Experiences with Combined Heat and Power during the August 14, 2003 Northeast Blackout

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Introduction

Distributed generation (DG) is the use of small-scale power generation technologies located at or near the point of use. DG has attracted increasing attention in recent years as projects have demonstrated its many benefits while allowing users to better manage their changing power needs. These needs include higher power quality, reliability, self-sufficiency, security and cost management. In some Northeast states, relatively high electricity rates, reliability concerns and DG friendly regulatory programs have encouraged high rates of DG development when compared to the rest of the country.

One type of DG is Cooling, Heating and Power (CHP) where technologies produce both electricity and useful thermal energy from one fuel. Because CHP systems recycle thermal energy, which is normally wasted, they are very efficient. These systems provide a highly reliable power supply especially when 'base loaded' (i.e., operate continuously). Many facilities in the U.S. demand a very reliable source of energy in order to maintain operations so CHP is becoming an increasingly sought after option to supply the electric and thermal needs of both commercial and industrial facilities.

On August 14, 2003, large portions of the Midwest and Northeast United States and Ontario, Canada experienced an electric power outage. An estimated 50 million people with an electric load of 61,800 MW were affected in the states of Ohio, Michigan, Pennsylvania, New York, New Jersey, and Connecticut. The outage disrupted businesses and factories, many of which experienced power outages and/or cutbacks for several days as power to the grid was gradually restored. The blackout began at 4:10 pm Eastern Daylight Time and continued for four days in some areas. The outage affected over 34,000 miles of high voltage transmission lines causing many power generation plants, including nine nuclear reactor-based plants, to disconnect and shut down. Parts of Ontario suffered rolling blackouts for more than a week before full power was restored. The area ground to a halt causing economic losses as businesses lost sales and manufacturers lost goods. Total costs to the US economy range between $4 billion and $10 billion. In Canada, gross domestic product was down 0.7% in August with a net loss of 18.9 million work hours.[i]

Some facilities continued to operate in the midst of the blackout because of their backup generators or DG resources, including Cooling Heating and Power (CHP). This paper summarizes discussions with facilities that operated CHP systems during the blackout and reports how these systems operated.

Objective and Methodology

This study developed an understanding of how CHP systems operated during the outage by identifying and selecting facilities located in the August 2003 blackout area (United

States) that have CHP systems installed and operating and by interviewing facility representatives at these sites. The study documents how the site and/or the local community benefited from their CHP system in detailed case study write-ups included in the report "Assessing the Benefits of On-Site Combined Heat and Power during the August 14, 2003 Blackout"[ii].

The initial step was to identify facilities within the blackout area that have CHP systems through the use of the CHP database.[iii] Maps of the blackout region from the North American Reliability Council (NERC) website and the U.S.-Canada Power Outage Task Force were used to approximate regions within each state that were without power. Using a mapping program, city and zip codes were used to locate sites within the approximated outage areas. This analysis indicated that 446 CHP systems are installed in areas affected by the blackout representing 9,280 MW of electric capacity. Individual site contacts were identified[iv] and contacted about their CHP system.

A team was formed, led by Oak Ridge National Laboratory (ORNL) and supported by Energy and Environmental Analysis, Inc. (EEA) and Motor and Generator Institute, to contact this targeted group of CHP facilities in the blackout region. The team developed a comprehensive interview guide that provided a standard format for discussions with facility personnel to ensure that consistent information was collected by interviewers. Questions were asked about operations on August 14, 2003, opinions of the system, and reasons for installation.

Profile of CHP in Blackout Area

The team analyzed the profile of sites with CHP in the area affected by the blackout to identify sites where interviews would likely result in useful information. The application for use of CHP technology was evaluated (see Table 1). Interestingly, the CHP profile in the blackout area has a larger percentage of commercial sites than the national population of CHP sites. Over 61% of the CHP systems in the blackout area serve commercial applications, 37% industrial applications, and 2% other applications. Compare this with nation-wide data where CHP commercial applications make up 50% of existing systems, with industrial applications at 44% and other applications at 6%. The blackout area also has a higher percentage of smaller systems probably because of the high number of commercial sites. The majority of the commercial sites are under 1 MW whereas the industrial sites have more evenly distributed size ranges with sites greater than 50 MW. Even though there are more commercial sites with CHP systems, the industrial sites account for the vast majority (80%) of the installed capacity (see Table 2).

The team identified applications where on-site CHP systems could have provided crucial support for continued or safe operations during the blackout: hospitals, nursing homes, multifamily housing, food processing, and chemical/pharmaceutical facilities. Sites in the blackout area in each of these applications were identified and focused on for interviews (see Table 3). Sites selected for interviews were primarily located in New York or New Jersey because these states have more CHP sites than other states in the affected region (see Table 4).

