CONTROLS

DISTRIBUTED GENERATION USE AND CONTROL IN BUILDINGS

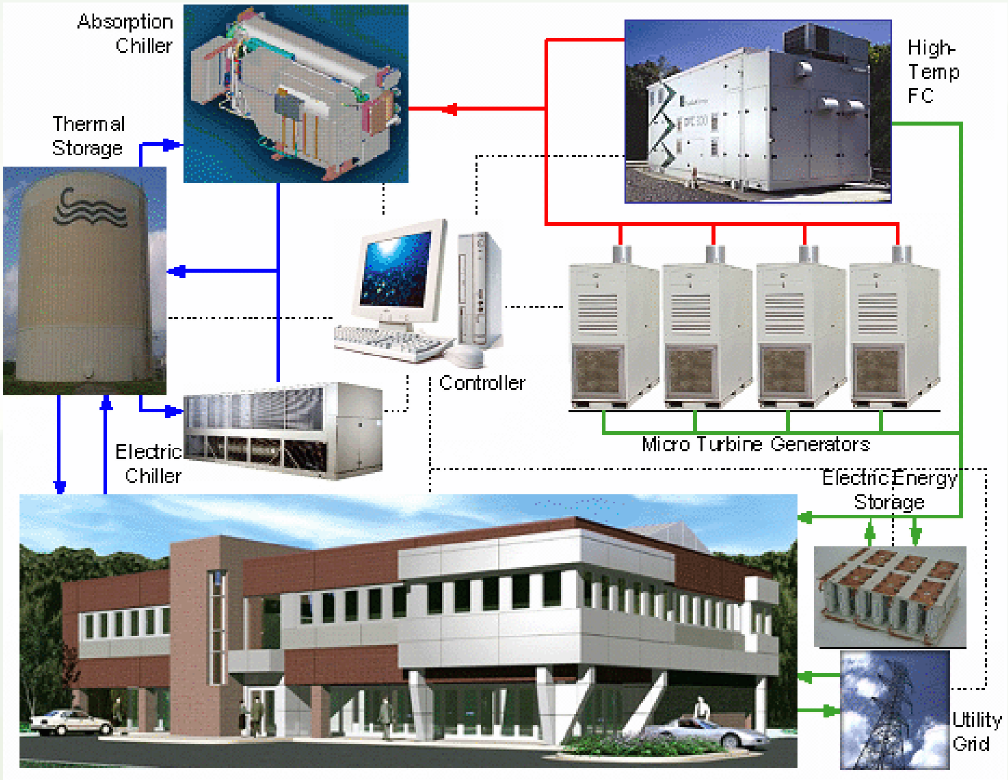
ABSTRACT

The increasing commercial development and deployment of fuel cells in distributed power applications has given rise to the need for novel control and dispatch strategies. Recognizing that consumer interest in fuel cell deployment will be largely economically motivated, a novel cost-minimization control strategy has been developed. The novel controller is designed to control operation of a variety of distributed energy resources, including fuel cells, reciprocating engines, and micro turbine generators (MTG). The control and dispatch algorithm is designed to continuously minimize energy costs by monitoring utility prices and building demand, while working within the context of the physical limitations and capabilities of the fuel cell and other distributed power devices.

Using Matlab Simulink, dynamic empirical models of each of the prime movers (e.g., fuel cells), energy conversion devices (e.g., absorption chillers), and energy storage devices (e.g., thermal energy storage) have been developed. Measurements of building electrical and thermal demand were made by the UC Irvine team on a 90,000 ft2 two-story commercial building. These dynamic load profiles were then used to analyze the dynamic performance of the several fuel cell systems as controlled and dispatched by the novel algorithm. The economics, efficiencies, and emissions of fuel cell system design and load scenarios are analyzed to highlight the key deployment needs and opportunities.

