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Valuation of Behind-the-Meter Energy Storage in Hybrid Energy Systems

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Abstract: Many remote communities are subject to poor electric service, with low power quality and reliability being common concerns. To compensate, many isolated communities operate diesel generation units to bolster utility inputs and/or fully support key loads in the event of an outage. While this is effective, it can be a very expensive mode of operation requiring oversized units to ensure reliable power. Declining prices of both renewable generation and energy storage systems have the potential to improve this situation, though careful planning is needed to make these hybrid energy systems financially attractive. This paper presents analytical methods to enable informed decision making with respect to future planning integrating renewable and energy storage systems to enhance system reliability and reduce operating costs. These methods are demonstrated in a case study for the San Carlos Apache Tribe, which is in a sparsely populated region next to Coolidge, Arizona that has limited power generation and transmission resources. Currently, their energy tariffs are expensive, and the system suffers from frequent power interruptions (around 100 interruptions per year on average). To reduce electricity costs and improve power quality, the tribe is installing solar photovoltaic arrays at several sites in the reservation. We have analyzed the potential benefits and optimization of pairing energy storage systems with this solar power generation to reduce the tribe's electricity costs and improve the reliability of power supply for their critical loads. Results show that the addition of an energy storage system could reduce electricity costs significantly and provide backup power for critical loads for several hours.

Introduction

- Many remote communities in the USA often suffer from unreliable power supply
- Diesel generation (DG) is often used to compensate because it is:
  - Cost-effective
  - Controllable
- Integration of DGs with renewable energy resources (RESs) or energy storage systems (ESSs) into hybrid energy systems (HESs) can be beneficial
  - Reduce fuel consumption
  - Optimize use of behind-the-meter (BTM) RES
- How should Battery ESSs (BESSs) be used to optimize the operation of the HES?

Project Goal:

- Perform a valuation study to ensure that well-informed energy project decisions can be made and resulting systems have a positive financial impact for the local community

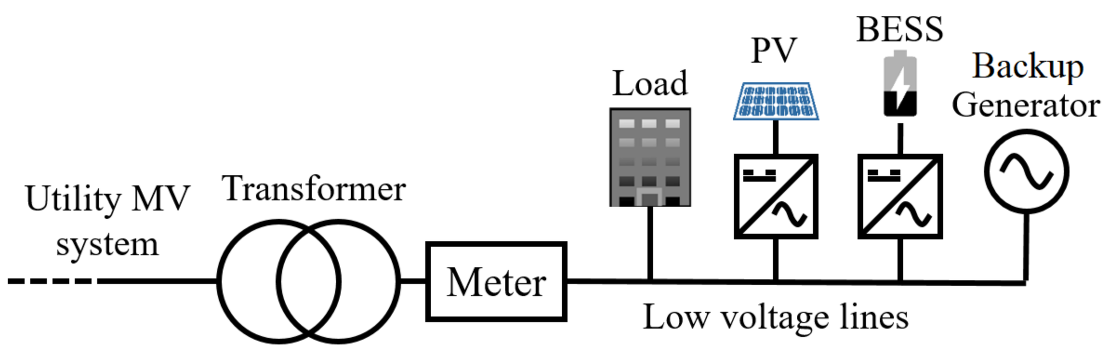

Fig. 1 Simplified behind-the-meter schematic of the hybrid energy system.

Assumptions

- DG, PV array and BESS are BTM
- BESS round trip efficiency: 86%[1]
- BESS throughput is less than the equivalent of 3,500 cycles at 80% depth of discharge over its life (10 years)[1]
- BESS and PV are AC connected
- BESS costs from BESS pricing survey/projections[1]
- Hospital's electric system is isolated from the grid during business hours in the monsoon season
- Historical monthly energy (kWh) for 2 years is known and assumed constant over 10 years
- Load profile is similar to nearby hospitals found in OpenData[2] and is adjusted by monthly mean kWh
- DG efficiency modeled using a quadratic function
  - Minimum of 30% rated power to avoid wet stacking
- Solar profile of PV array obtained with PVWatts[3]
- Price of diesel: $3.171/gallon (constant over period)
- Interest rate of 3% per year
- SCIP does not have net metering policy
  - Energy injected in SCIP's grid will not yield any benefit to the hospital
- SCIP's Industrial Rate Schedule
  - Demand: $7/kW
  - Energy: $0.0718/kWh
  - Monthly service charges: $250.00

