Modeling the impact of extreme summer drought on conventional and renewable generation capacity: methods and a case study on the Eastern U.S. power system

Hang Shuai[1], Fangxing Li[1] , Jinxiang Zhu[2], William Jerome Tingen II[1] , and Srijib Mukherjee[3]
[1] The University of Tennessee, Knoxville [2] Hitachi Energy [3] Oak Ridge National Laboratory

Natural Hazards Increasingly Threaten Power System Operation

- In the US, natural shocks account for the majority of outages at the national level.
- **Summer drought** frequently affects the western and southeastern United States.
- Future power grid should be planned and operated with careful consideration of the impacts of extreme summer weather events and climate change.

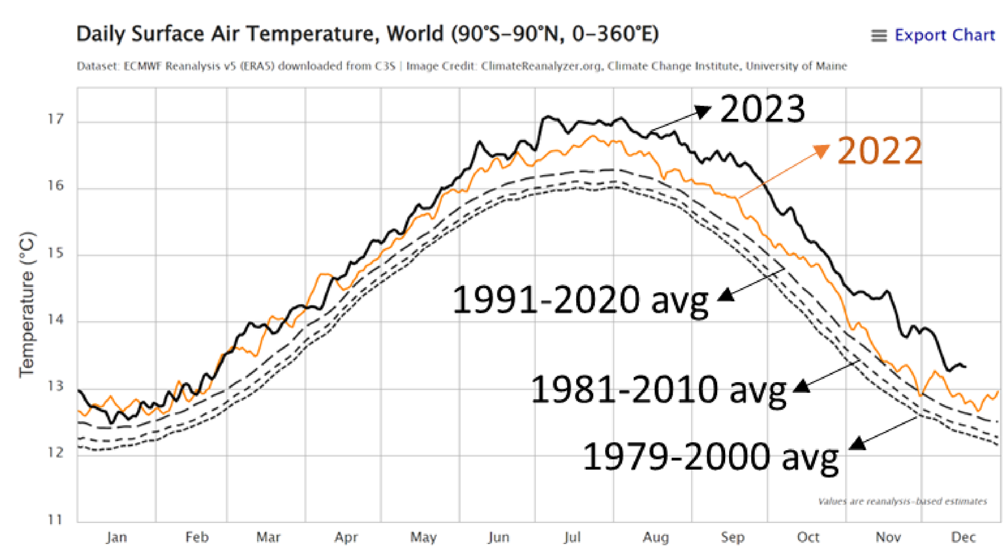

Fig. 1 Global air temperature in the past 40 years

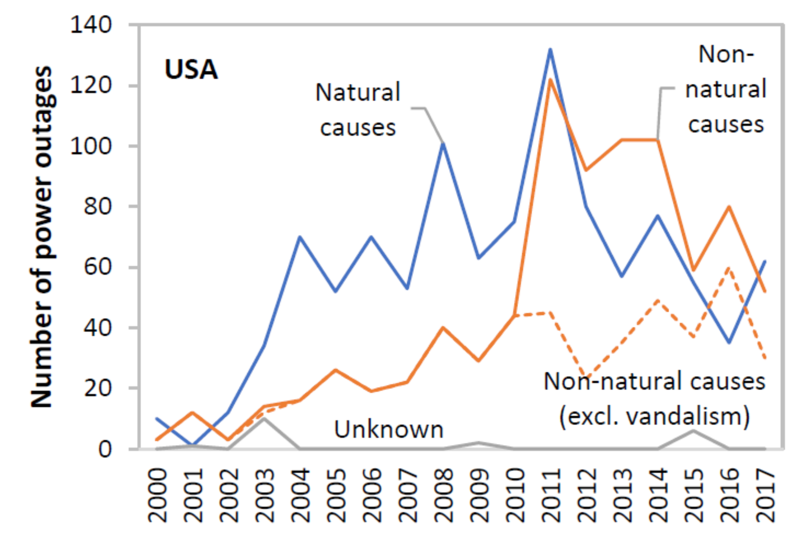

Fig. 2 Power outages in the USA caused by natural hazards

Modeling Impacts of Summer Drought on Generation Capacity

- Summer drought events affect the usable capacity of thermoelectric plants (with once-through cooling or recirculating cooling systems) using surface fresh water to cool the plant.

