The Value of Flexible Generation in ERCOT with High Renewable Penetration

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Overview (1)

Higher levels of variable renewables (wind and solar) require greater flexibility in the remainder of the system.

Natural gas generation can provide that flexibility.

Three natural gas generation technologies that are available today:

- Frame gas turbines (in simple- or combined-cycle configurations).
- Aero-derivative gas turbines.
- Reciprocating engines.

In addition to natural gas technologies, storage, and some types of demand response can also provide needed system flexibility.

Overview (2)

This study will address system costs and investment-level metrics when new combined cycle units are added to meet demand versus adding a mix of combined cycle units and reciprocating engines.

For this analysis we used Polaris Systems Optimization, Inc.'s *Power System Optimizer* (PSO) model running on the Newton Energy Group's pCloudAnalytics modeling environment.

The results presented here are preliminary. The analysis is ongoing and final results will be reported in the near future.

Prior Brattle Analysis of ERCOT

In 2013 and 2014[1] we completed two studies of the future of the ERCOT electricity marketplace through 2032 on behalf of the Texas Clean Energy Coalition (TCEC).

These studies investigated how renewable and gas-fired resources would develop in the next two decades under different assumptions.

We found that natural gas and renewable additions dominate the supply picture, with gas providing both energy and ancillary services that integrate wind and solar energy.

We did not model reciprocating engines in these studies. In this study we explore the role of reciprocating engines as part of the future ERCOT supply mix.

The TCEC studies used the PSO model.

[1] http://www.texascleanenergy.org/TCEC_Report%20Final%20Clean%2012%203%2013.pdf

http://www.texascleanenergy.org/TCEC%20Press%20Release%20on%20Brattle%20report%20FINAL%2011%20June%202013.pdf

The PSO Model

PSO is a unit commitment and dispatch model that is designed to simulate the set of decisions that are made in a market over time, and can be tailored to any market design.

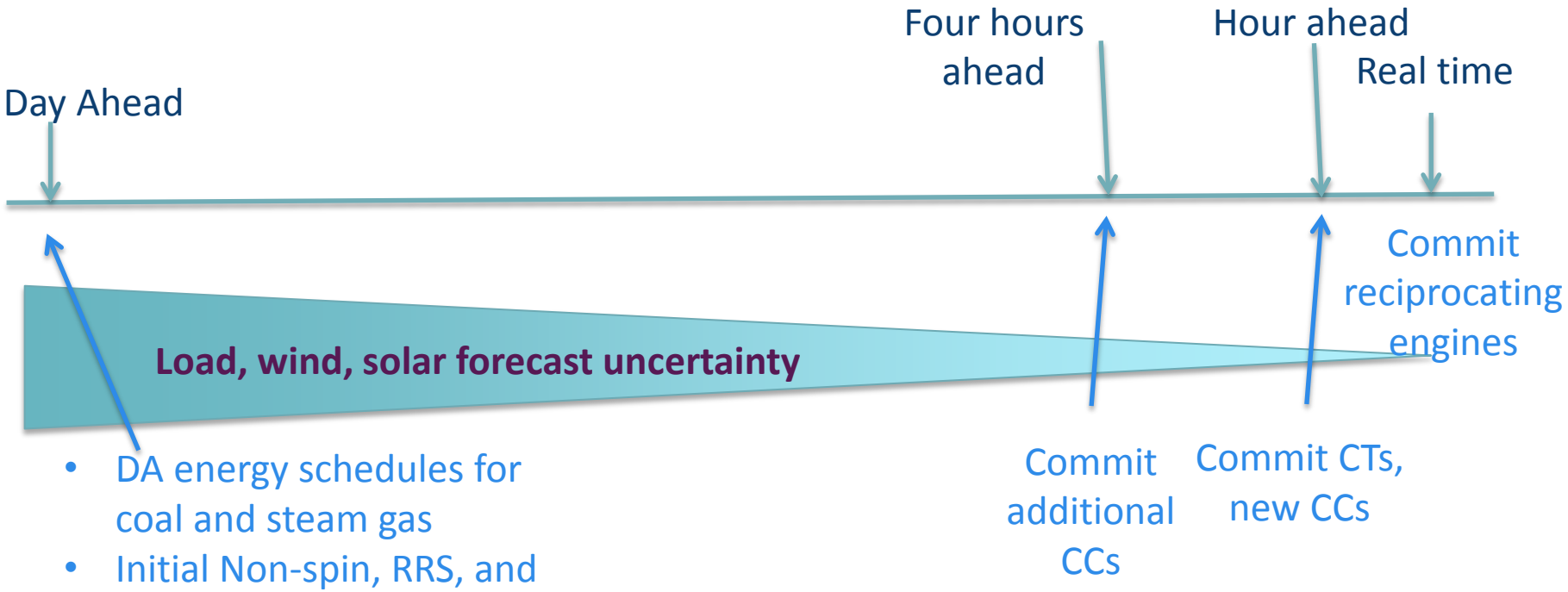
PSO makes it possible to simulate the dynamic operation of real markets. Most models do not do this and therefore cannot capture the value of flexible generation like reciprocating engines.

The Newton Energy Group has developed a cloud-based environment that makes it possible to run PSO studies efficiently.

- Since PSO is a chronological model, a run can be subdivided into time periods (a common strategy for solving these types of models).
- The Newton Energy Group's pCloudAnalytics modeling environment allows the user to divide a run into as many time periods as desired, sets up cloud-based machines, and reassembles the output.
- This permits the user to run any number of desired scenarios simultaneously and quickly.

