

Procedure for Conducting a Case Study of the Domain CHP Project in Austin, Texas

Adam Newcomer, University of Texas at Austin

David Eaton, University of Texas at Austin

Ed Mardiat, DBIA, Burns & McDonnell Engineering, Inc.

Rod Schwass, Burns & McDonnell Engineering, Inc.

Cliff Braddock, CEM, Austin Energy

Jan Berry, Oak Ridge National Laboratory

ABSTRACT

This article describes a packaged cooling, heating and power (CHP) system for a buildings project in Austin, Texas operated by Austin Energy, the municipal utility. The article develops measures to report system efficiency and also identifies the research agenda to evaluate the CHP project's performance.

INTRODUCTION

The Burns & McDonnell DOE CHP Development Project was installed at the Domain Technology Park in collaboration with the US Department of Energy, Distributed Energy Program and Oak Ridge National Laboratory. The packaged CHP system reduces capital cost using a modular design, while integrating on-site power generation and a thermally activated absorption chiller. As the project developer and system integrator, Burns & McDonnell, teamed with Solar Turbines, Broad USA, Turbine Air Systems, and Austin Energy to install the system. The project utilizes exhaust heat from a 4.5 megawatt combustion turbine to indirectly fire a 2,500 ton two stage absorption chiller. The system has been installed in an existing building and supplements an existing central utility plant with chilled water, while the combustion turbine generator runs in parallel with the Austin Energy grid. It provides low emission,

on-site reliable power to the high technology businesses. The absorption chiller provides 2,500 tons of chilled water and “free cooling” during peak demand and reduces the need to run existing electrical centrifugal chillers. In some initial tests, the system has a measured efficiency of more than 80 percent. The article describes the innovative CHP system and discusses the benefits to Austin Energy and to the Domain tenants. It also provides a method of assessing electrical, thermal and system efficiency based on detailed performance data from the system.

DOMAIN TECHNOLOGY PARK AND CHP SYSTEM OVERVIEW

The Domain Technology Park is a large industrial park that provides space for high-technology commercial and industrial tenants. The business park covers about one square mile and has about 1.9 million net rentable square feet of manufacturing and commercial space [1]. The electric load at the Domain is currently about 14 megawatts (MW) but may eventually grow to 100 MW at full capacity [2]. The current peak thermal load is approximately 4,000 tons of chilled water. The Domain CHP system was installed in 2004 and operates in parallel with existing on-site electrical centrifugal chillers and is configured to feed power to the local electric grid. The Domain packaged CHP system consists of a 4.5 MW Solar Centaur 50 natural gas fired combustion turbine and a 2500 ton Broad USA, two stage, heat recovery absorption chiller that provides electrical power and chilled water to buildings in the Domain (see Figure 1).

The Domain CHP system features inlet air cooling to increase turbine efficiency at hotter temperatures (typically above the ISO* point of 59 degrees Fahrenheit), and a bypass damper to vary the turbine exhaust flow into the absorption chiller. The packaged CHP system has a natural gas compressor, powered by a 350 horsepower electric motor, to provide high pressure gas to the combustion turbine.

The Domain CHP system is a packaged or modular system using standard, pre-manufactured components. The idea is to integrate the various package components into a pre-engineered package, which can be delivered to the site on skids. The modular system is designed to reduce the custom engineering, planning and project lead time that

*International Organization for Standards

is standard for most CHP systems. A packaged design using standard, pre-manufactured components allows systems to be scaled up or down in size to serve a variety of situations. Integrating technologies into modular systems that include on-site power generation, heat recovery, and thermally activated technologies is intended to achieve efficiency gains not possible from designing and building an on-site system[3].

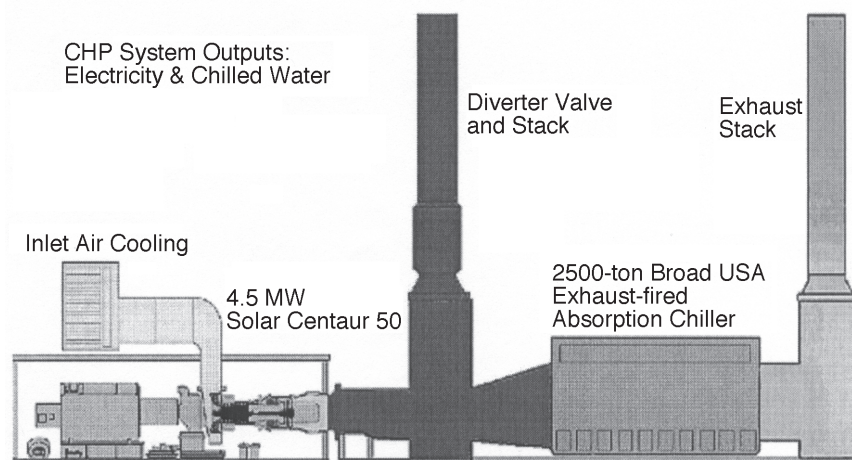


Figure 1. Domain CHP System Overview [4]

