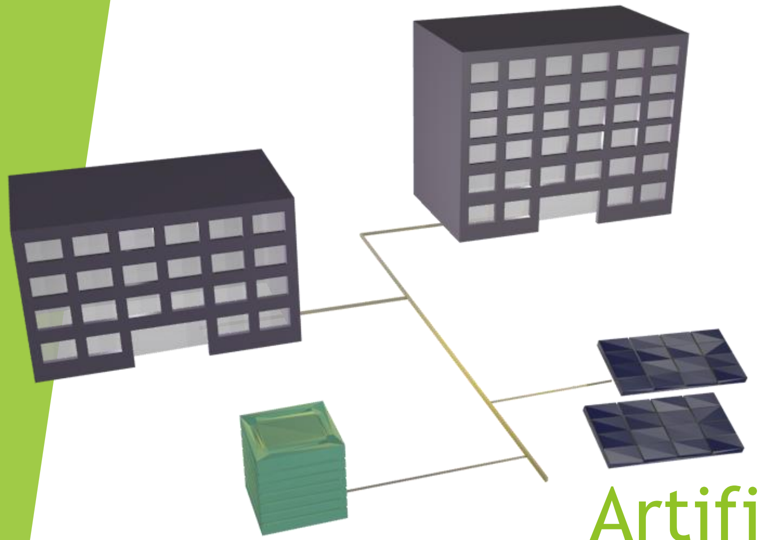

Artificial Neural Network Trained with Complementary Quadratic Programming for Realtime Unit Commitment and Microgrid Optimization Dispatch with CHP

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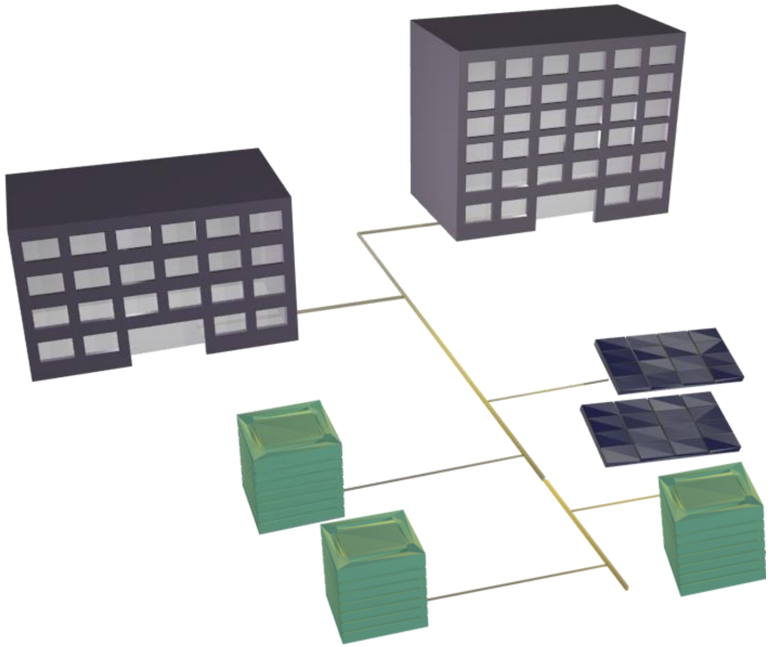
ANN trained with cQP for Realtime Unit Commitment and Microgrid Optimization

- Introduction of problem
- Review dispatch techniques
  - cQP techniques
  - ANN techniques
- Compare Artificial Neural Network results to complementary Quadratic Programming Results