$$P_{on} = \frac{\min\left(\gamma Q_i, W_{on}\right)\cdot \rho_w \cdot C_{p,w} \cdot \max\left(\min\left(Tl_{max} - T_w,\ \triangle Tl_{max}\right), 0\right)}{\frac{1-\eta_{net,i}-k_{os}}{\eta_{net,i}}}$$

- Hydroelectric generation reduction is proportional to water flow decrease.

$$P_{h,i} = min\left\{\frac{\eta_{net,i}\cdot\rho_w\cdot Q_i\cdot g\cdot H_{net,i}}{1000000}, P_{n,i}\right\}$$

- Usable capacity of wind fleet is affected by available wind speed. Power output of PV panels is affected by solar irradiance and system conversion efficiency.

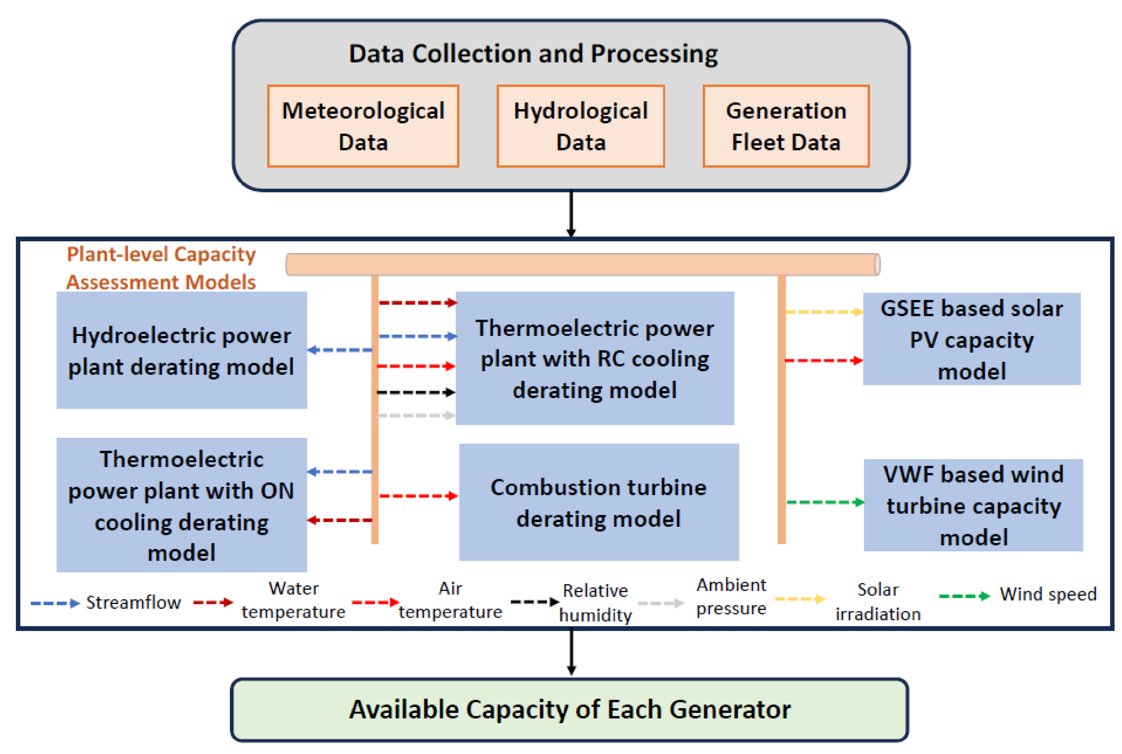

Fig. 3 Summer drought impact modeling framework

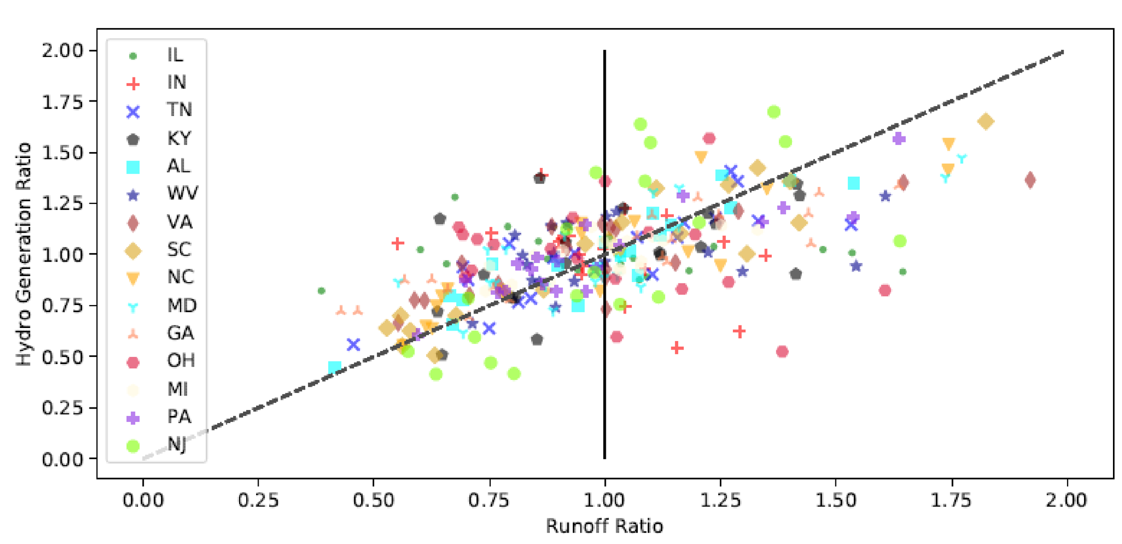

