## The Easy Way To Model Electric Energy Storage Using Excel

By

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Let G = all non CO<sub>2</sub> source MWh/h (MWs) left over not serving load directly. This excess energy is available to charge the storage. Let D = MWhs of demand not yet served directly from non CO<sub>2</sub> sources. Let S = the amount of MWHs in storage going into the current hour Let S<sup>+</sup> = the amount of MWhs in storage exiting the current hour Let S<sub>max</sub> = the maximum MWhs that can be stored in storage Let S<sub>min</sub> = 0 the minimum MWhs that can be stored in storage

Then storage can have these three outcomes exiting the current hour IF ( $S + G - D > S_{max}$  then  $S^+ = S_{max}$ ) IF (S + G - D < 0 then  $S^+ = 0$ ) Else ( $S^+ = S + G - D$ )

The Excel formula in a cell needed to execute the three above tests is:

IF(S+G–D>S<sub>max</sub>, S<sub>max</sub>, IF(S+G–D<0, 0, S+G–D)) all outcomes are  $S^+$ 

If the first equation is true then set storage to max, else do another test to set the storage to zero, and then the final Else is the level of storage.

Delta storage is  $S - S^+$  is < 0 for energy going into storage and > 0 for energy being extracted from storage and going to serve load.

To add losses to the above please continue on to the next page....

## Electric Storage Plus Charging and Shunt Losses

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Let E be the efficiency of charging which is the amount of charging energy going into the battery. E = 1 would be no losses. E = 0.9 means that only 90% of the energy charging the battery gets into the storage. The other 10% is simply lost energy.

Let R be the amount of running down of the battery over time just sitting there. R will be the MWh/hour drainage rate every hour. If we estimate the loss of energy in the battery to be 1% per day then  $1*S_{max}/24/100$  is the R value per hour. Interestingly R is the MWs continuous power loss of the battery just sitting there. If R is 1000 MW's then we might need to add another 1000 MWs of base loaded generation just to serve the loss. So the shunt drain loss is real money.

Then storage with losses can have these three outcomes each hour:

IF ( $S + G^*E - D - R > S_{max}$  then  $S^+ = S_{max}$ ) IF ( $S + G^*E - D - R < 0$  then  $S^+ = 0$ ) Else ( $S^+ = S + G^*E - D - R$ )

The Excel formula in a cell needed to execute the three above tests is:

IF( S+G\*E-D-R>S<sub>max</sub>, S<sub>max</sub>, IF( S+G\*E-D-R<0, 0, S+G\*E-D-R))

Delta storage is now  $S - R - S^{+}$  which is < 0 for energy going into storage and > 0 for energy being sent from storage to serve load.

These formulas are used in the following spreadsheets: <u>https://egpreston.com/ERCOT22B.xlsx</u> ERCOT 0 CO<sub>2</sub> w/battery storage <u>https://egpreston.com/ERCOT22C.xlsx</u> ERCOT 0 CO<sub>2</sub> using thermal storage <u>https://egpreston.com/PJM3.xlsx</u> PJM zero CO<sub>2</sub> with battery storage <u>https://egpreston.com/PJM4.xlsx</u> PJM zero CO<sub>2</sub> with thermal storage