GE Energy Consulting: GE’s grid experts for >100 years

GE EXPERTS, OEM AGNOSTIC

GENERATION INTEGRATION
- voltage & frequency performance

TRANSMISSION STRATEGY
- complex plant interconnection

ECONOMIC ANALYSIS
- grid value of technology

- Interconnection support
- Grid code testing and compliance
- Stability studies
- Network risk assessment
- Grid reinforcements
- Renewables planning and strategy
- Financial modeling and forecasting

Models
- Power flow
  - GE PSLF*
- Transients
  - milliseconds
- GE technology
  - 1/3 earth’s power | #1 clean energy fleet

Software
- GE EXPERTS, OEM AGNOSTIC
- Energy
  - GE MAPS*
- Capacity
  - GE MARS*

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~130 grid experts
9 countries
>100 patents
Introduction

• Variable renewable energy growth is changing power system operations and dispatch patterns
  • RPS requirements, corporate policies, and favorable economics all contribute to renewable growth
• Hydro generation is often seen as a tool to balance variability from renewable generation
  • Pros: Hydro generators have low marginal costs, high ramp rates, no emissions, inertial response
  • Cons: Many restrictions on hydro systems, public safety, flood control, environmental limits, fish, erosion, recreational limits, etc.
  • Closed loop pumped storage provides the benefits of hydro while minimizing the environmental cons
• Interest in firm renewable energy that can help keep the system balanced is increasing
  • Intermittent plus storage or dispatchable renewables (hydro, geothermal, biomass, etc.)
Corporate customers are signing renewable PPA’s to cover their annual load

- Annual loads are increasingly covered by renewables PPA’s
- However in any hour loads could be served by non renewable resources
- Serving load in every hour with renewables requires firm renewable resources

"NV Energy has asked Nevada regulators for authority to procure 350 MW of solar generation and up to 280 MW of energy storage to serve a planned Google data center in Henderson"

Source: https://www.utilitydive.com/news/google-nv-energy-renewable-deal-one-of-the-largest-includes-rare-storage/570131/

"corporean clean energy purchases surged to 19.5 GW in 2019: BloombergNEF”


“Apple now globally powered by 100 percent renewable energy”

Storage and renewables

Example: Providing firm renewable energy with pumped storage and co-located wind and solar generation

• 400MW Advanced Pumped Storage with 8.5 hours storage and no natural inflow and no pumping from non renewables

• Plant has ~1GW transmission capability to the grid

The total renewable + pumped storage hydro is dispatched to try to meet a firm demand profile everyday
Objective:

• Examine the value the PSH provides to firming renewables

Method:

• Compare the optimal buildouts for renewables with and without the pumped storage
• The renewables and PSH are trying to serve a daily load profiles which repeats 365 days per year
• Use the same 97% annual firmness target in both cases
• *Firmness is the amount of load served by renewables + pumped storage divided by total load measured annually*
Firm Load Profiles

Load represents the firm contractual energy sales, profiles are quantified by their peak load

Load Profiles (MW)

Percent Annual Energy

- 100% Firm
- 100% Firm Peak
- 100% Firm Peak and 50% Firm Off Peak
Significantly more renewables are built without PSH

**Without PSH capacity built is 1.5-4x higher**

**Wind is heavily favored without PSH**
Without PSH renewables provide lower level of firmness

- Buildouts including PSH have a higher level of firmness across
  - Target 97% firmness
- Without PSH firmness is relatively constant
  - No ability to shift generation from saturated periods to unserved periods
Energy Cost

- Cost per MWh of energy is much higher from the no PSH case
  - The difference could be used to pay for the storage
- Without PSH $/MWh is flat at all loads and constant firmness levels
  - More firmness would have higher cost at all load levels
Energy Firmness Impact

- Changing energy target firmness greatly impacts the amount of renewable capacity built at higher firmness levels
- Below 80% firmness targets buildouts are very similar
- Above 90% firmness buildouts can be several multiples of lower buildouts
Load Profile Impacts on Energy Firmness

- Wind and solar can provide a high degree of firmness
  - Target level 97%
- Firmness of energy declines as load increases
- The firmness can be calibrated by the amount of generation built to balance economics
- Wind alone can provide nearly the same firmness as wind and solar together
  - Solar alone struggles to provide high levels of firmness
Wind and solar build outs are mostly balanced

Wind is favored at low and high levels

Solar is favored in mid range and peak load case
Cost of Firm Energy

- Build costs and FO&M costs of wind and solar build on an annual basis divided by the firm MWh profile

- Analogous to PPA price requirements to finance project using only firm energy
  - Additional non firm sales could lower PPA price
Conclusions

• Renewables are saturating in many areas and do not necessarily correlate to the loads
• To increase renewable penetrations renewables need to better align with loads or be combined with storage
• Hydro systems can potentially provide renewable storage to balance systems
• Pumped hydro systems offer even more flexibility to shift renewable energy when it is needed
• Storage reduces renewable capacity required to meet firm profiles