Power Grid Studies
dba Eugene G Preston
6121 Soter Parkway
Austin, Texas 78735
512-892-3621 ofc
March 6, 2024

Re: ERCOT 2023 historical and 2024 estimated LOLE

To NERC, TRE, PUC, and ERCOT officials:

Study Objective:

Calculate the 2023 historical LOLE (loss of load expectation) and then repeat the study for 2024 to determine if ERCOT has sufficient installed fossil and nuclear generation capacity to meet the NERC LOLE of 0.1 days/year (one event/day in ten years) for 2024.

The Net Demand Model:

The 2023 hourly demand, wind, and solar MWs are posted on the ERCOT web site. File https://www.ercot.com/mp/data-products/data-product-details?id=PG7-126-M shows that August 10, 2023 had a peak demand of 85433 MWs with installed wind and solar nameplate capacities of 37676 and 16702 MWs on that day. The demand, wind, and solar are converted to hourly per unit values in file https://egpreston.com/Hdata23.txt.

The Hdata23 per unit data allows independent scaling of the hourly demands and annual wind and solar profiles so that the same file can be used for both 2023 and 2024 studies.

When RTS3 (an IEEE Reliability Test System program) reads in the Hdata23 per unit data, it immediately calculates demand, wind, and solar MWs. The hourly net demand each hour is calculated as the demand MW for that hour minus the wind and solar MWs.

Treating wind and solar as an hourly demand reducer is the only way to keep a perfect correlation between 2023 historical demand, wind, and solar. The randomness of the demand, wind, and solar is captured in the Hdata23 data file. 2023 had a worldwide heat wave that https://climatereanalyzer.org/clim/sst_daily/ suggests will continue into 2024.

The Random Generator Outage Model:

The ERCOT generation data used in this study is posted in the December 2023 CDR link at https://www.ercot.com/files/docs/2023/12/07/CapacityDemandandReservesReport_Dec2023.xlsx. Gas, coal, nuclear, and DC ties provide power when VER (variable energy sources) such as wind and solar are insufficient to serve the hourly net demands from the Hdata23 data. Files https://egpreston.com/G2023.txt and https://egpreston.com/G2024.txt has these generators and their expected summer maximum capacity and FOR (forced outage rates). All combinations of random generator outages are convolved together to create a COPT (capacity outage probability table). Because it is a table for every integer MW net demand load level, the hourly LOLP (loss of load probability) is a simple lookup process.

Calculating the Reliability Indices:

The LOLH (loss of load hours) is the hourly sum of the LOLPs for a year. The LOLEV is the number of loss of load events in a year. RTS3 looks for separate events in the AM and PM of each day. The loss of load hours per event is the LOLH divided by LOLEV. The LOLE (loss of load expectation) is the annual sum of the daily peak LOLP each day. The Monte Carlo method produces the same hourly LOLPs when iterated enough times.

Study Assumptions:

1) No hydro capacity is used because there isn't enough water to sustain the generation.
2) Full switchable capacity between regions adjacent to ERCOT is available to ERCOT.
3) Full DC tie capacity is available to ERCOT from adjacent regions tied to ERCOT.
4) No scheduled maintenance on generators is performed at any time during the year.
5) FOR (forced outage rate) values are from my previous NERC study using RTS3.
6) Maximum conservation and load management is already in the 2023 historical data.

Study Results:

To achieve a NERC (North American Electric Reliability Corporation) LOLE of 0.1 days/year, an additional 5000 MW of firm generation capacity is needed in ERCOT for the summer of 2024. Without this capacity the LOLE is 4.4 days/year.

The 2023 LOLE is 5.4 days per year. The 2023 LOLH is 14 hours per year with each event average time for loss of load being only 2.6 hours per event. This short period of time is probably the sundown time when wind, solar, and conventional generation cannot quite meet the load. This period could be covered by having more firm battery energy storage available or it could be covered by more quick start gas peaking generation.

This study is probably a lower estimate of the actual LOLE. Including maintenance could raise the LOLE if the demand is too high while generators are still being repaired. If generators outside ERCOT or DC ties are not available at times, the LOLE increases.