Modeling the ERCOT Market Using PSO

We modeled multi-level, nested time intervals with a simultaneous optimization of energy and ancillary services dispatch, in an uncertain operational environment.



Natural Gas Technology Characteristics

Technology	Ramp rate	Start Time	Minimum Load	Start Cost	Efficiency	Capital Cost
Frame Simple Cycle	Moderate	Slow	Moderate	High	Low	Low
Frame Combined Cycle	Moderate	Slow	Moderate	High	High	High
Aeroderivative	Fast	Moderate	Moderate	None	Moderate	Moderate
Reciprocating Engines	Very Fast	Very Fast	Low	None	Moderate	Moderate

Frame and aero technologies are most cost effective in large sizes (200 MW for frame CT; 600 MW for frame CC; and 100 MW for aero).

Reciprocating engines are 8-18 MW each, and are combined into plants with multiple independently operated engines.

- Pearsall in ERCOT has 210 MW in 24 x 8.7 MW Wärtsilä engines.
- Red Gate in ERCOT has 221 MW in 12 x 18.4 MW Wärtsilä engines.
- PGE Port Westward has about 221 MW in 12 X 18.4 MW Wärtsilä engines.

Wärtsilä will soon have a total of 2.7 GW installed in the US.

Engine Operation

Each engine in a multi-engine plant like Port Westward can be operated independently.

- Independent operation provides flexibility, high reliability, it also provides efficient operation of the overall plant.
- For example, to produce 100 MW, six engines could be operated at nearly full output with a heat rate of about 8,200 Btu/kWh. A 7F5 simple cycle turbine would have a heat rate of 13,000 Btu/kWh at 100 MW.

Because of the short start up times and rapid ramp rates, ERCOT deploys engines in real time.

In our study we represent engines as individual units to reflect the way they actually operate in ERCOT.

Study Design

For this study we began with a TCEC 2022 case:

- We modified the coal retirements to make them consistent with the EPA's 2014 IPM analysis of the CPP (Option1 State), retiring about 8.9 GW of existing coal.
- We specified renewable penetration consistent with current renewable trends in ERCOT: about 10 GW of solar PV and 24 GW of wind, or about 28% variable resources by generation.
- We used natural has prices consistent with the Energy Information Administration Annual Energy Outlook 2015 Reverence Case, which will also be used for the new ERCOT Long-Term Supply Assessment (about $5.25/MMBtu in 2015 dollars).

Base Case

We added about 10,200 MW of modern flexible F-class CCs (sixteen 639 MW nameplate units; 8,900 MW) to achieve a 13.5% reserve margin.

- 13.5% is the equilibrium reserve margin that the current energy-only market design is likely to achieve,[2] taking ERCOT's more recent summer reserve margin contribution values for wind:
  - 12% non-coastal wind.
  - 56% coastal wind.

[2] http://www.brattle.com/news-and-knowledge/news/brattle-economists-analyze-economically-optimal-planning-reserve-margin-for-texas-power-market

Scenario Specifications

Replace CC units with reciprocating engines to maintain a 13.5% reserve margin:

- 2000 MW Engine Case: Replace three CC units (1,917 MW nameplate; 1,671 MW summer capacity) with 91 x 18.4 MW engines.
- 2000 MW CT Case: Replace three CC units (1,917 MW nameplate; 1,671 MW summer capacity) with 9 x 210 MW CT units.

Capital Costs

Wartsila engine plants cost less per kW than CCs (about $850/kW vs $1,000/kW) on a nameplate basis, and cost significantly less in aggregate to serve the same summer load.

- 1,917 MW of CC capacity requires an investment of $1.92 billion vs $1.42 billion for engines that have the same summer capacity, or about half a billion dollars less.
- Per summer kW, engines are $850/kW while CCs cost $1,140/kW.

Preliminary Results – Discussion (1)

The addition of some engines instead of CC units lowers production costs and increases the efficiency of CC operation.

- Total production cost goes down.
- CC uplift goes down reflecting more efficient operations of the CC fleet.
- CC starts go down.
- CC capacity factors go up slightly.

Engine capacity factors are about 15-20% but are producing power for about 3,000 hours, and start about 2,000 times per year

During many hours, engines are also providing ancillary services.

Preliminary Results – Discussion (2)

To understand the differences in system performance impacts between engines and simple cycle units, we are investigating replacing 2,000 MW of CCs with 2,000 MW of CTs (instead of 2,000 MW of engines).

Initial results show limited benefit of simple cycle CT additions because they run at low capacity factors and have little benefit to overall generation fleet flexibility.

Next Steps

We will complete this study and prepare a white paper that will be available in the next two to three months.

The white paper will include a full set of results including investment-level metrics.

We plan a webinar to present the results.

Acknowledgement

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New Gas Unit Cost and Performance Parameters

	Configuration	Nameplate Capacity (MW)	Heat rate (Btu /kWh)	Min load (%)	VOM ($/MWh)	FOM ($/kW)	Startup cost ($/MW)	Startup time (minutes)	Ramp rate (MW/min)	Min up time	Min down time	Capital Cost ($/kW)
Combined Cycle (7F5)	2x1	639	7010	50.0%	2.00	14.9	45	60	50	4 hours	4 hours	1000
Frame CT (7F5)	N/A	236	10000	40.0%	1.00	7.1	65	10	50	1 hour	2 hours	650
Wartsila Reciprocating Engine	18V50SG	18.4	8072	20.0%	3.50	7.0	0	5	80% per min	10 mins	10 mins	850

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