Introduction to Combined Heat and Power

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(1PDH issued by Cummins)
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- Earn PDH

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Course Objectives

Participants will be able to:

- Define CHP project concepts and terminology to discuss customer CHP opportunities
- Identify economic, design, and operational criteria to propose different CHP configurations and equipment
- Identify the key tools and data required to create informed CHP feasibility studies
CHP Overview

- CHP, Combined Heat and Power
  - The utilization of both heat and electric energy from a Genset
  - Also known as Co-generation or Co-Gen
    - US EPA uses the term Co-generation

- CHP is not a new technology
  - Used in Thomas Edison’s first electric generating plant in 1891
  - Used in industrial, institution, and municipal applications today

- Cogeneration systems can provide hot water, steam, chilled water, or all 3 simultaneously
CHP Benefits

- **Energy efficiency**
  - Could reach 90% global efficiency

- **Financial savings**
  - Energy cost savings
  - Attractive return on investment (ROI)
  - Potential incentives for fuel efficiency and emissions reduction benefits of CHP

- **Environmental**
  - Reduced environmental footprint
    - Reduction in CO₂, NOₓ, and particulates compared to central power plant
  - Higher efficiency means better conservation of natural resources
A coal-fired plant turns only 30% of the fuel consumed into electricity. The rest is lost during production, transmission and distribution. (U.S. Average)
Generation with CHP

COMBINED HEAT AND POWER

IN
Fuel 100%

OUT
Heat losses 15%

OUT
Electricity 45%

OUT
Usable Heat 40%

= 85% energy output (U.S. Averages)

Natural gas plant

CHP is an efficient choice. Up to 85% of the fuel consumed can be turned into usable energy in properly sized and operated systems.
Application Considerations

- Electrical loads
  - Sufficient base electrical load or export capability

- Thermal loads
  - Sufficient equipment or process that can use the heat energy

- Balance between electrical and thermal loads is critical for optimum CHP performance
  - Available heat energy is dependent on the electrical output
  - If not balanced, either the excess heat must be dumped or the excess electrical power exported.
Heat Energy Sources

- When to use each heat source?

- Heat source temperatures
  - Low temperature (LT), or after cooler circuit (~ 40-60 °C, 104-140 °F)
  - High temperature (HT), or jacket water circuit (~90-110 °C, 194-230 °F)
  - Exhaust (~450-550 °C, 842-1022 °F)

- Typical heat uses and components
  - Steam production → Boiler (exhaust)
  - Hot water → EGHE, Engine Cooling HX (exhaust and/or HT, LT)
    - LT circuit sometimes used as pre-heat to prevent thermal shock
  - Cold water → Chiller (exhaust and/or HT)
Simplified CHP Schematic

Schematic of Typical Spark-Ignition Gas Engine CHP

- Lube Oil Cooling LT
- Engine Cooling HT
- Customer Water From Site
- Customer Water To Site
- Exhaust Heat Exchanger
- Alternator
- Electricity To Site
Required Information

Customer

- Electrical load profile
- Thermal load profile
  - Heat transfer media
    - Steam, water, oil, etc.
  - Process temperatures
    - Input and output
  - Process flowrates

Cummins (Datasheet)

- Genset kW rating
- Thermal energy from each heat source
- Heat source flowrates temperatures
Sample Data Sheet

Model: C1750 N6C
Frequency: 60 Hz
Fuel Type: Natural Gas MI 80 -

### HT Cooling Circuit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT Circuit Engine Coolant Volume, l (gal)</td>
<td>424 (112)</td>
<td>424</td>
<td>4</td>
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<tr>
<td>HT Coolant Flow @ Max Ext Restriction, m³/h (gal/min)</td>
<td>60 (264)</td>
<td>60</td>
<td>6</td>
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<tr>
<td>Maximum HT Engine Coolant Inlet Temp, °C (°F)</td>
<td>8 (97 (207))</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>HT Coolant Outlet Temp, °C (°F)</td>
<td>8 (110 (230))</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Max Pressure Drop in External HT Circuit, bar (psig)</td>
<td>1.0 (15)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>HT Circuit Maximum Pressure, bar (psig)</td>
<td>4.5 (65)</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Minimum Static Head, bar (psig)</td>
<td>1.5 (22)</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### LT Cooling Circuit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT Circuit Engine Coolant Volume, l (gal)</td>
<td>295 (78)</td>
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<td>295</td>
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<tr>
<td>LT Coolant Flow @ Max Ext Restriction, m³/h (gal/min)</td>
<td>38.00 (167)</td>
<td>38.00</td>
<td>38.00</td>
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<tr>
<td>Maximum LT Engine Coolant Inlet Temp, °C (°F)</td>
<td>9 (50 (122))</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>LT Coolant Outlet Temp, °C (°F) Reference Only</td>
<td>9 (60.0 (140))</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Max Pressure Drop in External LT Circuit, bar (psig)</td>
<td>1.0 (15)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>LT Circuit Maximum Pressure, bar (psig)</td>
<td>4.5 (65)</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Minimum Static Head, bar (psig)</td>
<td>1.5 (22)</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Equipment

- CHP system design must integrate the facility process to the available Genset heat
  - Heat exchangers
  - Radiators
  - Heat transfer media: steam, water, oil, etc.
  - Pumps, flows, piping design, thermal storage
  - CHP Control system(s)
  - Paralleling switchgear
HT and LT Heat Exchangers

Shell & Tube heat Exchanger
Operational Weight: 130kg (285lbs.)
Capacity: 120kW

Plate & Frame Heat Exchanger
Operational Weight: 20kg (44lbs)
Capacity: 120kW
Exhaust Heat Exchangers