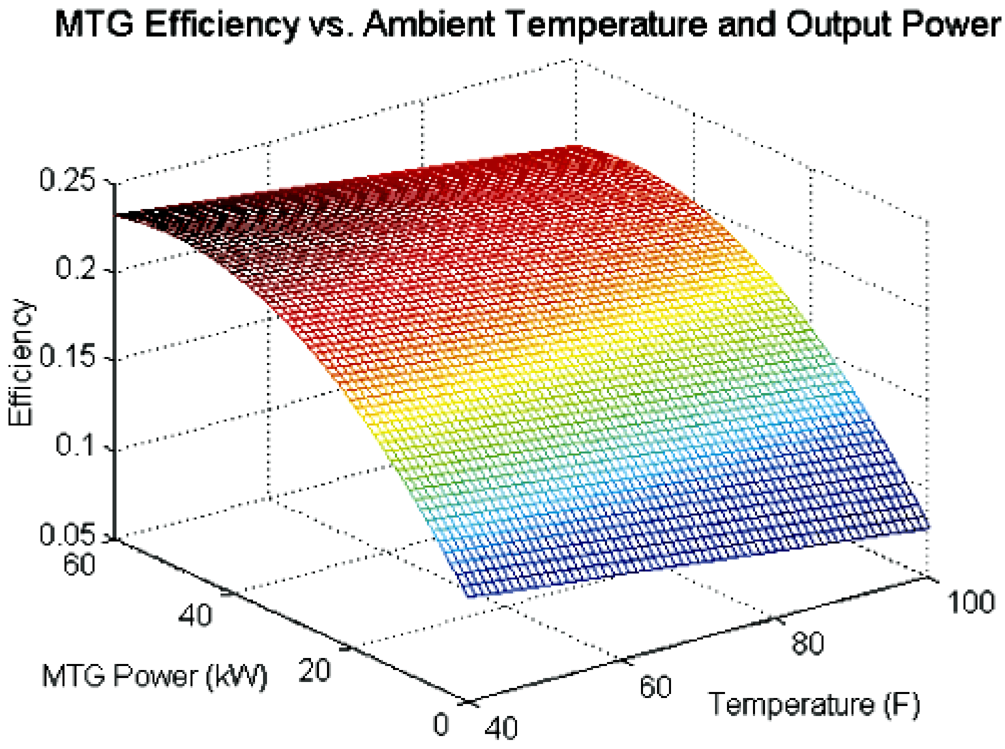
INTRODUCTION

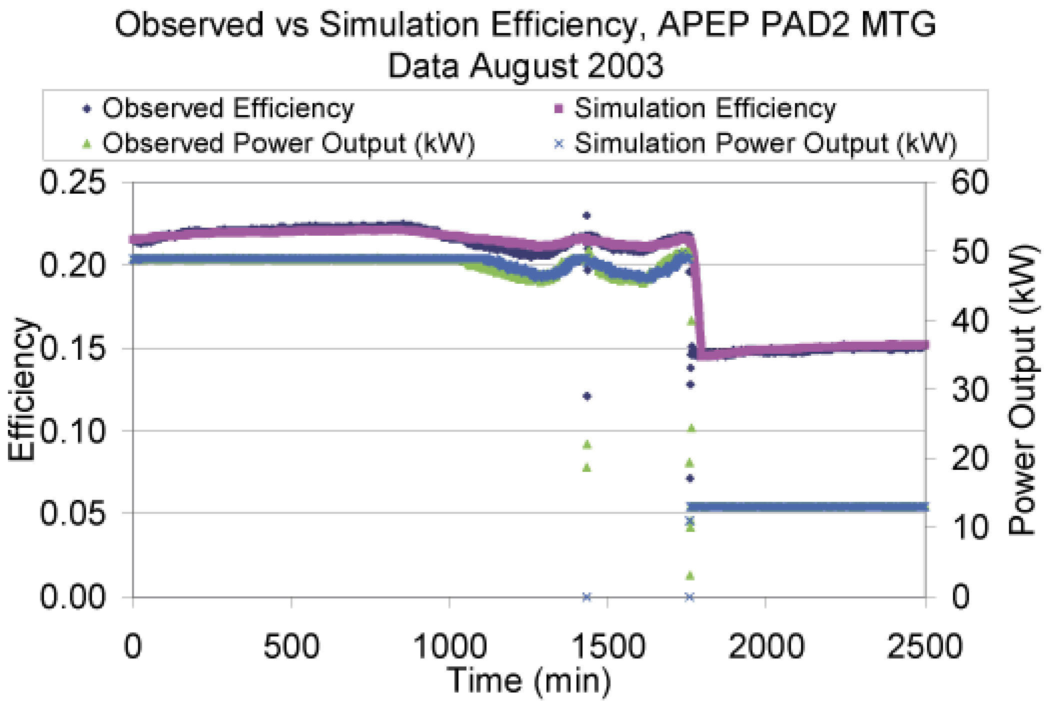
- Dynamic component models developed for a variety of Distributed Energy Resources in order to analyze novel control strategies, system configurations, and utility scenarios