Case Study

- San Carlos Apache Healthcare
  - 3 - 1.25 MW Diesel Generators
  - 2 MW solar photovoltaic array
- Power outages are very common during monsoon season (June through September)
- Hospital is islanded from distribution grid when storms are expected to hit the region
- DGs power the hospital during business hours
- To provide redundancy, multiple DGs operate at low load to be capable of providing power in case one of them goes offline
- Investigate if BESS can allow operation with 2 DGs instead of all 3 to reduce fuel consumption
- Cost savings come from reducing fuel and electricity costs when BESS is deployed with PV and diesel generators
- Power needed in the hours of the year that solar and a single generator (1250kW) were not sufficient to cover demand (Fig. 3).
- Low, Mid, and High BESS price scenarios for 2020 and 2030

Table. 1. Summary of results with 2 generators

$/kW	$/kWh	Price Source	ES kW	ES kWh	Energy Cost	Demand Cost	Fuel Cost	Total Annual	ESS Cost	10-Year NPV
No ES		---	---	---	**$ 254,340**	**$ 108,694**	**$ 144,601**	**$ 507,635**	**$ -**	**$ -**
106	248	Low 2030	468	1098	$ 240,457	$ 77,467	$ 136,276	$ 454,200	$ 322,000	$ 133,807
126	285	Mid 2030	423	837	$ 243,685	$ 81,467	$ 137,647	$ 462,799	$ 291,769	$ 90,694
138	332	High 2030	287	425	$ 248,804	$ 90,098	$ 140,541	$ 479,443	$ 180,633	$ 59,852
140	344	Low 2020	281	409	$ 248,998	$ 90,478	$ 140,669	$ 480,144	$ 180,104	$ 54,399
156	408	Mid 2020	211	307	$ 250,247	$ 93,824	$ 141,539	$ 485,609	$ 158,340	$ 29,544
171	467	High 2020	126	184	$ 251,828	$ 99,023	$ 142,689	$ 493,541	$ 107,488	$ 12,738

Table. 2. Summary of results with 3 generators.

$/kW	$/kWh	Price Source	ES kW	ES kWh	Energy Cost	Demand Cost	Fuel Cost	Total Annual	ESS Cost	10-Year NPV
Reference		Price Source	0	0	**$ 254,340**	**$ 108,694**	**$ 200,133**	**$ 563,167**	**$ -**	**$ -**
106	248	Low 2030	457	1038	$ 238,715	$ 78,313	$ 196,876	$ 513,904	$ 305,922	$ 114,299
126	285	Mid 2030	368	661	$ 244,092	$ 84,840	$ 197,483	$ 526,415	$ 234,908	$ 78,594
138	332	High 2030	281	409	$ 247,823	$ 90,485	$ 198,029	$ 536,337	$ 174,530	$ 54,334
140	344	Low 2020	279	405	$ 247,874	$ 90,590	$ 198,039	$ 536,502	$ 178,521	$ 48,931
156	408	Mid 2020	210	305	$ 249,419	$ 93,926	$ 198,377	$ 541,721	$ 156,931	$ 26,004
171	467	High 2020	111	161	$ 251,696	$ 100,062	$ 199,064	$ 550,822	$ 93,969	$ 11,332

