 -	3429	SANDOW 345	1	167.	0.000677	LOSTPN 3	WACO-CTX	0.44183
1918	SHERRY 345 -	1930	CENTURY3 345	1	818.	0.000345	DEC 1 G	DFW&NTX	0.16406
1870	BENB B T 345 -	1873	BENBRK 345	1	399.	0.000339	GRAM 2 G	SYSTEM	0.24992
2437	FORNEY 345 -	2474	ROYSE T 345	1	189.	0.000260	CALFRE1G	DFW&NTX	0.09959
7044	MARION34 345 -	7045	ZORN 34 345	1	155.	0.000184	GUALUP 2	AustEngy	0.57640
1887	EVER 2BT 345 -	1888	DEC T 345	1	327.	0.000181	DEC 1 G	SYSTEM	0.32035
1855	ALLIANCE 345 -	1859	EAGLE MT 345	1	379.	0.000177	EGMT 3 G	DFW&NTX	0.24269
2437	FORNEY 345 -	2453	CNVIL 345	1	727.	0.000140	MTNLK 3G	DFW&NTX	0.08787
3413	TEMPSSLT 345 -	3429	SANDOW 345	1	167.	0.000120	LOSTPN 3	WACO-CTX	0.44149
5211	HILL CTY 345 -	7044	MARION34 345	1	155.	0.000111	GUALUP 4	CPS	0.54848
1931	COURTLND 345 -	1933	KENNDLE2 345	1	818.	0.000107	DEC 1 G	DFW&NTX	0.14843
1886	EV EAST 345 -	1907	VENUS N 345	1	280.	0.000105	MELP 3	MINERL W	0.36282
3405	T HOUSE 345 -	3409	LAKE CRK 345	2	578.	0.000087	THSE 1 G	RND ROCK	0.68799
1902	JOHN SS 345 -	1907	VENUS N 345	1	200.	0.000061	TENASKA	SYSTEM	0.36242
1917	SHERRY T 345 -	1931	COURTLND 345	1	818.	0.000051	DEC 1 G	DFW&NTX	0.18340
2428	WATMILLE 345 -	2432	TRICORN 345	1	291.	0.000048	GATEWY4G	SYSTEM	0.22943
44650	SMTHRS 5 345 -	47000	BELAIR 5 345	50	636.	0.000047	WAP6	HLP	0.30981
5400	SPRUCE 345 -	5725	PAWNESW6 345	1	159.	0.000046	LAP #6	CPS	0.44980
3409	LAKE CRK 345 -	3414	TEMP SS 345	1	578.	0.000044	THSE 1 G	RND ROCK	0.51778
1906	VENUS S 345 -	3405	T HOUSE 345	1	818.	0.000027	THSE 2 G	DFW&NTX	0.26162
7042	ZORN 34 345 -	9074	LYTTON 345	1	253.	0.000027	HAYSN 3	RND ROCK	0.55832
3405	T HOUSE 345 -	3414	TEMP SS 345	1	578.	0.000019	THSE 1 G	RND ROCK	0.49990
3380	BIGBRN 345 -	3390	JEWETT S 345	1	327.	0.000016	BBRN 2 G	LIMESTON	0.49812
40255	CHAMBR 5 345 -	40900	KING 5 345	97	210.	0.000011	BTE ST4	LIMESTON	0.53200
5371	SKYLINE 345 -	5400	SPRUCE 345	1	426.	0.000005	JKS1	CPS	0.80675
1422	BOWMAN 345 -	1425	FISHRDSS 345	1	389.	0.000003	OKLAUN1G	SYSTEM	0.54954
2420	C HILL 345 -	2431	DESOTOSW 345	1	213.	0.000003	TRACEN1G	MINERL W	0.24902
5211	HILL CTY 345 -	5371	SKYLINE 345	1	155.	0.000003	GUALUP 1	CPS	0.30424
1029	ODEHV 2T 345 -	1030	MRGN CRK 345	1	180.	0.000002	TIE ST2G	SYSTEM	0.50242
1028	ODEHV 1T 345 -	1030	MRGN CRK 345	1	180.	0.000001	TIE ST2G	SYSTEM	0.47112
3134	RICHLND2 345 -	3380	BIGBRN 345	1	543.	0.000001	BBRN 2 G	DFW&NTX	0.29147
7048	GARFIE34 345 -	9074	LYTTON 345	1	167.	0.000001	LOSTPN 3	RND ROCK	0.35680

A complete listing of the contingencies and their severities are shown in file XXOP3 after each occurrence of “overload:”. Severities are ranked by the products of MW of circuit overload times the expected outage hours of each contingency. No generator outages are taken in this listing.

ERCOT Generation Adequacy Study

Studies were also performed in which 138 kV circuits are included in the study. The overall transmission LOLE for these studies is graphed on pages 7 and 9. A list of 138 kV limiting circuits is given below in the N-0 base case from file OP0.

BUS#	BUS NAME	BUS#	BUS NAME	ID	MW	MWH	GENERATOR >	LOAD AREA	PDF
1951	HANDLEYD 138 -	2109	WHITE 1T 138	1	430.	261.529755	HAND 4 G	SYSTEM	0.15738
42500	DOW345 5 345 -	42510	DOW138 8 138	A1	986.	206.749664	DOW1	HLP	0.15447
1027	ODES EHV 138 -	1128	LIQD AIR 138	1	180.	179.999451	TIE ST2G	MIDLAND	0.09911
1918	SHERRY 345 -	1920	SHERRY B 138	1	280.	179.962540	MELP 2	DFW	0.07834
6022	ENR_STP4 138 -	6582	MVIEWTP2 138	1	80.	15.024394	ENR_SP	SYSTEM	0.57620
1875	BENBRK B 138 -	2174	HORNE 13 138	1	399.	14.846711	GRAM 2 G	SYSTEM	0.03718
47610	CE_SIDE8 138 -	47750	UNIVER 8 138	91	140.	11.187838	AES1	SYSTEM	0.29541
9187	DECKER 138 -	9271	SPRINKLE 138	1	306.	6.945491	DECKR G2	LCRA-N	0.27586
2453	CNVIL 345 -	2454	CNVIL 138	1	150.	5.326462	OLINGR3	DFW	0.10316
1146	YORK IPP 138 -	1149	DOLRHIDE 138	1	80.	3.805273	YORK IPP	SYSTEM	0.37374
42515	DOW_A_ 138 -	42500	DOW345 5 345	A3	356.	3.562289	NLK 3 G	SYSTEM	0.02916
8314	LAPALM 4 138 -	8333	L.FRES 4 138	1	101.	3.191142	LAP #6	DC-MEX	0.39238
7202	HICROS13 138 -	7356	MARSFO13 138	1	45.	1.710330	SANDH G3	LCRA-N	0.11038
1919	SHERRY A 138 -	1920	SHERRY B 138	1	430.	1.656377	HAND 4 G	SYSTEM	0.07012
1883	EVERMN A 138 -	2224	OAK H 1T 138	1	89.	0.949735	DECT D G	SYSTEM	0.04219
6579	FTLCSTR2 138 -	6582	MVIEWTP2 138	1	80.	0.516326	ENR_SP	SYSTEM	0.28370
1339	ESKOTA 138 -	6260	ABSOUTH4 138	1	114.	0.497584	TRENTIPP	ABILENE	0.39920
2434	SGVL SS 138 -	2779	LAWSON 138	1	240.	0.141622	TDAD 6 G	DAL SUBS	0.08527
2164	HEMPHILL 138 -	2173	MIST 34 138	1	399.	0.079427	GRAM 2 G	SYSTEM	0.02565
1099	SWPORT T 138 -	1102	JUDKINS 138	1	167.	0.037361	PB 6 G	SYSTEM	0.15315
47600	E_SIDEB8 138 -	47610	CE_SIDE8 138	91	140.	0.030352	AES1	SYSTEM	0.29475
1886	EV EAST 345 -	1884	EVERMN B 138	1	280.	0.020674	MELP 2	SYSTEM	0.04217
7150	KENDAL13 138 -	7046	KENDAL34 345	1	52.	0.016537	HAYSN 1	WTU/LCRA	0.18061
6014	SWMTP2 138 -	6536	BIGLAK24 138	1	75.	0.016360	SWMESA	SYSTEM	0.31374
2054	IRVING 138 -	2408	NORWOD 1 138	1	531.	0.012404	MTCK 8 G	SYSTEM	0.05040
5005	AUSTIN 138 -	5435	TUTTLE 138	1	100.	0.011174	WBT3	SYSTEM	0.22398
1197	CRANE 138 -	1199	ARCO C T 138	1	80.	0.001628	KM_NWP	MIDLAND	0.42040
47515	AUSTIN 8 138 -	47730	POLK 8 138	90	140.	0.001557	AES1	SYSTEM	0.21372
42210	BRZPRT 8 138 -	43360	VLASCO 8 138	02	986.	0.001472	DOW1	SYSTEM	0.04890
1010	PERMIANB 138 -	1019	MOSS 138	1	139.	0.000149	PB 6 G	SYSTEM	0.17775
33	WATSONCP 138 -	3392	JEWETT 138	1	240.	0.000088	TDAD 6 G	BRYAN	0.08860
2173	MIST 34 138 -	2174	HORNE 13 138	1	399.	0.000063	GRAM 2 G	SYSTEM	0.02910
2184	WDGWD NT 138 -	2196	PRIMRSE1 138	1	291.	0.000042	WLFHOL2G	SYSTEM	0.04208
501	HILTOP 138 -	512	NWTHRFRD 138	1	126.	0.000038	MILLER3	SYSTEM	0.19598
5200	HELOTES 138 -	7151	CICO 13 138	1	52.	0.000022	LCP4	WTU/LCRA	0.17225
6309	PUTNAM 4 138 -	6773	PCANBYU4 138	1	25.	0.000022	PHANTM2G	TNP/VROG	0.12840
1027	ODES EHV 138 -	1199	ARCO C T 138	1	80.	0.000017	KM_NWP	SYSTEM	0.39574
47515	AUSTIN 8 138 -	47660	GARROT 8 138	90	140.	0.000011	AES1	SYSTEM	0.21326
42810	HOFMAN 138 -	42880	LKJACK 8 138	02	80.	0.000006	BASF1	SYSTEM	0.26981
7328	AUSTRO13 138 -	9187	DECKER 138	2	340.	0.000002	GIDEONG3	AustEngy	0.18272
1882	EV WEST 345 -	1883	EVERMN A 138	1	280.	0.000001	MELP 2	SYSTEM	0.04686