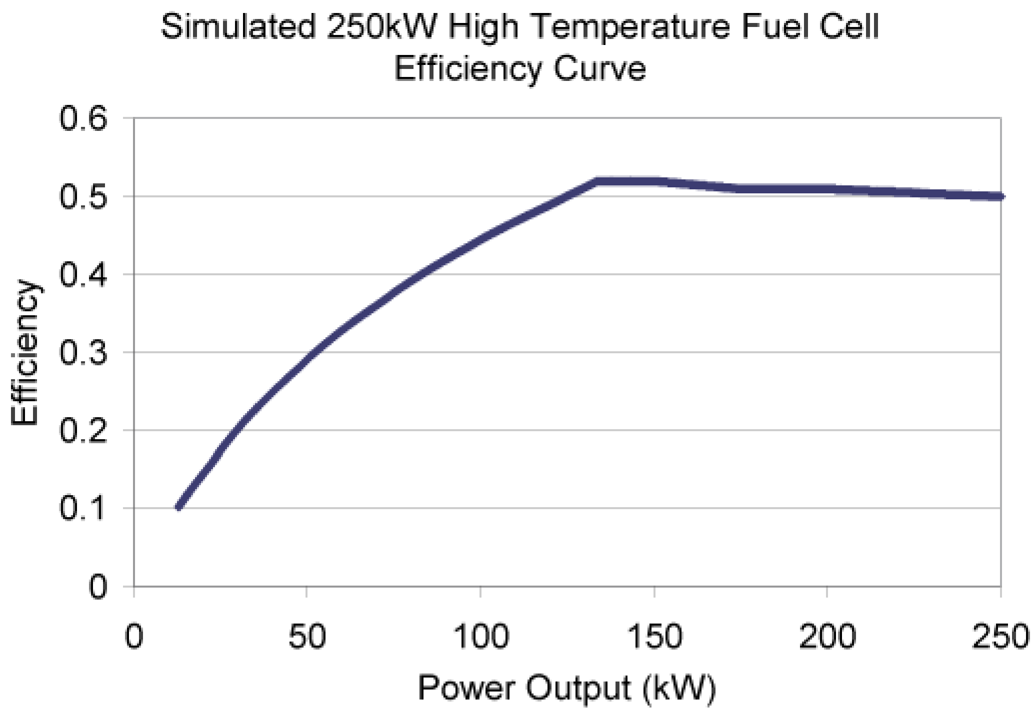


BACKGROUND

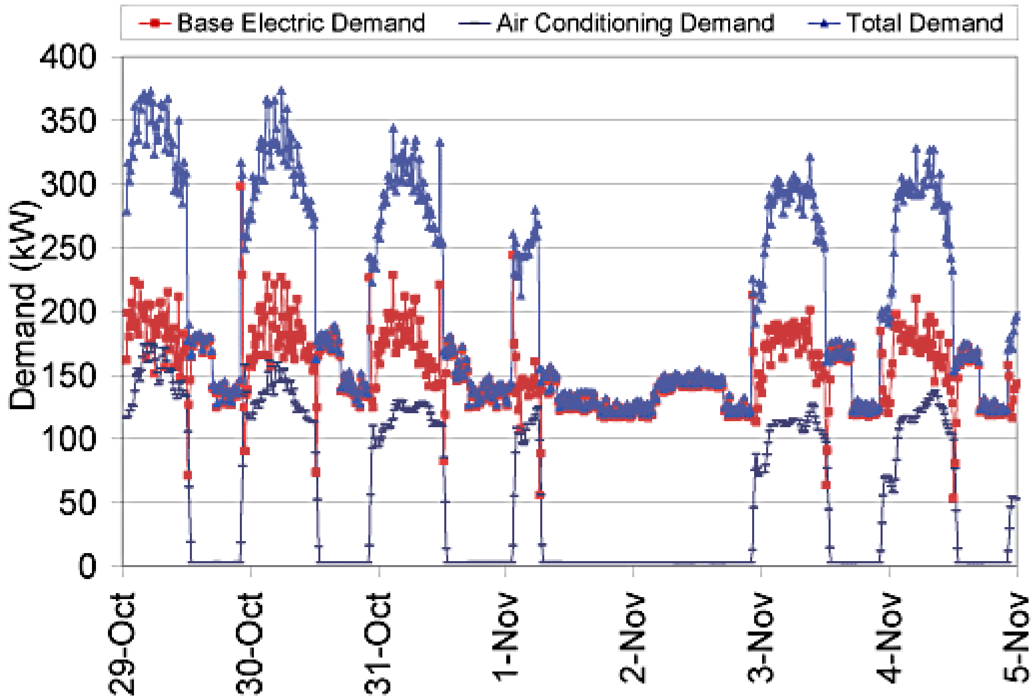
- Empirical models of generators and energy conversion devices used to enhance simulation performance and more closely reflect reality







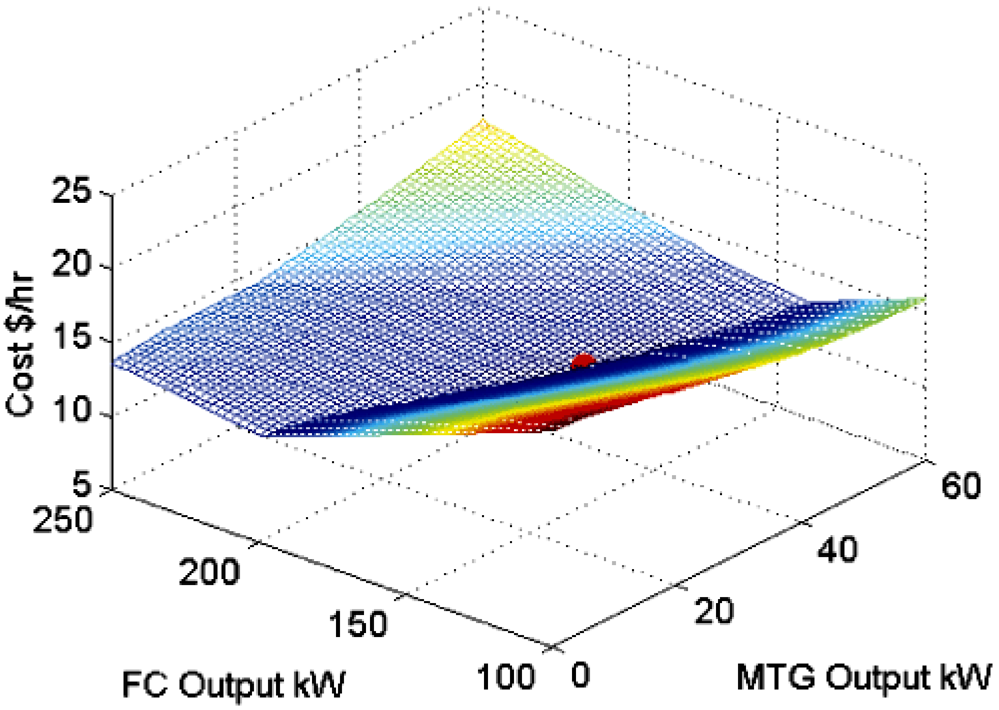
- Component models developed in Matlab Simulink programming environment, allowing for high-resolution, full year simulations in the order of hours
- Actual commercial building electrical and thermal demand data used for scenario analysis



