Designing Flexible Electric Generation Portfolios in Iowa

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Introduction

Iowa Electric Profile (2020 - Including Non-Utility Generation)

ELECTRIC GENERATION IN IOWA BY PRIMARY ENERGY SOURCE	2020 NAMEPLATE CAPACITY (MW)	PERCENT OF NAMEPLATE CAPACITY	2020 GENERATION (MWH)	PERCENT OF GENERATION
Coal	5,754.7	25.61%	14,146,835	23.72%
Wind	11,406.9	50.76%	34,182,302	57.32%
Nuclear	0.0	0.0%	2,904,863	4.87%
Natural Gas	4,215.0	18.76%	7,036,824	11.80%
Hydro	129.2	0.58%	1,025,215	1.72%
Other & Other Renewables	22.0	0.10%	207,440	0.35%
Petroleum	924.2	4.11%	111,111	0.19%
Solar	18.4	0.08%	22,082	0.04%
Total	22,470.4	100.00%	59,636,672	100.00%

https://iub.iowa.gov/iowas-electric-profile

Introduction

- Challenges in planning for the future:
  - Uncertainties
    - Demand
    - Costs (investment, fuel)
    - Requirements for using renewable sources
    - Future carbon emission limit
  - Need to make decisions at different stages

Flexible electric generation portfolio will provide a more reliable planning for the future

Problem description

- Decision variables: Choose capacity for each electricity technology at each stage
- Objective: Minimize total cost
  - Investment
  - Operations and maintenance
  - Cost of fuel generation
  - Salvage value
- Constraints
  - Capacity greater than demand
  - Power flow equations
  - Requirement that X% comes from renewable resources
  - Limit on carbon emissions
  - Limit on natural gas

} Uncertainties

D. Mejia-Giraldo and J. D. McCalley, “Maximizing future flexibility in electric generation portfolios,” *IEEE Transactions on Power Systems*, vol. 29, no. 1, pp. 279–288, 2014.

