Variable Energy Resource Capacity Contributions Consistent With Reserve Margin and Reliability

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Report to ERCOT on VER Capacity and Reserve Margin

ERCOT Reliability and Operations Meeting

Sept 7, 2017 by Gene Preston

Keeping The Lights On As We Transition To Renewables

UT Energy Symposium (UTES):

Sept 7, 2017 by Gene Preston

A Brief History of Grid Reliability

- The Great Northeast Blackout Nov 1965
- NERC is created in 1968 to insure reliability
- Regions build new transmission for reliability
- Texas completes 345 kV reliability loop 1970
- NERC reliability assessments are required
- US Blackouts In: 77, 82, 96, 98, 03, 11, 12
- Harvey – HEB microgrid keeps stores open
- Harvey – Chem Plant Explodes; loss of power
- Loss of critical loads can be devastating

Introduction

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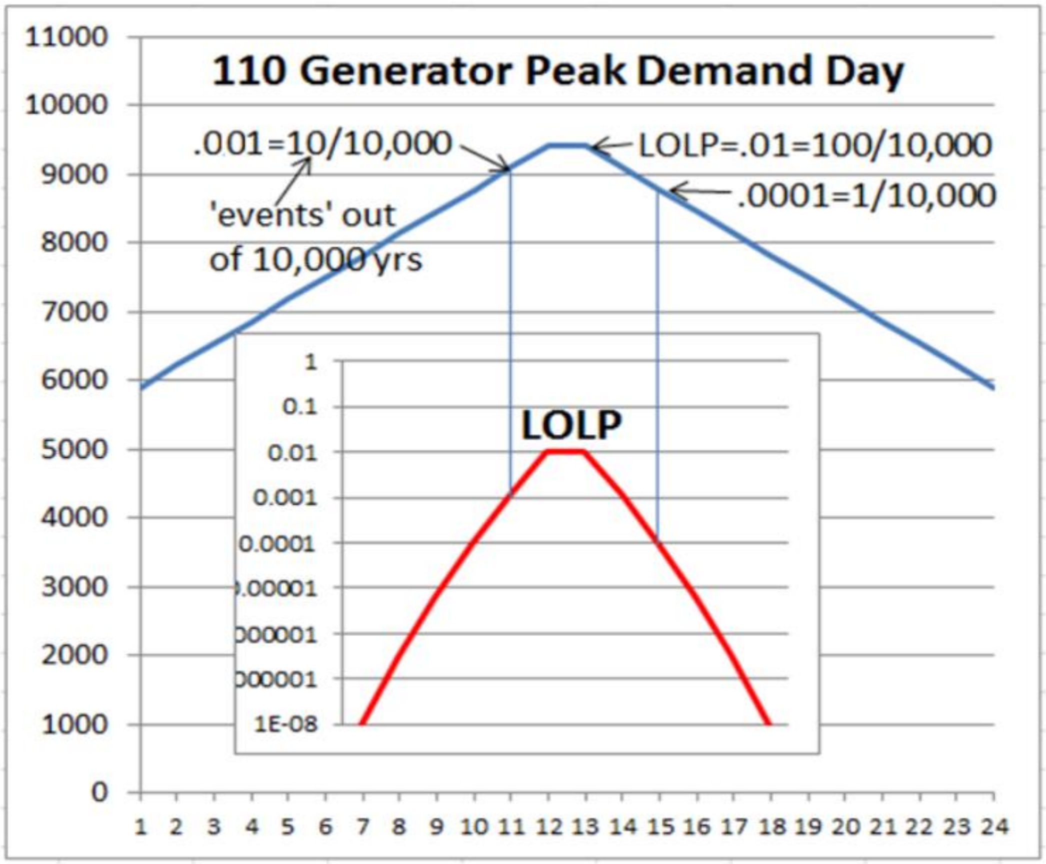
- The North American Electric Reliability Corporation (NERC) is responsible for ensuring the reliability of the bulk power system in North America as variable energy resources (VERs) are expected to grow.
- A minimum LOLE of one day in ten years is used to measure if planned generation capacity is sufficient, which now includes the addition of VERs.
- VERs are treated as negative load which creates a net demand and avoids complexities of having to create VER equivalent generator models.
- A future study year scales historic 2010-2015 demand and VER hourly profiles to maintain time synchronization.
- A COPT capacity outage probability table gives the hourly LOLP loss of load probability for conventional generators serving the net demand.
- The COPT is created in a special way to provide 'exact' reliability indices for the IEEE RTS model as verified from a 1986 RTS paper listing exact indices.
- The RM reserve margin is found for high and low VER capacity credits while the demand is adjusted so LOLE = 0.1 d/y is maintained in each instance.