Loss of Load Methodology (unserved energy by load area in file OP3):

LOLE transmission statistics are assigned to the load areas in which load is shed. In the PLF[1] model, a transmission circuit that is overloaded is associated with a load area and the generators with the highest PDFs[2]. The load area will typically be physically in the vicinity of the receiving end of power flowing over the overloaded circuit to the receiving area. The generator will be on the other side of the overloaded circuit. When the power is simultaneously reduced on the generator and the load, the circuit overload is removed with the least amount of MW reduction.

The graph below shows the transmission EUE[3] for N-3 level of contingencies for the individual load areas with the highest unserved energies due to transmission constraints.

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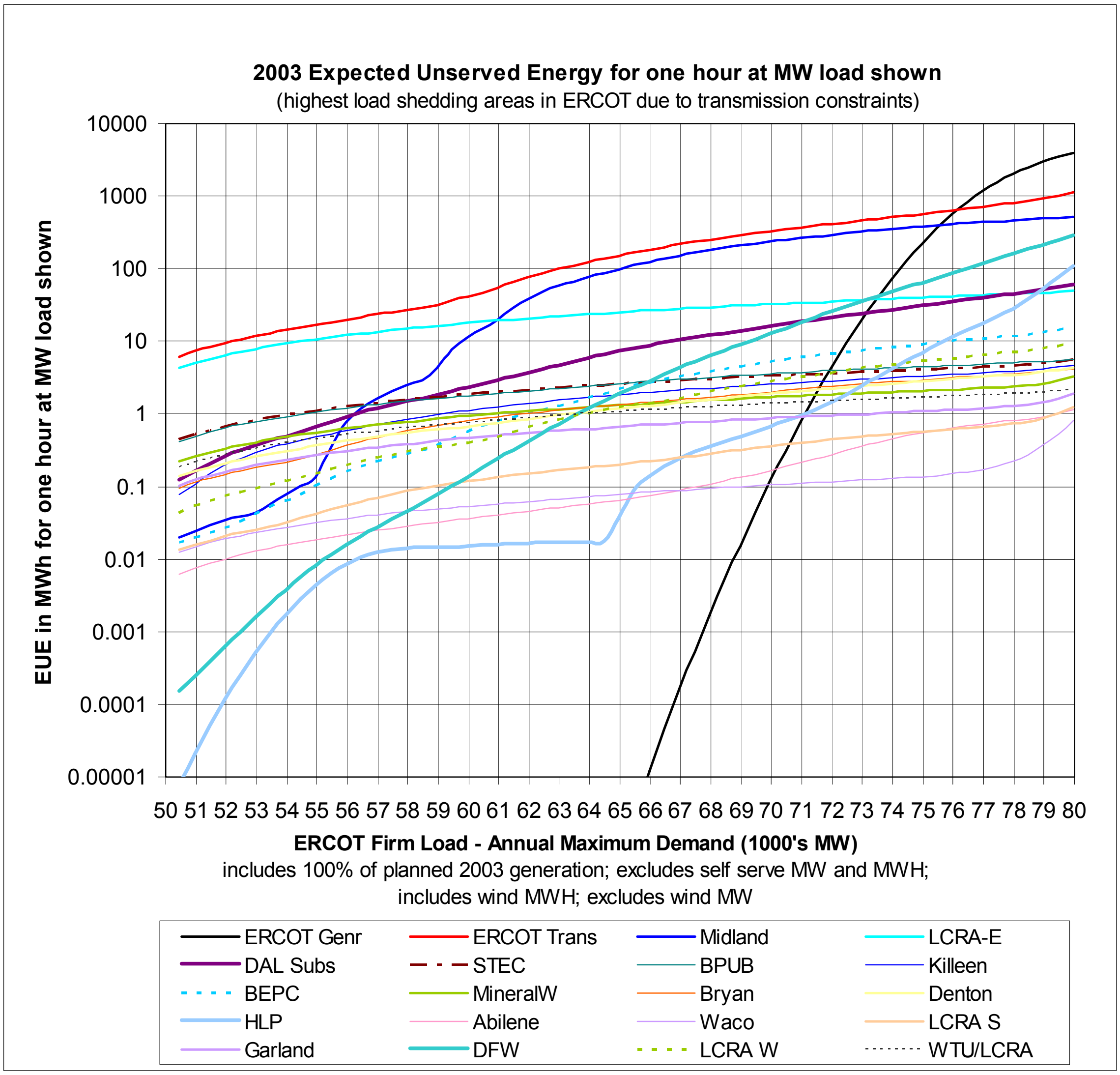
[1] Probabilistic Load Flow.
[2] Power Distribution Factor; the per unit power flowing in a circuit from a generator to a load area.
[3] Expected Unserved Energy in MWH. In this instance the test period is just one hour.



An alternate way of reviewing the amount of load shedding going on in each load area is shown below. The table below lists the unserved MWh energy during a period of one hour when the ERCOT load is 62956 MW. This information comes from file OP3 in which both 138 kV and 345 kV circuits are outaged.