Problem: Smart Grid Management



$$\sum Dem + Dem_{stor} = \sum Gen + Gen_{stor}$$

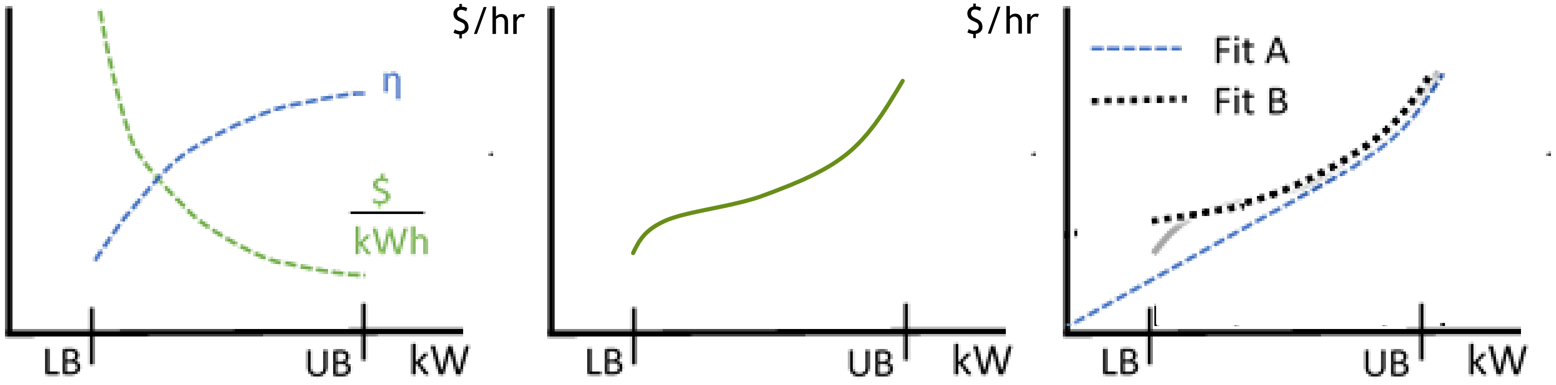
$$\sum Dem_E + Dem_{storE} = \sum Gen_E + Gen_{storE}$$

$$\sum Dem_C + Dem_{storC} = \sum Gen_C + Gen_{storC}$$

$$\sum Dem_H + Dem_{storH} = \sum Gen_H + Gen_{storH}$$

$$\min(Cost = \sum F_{cost}(Gen))$$

Problem: Mixed Integer Optimization Problem



- Zero intercept fit (Fit A)
  - Allows generator to shutdown/start up
- Non-Zero intercept fit (Fit B)
  - More accurate fit

Discontinuous lower bound → On/Off Decision → Unit Commitment

Problem: Economic dispatch requires solving unit commitment

- Generators:
  - Non-zero lower limit on power output
  - Non-linear efficiency curves
  - CHP use

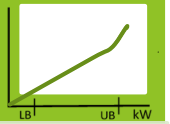
- Energy Storage:
  - Optimal use requires dispatch planning over the entire horizon
- Generators:
  - Startup Costs require evaluation over entire horizon

$$Number\ of\ Dispatches\ to\ Check = 2^{(number\ of\ generators)(number\ of\ timesteps)}$$

- To find minimal dispatch cost, must run an economic dispatch for all combinations of generators (off/on) at all timesteps

Complementary QP Technique Overview

Zero-Intercept Optimization

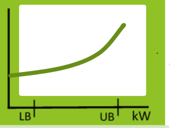


1 optimization	Estimate Storage Dispatch

Unit Commitment

nS x 2^(nG) optimizations	Finds optimal combination at each step for unit commitment over the horizon

Non-Zero-Intercept Optimization



1 optimization	Full Generator and Storage unit commitment and dispatch

Artificial Neural Network fundamentals

- Sorting
- Pattern recognition
- Image processing
- Training
  - Synapse connections “strengthen” until desired output is produced

