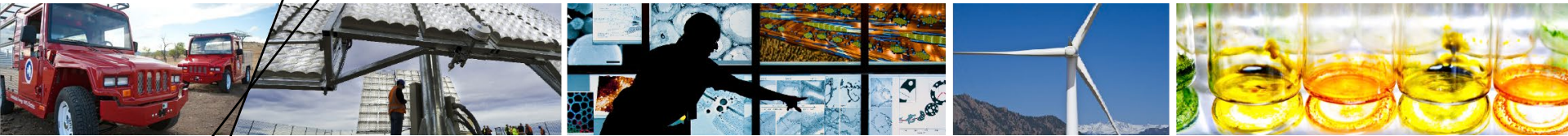


A Systematic Approach to Better Understanding Integration Costs



Gregory B. Stark, P.E.
National Renewable Energy Laboratory
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Integration Costs: Overview

- **Introduction**
- **Integration costs definition**
- **Study approach**
- **Results**
 - New generation effects
 - Operating parameters and self-scheduling effects
- **Conclusions**

Integration Costs: Three Questions

This work was sponsored by the Wind Program of the U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy to address three questions:

1. How does the addition of new generation affect a system's operating costs?
2. How do generation mix and operating parameters and procedures affect costs?
3. How does the amount of variable generation impact the accuracy of natural gas orders?

Integration Costs: Definition

Integration costs working definition:

- **The change in production costs associated with a system's ability to accommodate variability and uncertainty of the net load**

Two sources of variability and uncertainty:

- **Load**
- **Variable generation (VG)**

Four components of production costs:

- **Cycling costs**
- **Non-cycling VO&M costs**
- **Reserves provisioning costs**
- **Fuel costs**

Integration Costs: Study Approach

Study approach:

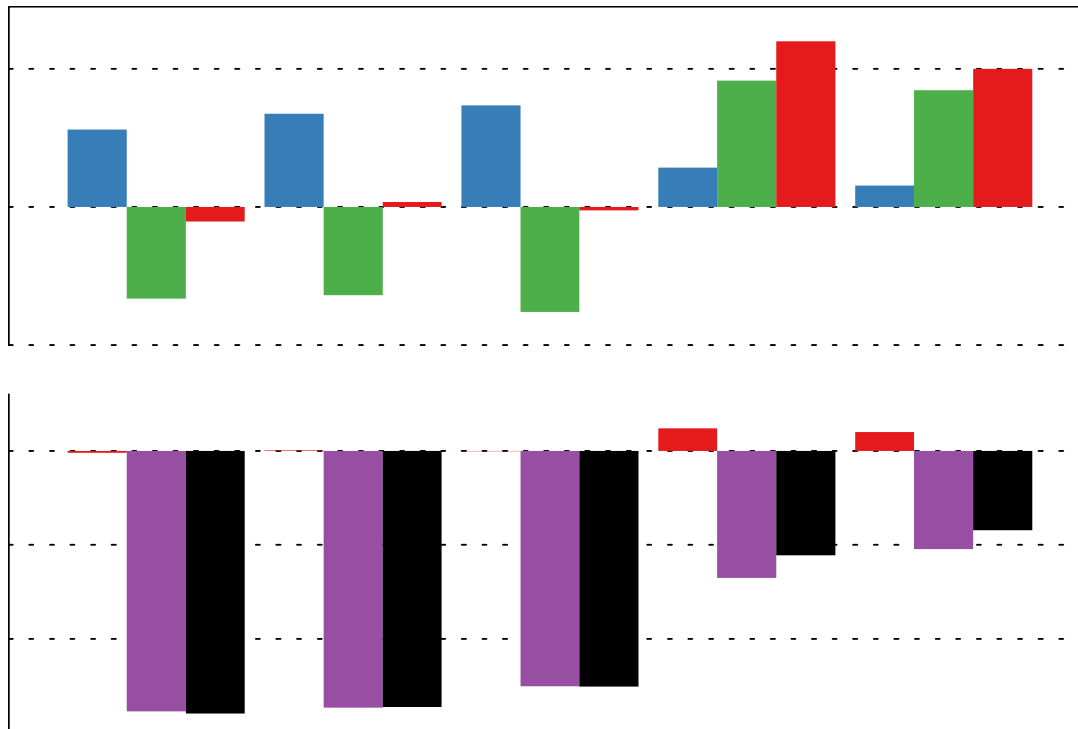
- Production cost modeling-based (DA, 4HA, & 5-min RT)
- Modified IEEE 118-bus overlaid with real loads:
 - Generation and transmission scaled by a factor of 2
 - Updated to 40% coal with sensitivities at 15% and 65% coal
 - 40% coal, 47% gas, 11% hydro, and 2% VG
 - Generator sizes ranged from 40 MW–840 MW, avg. size of 237 MW
 - Three regions: Avg. load: 7,324 MW; Peak load: 11,765 MW
 - Sacramento Municipal Utility District
 - Public Service Company of Colorado
 - Puget Sound Energy
 - Load & VG data: 2020, WECC and NREL supplied
- Designed in consultation with TRC to provide a reasonable approximation to an actual interconnection