Table 1. CHP Sites in Blackout Area by Application

Application	# Sites	Capacity (MW)
SIC 20: Food	26	269
SIC 22: Textile Products	1	1
SIC 24: Wood Products	2	5
SIC 25: Furniture	1	1
SIC 26: Paper	32	1,279
SIC 27: Publishing	3	4
SIC 28: Chemicals	46	1,556
SIC 29: Petroleum Refining	3	886
SIC 30: Rubber	6	389
SIC 32: Stone, Clay, Glass	2	31
SIC 33: Primary Metals	11	1,555
SIC 34: Fabricated Metals	5	58
SIC 35: Machinery	4	9
SIC 36: Electrical Equipment	1	1
SIC 37: Transportation Equip	12	1,118
SIC 38: Technical Instruments	2	56
SIC 39: Misc Manufacturing	6	182
Total Industrial	163	7,397

SIC 9900: Unknown	3	3
SIC 01: Agriculture	3	71
SIC 12: Coal Mining	1	33
SIC 13: Crude Oil	2	1
Total Other	9	108

Application	# Sites	Capacity (MW)
SIC 4000: Ground Transportation	1	10
SIC 4500: Air Transportation	2	10
SIC 4800: Communications	2	6
SIC 4939: Utilities	7	85
SIC 4952: Wastewater Treatment	3	14
SIC 4953: Solid Waste Facilities	10	841
SIC 4961: District Energy	3	94
SIC 5000: Wholesale/Retail	4	12.
SIC 5411: Food Stores	5	1
SIC 6512: Comm. Building	9	24
SIC 6513: Apartments	51	91
SIC 7011: Hotels	8	1
SIC 7200: Laundries	4	1
SIC 7990: Amusement/ Rec.	23	103
SIC 8051: Nursing Homes	35	4
SIC 8060: Hospital/Healthcare	37	185
SIC 8211: Schools	19	3
SIC 8220: Colleges/Univ.	26	346
SIC 8300: Comm Services	4	1
SIC 8400: Zoos/Museums	2	4
SIC 8900: Services NEC	12	7
SIC 9100: Government Fac.	1	1
SIC 9200: Courts/Prisons	2	5
SIC 9700: Military	4	389
Total Commercial	274	1,775
Grand Total	**446**	**9,280**

Table 2. CHP Sites by Application Class and Size Range (Blackout Affected Areas Only)

	0 - 1 MW		1.01 - 5 MW		5.01 - 50 MW		>= 50.01 MW		Total	
Application Class	Sites	MW	Sites	MW	Sites	MW	Sites	MW	Sites	MW
Commercial	195	33	34	82	32	460	13	1,200	274	1,775
Industrial	39	17	38	97	48	895	38	6,388	163	7,397
Other	4	2	2	2	2	49	1	55	9	108
Total	**238**	**52**	**74**	**182**	**82**	**1,403**	**52**	**7,643**	**446**	**9,280**

Interview Results

After evaluating the profile of CHP systems located in the area affected by the blackout, the team interviewed twelve sites of the 193 targeted facilities. The CHP systems at nine of the facilities continued operation during the blackout, one was undergoing maintenance at the time of the blackout, and two were not designed to continue operation

Table 3. Targeted Application Sites

SIC	Application	# Sites	Capacity (MW)
20	Food Processing	26	268
28	Chemicals	46	1,555
6513	Multi-Family Housing	51	91
8051	Nursing Homes	34	3.3
8060	Hospitals/Healthcare	36	184
	Total	**193**	**2,101**

Table 4. CHP Sites by State (Blackout Affected Areas Only)

State	# Sites	Percent of Sites	CHP Capacity (MW)	Percent of Capacity
Connecticut	18	4	8	0.08
Michigan	34	7.6	1,335	14.3
New Jersey	146	32.7	2,070	22.3
New York	209	46.8	5,001	53.8
Ohio	18	4	173	1.8
Pennsylvania	21	4.7	693	7.4
Total	**446**	**100**	**9,280**	**100**

during an outage. One of these sites requested confidentiality so interview results are not included in this paper. Case studies are to be published.[v]

Typical System Design

Interviewers obtained a detailed description of the CHP system at each site that was contacted. Combustion turbines were the most common prime mover, with the remaining sites operating reciprocating engines and steam turbines. Most sites use their CHP systems to provide baseload power with a significant proportion of their electric and thermal needs being met by the system. All but two of the systems are grid connected. The exceptions were two multi-family housing sites where interconnection with the grid was not cost effective. The majority of the sites own and operate their own CHP systems, three are operated by a third party, and only one is owned by a third party (see Table 5).

