Deriving the susceptance for each line l

X and R are in per unit.

GTEP Problem records

Experiment1

Only use the synthetic transmission lines + DC power flow formulation no transmission losses.

No transmission expansion considered.

Solve the LP relaxation of 15 year problem.

Obj: 214.260967

Results analysis:

We only observe generation capacity expansion at the second year.

Maybe because we ignored transmission losses in the model.

Experiment2

Try to run the model by CLL with the same 5 year data. (Here we have transmission losses). Solved to optimality with integer constraints.

Cost break down

variable\_operating\_cost

[8.358427567591859, 18.108136373920424, 20.181148242874325, 22.232146511276934, 24.484456336610258]

93.3643150322738

fixed\_operating\_cost

[2.2642952988429985, 3.2116475500653228, 3.042641572127982, 2.875879182142652, 2.709875809680907]

14.104339412859863

startup\_cost

[0.00513974911354366, 0.3153956061785252, 0.32753303217308566, 0.3317396436329091, 0.33243068636951645]

1.31223871746758

thermal\_generator\_cost

[1.0087276744340032, 90.39430930583781, 0.0, 0.0, 0.0]

91.4030369802718

extending\_thermal\_generator\_cost

[0.004868308934872064, 0.0, 0.0, 0.0, 0.003374942576056022]

0.008243251510928086

renewable\_generator\_cost

[4.454827814505195, 3.6475725241572237, 0.285875576793093, 0.0, 0.0]

8.38827591545551

extending\_renewable\_generator\_cost

[0.0, 0.0, 0.0, 0.007140727466949403, 0.0]

0.007140727466949403

storage\_investment\_cost

[0.0, 0.0, 0.0, 0.0, 0.0]

0.0

penalty\_cost

[0.0, 0.0, 0.0, 0.0, 0.0]

0.0

Try to run the model by CLL with the same 15 year data. The variable cost increase and then decrease. Does not make sense.

variable\_operating\_cost

[8.332889966915845, 16.22816065245911, 16.850355512025377, 16.128120407269883, 16.91497896029319, 7.686354780570984, 7.7099605325753, 7.681421599723842, 7.763880334596215, 7.736176575499836, 7.7395676328420535, 7.74344332150388, 7.721388513921309, 7.730652409347058, 7.667691897604664]

151.63504309714853

fixed\_operating\_cost

[2.256886173008326, 3.3334298939812563, 3.2313690722773223, 3.205207351389584, 3.033780113538584, 2.843766644861352, 2.6780626751041456, 2.5300596803490807, 2.368358230336179, 2.236776693077853, 2.113119875767271, 1.9864947964127038, 1.874473987908649, 1.768402744539485, 1.6402508831167486]

37.10043881566854

startup\_cost

[0.005977457350068572, 0.24343808914395337, 0.23603652357662036, 0.19828778221719534, 0.18537779459071557, 0.13014286169070385, 0.13191798340317595, 0.13287812736016555, 0.133332911775015, 0.13334765454551725, 0.14843880964745645, 0.14774766277962817, 0.14834308690843806, 0.1487540530540789, 0.14807687053720542]

2.272097668579938

thermal\_generator\_cost

[0.0, 101.46504310504282, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

101.46504310504282

extending\_thermal\_generator\_cost

[0.0015822096957860017, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0015822096957860017

renewable\_generator\_cost

[5.021243576588086, 4.606690922814303, 4.227596004563476, 7.761729740635365, 2.0160039848552382, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

23.633264229456472

extending\_renewable\_generator\_cost

[0.0, 0.0, 0.0, 0.007140727466949403, 0.0, 0.037641145005530646, 0.005878148909073299, 0.011027714530385677, 0.010355316820302529, 0.009733735882339672, 0.036632622303479516, 0.059157676622144696, 0.09427463834035368, 0.037711900999857495, 0.019668640625635128]

0.3292222675060517

storage\_investment\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

penalty\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

Experiment

change carbon tax to the one in readData.py, include transmission DC

costs break down. The values of thetas are the in order of 0.03-0.05

rimal simplex - Optimal: Objective = 2.4926318879e+02

Solution time = 2558.80 sec. Iterations = 124 (0)

Deterministic time = 469716.12 ticks (183.57 ticks/sec)

CPLEX> Solution written to file '/tmp/tmppxgqk1l8.cplex.sol'.

