PROJECT NO. 42302

REVIEW OF THE RELIABILITY STANDARD IN THE ERCOT REGION	**$ $ $**	**PUBLIC UTILITY COMMISSION OF TEXAS**

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Links: http://egpreston.com/EGP2on42302.pdf

When we last discussed the ERCOT reliability measures there was a discussion about the meaning of the LOLEV and new measures NERC is working on, such as a movement to a loss of load hours LOLH instead of the LOLE. The belief by many people is that the LOLH will give a better reliability measure than LOLE as regions become more dependent on renewables. A continuation of the LOLEV is necessary for calculating the average duration of outages. The average outage duration in hours/event = LOLH (hours per year) / LOLEV (# of events per year).

Definitions – These are in agreement with ERCOT's 2013 report[1]:

Binary Tree – expanding all combinations of generators being in either a repair or operational state; used in an 'exact' solution in a 1986 paper[2] for calculating the IEEE RTS reliability indices.

COPT[3] – capacity outage probability table; a monotone decreasing stair-step table for looking up the LOLP for serving a MW load level each hour; used to produce 'exact' LOLP calculations.

EUE – expected unserved energy in MWh or normalized to a per unit or percent value.

Event – a continuous period of loss of load due to insufficient generation capacity.

F&D MC – frequency and duration Monte Carlo, an hourly sequential modeling technique[1].

LOLE – loss of load expectation; historically the sum of daily peak demand LOLP's for a year. Renewables destroy this definition and it must be redefined to resuscitate its usefulness. The new definition is the sum of the daily maximum LOLP's. The LOLE 'counts' days per year of loss of load. One day in ten years means an outage happens once in ten years, not a full day.

LOLEV – loss of load events in a frequency and duration Monte Carlo simulation which is the counting of events rather than days. In ERCOT the LOLE and LOLEV are the same values.

LOLH – loss of load hours/yr; the sum of hourly LOLP's or the loss of load hours/yr in F&D MC.

LOLP – loss of load probability; a dimensionless number between 0 and 1. LOLP = 1 means the load is lost with 100% certainty. The LOLP is also a 'per unit' of time that load is not served.

RTS[4] – Reliability Test System, a 32 generator model for testing different solution methods.

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[1] http://www.ercot.com/content/news/presentations/2013/ERCOT%20Loss%20of%20Load%20Study-2013.pdf
[2] http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=4335006&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D4335006
[3] http://www.egpreston.com/VDC.txt verifies the COPT produces exactly the same LOLP's as a binary tree.
[4] https://www.ee.washington.edu/research/pstca/rts/pg_tcarts.htm

COPT versus Monte Carlo:

Relevant to this discussion is how we should be calculating the reliability indices. Monte Carlo is inherently slow to solve and lacks significant digits. Overlooked by industry is that a COPT, when constructed properly, gives the same 'exact' results as a full binary tree solution[2,3]. Hourly COPT and hourly F&D MC are shown to produce the same frequency of 'events'.

A 1986 paper[2] gives 'exact' solutions to the IEEE RTS[4], which is a small system with a 2850 MW peak demand, annual hourly loads, and 32 generators totaling 3405 MW. It is small enough to fully expand all 2^{32}=4,294,967,296 states of a binary tree. As you can see, the size of this tree grows exponentially as generators are added, which prevents its use for larger systems. Each of the 4.3 billion states has a probability and a MW value.

The COPT provides exact solutions and does not have the exponential growth problem. A new RTS COPT program[5] modeling the 1986 paper RTS has been written and it does reproduce the 'exact' LOLE, LOLH, and EUE values in the 1986 paper as expected.

The input data[6] for this new RTS program was generalized so other systems can also be modeled and 'exact' indices calculated. This simple program could model the entire US. The source code, an input data file, and its .exe executable are posted on my web page - free to use.

The program handles renewables by subtracting hourly historical variable sources from the historical hourly load. This is an approach that produces accurate answers. The LOLP for the net MW demand after renewables is a simple lookup in the COPT each hour.

LOLE versus LOLEV in ERCOT:

There is a widespread belief that F&D MC gives the frequency of 'events' whereas the COPT direct calculation does not. I ran a test between the 'exact' LOLE using the RTS program COPT and two[7] F&D Monte Carlo simulations on a summer peaking demand example. The MC LOLE and the MC LOLEV produced identical results[7]. This is expected because all 'events' were totally within the day they occurred. The MC model required 5 hours to run one million years which is 380,000 times longer than the COPT 'exact' solution required. These run times and number of significant digits in the reliability indices are important when trying to compare differences in study case scenarios. MC is handicapped by its lack of speed and accuracy.

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    DIRECT COPT 'EXACT' SOLUTION
     LOLH        LOLE       MWHEUE
   0.225305   0.099956    33.395 (0.047 seconds)
 MONTECARLO SEQUENTIAL F&D SOLUTION
     LOLH        LOLEV      MWHEUE (MC LOLE gives the same LOLEV values)
   0.232100   0.104200    34.014 (10,000 iterations 179 seconds)
   0.225614   0.100805    33.696 (1,000,000 iterations 17963 seconds)
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[5] http://www.egpreston.com/RTS2016.txt see the indices report at the bottom of the listing.

[6] http://www.egpreston.com/DATAIN.txt input data to the RTS program.