EUE-MWh	Area	Name	EUE-MWh	Area	Name	EUE-MWh	Area	Name	EUE-MWh	Area	Name
0.00000	200	EHVDC	0.00017	450	NORTHERN	0.00165	124	COMANCHE	0.56984	507	LCRA-N
0.00000	319	HLP/LCAP	0.00018	655	MVEC/W	0.00269	140	GAINESVL	0.58385	4	GARLAND
0.00001	659	CPL/MEC	0.00021	640	NORTH LI	0.00341	144	TYLER	0.73061	131	DFW
0.00002	235	TNP/HC-F	0.00022	142	SULPHR S	0.00343	709	AustEngy	0.84277	506	LCRA-W
0.00004	220	TNP/CLIF	0.00025	438	WESTERN	0.00359	222	TNP/VROG	0.94200	393	WTU/LCRA
0.00004	221	TNP/WLSP	0.00025	474	SAN ANG	0.00396	350	CPS	0.95999	3	DENTON
0.00004	310	STP	0.00025	801	DC-MEX	0.00428	151	TEMPLE	1.13138	2	BRYAN
0.00005	225	TNP/KTRC	0.00026	141	PARIS	0.00511	143	WILLS PT	1.15951	125	MINERL W
0.00007	154	HILLSBOR	0.00026	149	LIMESTON	0.00679	134	VENUS	1.28391	11	BEPC
0.00007	654	MVEC/E	0.00035	610	E VALLEY	0.00735	145	ATHENS	1.53806	152	KILLEEN
0.00008	870	MEC	0.00040	401	WRYBRN	0.00966	227	TNP/CLMX	2.23949	800	BPUB
0.00009	175	SESCO-E	0.00053	645	CENT LI	0.01706	301	HLP	2.31291	890	STEC
0.00009	400	WTUTEXLA	0.00054	620	N REGION	0.02668	176	SESCO-W	4.63386	135	DAL SUBS
0.00014	6	TMPA/GVL	0.00077	630	W REGION	0.05069	432	ABILENE	22.16757	504	LCRA-E
0.00014	148	CORSICAN	0.00084	615	W VALLEY	0.05082	146	LUFKIN	57.40374	161	MIDLAND
0.00016	440	CENTRAL	0.00104	625	C REGION	0.06742	153	WACO	99.17506		total
0.00016	470	SOUTHERN	0.00108	147	PALESTIN	0.16699	512	LCRA-S	(see line 108025 in OP3)		
0.00017	121	EASTLAND	0.00160	150	RND ROCK	0.23315	120	W FALLS			

Loss of Load Methodology (cont.):

Every generator not forced out of service is run at maximum output. If there are no transmission constraints (i.e. single area analysis in Phase II), the load that can be served is the sum of all the installed generation that is available at any time. Any load above what can be generated is loss of load. Without transmission constraints, as in the single area analysis, or in an extremely reliable transmission system, the load at each substation has the same reliability as the generation supply for the entire system. When transmission constraints are introduced, they will be site specific, dependent on the nature of the transmission constraints. If there are transmission constraints, less power can be delivered to the load.

PLF has the ability to interrupt contracted transactions. However, no bilateral transaction data was entered into the data for this study. Such data can significantly alter which areas receive the load shedding.

For any specific limiting circuit, if the load PDF is less than 3%, then load is shed uniformly throughout ERCOT as the offending generator is reduced in power. If power is sent to the system and the total PDF is well above 3%, then that limiting circuit is very near the offending generator and reducing the generator output reduces the circuit overload. If a generator is quite remote from a limiting circuit, then the circuit overload is probably due to serving load. If the PDF for such a circuit is low, then the load shedding areas are not well defined in the data, i.e. the area being load shed is not optimum and is probably not the set of bus loads the operators would have chosen. In this instance the area definition data needs to be corrected.

The PLF program minimizes the amount of load being shed by selecting generators and loads that have the highest distribution factors for removing the overload condition. How the load shedding areas are defined affects the load shedding amounts and how they are assigned.

Creating Load Shedding Areas:

Load shed areas are created from zones in the 2003 load flow data. The original 2003 case had only one major area called ERCOT. Although this could have been used, it would have given incorrect answers since every transmission constraint would have caused load shedding in the entire ERCOT system.

New load shedding areas are created by copying the zone data onto the area data within the PSS/E raw data file. These areas are numerous and small in MW load. There are many instances in which the MW of load shedding exceeds the load within the area receiving the load shedding. To overcome this problem, areas (zones) are combined together based on which zones can be used to unload an overloaded circuit. The PDFs of load shedding zones are identified for the top overloaded circuits. These zones are lumped together to create new load shedding areas. This results in clustering of zones within North Texas and within the Houston area and clustering together the zones within

LCRA, AEP, and AEN to make more logical load shedding areas. Some of the smaller load areas and zones are left unchanged (when no transmission constraints cause undue load shedding). The load shedding areas are different for the 138 kV and 345 kV studies.

The following areas are defined in the 345 kV study (in files XXOP3 and XXOP).

		GENERATION		---LOAD---		---LOSS---		INTERCHANGE		DIFF
A#	AREA	MW	MVAR	MW	MVAR	MW	MVAR	MW	MVAR	MW
2	BRYAN	243	88	408	75	5.1	47	-170	-34	0.00
11	BEPC	1709	1238	2921	906	84.1	349	-1296	-16	-0.01
120	W FALLS	0	0	615	146	34.1	90	-649	-236	0.00
121	EASTLAND	640	331	181	32	51.7	158	407	140	0.00
124	COMANCHE	0	0	242	63	13.8	0	-256	-64	0.00
125	MINERL W	700	657	291	69	18.7	104	390	484	0.00
131	DFW&NTX	16520	8589	23566	6990	755.3	3439	-7801	-1840	-0.03
134	VENUS	5972	2852	1286	429	127.7	1264	4559	1158	0.02
147	PALESTIN	691	244	227	68	24.0	39	440	135	0.00
149	LIMESTON	308	56	327	72	3.5	-93	-22	77	0.00
150	RND ROCK	897	350	1435	494	17.3	-29	-555	-114	0.00
151	TEMPLE	0	0	411	113	12.9	21	-423	-135	0.00
153	WACO-CTX	1716	712	1412	394	37.7	116	267	202	0.00
154	HILLSBOR	0	0	98	26	8.1	-16	-106	-10	0.00
161	MIDLAND	4725	1688	2169	664	214.9	1014	2341	9	0.00
176	SESCO-W	0	0	111	35	1.5	-14	-112	-20	0.00
200	EHVDC	700	0	0	0	3.6	37	696	-37	0.00
221	TNP/WLSP	0	0	59	8	1.0	-28	-60	20	0.00
222	TNP/VROG	0	0	25	3	0.2	0	-26	-3	0.00
301	HLP	23426	8811	25161	5476	326.1	3720	-2061	-385	0.00
310	STP	2622	664	0	0	59.1	759	2563	-95	0.00
319	HLP/LCAP	0	0	0	0	2.6	-1047	-3	1047	0.00
350	CPS	4208	1219	5239	1529	55.2	-397	-1086	87	0.00
393	WTU/LCRA	0	0	52	12	0.9	1	-53	-13	0.00
394	NHVDC	220	0	0	0	0.0	-61	220	61	0.00
432	ABILENE	18	62	426	128	26.5	0	-434	-66	0.00
438	WESTERN	953	280	269	99	77.1	254	607	-74	-0.01
440	CENTRAL	362	162	210	61	15.8	48	136	53	0.00
450	NORTHERN	971	170	193	68	33.9	78	744	24	0.00
470	SOUTHERN	85	72	182	64	38.0	121	-135	-113	0.00
474	SAN ANG	123	171	307	82	27.7	153	-212	-64	0.00
504	LCRA-E	3239	1173	698	174	50.3	397	2490	601	0.00
506	LCRA-W	6	0	1230	329	27.7	-114	-1252	-214	0.00
507	LCRA-N	703	345	1091	303	31.6	-115	-419	157	0.00
512	LCRA-S	2980	599	674	144	34.8	531	2271	-76	0.00
610	E VALLEY	261	279	451	78	23.2	184	-213	15	0.00
615	W VALLEY	2005	439	1106	284	29.9	265	869	-109	0.00
620	N REGION	1377	287	676	172	52.3	162	648	-46	0.00
625	C REGION	2321	575	1342	332	51.7	121	927	121	0.00
630	W REGION	188	412	979	179	63.2	127	-854	106	0.02
640	NORTH LI	0	30	288	53	1.4	6	-290	-29	0.00
645	CENT LI	530	182	708	229	5.0	83	-183	-130	0.00
651	CR COGEN	450	82	0	0	0.0	40	450	41	0.00
654	MVEC/E	0	0	85	24	8.7	17	-94	-42	0.00
655	MVEC/W	0	0	242	71	6.0	17	-248	-88	0.00
659	CPL/MEC	0	0	14	2	1.4	3	-15	-6	0.00
709	AustEngy	1758	827	3210	1122	83.9	286	-1536	-581	0.00
800	BPUB	80	134	597	42	1.5	25	-519	66	0.00
870	MEC	70	30	110	34	7.8	8	-48	-13	0.00
890	STEC	539	187	414	124	22.3	9	102	53	0.00
	TOTALS	84316	34013	81735	21819	2580.7	12193			