CPLEX> variable\_operating\_cost

[7.868016956011934, 12.685842163547601, 12.021011861628132, 10.185327329422433, 9.624971744145943, 8.442742260861834, 7.858086189293392, 7.720635929073144, 7.726851704653548, 7.639610108218112, 7.402493612209835, 7.524712665030446, 7.626735170041998, 7.758538594598119, 7.8453001916903995]

129.9308764804269

fixed\_operating\_cost

[2.2676656730289637, 2.333182767249326, 2.3860972872994943, 2.550148946283795, 2.543741670023905, 2.5125994450156934, 2.439146556607878, 2.3212047575582693, 2.17923860539584, 2.0647362561991978, 1.9618387178116836, 1.8431286204071065, 1.738609074966014, 1.63916809199822, 1.5161422969255989]

32.296648766770986

startup\_cost

[0.02642981563585751, 0.0295227032583807, 0.06577554175253347, 0.0587780583156367, 0.0577531455826309, 0.1555429703670394, 0.2375436676206282, 0.24098234406939525, 0.24658869575686335, 0.2384599628916951, 0.23818385715389095, 0.23412368900254493, 0.22407089810024178, 0.2138609627086748, 0.2030337175214034]

2.470650029737416

thermal\_generator\_cost

[2.2542612715445065, 10.748018959901973, 9.794051611710483, 14.14320469211441, 0.0, 10.968604763132223, 5.121996954808759, 0.5141684248296007, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

53.54430667804195

extending\_thermal\_generator\_cost

[0.0, 0.0, 0.0, 0.0, 0.0010893591334170708, 0.0, 0.0, 0.0, 0.0, 0.0018331032177558433, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0029224623511729143

renewable\_generator\_cost

[3.3446345595536022, 3.1211765240101896, 2.916432865345682, 5.540311480766161, 7.127856770916255, 1.7540846371759595, 1.5504811526857452, 1.3650369594873457, 1.1964665740644014, 1.0435703475312805, 1.7833120660616335, 0.0, 0.0, 0.0, 0.0]

30.743363937598257

extending\_renewable\_generator\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.011027714530385677, 0.010355316820302529, 0.009733735882339672, 0.036632622303479516, 0.059157676622144696, 0.09427463834035368, 0.03674570150824186, 0.016493030126788596]

0.2744204361340362

storage\_investment\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

penalty\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

experiment

cll’s model 15 years. Objective larger than DC model. Because DC model does not consider transmission losses.

variable\_operating\_cost

[8.397883764532587, 14.324072773012658, 12.859985818357305, 11.510965743330004, 11.53173695938686, 9.99756917224072, 9.002426725465408, 8.920993099847745, 8.91282711263374, 8.814889543238278, 8.424326665618795, 8.547966186326583, 8.63401091107861, 8.740290957706913, 8.788253580400792]

147.408199013177

fixed\_operating\_cost

[2.2550216222911263, 2.2615351916814097, 2.4339750905422584, 2.5531856039528344, 2.434162855203417, 2.4707712053390667, 2.447578120502488, 2.3229076381771003, 2.181164285972537, 2.06654492913329, 1.9674565867615261, 1.8486865759720748, 1.7440972419856318, 1.6450567219065457, 1.5235564435397009]

32.15570011296101

startup\_cost

[0.006459225032849071, 0.04127310873215253, 0.0835963114355094, 0.03163185507440262, 0.029723922156760813, 0.11523355543525621, 0.23491175345322196, 0.22189390982969928, 0.2469427001986692, 0.23459667938490517, 0.2681663257470389, 0.25212862783823853, 0.23917944695527216, 0.23509334044516034, 0.22704847635441563]

2.467879238073553

thermal\_generator\_cost

[0.0, 4.868732888672639, 20.13349020088286, 10.26047621041979, 1.1379402782877672, 14.698057575115028, 8.727991403789902, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

59.826688557167984

extending\_thermal\_generator\_cost

[0.0722000347599704, 0.03571048502975728, 0.0, 0.0, 0.010124827728168065, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.11803534751789575

renewable\_generator\_cost

[3.344634559553602, 3.1211765240101896, 2.916432865345682, 5.457003558698201, 2.0160039848552382, 1.7540846371759595, 1.5504811526857452, 1.3650369594873457, 1.1964665740644014, 1.0435703475312814, 2.2631331930856367, 0.0, 0.0, 0.0, 0.0]