Equivalent Definitions of LOLE and LOLEV:

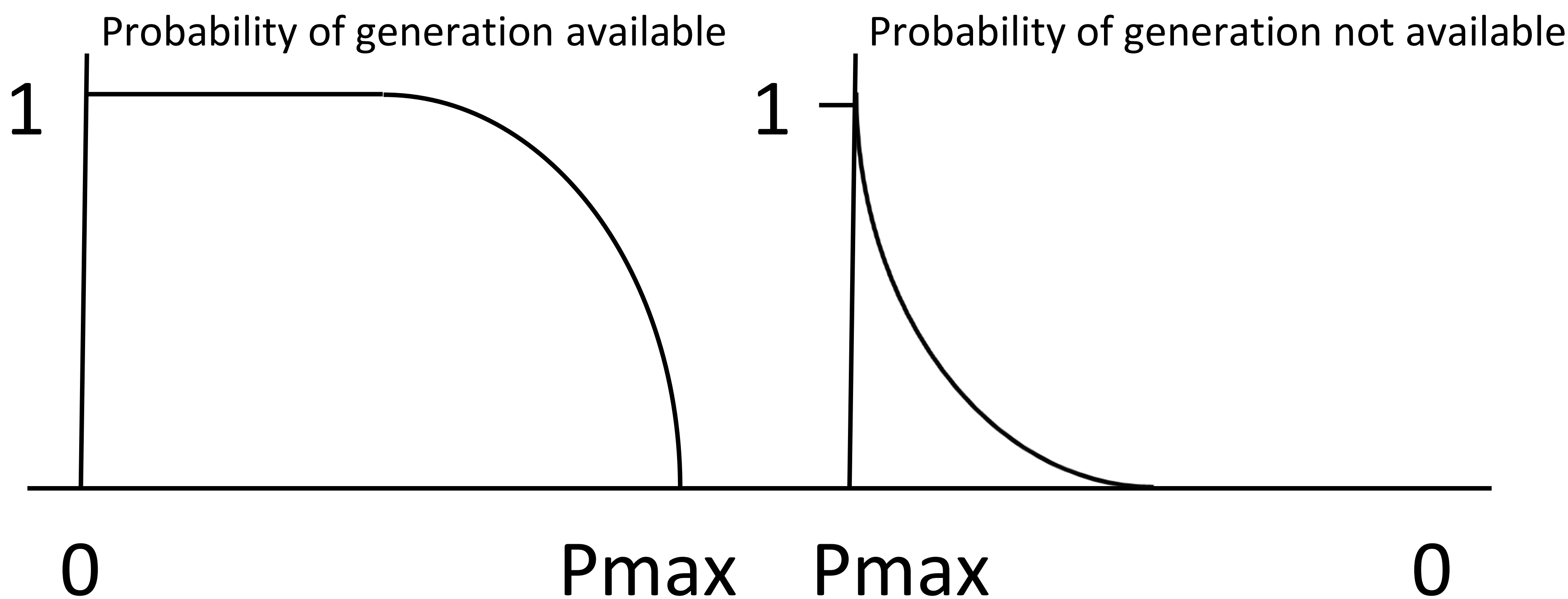
- LOLE = ∑ daily LOLPs = #days with events/trial years
- LOLEV = ∑ LOLP Peaks = # events (1 or 2/day)/trial yrs

Def: One day in 10 years for ERCOT means there is expected to be a loss of load lasting about 3 hours once every 10 yrs.



The COPT is a cumulative capacity distribution rotated 180 degrees.

CCD COPT



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The Exact IEEE RTS Calculator