The generation within each area is the generation physically located within the area. There is no ownership information in the above table. The load flow bus loads have been uniformly scaled throughout ERCOT to match total generation less total losses. Area loads are the sum of bus loads within areas. There is no area interchange.

Area interchange is calculated after the fact during the load flow solution process. All generation is at maximum output with no Var limits on generators, i.e. the effects of voltage variations, including voltage collapse, are not considered.

The following areas are defined in the 138 and 345 kV study (in files OP3 and OP0).

A#	AREA	GENERATION MW	GENERATION MVAR	LOAD MW	LOAD MVAR	LOSS MW	LOSS MVAR	INTERCHANGE MW	INTERCHANGE MVAR	DIFF MW
2	BRYAN	243	88	408	75	5.1	47	-170	-34	0.00
3	DENTON	178	118	363	16	2.5	31	-187	71	0.00
4	GARLAND	505	308	641	111	13.9	183	-150	13	0.00
6	TMPA/GVL	549	275	173	5	15.0	255	361	14	0.00
11	BEPC	1709	1238	2921	906	84.1	349	-1296	-16	-0.01
120	W FALLS	0	0	615	146	34.1	90	-649	-236	0.00
121	EASTLAND	640	331	181	32	51.7	158	407	140	0.00
124	COMANCHE	0	0	242	63	13.8	0	-256	-64	0.00
125	MINERL W	700	657	291	69	18.7	104	390	484	0.00
131	DFW	4711	3420	12915	3872	340.5	1735	-8544	-2188	-0.03
134	VENUS	5972	2852	1286	429	127.7	1264	4559	1158	0.02
135	DAL SUBS	475	830	5666	1841	96.0	-881	-5287	-129	-0.03
140	GAINESVL	80	43	509	144	10.8	-5	-439	-95	0.00
141	PARIS	2573	1025	287	76	64.0	662	2222	286	0.01
142	SULPHR S	1812	921	212	61	86.2	573	1514	287	0.01
143	WILLS PT	0	0	87	23	2.7	0	-89	-22	0.00
144	TYLER	3135	997	717	211	49.9	671	2368	114	0.01
145	ATHENS	1374	355	168	47	49.9	285	1156	22	0.01
146	LUFKIN	42	0	714	262	9.4	-95	-681	-166	0.00
147	PALESTIN	691	244	227	68	24.0	39	440	135	0.00
148	CORSICAN	1086	291	174	46	10.5	26	902	218	0.00
149	LIMESTON	308	56	327	72	3.5	-93	-22	77	0.00
150	RND ROCK	897	350	1435	494	17.3	-29	-555	-114	0.00
151	TEMPLE	0	0	411	113	12.9	21	-423	-135	0.00
152	KILLEEN	0	0	550	155	8.4	-26	-558	-128	0.00
153	WACO	1716	712	809	230	24.6	152	882	329	0.00
154	HILLSBOR	0	0	98	26	8.1	-16	-106	-10	0.00
161	MIDLAND	4725	1688	2169	664	214.9	1014	2341	9	0.00
175	SESCO-E	0	0	125	35	0.7	0	-125	-35	0.00
176	SESCO-W	0	0	111	35	1.5	-14	-112	-20	0.00
200	EHVDC	700	0	0	0	3.6	37	696	-37	0.00
220	TNP/CLIF	0	0	52	8	4.7	-9	-57	1	0.00
221	TNP/WLSP	0	0	59	8	1.0	-28	-60	20	0.00
222	TNP/VROG	0	0	25	3	0.2	0	-26	-3	0.00
225	TNP/KTRC	0	0	78	16	0.7	0	-79	-16	0.00
227	TNP/CLMX	0	0	29	6	0.3	0	-29	-6	0.00
235	TNP/HC-F	0	0	35	10	0.0	0	-35	-10	0.00
301	HLP	23426	8811	25161	5476	326.1	3720	-2061	-385	0.00
310	STP	2622	664	0	0	59.1	759	2563	-95	0.00
319	HLP/LCAP	0	0	0	0	2.6	-1047	-3	1047	0.00
350	CPS	4208	1219	5239	1529	55.2	-397	-1086	87	0.00
393	WTU/LCRA	0	0	52	12	0.9	1	-53	-13	0.00
394	NHVDC	220	0	0	0	0.0	-61	220	61	0.00
400	WTUTEXLA	0	0	131	28	0.1	-3	-131	-25	0.00
401	WRYBRN	0	0	544	171	2.1	-1	-546	-170	0.00
432	ABILENE	18	62	426	128	26.5	0	-434	-66	0.00
438	WESTERN	953	280	269	99	77.1	254	607	-74	-0.01
440	CENTRAL	362	162	210	61	15.8	48	136	53	0.00
450	NORTHERN	971	170	193	68	33.9	78	744	24	0.00
470	SOUTHERN	85	72	182	64	38.0	121	-135	-113	0.00
474	SAN ANG	123	171	307	82	27.7	153	-212	-64	0.00
504	LCRA-E	3239	1173	698	174	50.3	397	2490	601	0.00
506	LCRA-W	6	0	1230	329	27.7	-114	-1252	-214	0.00
507	LCRA-N	703	345	1091	303	31.6	-115	-419	157	0.00
512	LCRA-S	2980	599	674	144	34.8	531	2271	-76	0.00
610	E VALLEY	261	279	451	78	23.2	184	-213	15	0.00
615	W VALLEY	2005	439	1106	284	29.9	265	869	-109	0.00
620	N REGION	1377	287	676	172	52.3	162	648	-46	0.00
625	C REGION	2321	575	1342	332	51.7	121	927	121	0.00
630	W REGION	188	412	979	179	63.2	127	-854	106	0.02
640	NORTH LI	0	30	288	53	1.4	6	-290	-29	0.00
645	CENT LI	530	182	708	229	5.0	83	-183	-130	0.00
651	CR COGEN	450	82	0	0	0.0	40	450	41	0.00
654	MVEC/E	0	0	85	24	8.7	17	-94	-42	0.00
655	MVEC/W	0	0	242	71	6.0	17	-248	-88	0.00
659	CPL/MEC	0	0	14	2	1.4	3	-15	-6	0.00
709	AustEngy	1758	827	3210	1122	83.9	286	-1536	-581	0.00
800	BPUB	80	84	297	42	1.5	25	-218	16	0.00
801	DC-MEX	0	49	301	0	0.0	0	-301	49	0.00
870	MEC	70	30	110	34	7.8	8	-48	-13	0.00
890	STEC	539	187	414	124	22.3	9	102	53	0.00
	TOTALS	84316	34013	81735	21819	2580.7	12194			

ERCOT Generation Adequacy Study

The following areas are defined in the 138 and 345 kV study with 50% of the new generation scheduled from 2000 – 2003 (in files OP3-50 and OP0-50).