Operation during the Blackout

During the northeast blackout, each CHP facility had unique operational experiences, ranging from not noticing there was a blackout to losing power with the grid and not being able to bring the system online until grid power was restored. The majority of systems performed exactly as designed. Some do not have stand-alone capability, which caused them to lose power with the grid. Other systems that have stand-alone capability require a period of adjustment before the system could power the facility load. It was noted that an area for technology development is cost-effective control system that would make this shift more quickly and without disruption. Two sites with stand-alone

Table 5. CHP System Descriptions by Facility Type

Application	Prime-mover	Capacity MW	% Electric	% Thermal	System description	Owner
Food Processing	RE	5.1	100%	majority	grid con., stand alone, baseload	3rd party owned and operated
Food Processing	ST	10	100%	100%	grid con., stand alone, baseload	self owned and operated
Chemical Co.	ST	196	75%	100%	grid con., stand alone, baseload	owned by facility, run by 3rd party
Pharmaceutical Plant	CT	3.1	40-60%	80%	grid con., stand alone, baseload	self owned and operated
Pharmaceutical Plant	CT	11.5	50%	~50%	grid con., supplemental	owned by facility, run by 3rd party
Pharmaceutical Plant	CT	7.6	100%	~80%	grid con., baseload	owned by facility, run by 3rd party
Multi-Family Housing	RE	7.5	100%	100%	NOT grid con., stand alone, baseload	self owned and operated
Multi-Family Housing	ST	18	100%	100%	NOT grid con., stand alone, baseload	self owned and operated
Hospital	CT	10	100%	100%	grid con., stand alone, baseload	self owned and operated
Hospital	CT	2	80%	100%	grid con., stand alone, baseload	self owned and operated
Hospital	RE	1.3	~90%	~90%	grid con., stand alone, baseload	self owned and operated

capability were caught off guard because maintenance was being performed on the system and it could not handle the facility load or operate independent of the grid because the control system was temporarily dependent on the grid. One site was able to recover by black starting the CHP system and carrying on operations. The other site remained down for the duration of the outage. The following list summarizes the operation of each facility during the blackout, grouped by sites that were and were not operating.

CHP systems that remained operational**:**

- Chemical Plant, Rochester NY – The CHP system continued operation throughout the blackout, but the facility had to scale back their processes because the system does not provide enough power for all needs of the site.
- Entenmann's Bakery, Bayshore NY – The CHP system continued to operate through the blackout and the plant was not affected.
- Montefiore Medical Center, Bronx NY – This system went down for five minutes when the blackout started, which is expected, but came back online to operate throughout the outage.

- Norwalk Hospital, Norwalk, CT – The CHP system went down for one hour when the blackout started, as expected, but operated for the duration of the outage.
- North Shore Towers (owned by Three Towers Associates), Floral Park NY - This site relies solely on its CHP system, which continued to work normally throughout the blackout, allowing business to continue.
- Pharmaceutical Plant, Rochester MI – The CHP system tripped offline at the beginning of the blackout, but system operation was restored quickly and operated throughout the blackout.
- South Oaks Hospital, Amityville NY – The CHP system operated exactly as planned and the facility never lost power, normal operations continued throughout the outage.
- Spring Creek Towers, Brooklyn NY – This site relies solely on its CHP system, which continued to work normally throughout the blackout. The site never lost power and was able to provide for some needs of the local community.

CHP systems that were non-operational during the blackout**:**

- Food Processor, Brooklyn NY – Although the CHP system was designed with stand alone capability, it was undergoing maintenance and went down with the outage.
- Pharmaceutical Plant, Nutley NJ – The CHP system did not operate through the blackout because it is not designed to function without power from the grid.
- Pharmaceutical Plant, Union NJ - The CHP system did not operate through the blackout because it is not designed to function without power from the grid.

Additional Facilities: While the team conducted detailed interviews with some facility representatives, anecdotal information on other site experiences was obtained. Three chemical plants and two paper mills, with a combined capacity of 339.9 MW, managed by the same energy service company, did not operate during the blackout because the systems were not designed with stand-alone capability. When the blackout occurred, the University of Michigan Hospital CHP system that provides for the university campus and hospital shifted to stand-alone operation and provided all of the electrical and thermal needs of the hospital. Services at the hospital were able to continue in a normal fashion including surgeries.

Economic Impact: In contrast to the sites where the CHP system provides sufficient power to continue operation, sites with on-site power sufficient to meet part of their load scaled back their business resulting in lost revenue. Two facilities, a food processor and a pharmaceutical plant, with systems that were designed for stand-alone operation but went down during the outage were hit hard financially. One lost product due to the outage while the other suffered from costly cleanup expenses as well as overtime pay for employees. Two pharmaceutical plants that were not equipped with stand-alone capability did not lose product since they used emergency generators to power critical processes.

One result of the August 2003 blackout may be a re-evaluation by new users of the value of stand-alone capability. The incremental costs for larger users (estimated to be between $100 and 200/kW) for ride-through capability may be a wise investment given the experience of the August blackout. For smaller users, the incremental costs include the difference in costs between an induction generator and a synchronous generator, and the increased costs of interconnecting a synchronous generator which can be significant depending on individual utility requirements.