Integration Costs: New Generation

Two types of new generation:

- **Additional variable generation**
 1. 10% VG
 2. 20% VG
 3. 40% VG
- **New coal baseload**
 1. 840-MW flexible generation
 2. 840-MW inflexible generation

New Generation: Operating Costs



ⁿ
an expanded scale
so that differences
are visible

New Generation: Cycling Cost Breakout

Increases (Decreases) in Cycling Costs per MWh of New Generation Added (\$/MWh New Generation):

Type	10% VG	20% VG	40% VG	Flexible Coal	Inflexible Coal
Coal	0.14	0.12	0.26	0.30	0.30
CC	0.49	0.52	0.30	0.15	(0.10)
CT Gas	0.43	0.57	0.75	0.08	0.09
Wt. Avg.	1.12	1.35	1.47	0.57	0.31

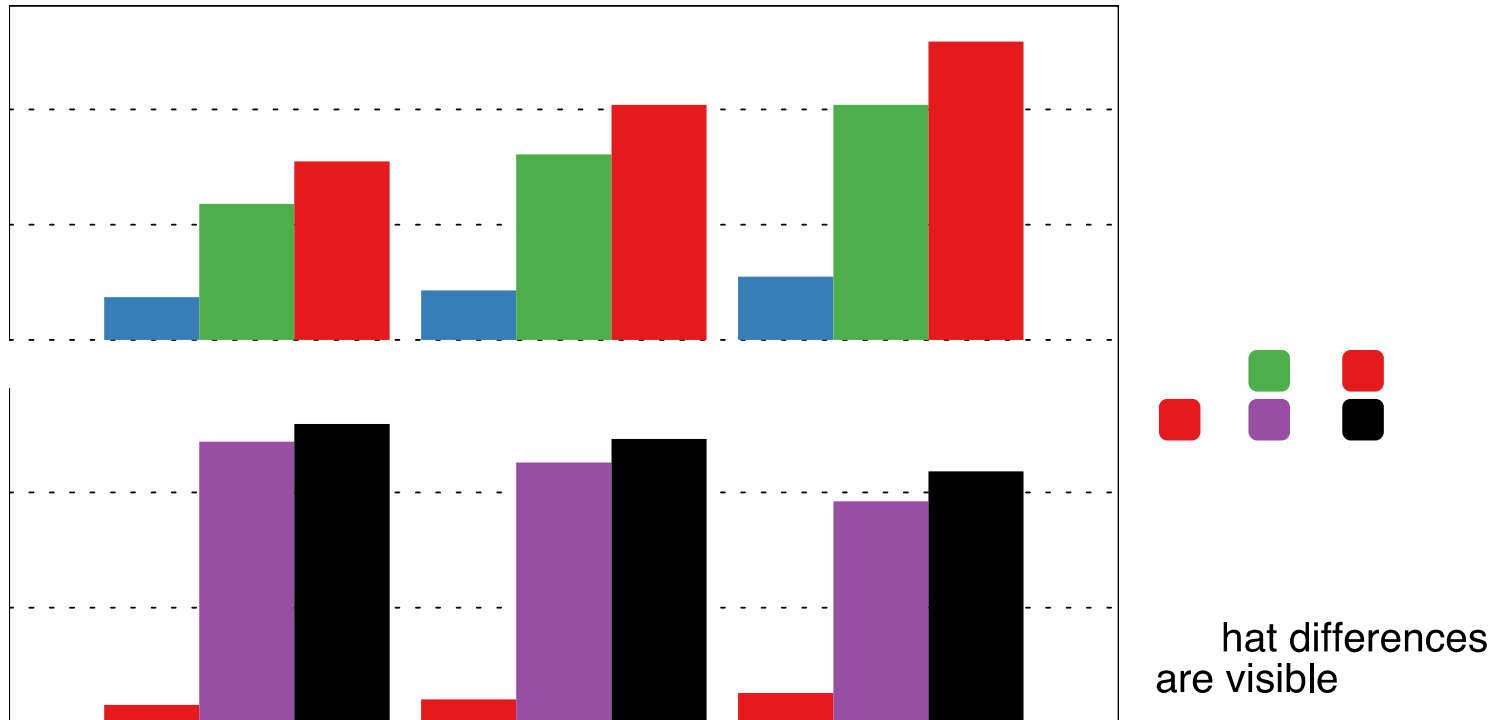
	Coal (\$/MWh)	CC (\$/MWh)	CT Gas (\$/MWh)	Wt. Avg. (\$/MWh)
Reference Cycling Costs	0.26	0.47	6.34	0.43