This study is not based on reserve margins. Wind and solar capacity credits drop as more wind and solar is added. ERCOT has been ignoring these NERC supported study results: https://egpreston.com/NERCposter.pdf and https://egpreston.com/NERCpaper.pdf
ERCOT's reserve margin in the CDR is overstating wind and solar dependable capacity percentages. Improved wind and solar dependable capacity estimates should be calculated from either LOLP ELCC (effective load carry capability) studies or just simply calculating the spreadsheet wind and solar average percentage contributions during peak net demand hours. This approach best captures the times when the LOLPs are highest.

Computer output summaries and input file information are listed on the following pages.

Sincerely,

Eugene G. Preston

Eugene G. Preston

STATE OF TEXAS
E. G. PRESTON
37393
REGISTERED
PROFESSIONAL ENGINEER
TBPE F-2935

2023 RTS3 Summary Output Report:

```
GDATA File: G2023.txt
HDATA File: HDATA23.txt

ERCOT 2024 GENERATION DEC 2023 CDR
37676 MW Wind & 16702 MW Solar are 2023 Actuals on Aug 10 2023
ERCOT 2023 Actual Hourly Demand - Wind - Solar
Hourly Demand Side Load Management is already in the demand hourly MWs

MAX GENR  =      73030 MW
VARBL RES =      23744 MW
GENR+VRES =      96774 MW
MAX COPT  =      20693 (90000 MAX)

2023 RESULTS:
PERIOD    =       8760 HOURS
PEAK DEMD =     85433. MW
RESERVE   =       13.6 %
LOAD ENGY =    446823. GWh
LOAD FACT =     59.704 %
PEAK NETD =     70231. MW (DEMD-VR)
VR E USED =    139956. GWh
VR E LOST =         0. GWh
Indices for a  0.00% LFU:
LOLE(AM)  =   0.000000 d/y
LOLE(PM)  =   5.372764 d/y
LOLE      =   5.372764 d/y
LOLEV **  =   5.372831 events/y
LOLEMW    =      1228. MW
LOLH      =  14.044207 h/y
LOLH/event=   2.613931 h/event
EUE MWh   =     17245. MWh
EUE ppm   =      38.59 pu ppm
EUE %     =   0.003859 %
LOLP>1.E-4=        251 hrs

Variable Resource Capacity Credits
Max Net Demand hrs for LOLP>1.E-4:
 20.4%  41.4%  (these are estimated capacities for wind and solar)

PS peak shaving max energy      231. MWh/day
PS peak shaving max power       231. MW/day
PS peak shaving avg power       221. MW/day
VER storage maximum energy        0. MWh/day
VER storage maximum power         0. MW/day
VER storage average power         0. MW/day
net demand ramp increase      10476. MW/hr

** LOLE  measures events/24 hrs
   LOLEV measures events/12 hrs
```