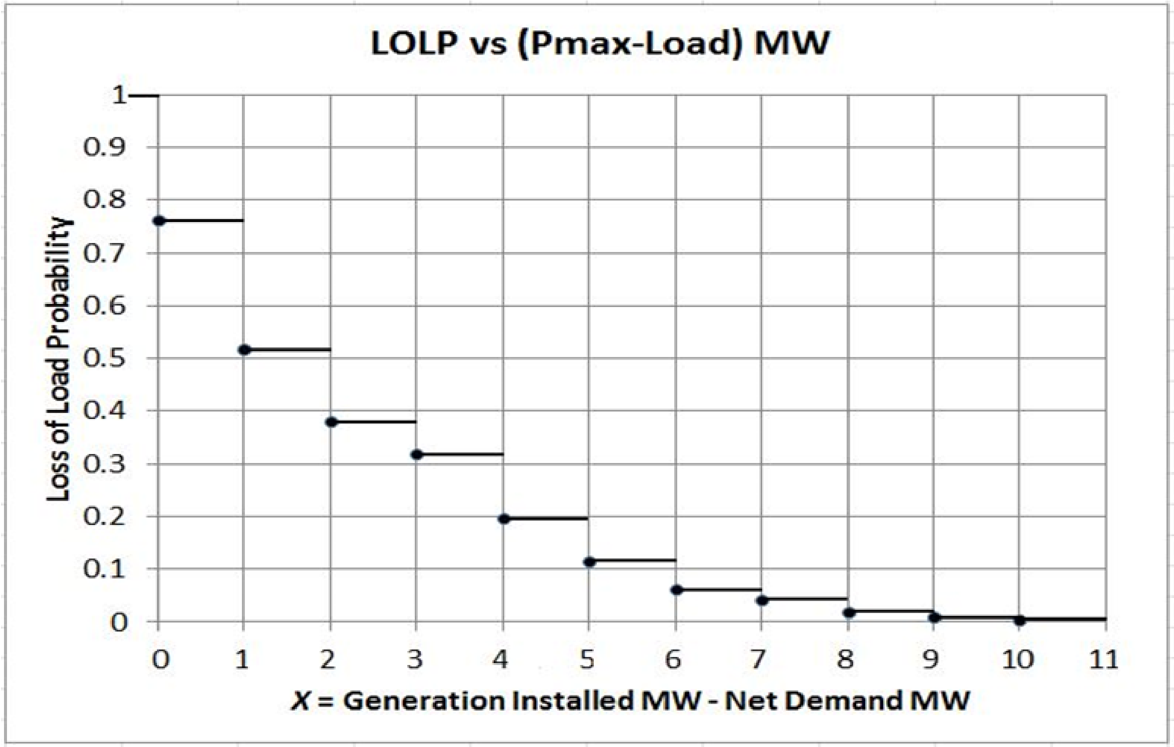

Fig. 1 RTS Program Capacity Outage Probability Table - COPT

- Uses the following cumulative distribution *F(x)* before and *F(x)*$^+$ after convolution: $[F(x)^+ = (1-FOR_k)\cdot F(x) + FOR_k \cdot F(x-C_k)]\ \forall\ x = 0, x_{max}$
- This process produces the published 'exact' indices for the IEEE RTS.
- *F(x)* can only be used for conventional fully dispatchable generators.

3 Modeling Sequential Events Using a COPT

- Time dependent historical demand MW and VER MWs from 2010-2015 are scaled to a future test year to calculate hourly net demands for the COPT.
- The hourly LOLP is a lookup process from the COPT table.
- Each scaled forward historical year to future test year is given equal weight.
- From the hourly LOLP all the indices LOLE, LOLH, and EUE are calculated.
- The direct calculation produces the same indices as a Monte Carlo solution.

```
ERCOT 2010-2015 Hourly Demand & VERS
YYYYMMDDHH,D,ERCOTLD,NonCst,Coastl,Solar,  <- type of VER
              70000   19000  2000   1500   <- peak demd & installed MWs
2010010101,6,0.48711,0.1716,0.6714,0.000,  <- historical profiles
    :      :    :      :      :      :
2010010108,6,0.54340,0.3457,0.3416,0.062,
2010010109,6,0.54612,0.2553,0.2764,0.336,
    :      :    :      :      :      :
2015123124,5,0.49733 0.2667 0.2667 0.000,
end,,,,
```

Simulation Results

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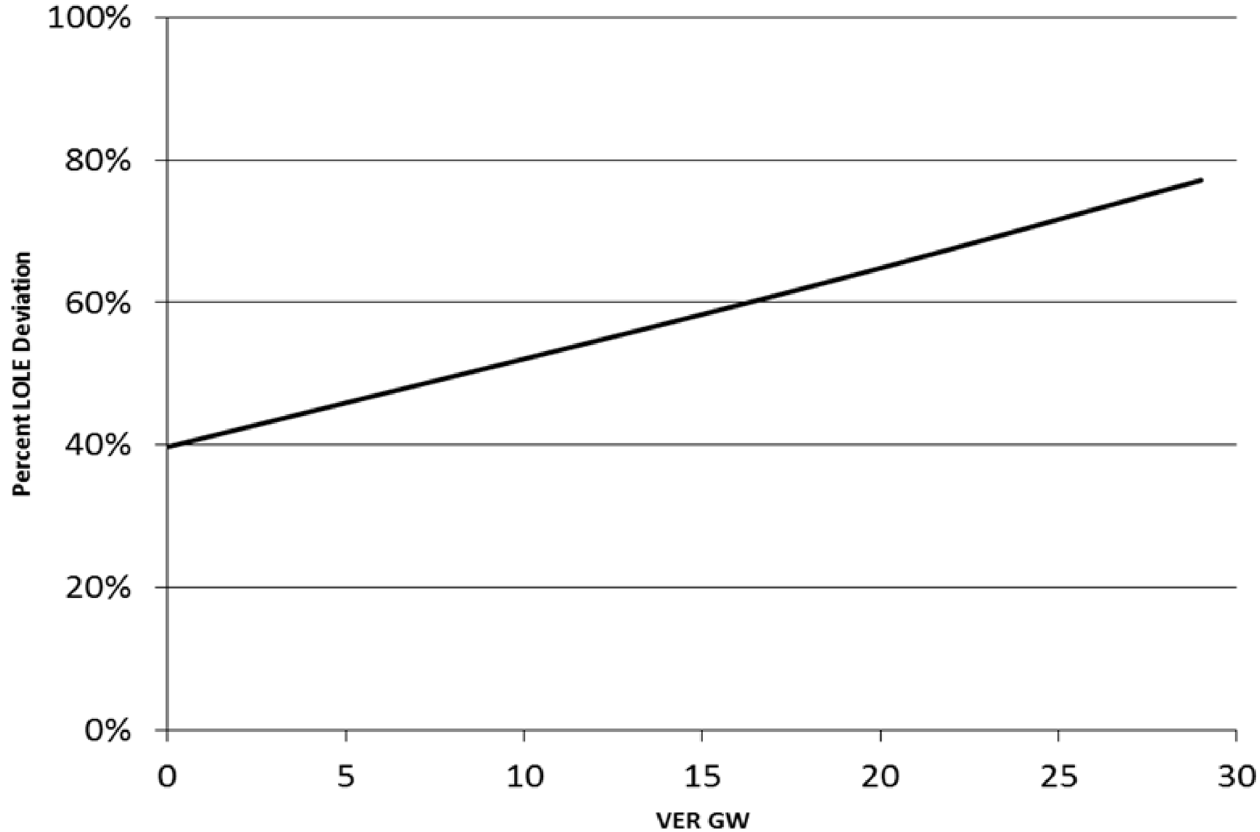