Related research

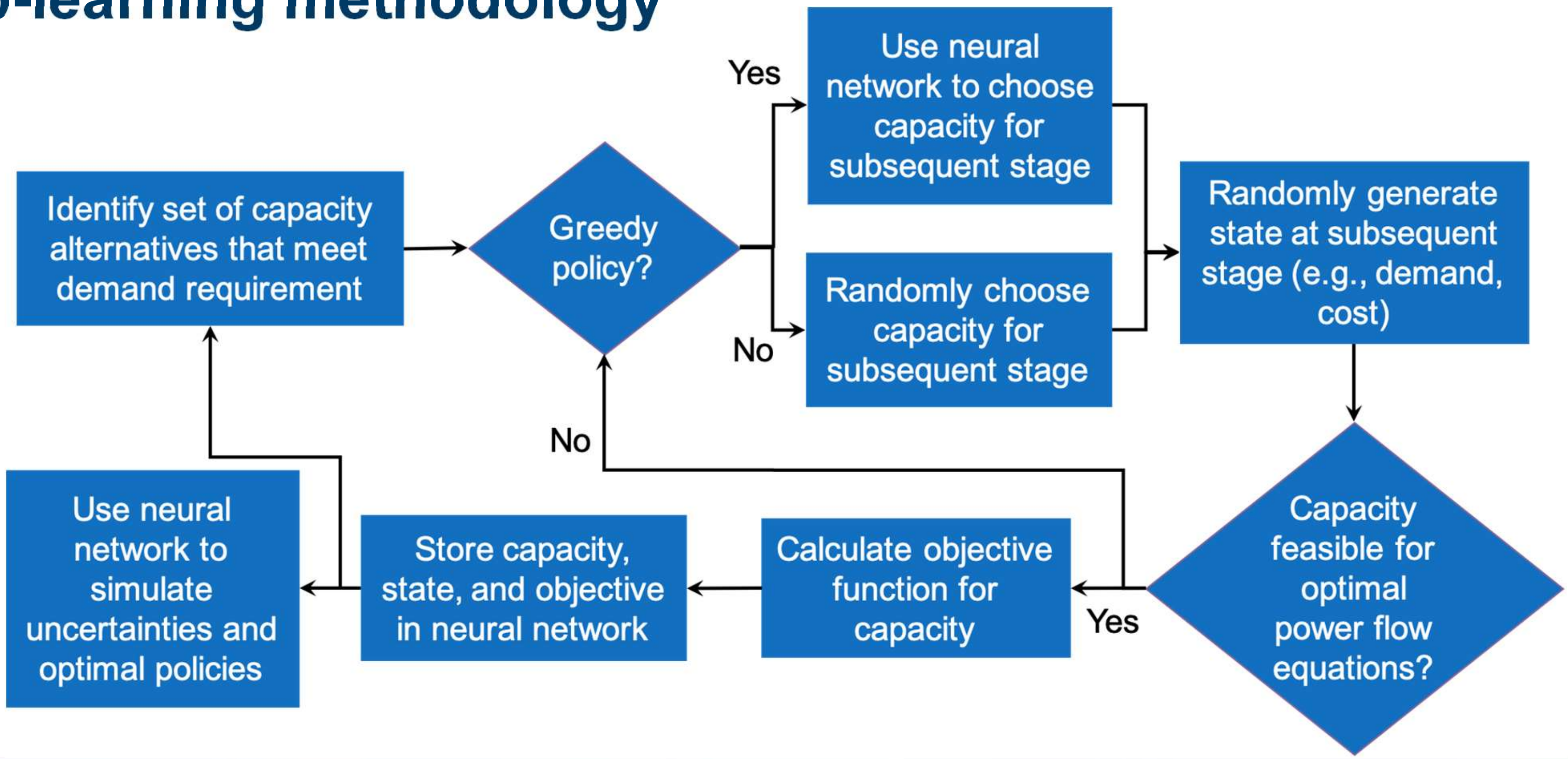
- Electric generation planning with uncertainty → Stochastic programming
  - Two-stage stochastic optimization
  - Multi-stage stochastic optimization
  - Large number of uncertain scenarios: scenario reduction methods
- Limitations:
  - The number of required scenarios needs to be decided
  - The selected scenarios might ignore the valuable information from eliminated scenarios.

Methodology

- **Deep reinforcement learning**
  – Provide the optimal generation planning for each simulated uncertain scenario using a learned neural network
  – The neural network is trained by the action and reward pairs
- **Myopic planning**
  – Decision making that focuses on optimizing for the current period
  – Combine the Monte Carlo simulation with myopic planning to generate long-term planning for electric generation.

R. Giahi, 2020. “Sequential decision making and simulation-optimization for the design of complex engineering systems.” PhD Dissertation, Iowa State University. https://lib.dr.iastate.edu/etd/18317/