Fig. 4 Impact of streamflow on hydro generation

Case Study

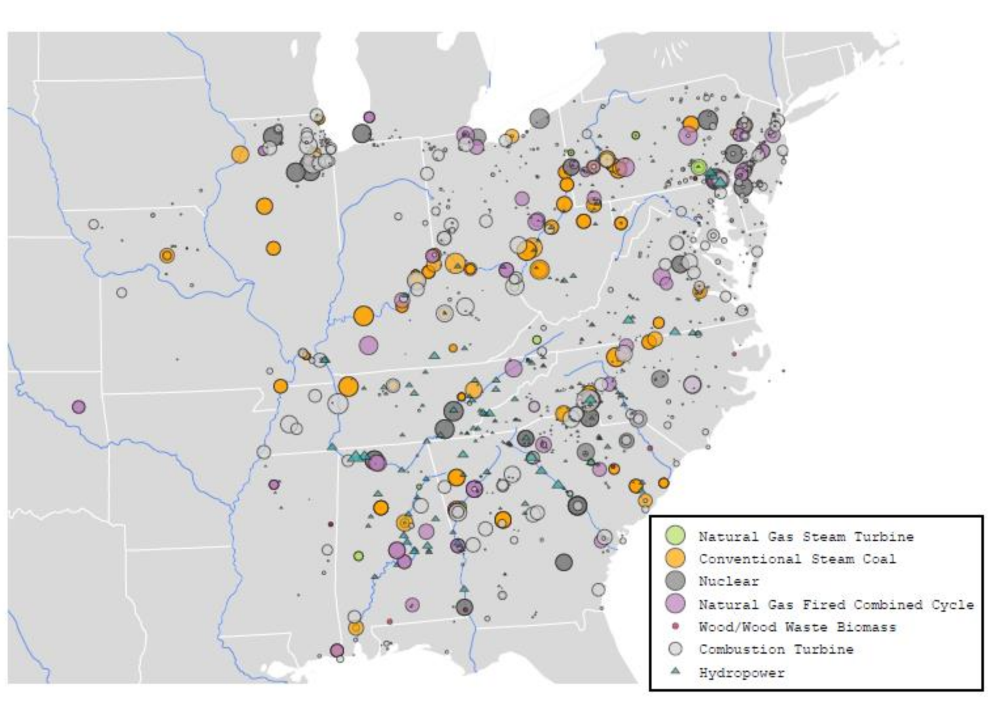

Fig.5 Locations of at-risk generators in the PJM and SERC regions by 2025

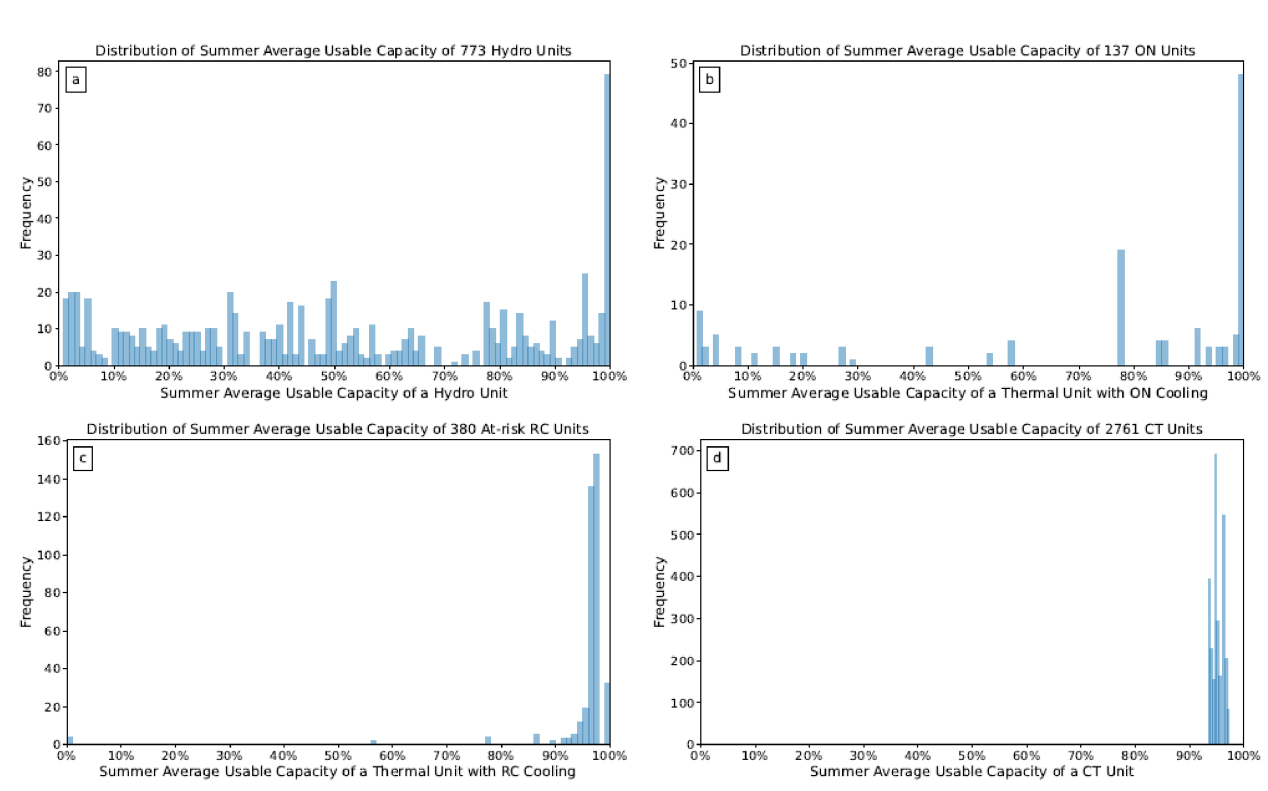

Fig. 6 Summer average usable capacity distribution of at-risk hydro and thermal generators under summer weather from 2006 to 2019