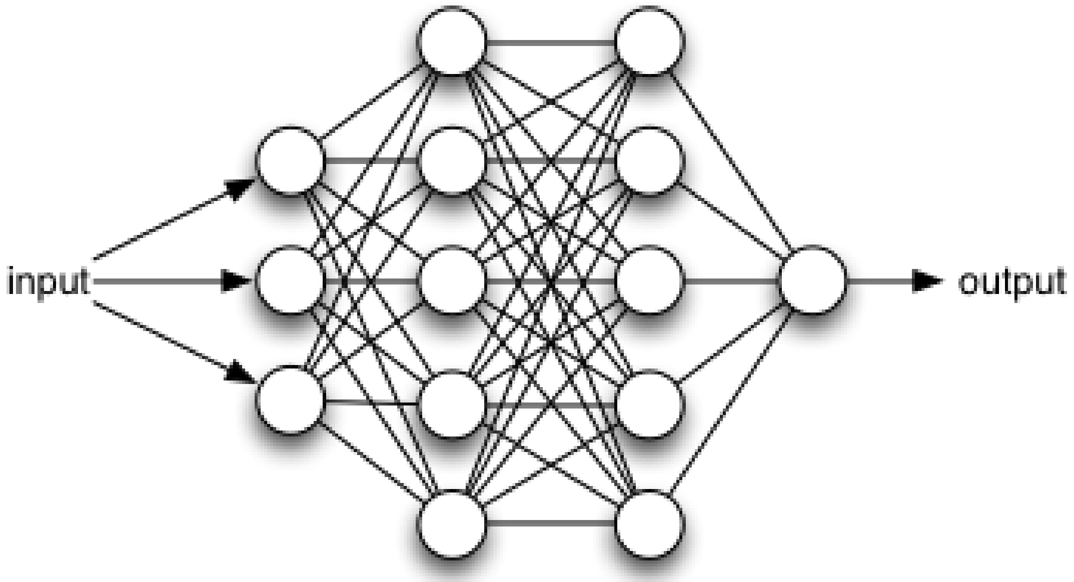


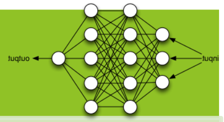
Image from:
http://briandolhansky.com/blog/2013/9/27/artificial-neural-networks-backpropagation-part-4

ANN Technique

cQP for historical data

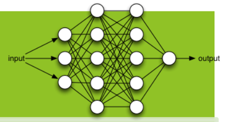
Length of historical data x {nS x 2^(nG)}	Create a training set of optimal dispatches

Train Network



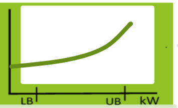
1 optimization	Create single layer ANN for unit commitment

Use Trained Network



1 matrix multiplication	Finds optimal combination at each step for unit commitment over the horizon

Non-Zero-Intercept Optimization



1 optimization	Full Generator and Storage unit commitment and dispatch

Comparison of ANN and cQP

Complimentary Quadratic Programming	Artificial Neural Network
▶ Dispatch computational demand increases as nS*2^(number of generators) ▶ Evaluates entire search space ▶ No training data required	▶ High computational efficiency ▶ 1 time through network ▶ Simple ANN can be used for unit commitment ▶ Training data required

Test Setup: Campus Microgrid

Electric

- 1 Internal Combustion

Engine

- 1 Microturbine

Heat

- Waste heat from ICE
- Waste heat from mGT
- 1 Hot Water Tank (storage)

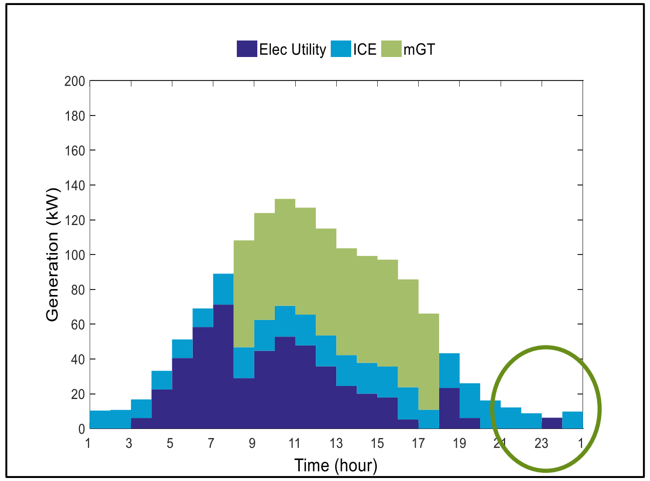
Grid Connection

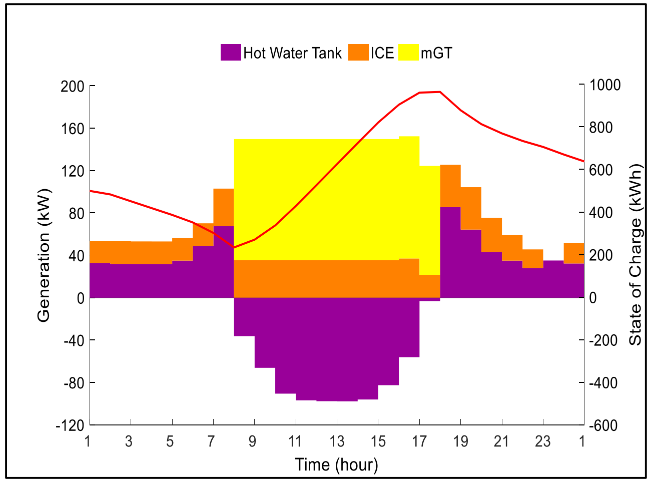
- Electric Utility with time of use pricing
- Gas Utility with flat rate pricing