Fig. 2 Historical LOLE Deviation Increases with VER

- As VERs are added to the system, the LOLE deviation from historical year to historical year increases in ERCOT from 40% with no VERs to 80% for planned 2026 VERs.
- Adding VERs to the system creates additional risk for serving load.

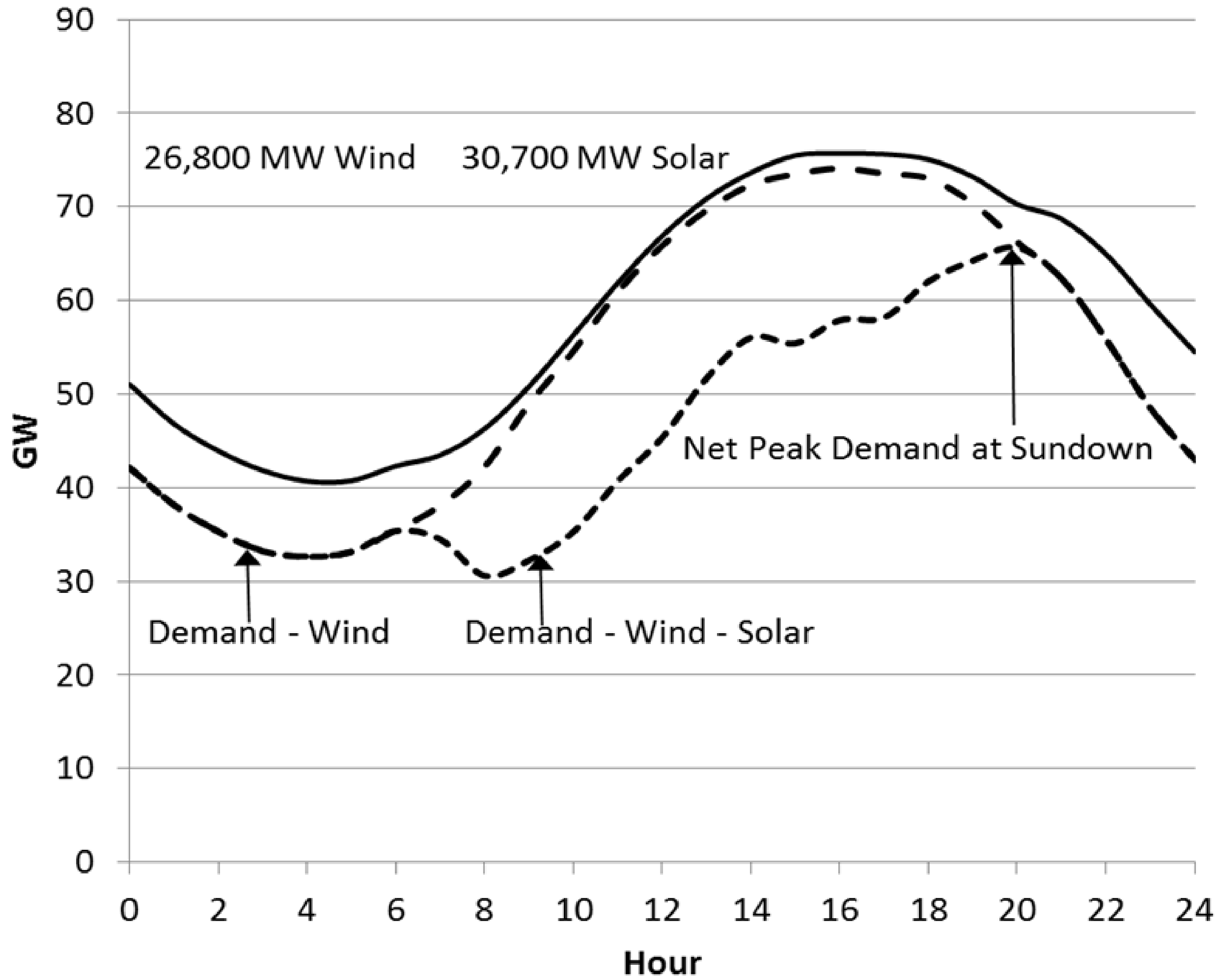
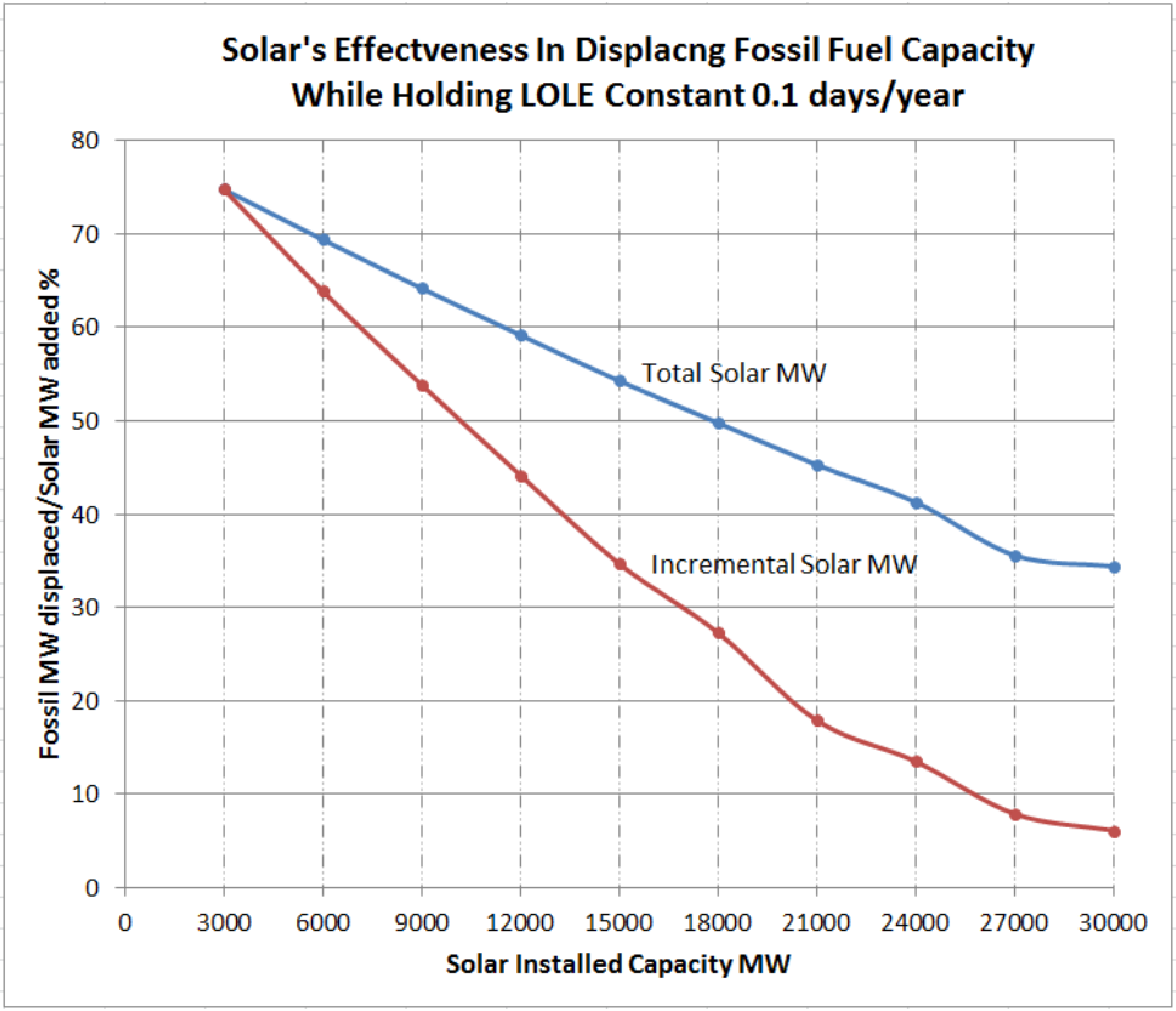