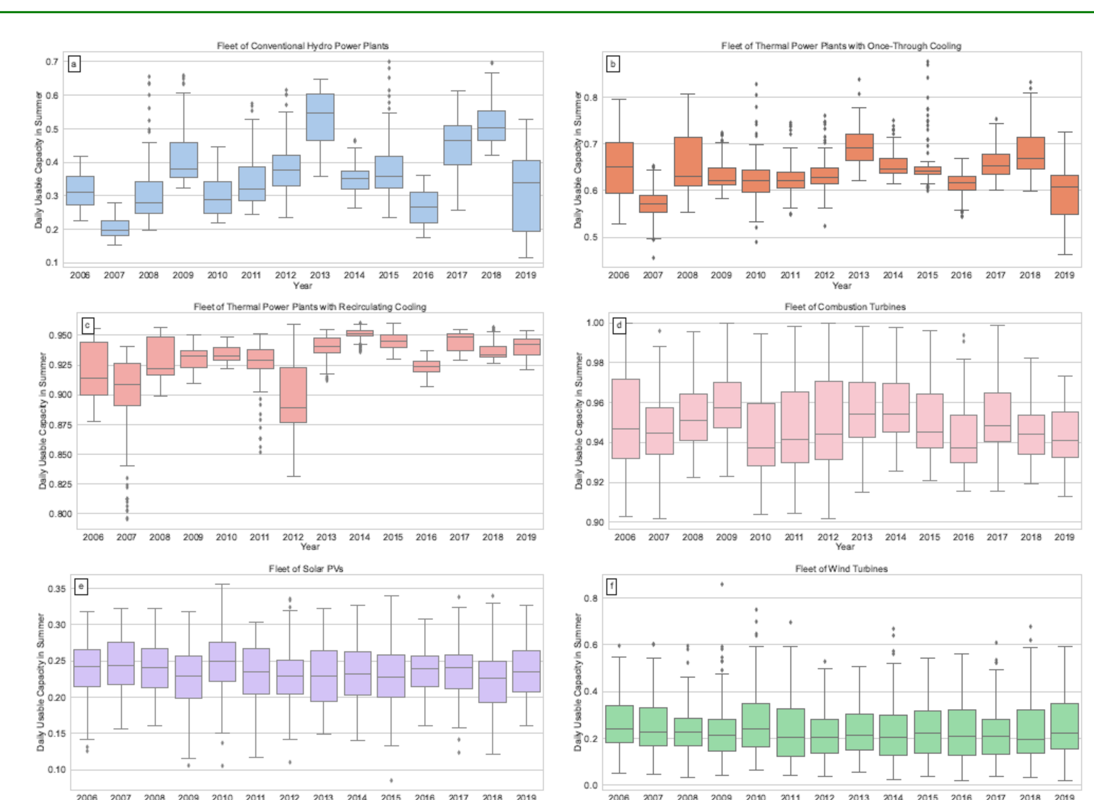

Fig. 7 Total usable capacity of different generation technologies in the 2025 PJM and SERC regions' generation fleet under historical summer conditions from 2006 to 2019

Conclusions

✓Available capacities of the hydro fleet and thermal fleet with once-through (ON) cooling systems could be significantly affected by hydrological conditions.

✓Impact of summer conditions on combustion turbines and thermal power plants with recirculating (RC) cooling is relatively minimal compared to hydro and ON cooling based thermal power plants.

✓If conditions similar to the extreme summer drought of 2007 were to recur in the near future, the generation fleet could face a significant decrease of approximately 8.5 GW in available capacity (median value) compared to a typical summer.