Dispatch Comparison

cQP: 0.8813 s/dispatch

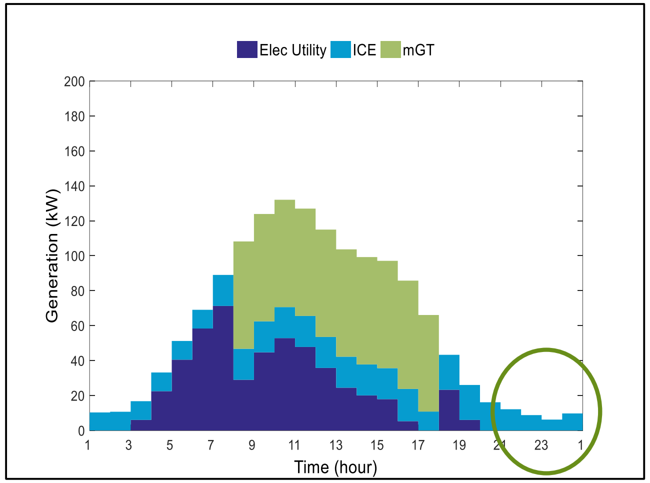
cQP Computational demand increases as:
nSx2^nG= 24x2^(2)
= 96

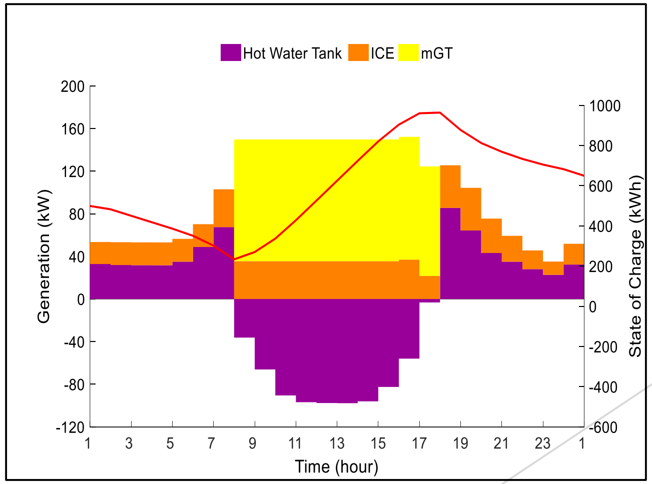




ANN: 0.0392 s/dispatch

ANN Computational demand remains the same regardless of number of generators:
1 time through ANN





Test Setup of larger grid: Campus Microgrid

Electric

- 2 CHP Fuel Cells
- 2 CHP microturbines
- 1 non-CHP microturbine
- 1 Diesel Generator
- 1 Battery
- 1 Solar PV Array

Cooling/Heat

- 3 Chillers
- 1 Absorption Chiller
- 1 Cold Water Tank (storage)
- 1 Heater
- 1 Hot Water Tank (storage)

Grid Connection

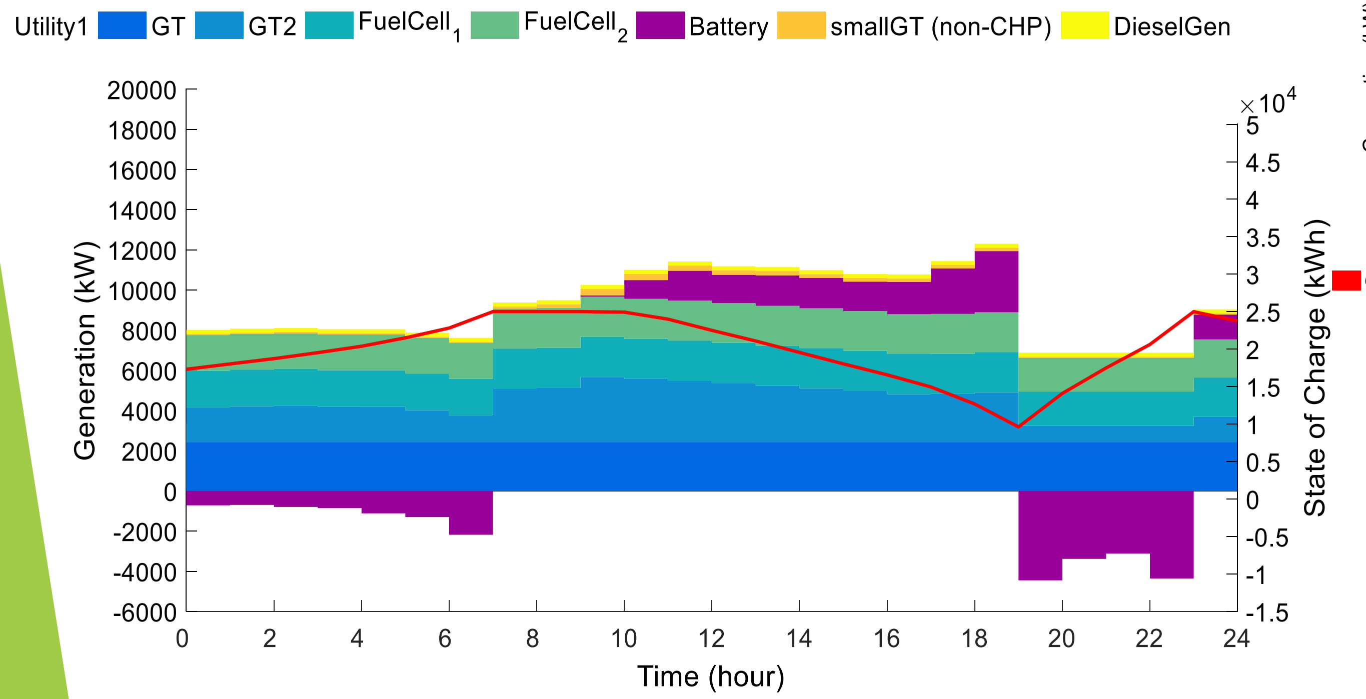
- Electric Utility with time of use pricing
- Gas Utility with flat rate pricing