- Novel cost minimization controller developed with the following target function

$$Cost = (P_{bldg} - P_{DG})C_e + \left(\frac{P_{DG}}{\eta_{DG}(P_{DG}, T_{amb})}\right)C_{NG} + K_{ws}(Th_{bldg} - Th_{DG}(P_{DG}, T_{amb})COP_{ac})\left(\frac{C_e}{COP_{ec}}\right)$$

- Example instantaneous minimized solution (red dot below) for specific building demand and utility price scenario for a system with (1) 250kW HTFC and (1) 60kW MTG



Note: Cost of electricity is $0.15/kWh, cost of natural gas is $0.585/therm, building electrical and thermal demands are 100kW and 85TR respectively, and ambient temperature is 75F.

- For this study, the following utility costs and capital costs were assumed:

Parameter	***Value***
Electricity Rate Schedule	SCE TOU-GS-2*
Cost of Natural Gas (per MMbtu)	$7
Installed Capital Cost of HTFC (per kW)	$3,000
Installed Capital Cost of MTG (per kW)	$1,500
Installed Capital Cost of Absorption Chiller (per TR)	$2,000
Installed Capital Cost of Electric Chiller (per TR)	$500

* http://www.sce.com/NR/sc3/tm2/pdf/ce63-12.pdf

RESULTS AND CONCLUSIONS

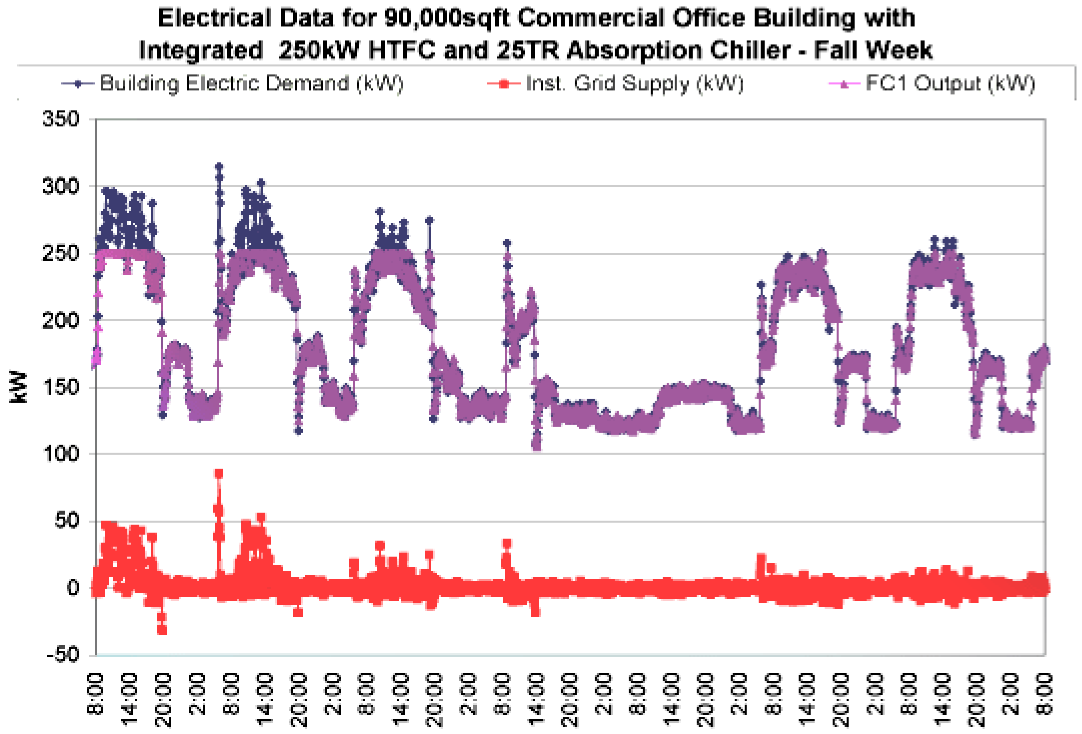
- Peak electrical load (without air conditioning) of building examined is approximately 250kW; accordingly, three DER scenarios were analyzed:
  1. 1-250kW HTFC with 25TR Absorption Chiller
  2. 4-60kW MTGs with 100TR Absorption Chiller
  3. 1-125kW HTFC and 2-60kW MTGs with 63TR Absorption Chiller
- Heating not considered in this study due to low heating requirements of So. California location