Exhaust Gas HX (EGHE)

QSV91G 1750 kW produces approximately 1.37 Ton/hr (2740 lb/hr) of steam at 8 bar(g) (116 psig)
Boiler Requirements

- Steam pressure and flow rate
  - Steam tables are great reference
- Water inlet temperature and flow rate
- Safety equipment
  - Pressure relief valve
  - Pressure gauges
  - Water level sensor
  - Applicable pressure vessel local regulations
  - Insulation
- Water treatment
Utilizing the Exhaust

- Equipment using exhaust as heat source must be bypassed during engine start-up
- Water, or heat transfer media, must be running through heat exchanging equipment before start-up
- Having a common exhaust pipe will affect heat output when not all engines are running
  - Affects heat exchanging equipment size
- Valve, bypass pipe, non-common exhaust, control, purging
- After-treatment equipment must be installed upstream heat exchangers/boilers
  - After-treatment has a specific temperature operating range
Absorption Chillers

John Wayne Airport, Los Angeles, CA
- 2x 535 Ton Hot Water Absorption Chillers
- 4x C1750N6C gensets
Radiators
General Installation Considerations

- Pressure & temperature indicators
- Thermostatic valves
  - Better temperature control
  - Higher efficiency
  - Lower temperature to the cooling circuit affects heat energy output, temp, flow rate
- Pipe insulation
- Pumps need to be installed before heat exchanging equipment
  - Pressure relief valve needs to be installed right after pump outlet to protect downstream equipment
- Isolation valves are recommended for each equipment for better serviceability
CHP Control System

- CHP system requires a dedicated control system
  - Typically, PLC with HMI
  - Genset and Master Controls do not operate the CHP system
Paralleling Switchgear

- For optimum performance, CHP system runs at a constant load parallel to the utility
- Electric power could be used internally or exported
Carbon Dioxide (CO₂) Recovery

Bottling Companies

Green House (Ready, Set, Grow)
Cummins Green House Campaign

www.cumminsgreenhouse.com
Greenhouse Applications

Traditional System

Grid Power

Boiler

CHP System

30% Cost Savings

ENERGY

FERTILIZER

CO₂

HEAT

Natural Gas Generator Set

45% Efficiency

90% Efficiency

- May be higher due to surplus energy sold, water from exhaust for greenhouse operations, heat storage for later use
Who can use CHP?

- Hospitals
- Greenhouses
- Hotels
- Industrial/Chemical Plants
- Manufacturing Facilities
- Commercial Facilities
- Government Facilities
- Colleges and Universities
- Food Processing Plants
- Health Clubs
- Swimming Pools
- Nursing Homes
- District Heating
- Landfills and Sewage Treatment Plants
- Coal Mining and Oil Fields
CHP Case Study:
De Breuck Greenhouses, Belgium

Compared with separate heat and electricity production, the CHP system realizes an energy savings of about 25 percent.

Where:
At the tomato greenhouses of Geert De Breuck in Sint-Gillis-Waas, Belgium

What:
A lean-burn gas generator set producing heat and electric power to reduce energy costs and accelerate growth of tomatoes

Purpose:
Generate electricity for on-site use and for sale to the power grid, while simultaneously producing heat and carbon dioxide for plant growth

Primary choice factors:
High fuel efficiency, reliability, high specific heat output and expert help from Cummins Power Generation to optimize system operating parameters
Desmet Greenhouse, Belgium

- Commercial tomato grower Desmet in Aardooie, Belgium
- 2MWe & 2.7MWth production
- Exhaust gas clean-up allows for CO2 recovery into the greenhouse
- Global efficiency >90%
CHP Case Study: Chicago Museum of Science and Industry

“Before we turn the air conditioning on, the system is carrying about 90 percent of the building’s total electrical load. It pleases me how well it works,”

Bill Vanderbilt, facilities manager, Museum of Science and Industry

Where:
Museum of Science and Industry, Chicago, IL, USA

What:
Cogeneration installation featuring a Cummins Power Generation 1.75 MW lean-burn gas generator set, heat-recovery boiler and desiccant dehumidifier providing electricity, heating/cooling and domestic hot water

Purpose:
Demonstrate how a cogeneration or combined heat and power (CHP) system can save energy and money

Primary choice factors:
Cummins Power Generation lean-burn engine technology that delivers high fuel efficiency, low emissions and high specific heat output
Facility evaluation for CHP

1. Have all reasonable steps been taken to reduce both electric and heat energy consumption?
2. Is the base electrical load of the facility greater than an available Genset continuous rating?
3. Is the thermal load of the facility greater than the available thermal energy from the Genset?
4. Is the duration of simultaneous need for heating/cooling and electric power greater than 6000 hours/year?
5. Are electric rates high in relation to NG rates?
6. Is the site suitable for installation of a co-gen system?
7. Is reliability of electric service a major economic concern?
8. Has an economic analysis been done?
Summary

- CHP can provide several advantages including energy efficiency, reduced environmental footprint, and financial savings
- Start by understanding site energy use – both heat and electricity
- CHP system design depends on energy utilization, customer processes, site considerations, and Genset characteristics
- Contact Cummins Power Generation for assistance in performing facility evaluation and ROI analysis
Q&A

- Type your questions, comments, feedback in the WebEx Q&A box. We will get to as many questions as we can.
- We will publish consolidated FAQ along with presentation and webinar recording on powersuite.cummins.com

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Closing

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- Please contact Mohammed Gulam if you have any questions related to the PowerHour webinar (mohammed.gulam@cummins.com)