Integration Costs: Generation Mix

Three generation mixes:

- **15% Coal**
- **40% Coal (Reference)**
- **65% Coal**

Generation Mix: Operating Costs



Generation Mix: Cycling Cost Breakout

Average Cycling Costs by Generator Type (\$/MWh Delivered):

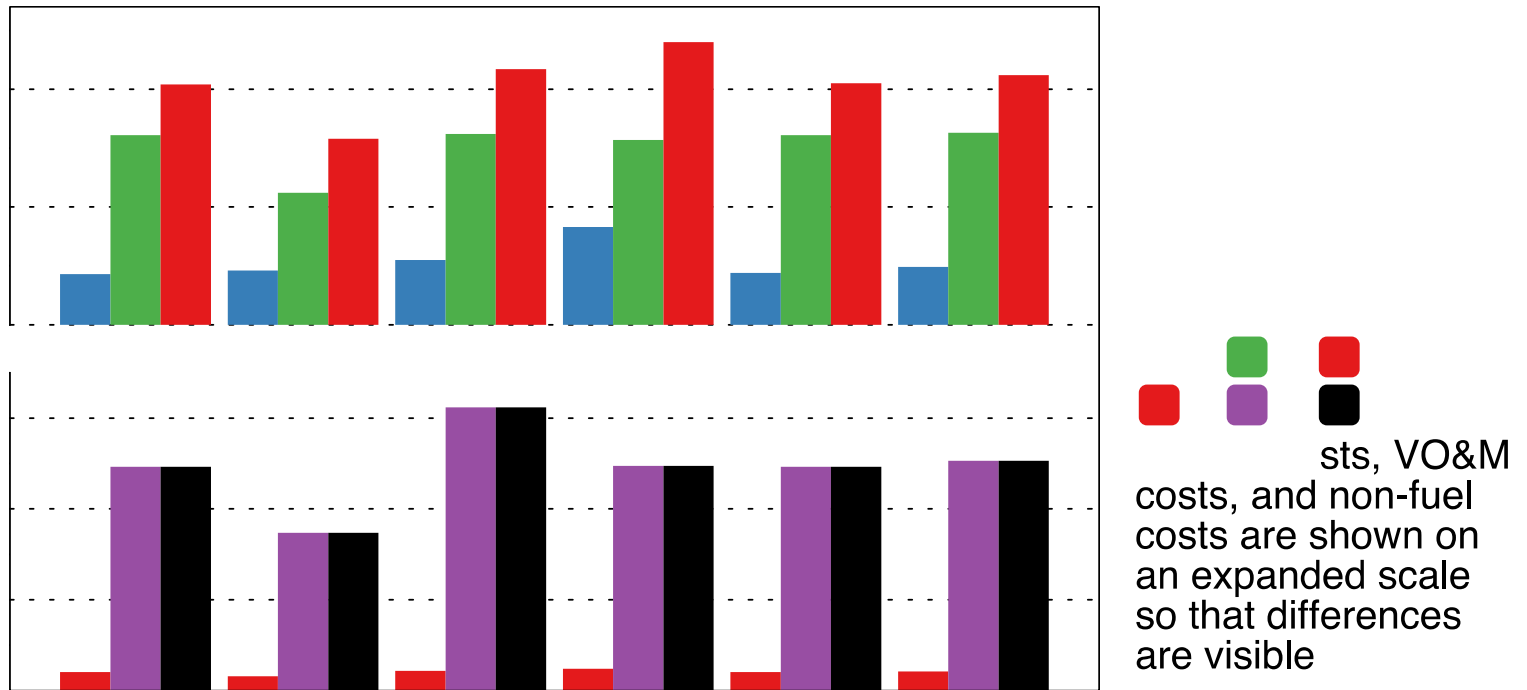
Type	40% Coal		
	15% Coal	(Reference)	65% Coal
Coal	0.22	0.26	0.29
CC	0.30	0.47	1.08
CT Gas	4.51	6.34	7.67
Wt. Avg.	0.37	0.43	0.55