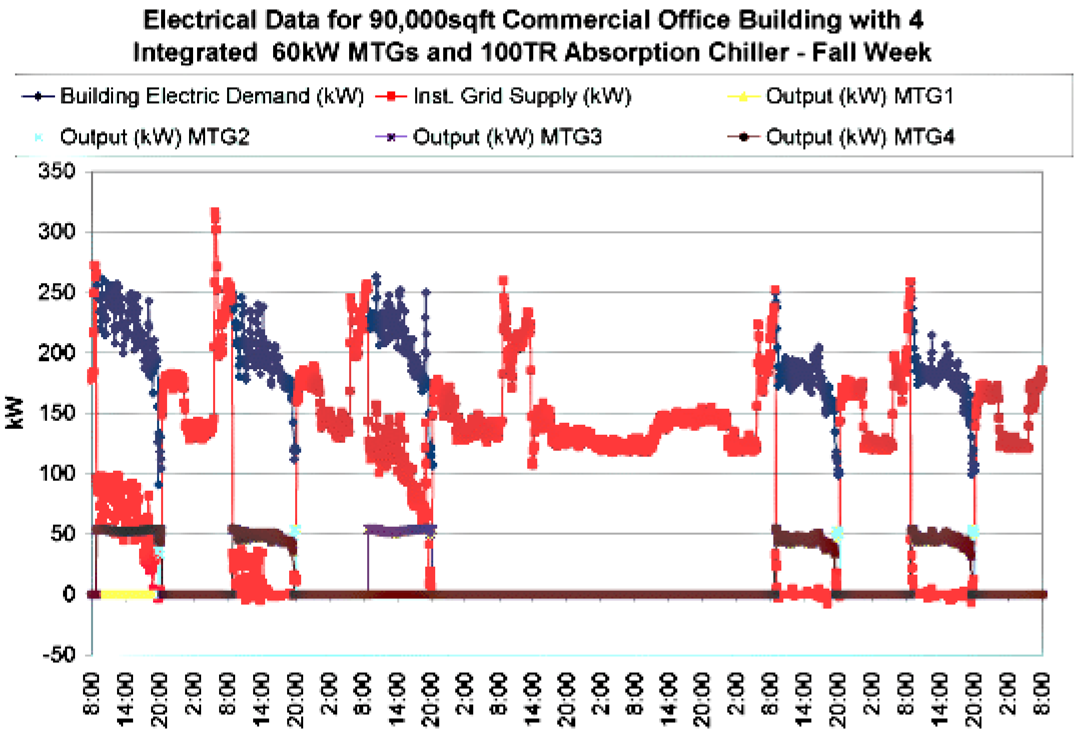
Scenario	*Total System Cost*	*Yearly Operating Cost*	*Yearly Operating Savings*	*Simple Payback (yrs)*
No DER	-	$237,822	-	-
250kW HTFC	$860,000	$148,486	$89,336	9.6
4-60kW MTGs	$620,000	$158,420	$79,402	7.8
125kW HTFC + 2-60kW MTGs	$740,000	$140,209	$97,613	7.6

Note: Assumes 93% availability for MTGs and HTFCs. Installed capital costs (per kW) of DG: $3000 for HTFC and $1500 for MTG. Installed capital cost (per TR) of chillers: $2000 for absorption chiller and $500 for electric chiller.