Other Services: Three sites were able to provide services to their respective utilities or surrounding communities. One hospital accommodated extra patients and provided space in its air-conditioned lobbies for elderly citizens to escape the summer heat. The local utility asked a pharmaceutical plant to reduce their load facilitating power restoration to others. A multi-use housing complex that includes a supermarket within its power network provided the community with a place to purchase food and supplies to endure the blackout. Even though one of the hospitals has an agreement with a nursing home to accommodate patients during power outages the agreement was not used.

Typical Views of CHP

Facilities characterized in this paper had positive views of their CHP systems. Even sites whose system was not operational during the blackout resulting in financial loss concluded that their CHP systems were well worth the investment. Several site contacts would "definitely" or "absolutely" recommend CHP systems to other sites. Some noted the importance of understanding issues related to CHP systems such as cost of fuel, thermal demand vs. electric output, and maintenance costs. However, the resounding opinion was positive, primarily based on significant energy savings experienced since installing CHP systems.

Even though the interviewed sites have positive views of CHP, there did appear to be a trend in how enthusiastic a site contact was about their system. For sites that owned and operated the systems, the opinion was positive yet reserved. These site representatives were more likely to conditionally recommend CHP to others: CHP systems are more easily justified when the cost of electricity is high and the price of natural gas is relatively low; the site should understand technical issues related to operating CHP systems. More enthusiastic praise came from sites were the system is maintained by a third party. The authors speculate that this enthusiasm is because sites that do not maintain the system themselves see the cost/benefit to the facility rather than day-to-day operational issues involved with running the system.

Most interviewees recognized cost savings as the primary reason for installing their CHP systems. Due to the high electricity prices, common in the area affected by the blackout, CHP system installations supply base-load power reducing the need to purchase power from the local utilities. Electric reliability was also noted as a primary reason for installing CHP because of the cost of power interruptions. Only one site considered reliability above cost: a hospital that uses CHP for all of its backup power. Interviewees also recognized that their CHP systems provide them with a competitive advantage. Hospitals enhance their revenue-generating programs and provide funding to patient care with operational cost savings from the CHP system. Representatives of both multi-family housing complexes sited the CHP system as a significant competitive advantage, especially after the blackout, since they have experienced increased demand as residents in the area seek to live in buildings with more energy security. In fact, one complex publicizes the CHP system in its promotional material.

Conclusions

Interviews were conducted with representatives of 12 CHP facilities in the area affected by the August 14, 2003 blackout focusing on sites where on-site CHP systems could provide crucial support during the blackout. Interviews were conducted with three hospitals, four chemical manufacturers, two food processors, and two multi-family housing complexes.

The majority of CHP systems operated as designed during the blackout, 10 of the 12 sites performed exactly as planned during the outage including the sites that were not designed with stand-alone capability. Those systems designed with stand-alone capability operated as planned except in two cases where the CHP system was undergoing maintenance. A few sites had temporary outages as power supply shifted from grid connected to stand alone operation.

Several sites were not designed to run during grid failures. They decided not to invest in CHP stand-alone capability and rely on backup power generators to provide protection to critical or sensitive processes. In fact, 11 of the 12 sites installed a CHP system to reduce operational costs. Enhanced power reliability was mentioned as a secondary benefit, but this benefit was outweighed by operational costs. Only one site considered reliability above cost: a hospital that provides all its backup power with CHP.

The reaction of CHP users was positive. Even sites that did not stay operational throughout the blackout expressed satisfaction with their systems. Site contacts said that the CHP system gives them a competitive advantage by allowing energy savings to be used for other purposes recommending that others evaluate a CHP system for their site.

References

[i] "Final Report on the August 14, 2004 Blackout in the United States and Canada", U.S.-Canada Power System Outage Task Force, April 2004.

[ii] Assessing the Benefits of On-Site Combined Heat and Power during the August 14, 2003 Blackout, public report for Oak Ridge National Laboratories.

[iii] Energy and Environmental Analysis, Inc (EEA) CHP Database 2003 – A database of over 2,700 CHP facilities representing 77,700 MW of installed electric capacity. Information included in the database for each facility includes site location, application (e.g., hospital, hotel, food processor, etc.), CHP system type (recip engine, gas turbine, combined cycle, boiler/steam turbine, other), fuel type, and servicing utility.

[iv] Contacts were identified through the use of the U.S. Department of Energy's Energy Information Administration (EIA) Non-Utility Power database, and internal EEA data.

[v] *Assessing the Benefits of On-Site Combined Heat and Power during the August 14, 2003 Blackout,* June 2004, Oak Ridge National Laboratory by Energy and Environmental Analysis, Inc., to be published.