Integration Costs: Operating Changes

Three types of operating changes:

- **Gas prices**
 - \$2.50/MMBtu, \$4.50/MMBtu, \$6.50/MMBtu
- **Fast-start generation**
 - 4-hr coal, 1-hr CC (reference: 24-hr coal, 4-hr CC)
- **Self-schedule**
 - Self-commit
 - Self-dispatch

Operating Changes: Operating Costs



Operating Changes: Cycling Cost Breakout

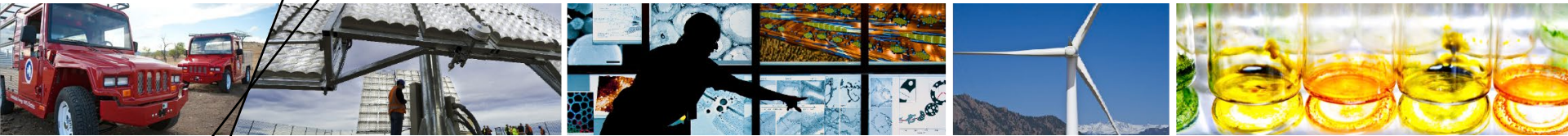
Average Cycling Costs by Generator Type (\$/MWh Delivered):

Type	Reference	Low Gas Price	High Gas Price	Fast-Start Generation	50% Self-Commit	50% Self-Dispatch
Coal	0.26	0.56	0.25	0.22	0.25	0.25
CC	0.47	0.28	0.69	1.03	0.49	0.61
CT Gas	6.34	5.68	7.60	99.98	6.62	2.54
Wt. Avg.	0.43	0.46	0.55	0.83	0.44	0.49

Integration Costs: Conclusions

- **New generation:**
 - Cycling costs increased with both additional VG and new baseload
 - \$1.12 to \$1.47 per MWh of new VG and \$0.31 to \$0.57 per MWh of new coal
 - Non-cycling VO&M costs decreased with additional VG and increased with new baseload
 - A decrease of \$1.28 to \$1.52 per MWh of additional VG and an increase of \$1.69 to \$1.83 per MWh of new baseload
 - The largest impact on coal cycling costs was new baseload
 - The largest impact on CC cycling costs was medium penetration VG
- **Generation mix**
 - Cycling costs increased with increasing coal penetrations (54% higher at 65% coal than at 15% coal)
 - Non-cycling VO&M costs increased with increasing coal penetrations (68% higher at 65% coal than at 15% coal)
- **Operational parameters and self-scheduling**
 - Self-scheduling increased both cycling (12% to 30%) and total generation (3%) costs

A Systematic Approach to Better Understanding Integration Costs



Thanks! Questions?

Gregory B. Stark, P.E.
greg.stark@nrel.gov

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