		GENERATION		---LOAD---		---LOSS---		INTERCHANGE		DIFF
A#	AREA	MW	MVAR	MW	MVAR	MW	MVAR	MW	MVAR	MW
2	BRYAN	243	65	372	68	4.1	40	-133	-43	0.00
3	DENTON	178	58	331	14	1.6	22	-154	21	0.00
4	GARLAND	468	203	585	101	10.6	145	-128	-43	0.00
6	TMPA/GVL	549	238	158	5	10.9	199	380	33	0.00
11	BEPC	1584	1008	2662	825	66.8	228	-1145	-45	0.01
120	W FALLS	0	0	560	133	23.0	22	-583	-155	0.00
121	EASTLAND	640	161	165	29	29.2	-52	446	184	0.00
124	COMANCHE	0	0	220	58	8.3	-36	-229	-21	0.00
125	MINERL W	350	391	265	63	12.4	23	72	304	0.00
131	DFW	4709	2003	11771	3530	231.4	59	-7294	-1586	0.01
134	VENUS	5294	1864	1172	391	89.0	669	4033	803	-0.01
135	DAL SUBS	316	403	5164	1678	70.7	-1450	-4920	174	0.01
140	GAINESVL	80	28	464	131	9.0	-24	-393	-78	0.00
141	PARIS	2296	684	262	69	48.4	460	1985	153	0.00
142	SULPHR S	1812	675	193	55	74.4	431	1544	188	0.00
143	WILLS PT	0	0	79	21	2.1	-3	-81	-17	0.00
144	TYLER	2658	639	653	192	37.7	381	1967	64	0.00
145	ATHENS	807	148	153	43	34.0	44	620	60	0.00
146	LUFKIN	42	0	651	238	6.9	-136	-615	-102	0.00
147	PALESTIN	691	159	206	62	20.0	0	465	97	0.00
148	CORSICAN	1086	179	158	42	7.8	-3	920	139	0.00
149	LIMESTON	308	31	298	65	3.4	-99	7	65	0.00
150	RND ROCK	897	259	1308	450	14.3	-55	-425	-135	0.00
151	TEMPLE	0	0	374	103	9.5	-19	-384	-84	0.00
152	KILLEEN	0	0	501	141	6.5	-61	-508	-79	0.00
153	WACO	1716	527	738	210	21.6	97	957	219	0.00
154	HILLSBOR	0	0	89	24	5.7	-28	-95	4	0.00
161	MIDLAND	3771	755	1977	605	122.3	236	1671	-87	0.00
175	SESCO-E	0	0	114	31	0.6	0	-114	-32	0.00
176	SESCO-W	0	0	101	32	1.3	-16	-102	-15	0.00
200	EHVDC	700	0	0	0	3.5	35	696	-35	0.00
220	TNP/CLIF	0	0	48	7	3.6	-17	-51	9	0.00
221	TNP/WLSP	0	0	53	7	0.8	-30	-54	23	0.00
222	TNP/VROG	0	0	23	3	0.1	0	-23	-2	0.00
225	TNP/KTRC	0	0	71	15	0.5	0	-71	-14	0.00
227	TNP/CLMX	0	0	26	5	0.2	0	-27	-6	0.00
235	TNP/HC-F	0	0	32	9	0.0	0	-32	-9	0.00
301	HLP	22169	6912	22933	4991	267.0	2608	-1031	-687	0.00
310	STP	2622	484	0	0	39.6	562	2582	-78	0.00
319	HLP/LCAP	0	0	0	0	2.0	-1093	-2	1093	0.00
350	CPS	4208	936	4775	1394	56.7	-470	-624	13	0.00
393	WTU/LCRA	0	0	47	10	0.6	0	-48	-11	0.00
394	NHVDC	220	0	0	0	0.0	-63	220	63	0.00
400	WTUTEXLA	0	0	119	26	0.1	-3	-119	-22	0.00
401	WRYBRN	0	0	496	156	1.6	-3	-498	-153	0.00
432	ABILENE	18	25	388	116	13.8	-35	-384	-56	0.00
438	WESTERN	588	92	245	91	32.2	57	310	-56	0.00
440	CENTRAL	362	123	192	56	10.0	34	160	32	0.00
450	NORTHERN	971	27	176	62	28.3	35	766	-69	0.00
470	SOUTHERN	85	56	165	58	18.6	25	-99	-27	0.00
474	SAN ANG	123	110	280	74	12.0	-10	-169	46	0.00
504	LCRA-E	2739	826	636	159	35.0	247	2067	419	0.00
506	LCRA-W	6	0	1121	300	19.3	-198	-1134	-101	0.00
507	LCRA-N	703	230	994	276	23.7	-190	-315	144	0.00
512	LCRA-S	1498	197	615	131	19.8	34	864	31	0.00
610	E VALLEY	261	205	411	71	18.7	151	-169	-17	0.00
615	W VALLEY	1630	364	1008	258	22.2	174	600	-68	0.00
620	N REGION	1377	220	616	157	43.3	118	717	-55	0.00
625	C REGION	2321	502	1224	302	46.6	77	1051	122	0.00
630	W REGION	188	327	892	163	38.9	42	-743	121	0.01
640	NORTH LI	0	11	263	48	1.1	3	-264	-40	0.00
645	CENT LI	265	145	645	209	4.0	34	-384	-97	0.00
651	CR COGEN	450	55	0	0	0.0	40	450	15	0.00
654	MVEC/E	0	0	77	22	6.8	11	-84	-34	0.00
655	MVEC/W	0	0	220	64	4.0	8	-224	-72	0.00
659	CPL/MEC	0	0	13	2	1.0	1	-14	-4	0.00
709	AustEngy	1668	613	2926	1022	70.0	65	-1328	-473	0.00
800	BPUB	80	78	271	38	1.2	20	-192	18	0.00
801	DC-MEX	0	31	274	0	0.0	0	-274	31	0.00
870	MEC	70	23	100	31	6.5	3	-37	-10	0.00
890	STEC	539	132	377	113	17.8	-16	143	34	0.00
	TOTALS	76353	23220	74499	19888	1854.5	3332			

Application of the Transmission FOR Methodology:

In the 138 and 345 kV transmission analysis, one thousand circuits and autotransformers are selected out of a total of 3398. In the 345 kV study, 257 circuits are selected out of 270. Generator step-up transformers are excluded as well as all circuits and transformers connected to buses less than either 100 kV or 300 kV respectively. The selected circuits are the most heavily overloaded circuits due to single circuit outages in the base case (non probabilistic). Circuit outages causing other heavy circuit overloads are also selected. The selected (retained) set of circuits includes both monitored and outaged circuits. Single circuit outages causing system separation (islanding) are skipped from further analysis. LOLE due to islanding is not calculated.

Multiple circuits to be outaged together are given in file COMM2. PLF calculates the probability of all combinations of single and multiple circuit outages through triple circuit outages (N-3). If an outage probability is too low, the contingency will be skipped from further analysis. In this study, the cutoff probability is .03 hours out of a total study period hours of 3672, which is .03/3672 = 8.17e-6. File COMM2 allows circuits on common structures to have a higher probability of outage than if the circuits were independently randomly outaged.

PLF uses the generic transmission FOR = .0004 + .00002*L where L is the circuit length in miles. A circuit with a length of 100 miles would have an FOR of .0024 which is equivalent to about 8.8 hours/year for the summer study period used in this study (.0024*3672 hr). A circuit of 0 length has an FOR=.0004 which easily passes the 8.17e-6 cutoff test. However, two circuits randomly outaged will only pass this test if they have a length longer than 8.17e-6=$(.0004+.00002*L)^2$, or rather L>122 miles. They need not be on the same right of way. However, they must also pass another test that says they must have an electrical coupling of at least 3%, i.e. the interrupted current in the outaged circuit causes at least 3% of that amount of current in the circuit being tested for overload. The common circuit FOR in COMM2 overcomes the probability test limitation by allowing shorter circuits to pass the probability minimum cutoff of 8.17e-6, for circuits down to a length of 8.17e-6 ≈ .00001*L, or rather L>0.8 miles. Usually circuits in COMM2 will be electrically close enough to pass the 3% electrical coupling test. If not, then the common circuits will not be outaged even if they are listed in COMM2.