2024 RTS3 Summary Output Report:

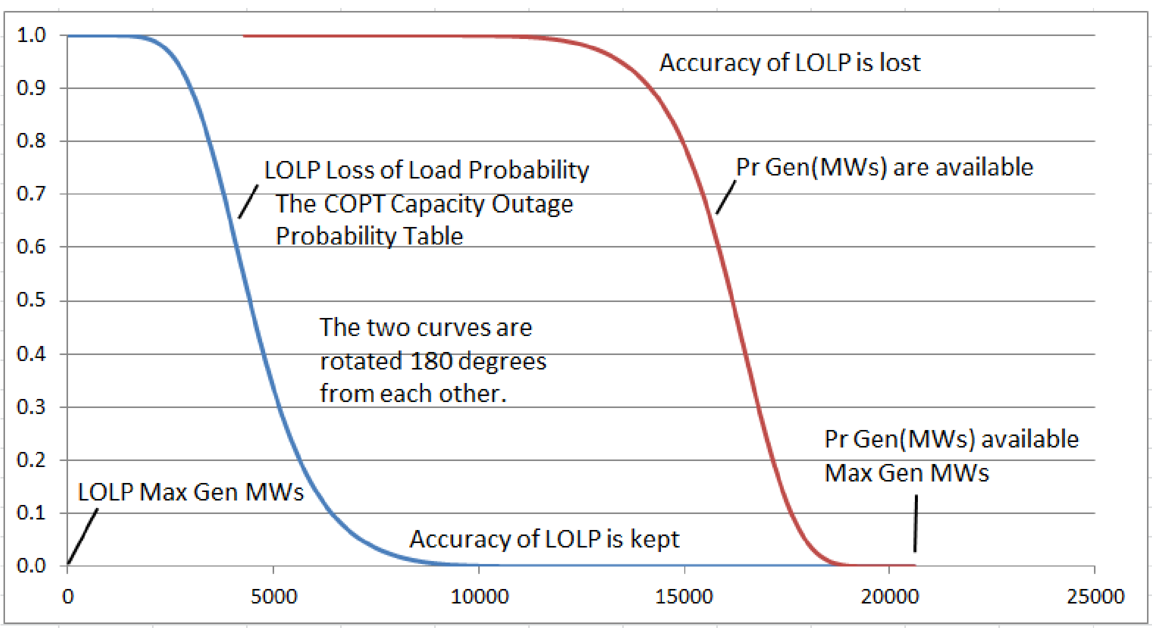
```
GDATA File: G2024.txt
HDATA File: HDATA23.txt

ERCOT 2024 GENERATION DEC 2023 CDR     38910 MW Wind & 22267 MW Solar
ERCOT 2023 Hourly Demand - Wind - Solar profiles with 2024 max values
Hourly Demand Side Load Management is already in the demand hourly MWs

MAX GENR  =      73030 MW
VARBL RES =      28486 MW
GENR+VRES =     101516 MW
MAX COPT  =      20693 (90000 MAX)

2024 RESULTS:
PERIOD    =       8760 HOURS
PEAK DEMD =     87142. - 82293 = ~5000 MW new gen for LOLE = 0.1 d/y
RESERVE   =       18.8 %
LOAD ENGY =    455761. GWh
LOAD FACT =     59.704 %
PEAK NETD =     70096. MW (DEMD-VR)
VR E USED =    154073. GWh
VR E LOST =         0. GWh
Indices for a  0.00% LFU:
LOLE(AM)  =   0.000000 d/y
LOLE(PM)  =   4.369415 d/y
LOLE      =   4.369415 d/y
LOLEV **  =   4.369431 events/y
LOLEMW    =      1258. MW
LOLH      =  10.164393 h/y
LOLH/event=   2.326251 h/event
EUE MWh   =     12791. MWh
EUE ppm   =      28.06 pu ppm
EUE %     =   0.002806 %
LOLP>1.E-4=        169 hrs

Variable Resource Capacity Credits
Max Net Demand hrs for LOLP>1.E-4:
 21.8%  25.7%  (these are estimated capacities for wind and solar)

PS peak shaving max energy     1790. MWh/day
PS peak shaving max power      1790. MW/day
PS peak shaving avg power      1356. MW/day
VER storage maximum energy        0. MWh/day
VER storage maximum power         0. MW/day
VER storage average power         0. MW/day
net demand ramp increase      12565. MW/hr

** LOLE  measures events/24 hrs
   LOLEV measures events/12 hrs
```