Dispatch Comparison

cQP: 16.2207 s/dispatch

cQP Computational demand increases as:
nS x 2^(nG) = 24 x 2^(6) x 2^(4)
= 24576

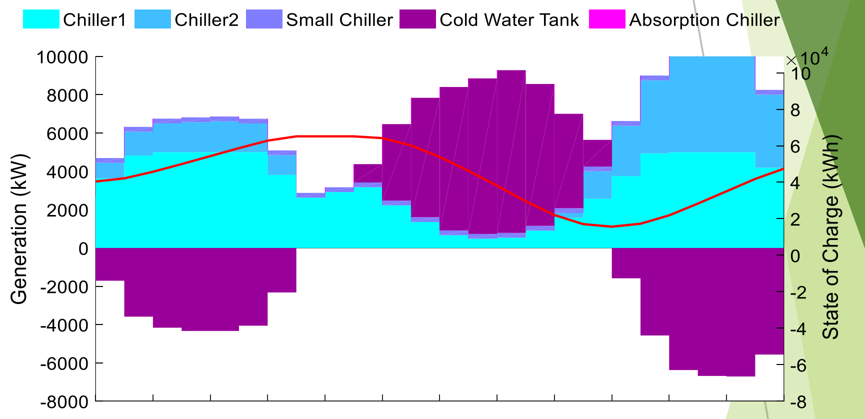
Standard deviation: 0.1785 sec

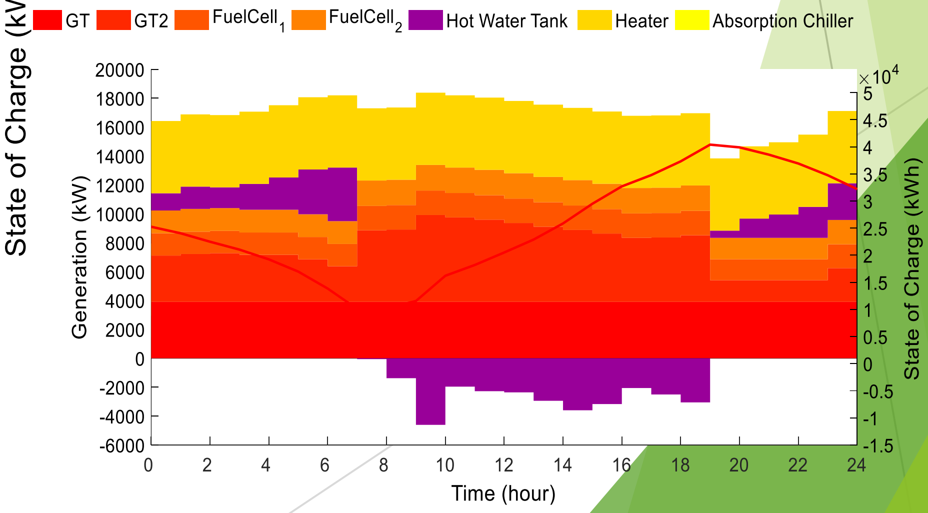


ANN: 0.03809 s/dispatch

ANN Computational demand remains the same regardless of number of generators:
1 time through ANN