26.028024356493283

extending\_renewable\_generator\_cost

[0.0, 0.0, 0.0, 0.007140727466949403, 0.0, 0.037641145005530646, 0.005878148909073299, 0.011027714530385677, 0.010355316820302529, 0.009733735882339672, 0.036632622303479516, 0.059157676622144696, 0.09427463834035368, 0.037711900999857495, 0.019668640625635128]

0.3292222675060517

storage\_investment\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

penalty\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

>>> m.obj.expr()

268.3337488928969

experiment

change carbon tax to 0. Solve CLL’s model for 15 years. No renewables are built. Thermal capacity keep increasing. Objective almost decreases by half.

1.3216017187e+02

variable\_operating\_cost

[8.582967531254157, 8.271350249361896, 7.915682689669724, 7.388810787767272, 7.063452946411977, 6.736797109614607, 6.523692806588799, 6.285675533150278, 6.118470043230724, 5.903447462761495, 5.723884596192004, 5.555610865046141, 5.388717333403417, 5.238844611908194, 5.039424944369209]

97.7368295107299

fixed\_operating\_cost

[2.220376926837, 2.100640422740776, 1.9873608540593903, 1.8801900227619592, 1.7901859706822354, 1.7059848661865726, 1.6258225309635161, 1.5495015864475032, 1.4768344673651674, 1.407642926330895, 1.3417575637830745, 1.274249984131357, 1.2101855969822548, 1.149386747784454, 1.0916850358067396]

23.811805502862896

startup\_cost

[0.007600315170020134, 0.00789246013642603, 0.006734199826896043, 0.005809761328206789, 0.005829974419391543, 0.005683044948982581, 0.0054135633977514044, 0.0046947693658683206, 0.003720867946071918, 0.003440532745572705, 0.0033955146719450518, 0.003200667269554677, 0.002644288276690965, 0.0025771548581397003, 0.002941228353331995]

0.07157834271484985

thermal\_generator\_cost

[0.0, 0.0, 0.0, 0.0, 1.039924210046971, 1.1027728814176891, 1.031473754390458, 0.9663903817543358, 0.903858846632968, 0.8438657088688801, 0.7862505823804496, 0.6191900569466214, 0.5700040594837112, 0.5244874583615279, 0.4813198016448645]

8.869537741928475

extending\_thermal\_generator\_cost

[0.3933761981860087, 0.04327650327488413, 0.013129056926889529, 0.012082126948832383, 0.14122426181963946, 0.2106869544498029, 0.05334385437828786, 0.0, 0.17745480499836042, 0.003868646976185884, 0.0, 0.06555793715349008, 0.05005632853338013, 0.0222747110891622, 0.1548671177980468]

1.3411985025329705

renewable\_generator\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

extending\_renewable\_generator\_cost

[0.0, 0.0, 0.0, 0.007140727466949403, 0.0, 0.037641145005530646, 0.005878148909073299, 0.011027714530385677, 0.010355316820302529, 0.009733735882339672, 0.036632622303479516, 0.059157676622144696, 0.09427463834035368, 0.037711900999857495, 0.019668640625635128]

0.3292222675060517

storage\_investment\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

penalty\_cost

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

0.0

renewable\_capacity

[3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994, 3479.57994]

52193.69910000002

thermal\_capacity

[75787.901, 75787.901, 75787.901, 75787.901, 76769.00193483468, 77892.48208108239, 79031.69094937755, 80186.84874182881, 81358.17874337442, 82545.90736494168, 83750.26418721088, 84971.48200499182, 86209.79687222173, 87465.44814759279, 88738.67854081915]

1212071.383568276

total\_capacity

[79267.48094, 79267.48094, 79267.48094, 79267.48094, 80248.58187483468, 81372.06202108238, 82511.27088937754, 83666.42868182881, 84837.75868337441, 86025.48730494168, 87229.84412721088, 88451.06194499182, 89689.37681222173, 90945.02808759279, 92218.25848081915]

1264265.0826682758