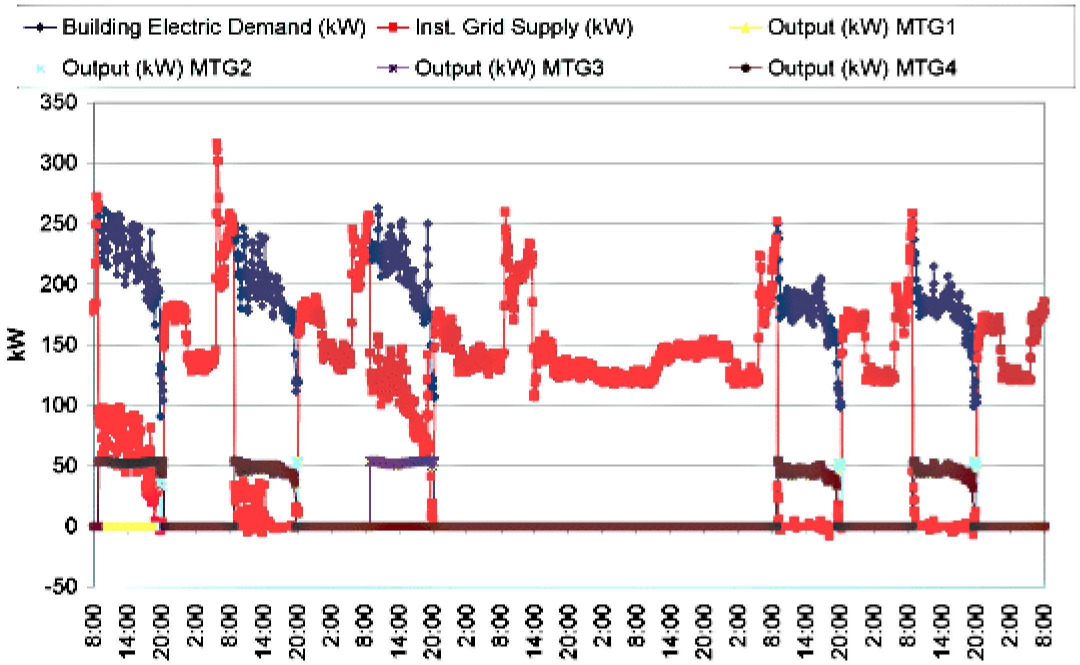
Scenario	System Efficiency	Primary Fuel Savings (Mmbtu/yr)	NOx Reduction (lbs/yr)	CO2 Reduction (lbs/yr)
No DER	35%	-	-	-
250kW HTFC	61%	6166.8	4767	1,076,593
4-60kW MTGs	39%	540.4	2189	441,778
125kW HTFC + 2-60kW MTGs	51%	4218.9	4264	906,172

Note: Grid efficiency including generation, transmission and distribution is assumed to be 35%. NOx and CO2 calculations are based US EPA eGRID data (2) and DG emission values of 7e-4 lbs/kWh NOx and 1.5 lbs/kWh CO2 for MTGs, 7e-5 lbs/kWh NOx and 0.85 lbs/kWh CO2 for HTFC.