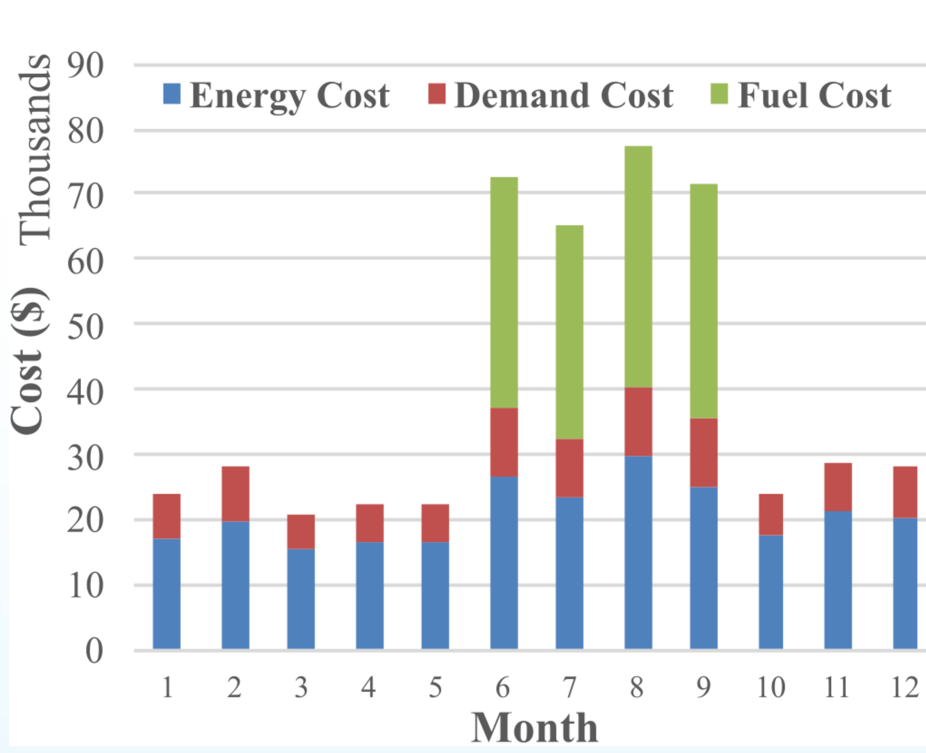

Fig. 2 Monthly Energy Costs - 2 Generators, 2020 ES pricing.

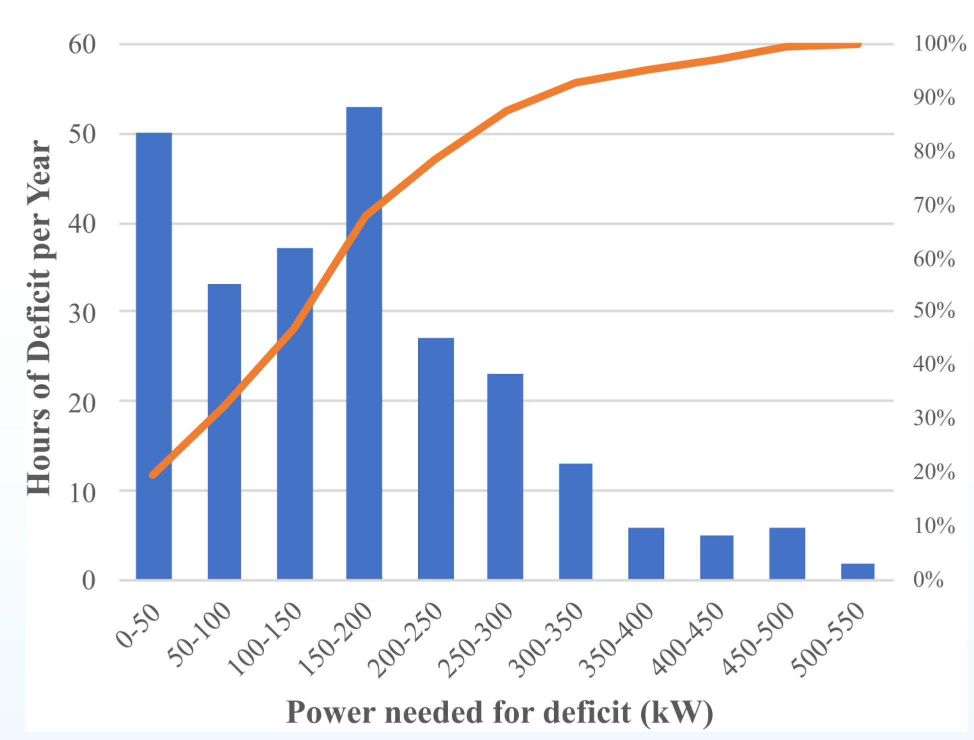

Fig. 3 Shortages in power throughout the year.

Results

- Solution to problem of optimal scheduling of BESS, PV and diesel generators and optimal sizing of BESS to maximize NPV of cost savings obtained by a script written using Pyomo and solved with Gurobi

$$NPV = \sum_{k=1}^{n_y} \frac{R_k}{(1+i_r)^k} - C_{in}$$

$$C_{in} = p_{kW}\overline{q^m} + p_{kWh}\bar{S}$$

- R_k: estimated cost savings in fuel and electricity charges due to use of BESS (per year)
- i_r : interest rate (per year)
- C_{in}: cost of capital investment
- n_y: number of years (10)
- p_{kW}: price of BESS per kW
- $\overline{q^m}$: power capacity of BESS
- p_{kWh}: price of BESS per kWh
- $\bar{S}$: energy capacity of BESS

Conclusions

- BESS can reduce fuel costs and electricity charges for the hospital
- Cost savings are due mainly to reduction in demand charges, PV curtailment, and fuel costs
- Net present value of profit is positive
- With perfect load and generation foresight, cost savings over 10 years can pay for BESS investment
- Without perfect foresight of load, performance of controllers deployed in the field is expected to be sub-optimal, therefore cost-savings should be reduced
- Capital costs on BESS have a large impact on NPV

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