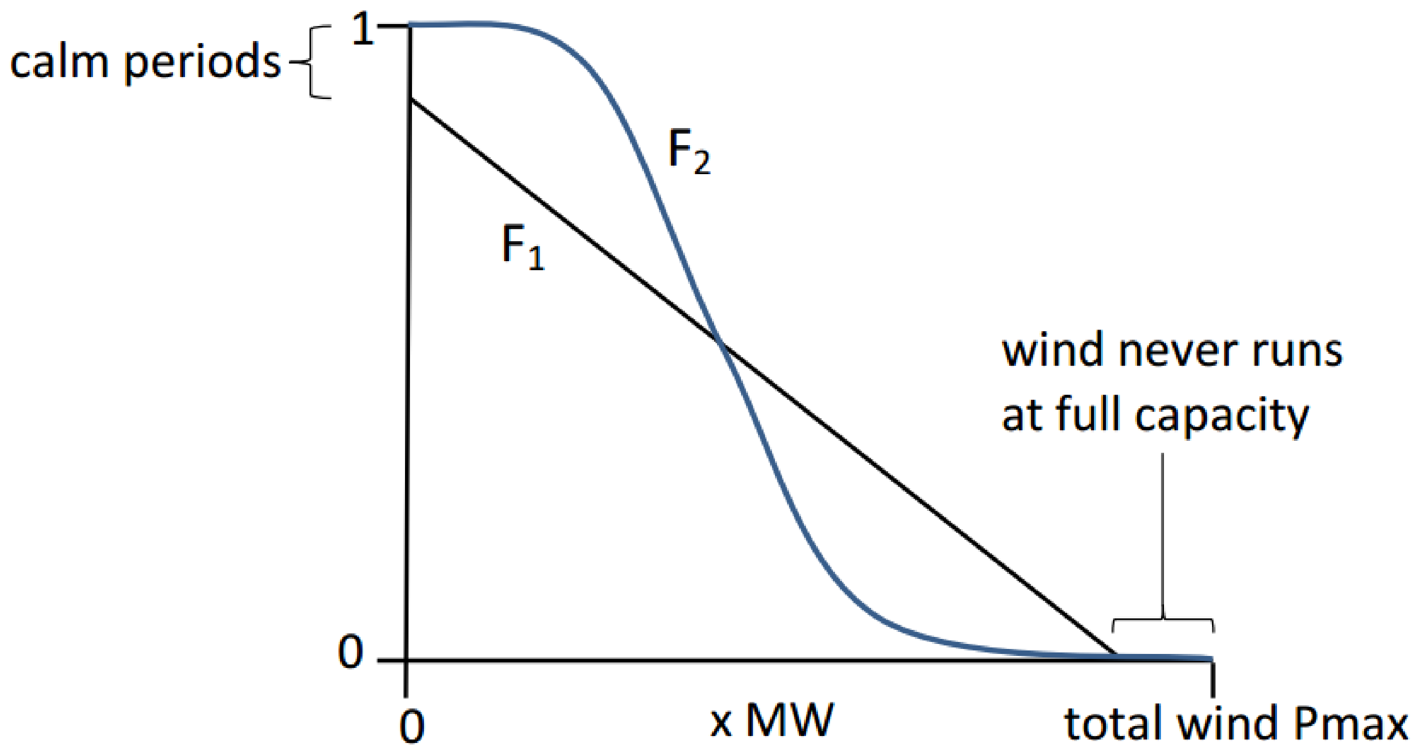
Fig. 4 Solar Shifts the Net Peak Demand to Sundown.

- Solar capacity will eventually shift the peak to sundown.
- This is known as the duck curve effect in CAISO.
- Solar incremental capacity credit drops to zero percentage.


Solar's Effectveness In Displacng Fossil Fuel Capacity
While Holding LOLE Constant 0.1 days/year
Fossil MW displaced/Solar MW added %
Solar Installed Capacity MW
Total Solar MW
Incremental Solar MW
0
10
20
30
40
50
60
70
80
0
3000
6000
9000
12000
15000
18000
21000
24000
27000
30000

Modeling wind and solar interruptible sources of power:

- The ERCOT annual wind curve $F_1(x)$=Pr[x MW is available] is almost linear.



- If wind farms are treated as generators and convolved together, then the capacity duration curve F_2 appears as shown. F_2 should match F_1.
- This error is caused because wind farm MW outputs are not independent.
- To overcome this problem we <u>must</u> treat wind as an hourly load reducer.