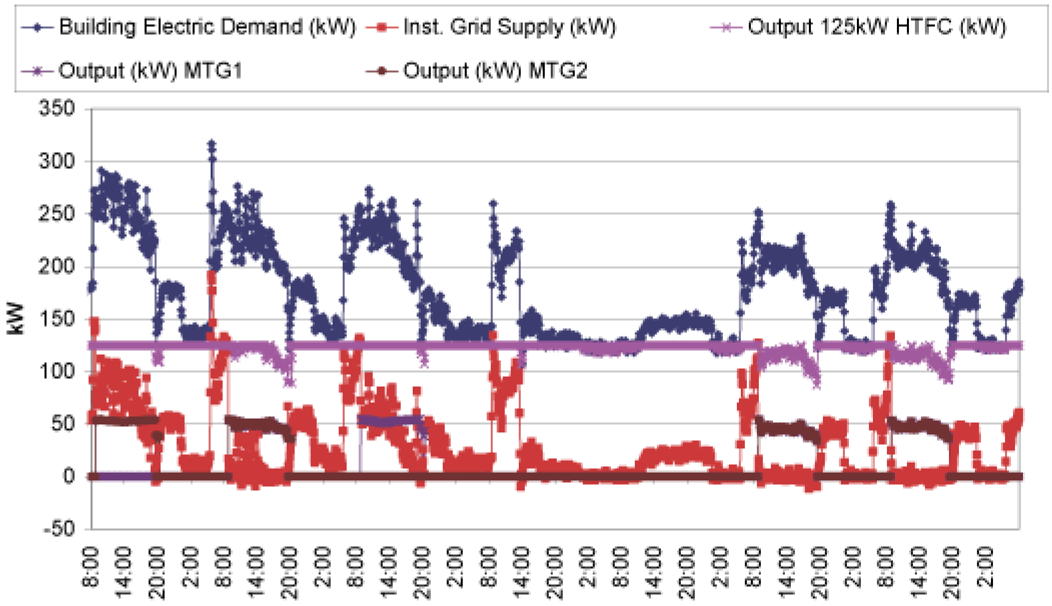




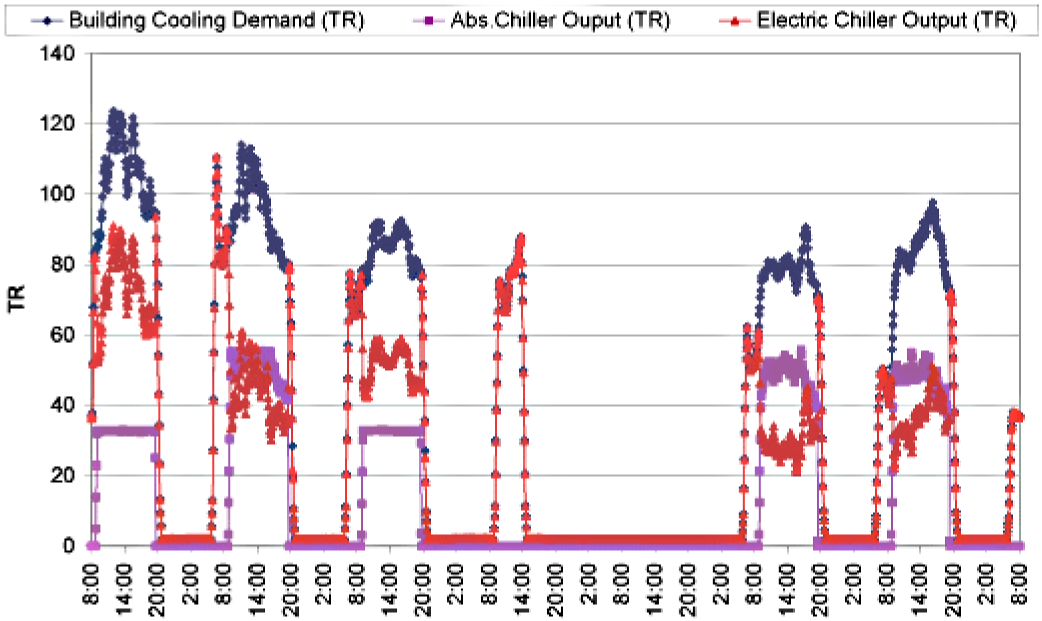
- Electrical grid impact varies greatly with system configuration



Electrical Data for 90,000sqft Commercial Office Building with 4 Integrated 60kW MTGs and 100TR Absorption Chiller - Fall Week



Electrical Data for 90,000sqft Commercial Office Building with 1 Integrated 125kW HTFC, 2-60kW MTGs, and 63TR Absorption Chiller - Fall Week



Thermal Cooling Data for 90,000sqft Commercial Office Building with 1 Integrated 125kW HTFC, 2-60kW MTGs, and 63TR Absorption Chiller - Fall Week

- Optimum configuration for this scenario w.r.t. payback is combination HTFC-MTG system.
- HTFC system alone provides greatest fuel savings and emissions reduction

RECENT PUBLICATIONS

Meacham, J.R., Brouwer, J., Jabbari, F., and Samuelsen, G.S., "Simulation of Control and Dispatch Scenarios for Distributed Energy Resources," First Industrial Conference on Power Electronics for Distributed and Co-Generation, Irvine, CA, March 22-24, 2004.

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