Individual dispatchable generation for RTS3 is entered into a G2023.txt file and a G2024.txt file for the year to be simulated. The first few lines of each file are described below so you can see the data going into an RTS3 simulation. This is the G2023.txt file:

```
24 ERCOT 2024 GENERATION DEC 2023 CDR   37676 MW Wind & 16702 MW Solar are 2023 Actuals
HDATA23.txt             hourly sequential demand and VR data for this generator data (a
85433, 0, 0,  .0001,    2023 Actual Peak Demand in MW, %LFU, 0 same LFU all year or a 2
2, 90,  257, 1, 100,    VERs (20 max), 90% storage efficiency, 257 MW battery storage 1
   28,   79,            VER wind and solar % capacity credits used in the reserve margi
    0,    0,            wind and solar capacity feeding directly into energy storage de
37676,16702,            MW wind and solar data is read through column 24  wind and sola
 PMAX ,RM%, FOR,DFR,DMW,  GENERATOR NAME  ,ID,   These FORs were used in previous studi
1205.0,100,.016, .0,  0,  CPSES_UNIT1     ,NU,   ERCOT LOAD FLOW ID'S:    FOR   ID
1195.0,100,.016, .0,  0,  CPSES_UNIT2     ,NU,   -----------------------  ---   --
1293.2,100,.016, .0,  0,  STP_STP_G1      ,NU,   U is nuclear            .016   NU
1280.0,100,.016, .0,  0,  STP_STP_G2      ,NU,   L is coal and lignite   .058   CO
 655.0,100,.058, .0,  0,  COLETO_COLETOG1 ,CO,   N is non CC natural gas .070   GA
 604.0,100,.058, .0,  0,  FPPYD1_FPP_G1   ,CO,   C is combined cycle gas .070   GA
 599.0,100,.058, .0,  0,  FPPYD1_FPP_G2   ,CO,   R is bio renewables     .058   BI
 437.0,100,.058, .0,  0,  FPPYD2_FPP_G3   ,CO,   H is hydro              .000   HY
 560.0,100,.058, .0,  0,  CALAVERS_JKS1   ,CO,   EQ is equivalent        .000   EQ
 785.0,100,.058, .0,  0,  CALAVERS_JKS2   ,CO,   S is solar              .000  the var
 824.0,100,.058, .0,  0,  LEG_LEG_G1      ,CO,   W is wind               .000  the var
 836.0,100,.058, .0,  0,  LEG_LEG_G2      ,CO,   OT is the DC tie        .000
```

The 24 on the first line tells RTS3 to read 24 columns on each line of data.
The hourly profile file name is read on the 2nd line and peak demand on the 3rd line.
The 4th line is the number of variable resources (wind and solar) and some battery info.
The 5th line is ERCOT's capacity credits for wind and solar. The 6th line is not used.
The 7th line are the installed wind and solar MW nameplate capacities.
The rest of the data are dispatchable generator's MWs and FOR's (forced outage rates).
The G2024.txt file is the same as the 2023 file except the demand, wind, solar, and battery storage MWs have been changed to 2024 projections.

The RTS3 2023 COPT in blue is compared with a comparable cumulative capacity table shown in red. The red line has a loss of load LOLP problem which is explained.



The blue curve is the ERCOT 2023 COPT and the red curve is an inaccurate generation availability curve. Both curves grow to the right as generators are convolved into the curves. However the COPT maintains high accuracy as the probabilities become very small along the bottom axis. The red curve LOLP is 1 minus the red curve which leaves no accuracy for small LOLPs. Therefore RTS3 uses only the COPT blue curve process.

To add a generator to the blue curve the generator FOR is multiplied times blue curve and shifted it to the right by the MWs of the generator. Then 1-FOR is multiplied times blue curve, not shifted, and is added to the shifted curve to make a new blue curve. Repeat this process for all the dependable generators in the system. As ever larger LOLPs are added to the smaller LOLPs to the bottom right of the blue curve as it grows to the right the numerical roundoff errors of earlier generators becomes smaller and smaller. The result is that the blue curve maintains high accuracy no matter how many generators are convolve together. This COPT has no upper bound on the size of the system studied!

Once the COPT has been created, the net demand each hour from the hourly loads file allows a simple lookup of the LOLP each hour. The reliability indices are calculated and printed in the output report(s). The COPT solves a vexing problem in math I need to make a youtube video on to explain how and why it's so important as a scientific tool.

Battery Storage:
The battery storage is listed as PS meaning pumped storage. ERCOT has no pumped storage so battery MWs are entered. The 1 hour assumed means that there is that much energy available for peak shaving. However peak shaving is a simple deterministic cut of the peak energy and filling by off peak demand periods a few hours earlier. I.e. the shape of the demand profile is modified on the fly sweeping through the hours. The batteries are charged during light load hours and discharged during daily peak load hours. The battery efficiency is assumed to be 90%. A detailed listing of the hourly battery charging and discharging is posted at https://egpreston.com/PS24.txt

Hourly listing of LOLPs:
Days with significant LOLPs are posted at https://egpreston.com/OPH24.csv

COPT for 2023 used in this report https://egpreston.com/COPT23.txt