For autotransformers, an FOR of .02 (no generator step-ups are outaged) is used. This is equivalent to a 6 month outage time every 25 years or a 1 year outage time every 50 years. Two autotransformers outaged simultaneously have an FOR=$(.02)^2$ = .0004, which easily passes the 8.17e-6 probability cutoff test. However, three autotransformers have a probability of being randomly simultaneously out of service of $(.02)^3$ = 8e-6, which barely fails the test and will not be run. I found through extensive testing that allowing all combinations of three autotransformers to be outaged doubles the number of cases to be studied, doubles the computer runtime, and creates many problems in the system. However, the very low probability of these events, even when taken all together, amounted to only a small increase in the overall LOLE. Therefore, I chose a probability cutoff factor that would not allow N-3 autotransformer outages so I would have more computer time available to study more interesting network problems.

One important N-2 contingency allowed is one autotransformer out of service and one other circuit out of service. This is allowed for circuits greater in length than 8.17e-6 = .02*(.0004+.00002*L), or rather L>0.4 miles. The 3% electrical coupling cutoff test must also be satisfied, else the N-2 contingency will not be run.

PLF also provides for an increased probability for two and three circuits outaged simultaneously. For example, the first entry in file COMM2 shows a double circuit 345 kV circuit 77.3 miles long from San Miguel to Marion. Each circuit has an FOR = .0004+.00002*77.3 = .001946. The common circuit FOR adder is .00001*77.3 = .000773. This is added to the probability of random simultaneous outage of $(.001946)^2$ = .0000038 to produce a common outage probability of .000777. Dividing this common FOR by the sum of the two single circuit outages plus the common outage occurrences shows that common outages are expected to occur about 16.6% of the time. The rest of the 83.4% of the time a single circuit outage will occur. Note that these are long term outages of hours and possibly days, not relaying trips and reclosures for such things as lightning strikes. The transmission FOR in the PLF reliability model represents equipment failures (or extended scheduled outages such that the circuit taken out of service cannot be restored when needed, even if there is an emergency condition).

The transmission FOR values used in this study are reasonable. When developing these models a few years ago, I reviewed data used in other short courses, the IEEE journals, and circuit outage data from Austin and Houston. I have seen data showing the mean time to failure of large EHV autos to be only 11 years! I recall a conversation once with another engineer in which he said that every NERC meeting he attended had a discussion about how many autos had blown up since the last meeting.

Only 345/138 kV autos are outaged in this study (no 138/69 kV auto outages). PLF shows that there are 153 345/138 kV autotransformers of 100 MVA or greater. Using an FOR=.02 for autotransformers produces an average of 4 EHV transformers out of service at any time in ERCOT. If ERCOT has more or fewer than this number, then the FOR should be changed to reflect what is actually occurring in the system. Likewise, there are 239 EHV circuits greater than 900 MVA capacity. Using the transmission FOR formula of .0004+.00002*L, there should be about 1.1 EHV circuits forced out of service in ERCOT on any day during peak hours in the summer.

The transmission FOR formula can be tuned to actual conditions by collecting a little bit of data. The number of 345 kV circuits out of service (because of equipment failure) at the same time every afternoon, say 3 PM, is written down. At the end of the summer the numbers are averaged. Then the transmission FOR parameters are scaled such that the daily average produced by the model is the same as the average number of 345 kV circuits that are actually forced out of service in the system. I have been told that there is usually one 345 kV circuit out of service in ERCOT, therefore, I think the formula used in this study is representative of the actual system performance.

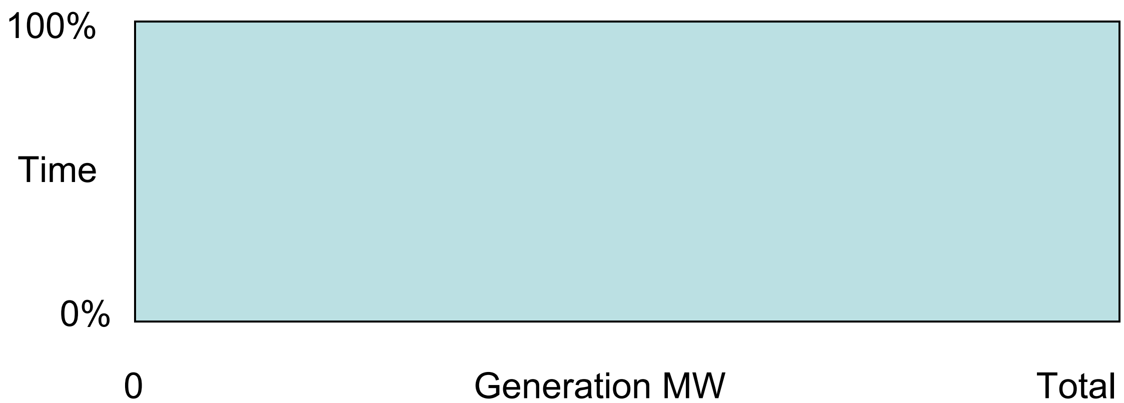
ERCOT Generation Adequacy Study

Single Area Solution Methodology in Phases I and II:

1. Generator unit MW and FORs (and DFORs) are put into a file, hourly load shapes in another file, the load forecast, and the load forecast uncertainty.
2. Begin with a graph that looks like a rectangular box with the x axis from 0 to the sum of all MW generation and the y axis is the probability axis from 0 to 1. Start with a curve having y=1 for all x < sum of all generation and y = 0 for x greater than the sum of all generation.
3. Choose the next generator to outage. Let this generator have an FOR of 15% and capacity of 100 MW as an example. The convolution process is to scale the initial curve y values to .85 of their value with no shift left or right and then add that to the initial curve scaled to .15 of their values and shifted to the left by 100 MW. Then add the .85 and the .15 scaled curves together to create a new y valued function. The notched area in the upper right hand of the graph is the unserved demand and energy. Probability represents an amount of time the generation is not in service.
4. Repeat step 3 for all generators.
5. Look up the probability of not being able to serve load every hour from the curve created in steps 3 and 4. Unserved energy is the integral of the area above the curve from 0 to the MW load for that hour.

Graphical Explanation of the Phase I and II Solution Procedure:

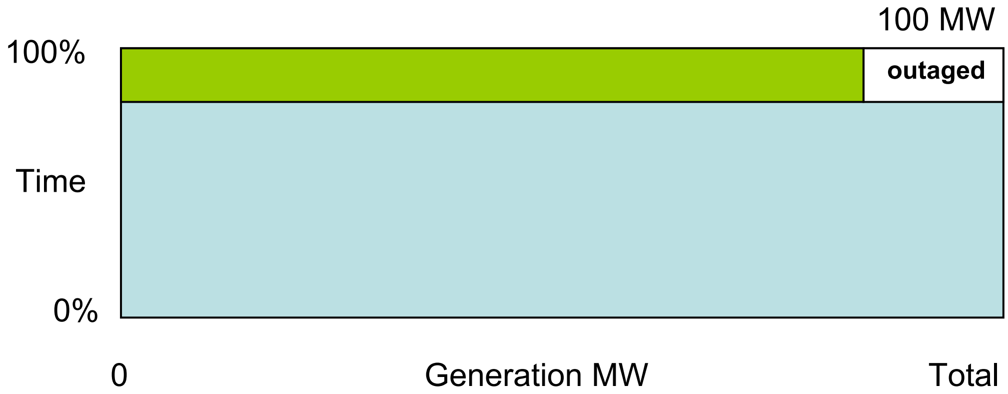
Start by assuming generation is available 100% of the time as shown in the graph below.