PERFORMANCE MONITORING AND MEASUREMENT

The Domain packaged CHP system is a unique system designed for efficiently producing electricity and cooling, with low emissions and detailed performance monitoring and measurement. The Domain CHP system is designed with extensive data measurement and performance monitoring equipment. The system is equipped with an array of data sensors that monitor and record the system inputs and outputs as well as intermediate conditions. The system has over 30 sensors monitoring and recording electric and thermal data for all components of the system: the natural gas compressor, turbine, generator, chiller, cooling tower, and auxiliaries. The Domain packaged CHP system is producing real-time, empirically verifiable performance data. All parties involved, the operating utility, equipment providers, Oak Ridge National Laboratory and The University of Texas at Austin, are working to assess the system's

performance in a manner that is accurate, transparent and verifiable. A goal of the initial performance monitoring is to provide performance data in a form that is accurate and makes sense to energy professionals and others who may be considering installing a packaged CHP system to meet electric and thermal needs in an efficient manner.

RESEARCH AGENDA

The packaged CHP system is anticipated to have benefits over systems using traditional grid electricity and standard heating, ventilation and air conditioning (HVAC) technologies as well as over custom engineered CHP systems. A research agenda was developed to determine these benefits and to compare performance to other systems. The agenda for research is designed to understand the performance of the CHP system under all operating conditions, and to determine what may be optimal operating parameters for the system. As part of the research agenda, system performance can be evaluated through thermal, electric and system efficiency measurements, as well as through identifying a family of system performance curves based on varying operating parameters.

EFFICIENCY

System performance can be monitored through measures of efficiency. Collected performance data allow for the determination of electric, thermal and system efficiency. An efficiency measurement is useful way to compare the performance of various technologies as well as whole systems.

The performance data collected from the Domain CHP system are complete enough to allow for efficiency to be reported in a number of ways. In particular, the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) protocols may be useful for evaluating the Domain CHP performance as well as comparing the performance to other systems because these are peer-reviewed sets of distributed generation testing protocols [5]. ASERTTI established interim protocols for laboratory testing, field testing, long-term monitoring, and case studies of microturbines, reciprocating engines, and small turbines

up to 3 MW. The protocols include methods for determining electrical efficiency, thermal efficiency and system efficiency for CHP systems. The test protocols cover microturbines from 10 kW to 250 kW capacity, and reciprocating engines and turbines up to 3 MW [6]. Although the ASERTTI protocols were not developed for the large CHP system installed at the Domain, the project is using ASERTTI measures of efficiency to evaluate system performance.

Efficiency for CHP systems is a more complicated measure than for conventional grid electricity and HVAC equipment because there are multiple useful outputs. A challenge is to identify a measure or set of measures that best accounts for the multiple useful outputs of a CHP system given a fuel input. Another challenge is appropriately factoring in efficiency losses from auxiliary systems, such as electric pumps, fan and controls.

CHP electrical, thermal and system efficiencies may be defined according to the following equations. Equation 1 describes net electric efficiency. Losses from parasitic loads, or auxiliary systems, may not be well measured for all systems. When determining efficiency, measures of net electrical efficiency may be appropriate, because net electrical output includes auxiliary losses.

$$\eta_{\text{net elec}} = \frac{\text{net electrical output}}{\Sigma \text{ fuel energy input}} \quad (\text{Eq 1})$$

where net electrical output equals gross electrical output minus auxiliary electrical inputs.

Equation 2 describes the thermal efficiency of the entire CHP system.

$$\eta_{\text{therm}} = \frac{\Sigma \text{ net usable thermal output}}{\Sigma \text{ fuel energy input}} \quad (\text{Eq 2})$$

It is important to note that Equation 2 is not the thermal efficiency of just the absorption chiller, but the thermal efficiency of the entire system.

Equation 3 represents system efficiency. It is the sum of the electrical and thermal efficiencies.

$$\eta_{\text{sys}} = \eta_{\text{elec}} + \eta_{\text{therm}}$$

$$\frac{\text{net electric output} + \Sigma \text{ net usable thermal output}}{\Sigma \text{ fuel energy input}} \quad (\text{Eq 3})$$

In all equations above, sigma denotes the usual sum over all sources of inputs or outputs, as indicated. Usable thermal output is considered to be the total thermal energy recovered from the CHP system (either cooling and/or heating) in a reporting interval. Fuel energy input is considered to be the energy of the input fuel based on the higher heating value in a reporting period. In the case of the Domain, the input fuel is exclusively natural gas. Because efficiency is a dimensionless number, all of the quantities must be reported in the same units.

SYSTEM PERFORMANCE

A goal of the research agenda is to test and monitor system performance under a variety of operating conditions. To study performance, a testing program was developed to vary the operating parameters of the system and record the system outputs and performance. The testing program is designed to understand the operation of the system under the various operating conditions outlined in the following table. Table 1 lists the minimum tests that are planned for the Domain CHP system.