Deep-learning methodology

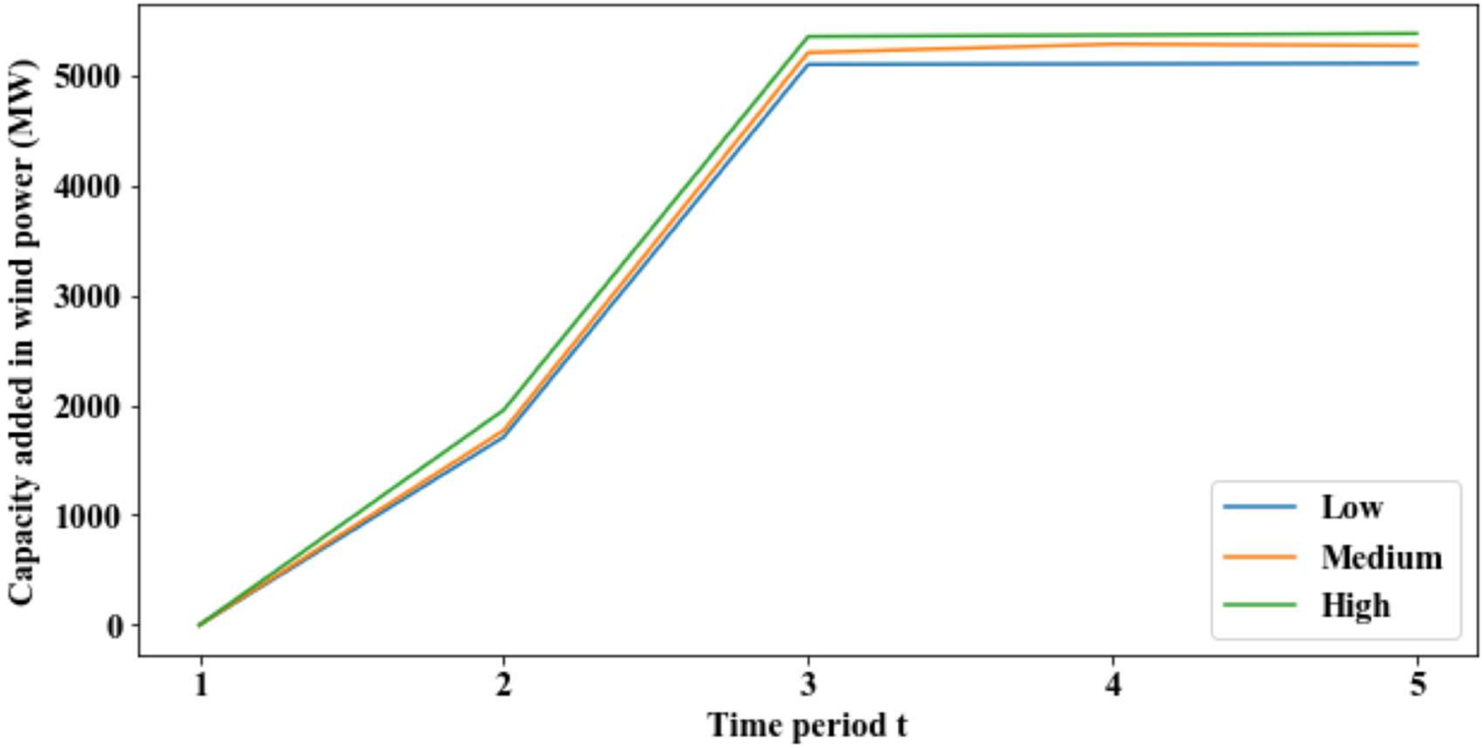


Application

- Planning horizon = 10 years = 5 periods
- Each period consists of 3 demand profiles
- Uncertainties:
  - investment in wind power
  - demand for each time period
  - renewable power source percentage
  - carbon emission limit
- For each uncertain parameter, 2 potential change rates are considered
- Assume that the fuel-based technology using coal and natural gas will need to retire in the next 10 years

Alternatives for electricity generation

Myopic planning results for the state of Iowa



Preliminary conclusions

- Wind energy is most cost-effective solution in Iowa for new generation sources
- Neural network in deep reinforcement learning (PyTorch)
  - Did not produce accurate results in a reasonable amount of time
  - Potential fixes
    - Adjust parameters in neutral network
    - Additional GPUs
    - Adjust algorithm to sample more intelligently

Future work

- More research needs understand the conditions when reinforcement learning provides more accurate results than myopic planning
- Include additional energy sources such as solar power and petroleum
- Additional complexity (e.g., time to install new generation)
- Additional constraints to reflect policy goals for renewable resources

- Acknowledgements
  - Iowa Energy Center (Solar and Wind Energy using Engineering Economics Theory, SWEEET, https://www.imse.iastate.edu/sweeet)
  - Diego Mejia-Giraldo for providing data file from his original study

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Q&A

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