Convolution of generation proceeds as shown on the next page. The numerical examples are given to illustrate the procedure.

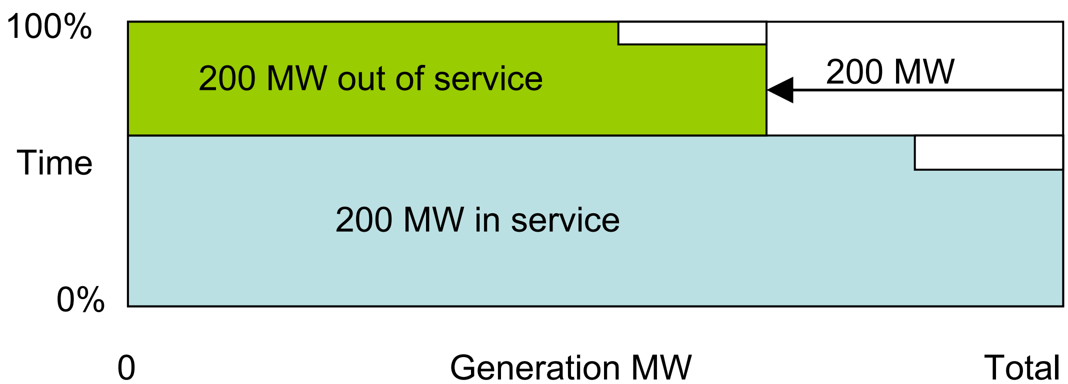
ERCOT Generation Adequacy Study

As an example, let 100 MW be forced out of service 20% of the time.



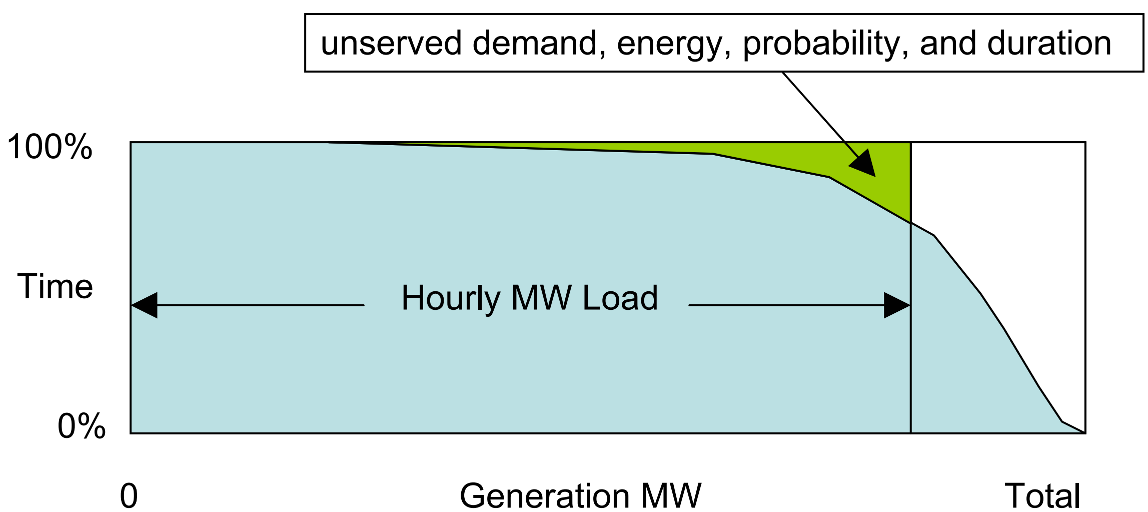
= sum of a 20% shifted 100 MW graph ( ) and an 80% not shifted graph ( )

Then, let 200 MW be forced out of service 40% of the time.



= sum of a 40% 200 MW shifted graph ( ) and a 60% no shift graph ( )

Repeat this process until all the generators are outaged, producing the curve below.



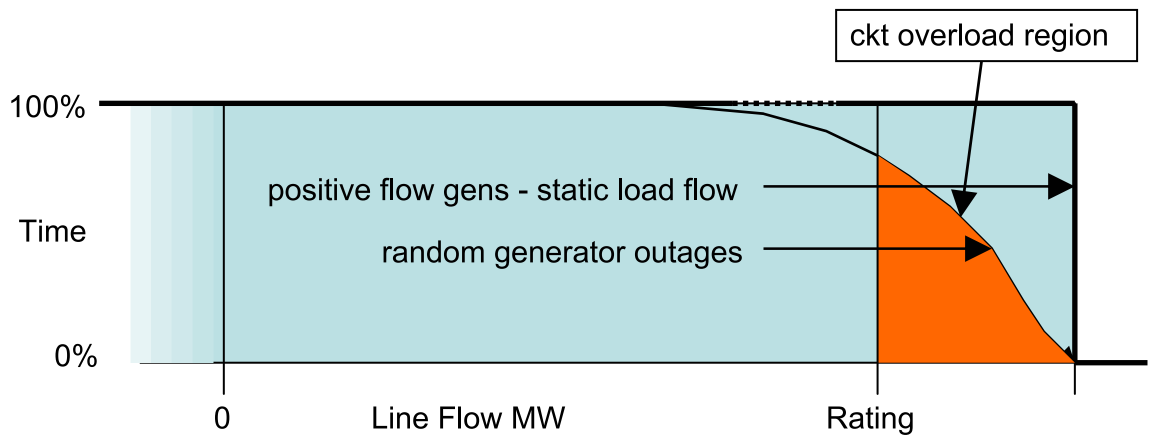
ERCOT Generation Adequacy Study

Transmission Constraints Solution Methodology in Phase III:

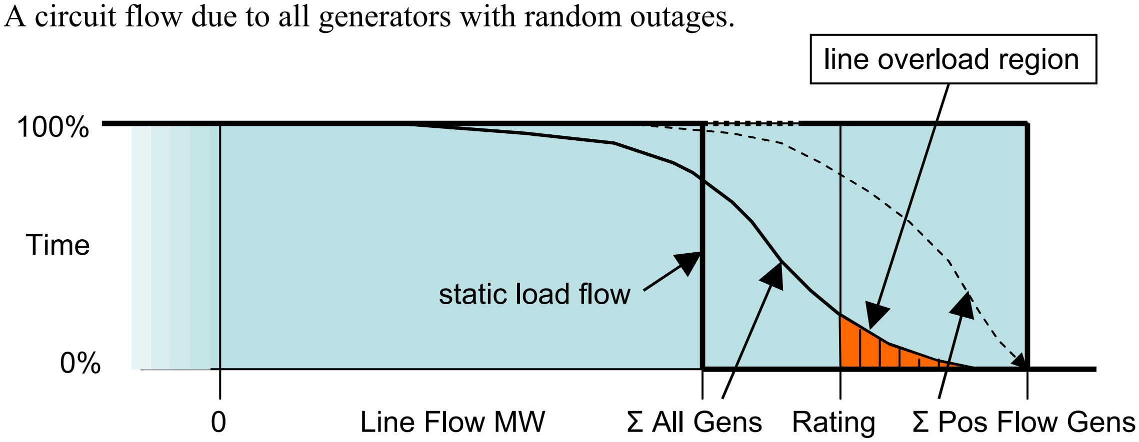
1. Use the same generator data as the single area study plus a load flow raw data file. Generators are given their bus number locations in the load flow data file.
2. Repeat the single area convolution process, except this time, calculate incremental load flow powers based on the outage of each individual generator. Create a probability curve for the MW flow on every transmission constraint.
3. Identify the circuit with the greatest probability of overload and choose a small MW increment of this circuit to unload.
4. Choose the generator and load area that will be used to remove this small overload increment. Reduce their MW generation and load. Collect loss of load statistics for the load area. Recalculate all network circuit flows due to this increment and go back to step 3 to repeat the process until no more circuit overloads exist.
5. Choose the next circuit to outage and repeat steps 2 through 4. Each circuit outage state is a separate calculation from the beginning to the end of the process.