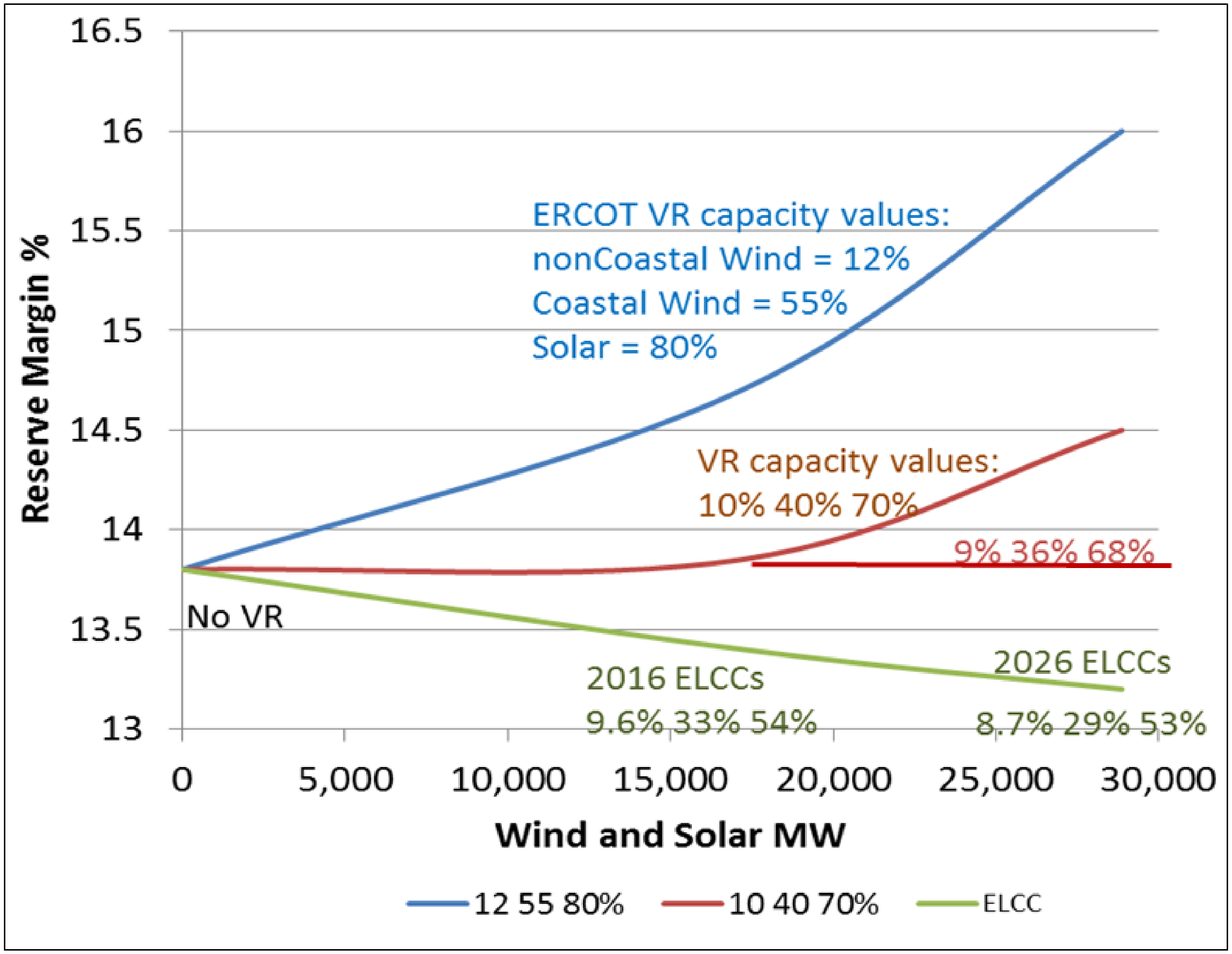


Fig. 5 ERCOT VER RM at Different Capacity Contributions.

- The capacity value of VER diminishes as more VER is added, causing an increase in the RM to hold LOLE at 0.1 d/y.
- VER capacity values are not unique and couple nonlinearly.
- Frequent LOLP analysis is needed to find VER capacity values.