[7] http://www.egpreston.com/OPMC3.txt LOLE and http://www.egpreston.com/OPMC3v.txt LOLEV

LOLE versus LOLEV continued:

The MC LOLE counts only one event per day even if there are two. MC LOLEV counts each event ignoring whether the event aligns with the day or not. The test case shows they are identical for a summer peaking demand profile. LOLEV would be higher than LOLE if there were two peak demands during the peak demand days, which might eventually occur if ERCOT solar forms the so called duck curve[8]. LOLEV might be lower than LOLE if loss of load extends from one day to the next day (unlikely). LOLEV might depart from LOLE if repair times of failed generators are less than a day (>1 day in this test case). Because generation is scheduled each day, the LOLE seems to me to be a more logical index than the LOLEV. The LOLEV can calculate the expected duration of outage events. If the COPT LOLE counts AM and PM LOLP peaks, the LOLE can also calculate expected outage durations. By classifying LOLE as AM and PM we could separate those events in both the COPT and F&D MC methods. We have seen that both direct and MC models need to use either the LOLE or LOLEV along with the LOLH to calculate the average duration of outages. NERC's desire to omit the LOLE and/or LOLEV in favor of LOLH is shortsighted considering how well the LOLEV (or LOLE) and LOLH work together as a set.

Renewables Modeling Mistakes:

Suppose we have a computer program in which we enter all wind farms as individual generators in the model (either a direct COPT or a F&D MC model). Let each wind farm's capacity factor be 40% (from the actual hourly data) and an equivalent forced outage rate is entered as 60% for each generator modeling each wind farm. The model shows each wind farm generates with a 40% energy capacity factor. It also shows that during peak demands ~40% of the wind capacity is available. The LOLE and LOLH in the output report are acceptable values.

We run the study again with the wind not being entered as generators. This time the actual hourly wind and demands are combined as a net demand. Now the very same computer program produces much higher LOLE and LOLH values. What has caused the different results?

Weather patterns drive the wind farms together in time synchronized patterns. When the wind blows, it blows nearly everywhere. And when the wind stops blowing it tends to be calm over a wide area. These calm periods create LOLP spikes. When wind is modeled as generators, we miss these common mode light wind and no wind periods. Modeling wind farms as independent random generators creates a major source of simulation error.

Another source of error is a simple averaging of the actual wind data. For example, we may think that averaging the wind power for 20 peak demand hours gives the effective capacity of wind during peak load hours. This is incorrect. The correct way to do this calculation is to first sum the LOLPs from the COPT lookup table with the actual wind applied as a load reduction. Then iteratively find a constant load reduction for those same hours so that the sum of LOLP's is the same as the first sum of LOLPs. This reduction is the correct capacity.

[8] https://energyathaas.wordpress.com/2016/05/02/the-duck-has-landed/

Another source of error is not accounting for the drop in wind or solar capacity as the resource is increased. As more and more wind and solar are added, hours of high renewables output no longer have high LOLPs. The remaining highest LOLPs occur during hours renewables are not producing power. The duck curve[8] is a good example. When ERCOT has 20 GW of solar a duck curve is likely. The peak demands are before sunrise and after sunset. Adding more solar deepens the curve and does not contribute capacity toward serving the peak demands.

This dropping of effective capacity creates a new problem in the ERCOT CDR[9]. The effective capacities of wind and solar at the beginning of the CDR are probably much lower at the end of the CDR period if these are a larger percentage of the capacity. A COPT or MC reliability study of the last year in the CDR is needed to ensure the system is actually reliable.

<u>A Major Reliability Concern for ERCOT:</u>

ERCOT has been assuming in their studies the gas supply is reliable and affordable. Without natural gas plants responding rapidly to the variability of wind and solar power, these sources are not a valid stand-alone power source. This makes ERCOT too dependent on natural gas. In reliability studies, being too dependent on a single fuel creates risk. With this concern in mind I have modeled several scenarios with the dependence on fossil fuels reduced as much as possible both in capacity and energy and posted the computer printouts on my web page.

Here is a summary of my findings. Case 6 burns no fossil fuel with 144 GW of wind and solar, but it requires a very expensive 330 hour 6.6 trillion dollar battery to work. There is no way to finance the battery, making Case 6 not feasible. Case 6a has 144 GW wind and solar with a smaller 500 billion dollar 14 hour battery, and fossil fuels do generate only 2% of the annual energy; however, the existing fossil fuel generation must remain operable to cover extended periods of low renewable energy production. This is not feasible because the market cannot support that much fossil fuel standby generation. Case 8 is a 52 GW nuclear plan using new nuclear plant designs that burn waste, follow load, and provide spinning reserve. At $10/watt the plan costs 520 billion dollars. Electrically case 8 works beautifully, but it is not feasible in ERCOT because there is no way to finance it. The stark reality is that there are no long range non-fossil plans for ERCOT that work on paper, in computer models, and can be financed. Microgrids could open up new possibilities if ERCOT works to develop them[10].

Sincerely,

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[9] http://www.ercot.com/content/gridinfo/resource/2015/adequacy/cdr/CapacityDemandandReserveReport-December2015.pdf

[10] http://egpreston.com/PrestonFeb2016.pdf and see the last two pages for benefits of microgrids