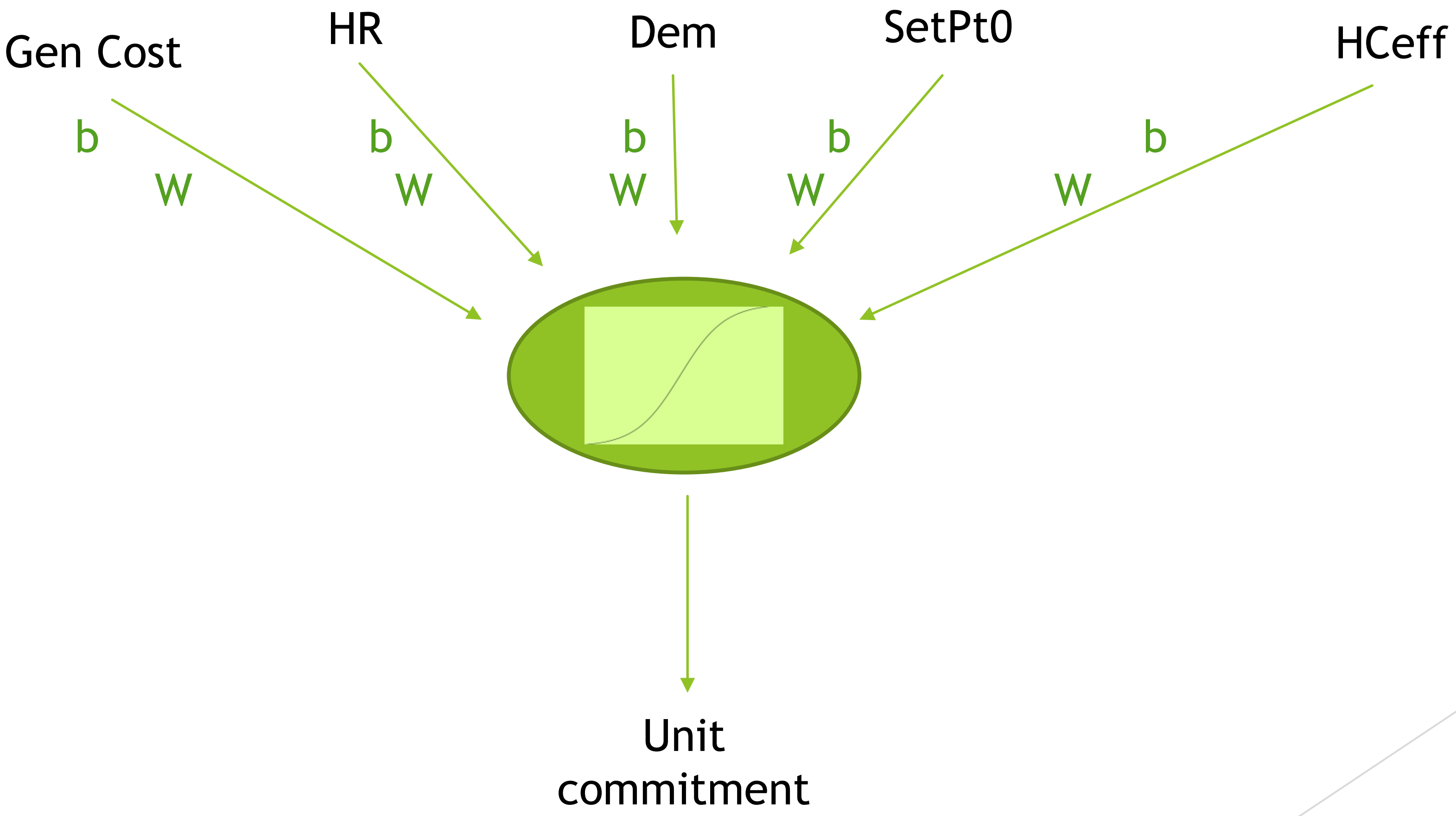
Standard deviation: .0501 sec





ANN Structure and Training

Zero Intercept Optimiztaion(SetPt0): component setpoints over entire horizon given by the zero-intercept fit optimization



Conclusion

- ANN Techniques can replicate and improve upon conventional unit commitment techniques
- ANN Techniques have potential for expansion to include dispatch as well as unit commitment further reducing computational demand
- ANN Techniques have potential for expansion to include non-linear demand relationships such as active-reactive power

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Potential Expansion of ANN

- Current ANN is very simple
- Multilayered ANN could be used for unit commitment and dispatch
- Change from 3 steps, to 1 step
- Active-Reactive Power and other non-linear relationships