Recommendations

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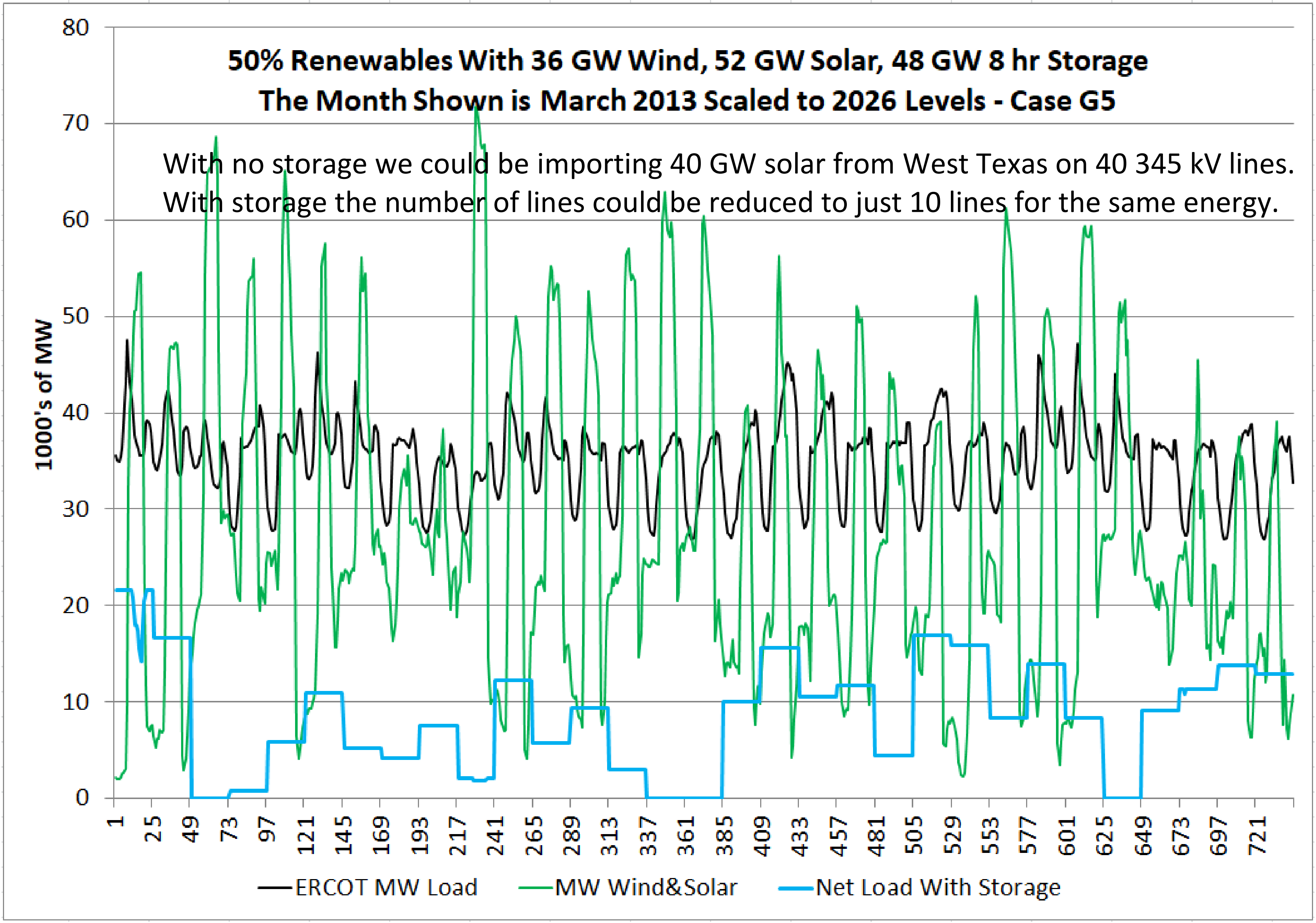
- NERC regions should provide reliability evaluations of VER impacts.
- It's very important to maintain chronology between different variable energy generation sources and load.
- It will be necessary to develop and maintain public databases of wind, solar, and hydro historical production.
- VERs should be given capacity credits from the running of loss of load probability studies.

Showing A Need For Storage As Renewables Grow:



Test Cases Pushing Renewables To Very High Levels:

ID G#	Futr Year	Demd (MW)	Wind (MW)	Win+ Storg	Coast Wind	CW+ Stor	Solar (MW)	Solar+ Storg	Total (MW)	Pump Storg	PS hr	Total Storag	TS hr	Rnew %Eng	Ramp MW/h	Coal Retire	Gas Retire	StoC $Bn	StoE $Bn	Stor Bn$
G0	2016	68000	14727	0	2001	0	600	0	17328	0	0	0	0	14.6	7518	0	0			
G1	2026	75708	23840	0	2971	0	4700	0	31511	0	0	0	0	23.5	12377	0	0			
G2	2026	75708	23840	0	2971	0	14000	0	40811	0	0	0	0	27.5	16134	3978	0			
G3	2026	75708	23840	0	2971	0	14000	0	40811	5000	4	5000	4	27.6	12919	8877	0	5	5	10
G4	2026	75708	23840	0	2971	0	14000	22000	62811	5000	4	27000	8	36.7	10170	18369	0	27	54	81
G5	2026	75708	26000	6000	3000	1000	16000	36000	88000	5000	4	48000	8	50	10228	18369	6323	48	96	144
G6	2026	75708	24000	20000	3000	3000	16000	82000	148000	5000	4	110000	10	75	5010	18369	11941	110	275	385
																storage is priced at		1$/W	250$/kWh	

The RTS3 program and the RTS test system data is posted on line for your use and inspection.
The Watcom F77 compiler which is now in the public domain runs RTS3 the fastest:
https://onedrive.live.com/?id=7977301446550C3C%2130300&cid=7977301446550C3C
RTS data and Matlab version are posted here: http://www.egpreston.com/RTS3.zip
A youtube video of RTS3 seeking a target demand automatically is here:
https://www.youtube.com/watch?v=7C-q-8HTha8&feature=youtu.be
Modernization of the RTS model is posted here: https://github.com/GridMod/RTS-GMLC
I'll be applying RTS3 to this model and preparing papers giving "exact" indices.