Table 1. Domain CHP Testing Plan [7]

<i>Fix</i>	<i>Vary</i>
Turbine output	Chiller output
Chiller output	Turbine output
Chiller output	Bypass valve
Chiller output	Damper position
Close bypass valve	Turbine output
Turbine output	Chiller water flow
Turbine output	Condenser water flow
1. Repeat tests with full, partial and no inlet cooling.	
2. Repeat tests at various temperatures and humidity levels.	

The testing plan is designed to determine a family of performance curves for the system with the goal of identifying an overall system performance curve (or set of curves). Although, it is likely that equipment manufacturers have data for the individual subsystems, these curves for the entire system are not known. The goal of the testing plan is to be able to quantify these subsystem curves, plot overall system curves with the data collected from the system, and determine optimal system performance. Table 2 lists some of the various system and subsystem curves that describe performance.

Table 2. System Performance Curves [8]

Efficiency vs. turbine output
Efficiency vs. chiller output
Efficiency vs. ambient conditions
Efficiency vs. damper position

CONCLUSIONS

Packaged CHP systems, such as the Domain CHP system, which includes a 4.5 MW combustion turbine and a 2,500 ton absorption chiller, are an emerging technology that has great potential to provide users with cost effective, reliable energy with low emissions. The Association of State Energy Research and Technology Transfer Institutions (ASERTTI) developed a standard protocol to assess system performance. In order for an end user to decide if they want to adopt this technology, they need to be able to compare performance among alternative CHP systems as well as existing technologies in terms that are appropriate and meaningful. An important step to promoting packaged CHP systems is to report system performance in a meaningful way. A next step is to implement the developed research agenda, designed to understand the performance of the CHP system under all operating conditions, and to determine what may be optimal operating parameters for the system. Through this testing, system performance can be evaluated through thermal, electric and system efficiency measurements, as well as through identifying a family of system performance curves based on varying operating parameters. Completing this field performance assessment for the Domain will help to identify the realized benefits of the packaged CHP system.

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ABOUT THE AUTHORS

Adam Newcomer currently works to identify greenhouse gas emission reduction strategies for public power utilities. His research focuses on air quality issues and climate change policy. He holds a Masters degree from the LBJ School of Public Affairs at the University of Texas at Austin, where he held a scholarship from the American Public Power Association. He also has a Master of Science in Physics from the University of Arizona.

David J. Eaton, Ph.D. is the Bess Harris Jones Centennial Professor in Natural Resource Policy Studies at the LBJ School of Public Affairs at The University of Texas at Austin. Professor Eaton has over 30 years experience in natural resources. His research interests include energy, environmental engineering, non-profit studies, water management, natural

resources management, agriculture, and human health, both in the U.S. and other nations. His recent energy publications include three books and numerous reports and articles on electricity markets, distributed generation and cooling, heating and power systems. He earned a Ph.D. in environmental engineering and geography from The Johns Hopkins University.

Ed Mardiat, DBIA, is a principal and director of combined heat and power development for Burns & McDonnell. Mardiat has more than 25 years of design and project management experience, with the past 10 years focused on marketing and business development for utilities and infrastructure projects. He works with industrial, commercial and institutional clients to help them understand the impact of utility deregulation on their facilities. Mardiat currently serves on the executive board of the U.S. Combined Heat & Power Association. He may be reached at emardiat@burnsmcd.com.

Roderick G. Schwass is a program manager for Burns and McDonnell. As an engineering consultant in the Business and Technology Services Division of Burns and McDonnell Engineering, he has managed a diverse set of projects including analysis of public and private utility operations and management, assessment of commercial and military critical infrastructure vulnerabilities, and research and development of energy efficiency and distributed generation technologies. Mr. Schwass holds a BS in Physics from Holy Cross College, an MBA from National University and an MA in Strategic Studies from the Naval War College. A former active duty senior naval officer, he has over 19 years of engineering, management and organizational planning experience. He may be contacted at rschwass@burnsmcd.com.

Cliff Braddock, C.E.M., director of Energy Business Development for Austin Energy, is responsible for the development of new energy business for Austin Energy, the City of Austin's municipal utility. The new business ventures support the City of Austin's goal to be recognized as the 'Clean Energy Capital of the World.' Austin Energy is a recognized leader in conservation and demand-side management programs and has earned the distinction of being the leading utility in the United States for sales of renewable energy... Braddock may be reached at cliff.braddock@austinenergy.com

Jeanette (Jan) B. Berry is the program manager for combined heat and power systems at the Oak Ridge National Laboratory. Jan manages projects to design and install prototype CHP systems that utilize 3 to

5 MW gas turbines, absorption chillers, and 200-kW fuel cells. She is a member of the American Institute of Chemical Engineers and the American Society of Heating, Refrigerating, and Air Conditioning Engineers. She has authored or co-authored over 90 papers. Ms. Berry has a Master of Science in Chemical Engineering from the University of Tennessee and a Bachelor of Science in Chemical Engineering from the University of Florida. She may be contacted at berryjb@ornl.gov.