Graphical Explanation of the Phase III Solution Procedure:

A circuit flow due to only generators causing increased loading.

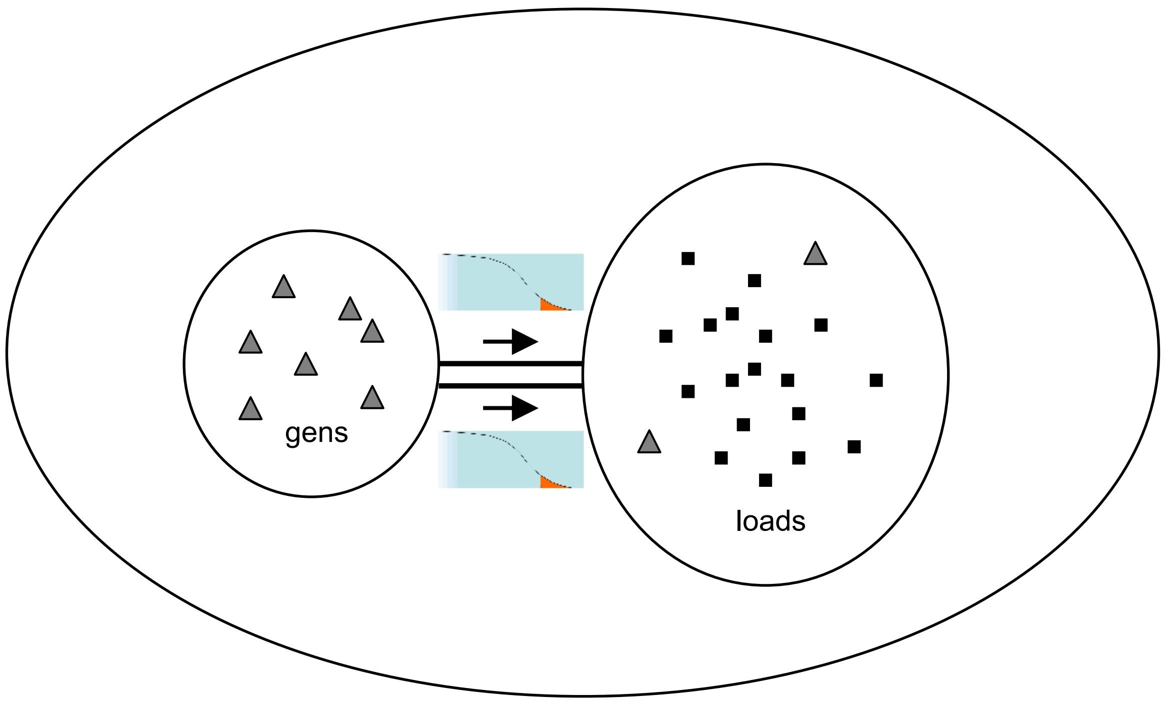


A circuit flow due to all generators with random outages.



In the previous graph, the circuit overload region is broken into several smaller MW increments. Load areas and generators are identified that will be reduced in MW amount to remove the overloaded segment. As each segment of overload is removed, the circuit flows on the other overloaded circuits are reduced. Circuits are unloaded in decreasing sequence of the percent time of overload (i.e., highest probability of overload is selected).

Load shedding areas and generators are selected to remove a circuit overload.



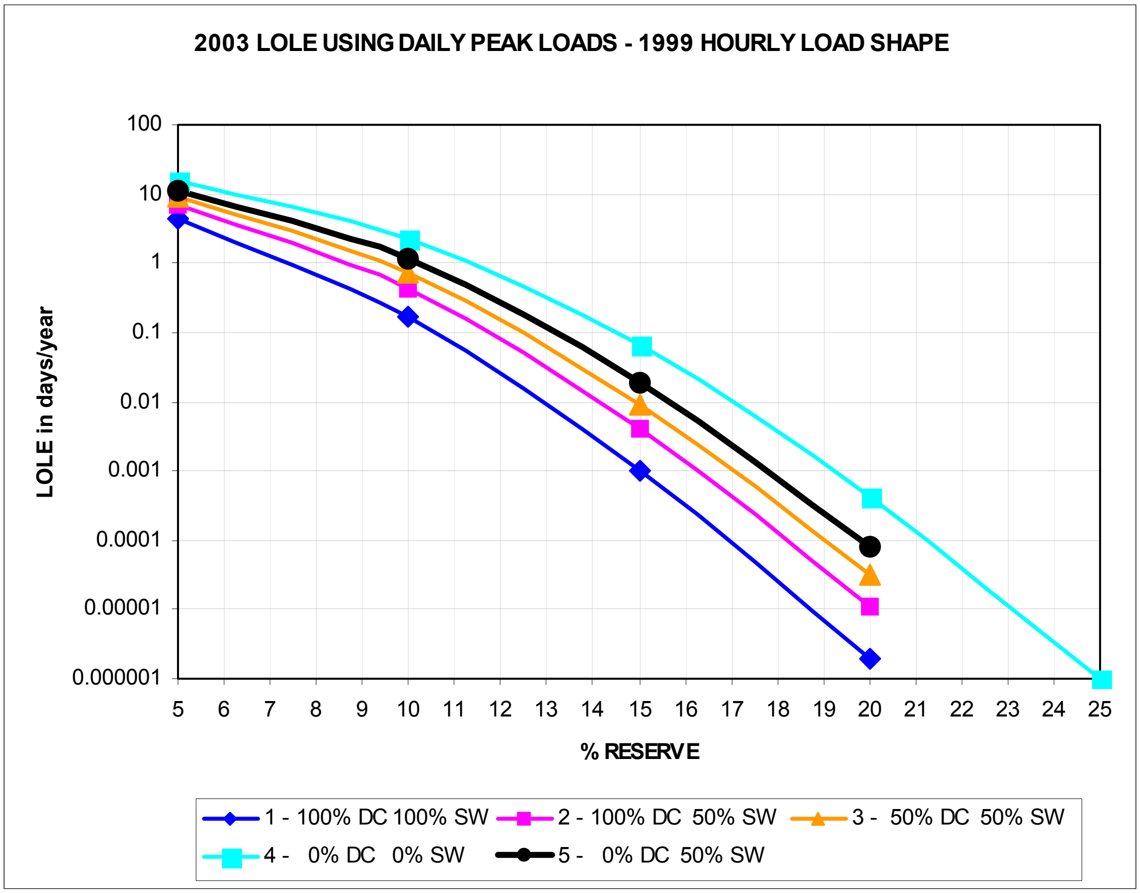
Transmission Constraints for Circuit Outage States:

Circuit and transformer outage states are not a convolution process as they are in the modeling of generator outages. Each transmission configuration is set up and solved as a separate set of loss of load calculations. More information about the solution procedures outlined in this report are given in the reference papers on web page http://k5gp.home.texas.net/relstudy.htm.

ERCOT Generation Adequacy Study

Phase IV Details and Results:

Phase IV is similar to Phase II, except corrections are made to the hydro FOR. The purpose of Phase IV is to test the sensitivity of the year 2003 ERCOT reliability indices to 0%, 50%, and 100% of the DC tie and switchable units being available to ERCOT. The graph below shows the findings.



Each curve shows a different combination of DC tie capacity and switchable generation. In each case, the percent reserve is based on 1) 20% of wind capability, 2) 0% of DC tie capacity, and 100% of switchable generation capability.

2003 Generation by Category:

14932 MW combined cycle
12699 MW combustion turbine
31 MW diesel
46262 MW steam
4944 MW nuclear
501 MW hydro - some units are derated
1711 MW wind (before derating)
920 MW DC tie
1404 MW switchable in/out of ERCOT

(see file 2003GENS.txt for details)