How To Determine The Proper Size, and Generator Type For Municipal Size Power Projects

10/4/17
Agenda

• Why Recips & Turbines?
• The Case for Recips
  – Fuel Considerations
  – Hours of Operation
  – Example Projects
• The Case for Turbines
  – Hours of Operation
  – Example Projects
• Final Recommendations
• Questions & Comments
History of Caterpillar

Founded in 1925

• Product line included 5 tractors
• 1st years sales = $13.8 Million

Today

• Product line now exceeds 300 products
• Revenues exceeding $47 Billion
• CAT Inc. is a Fortune 50 Company
• One of 30 companies on the Dow Jones Industrial Average
• Global footprint – with equipment in over 180 countries
• CAT has over 24 GW of gas engines in operation globally, and over 28,000 units.
Why Recips & Turbines?

25 Michigan coal plants set to retire by 2020

- DTE's Harbor Beach - 121 megawatts - 1 unit retired in 2013
- DTE's Trenton Channel - 240 megawatts - 2 units retired in 2016
- Consumers Energy's BC Cobb plant in Muskegon - 312 megawatts - 2 units retired in 2016
- Consumers Energy's JC Weadock plant in Essexville - 312 megawatts - 2 units retired in 2016
- Consumers Energy's JR Whiting plant in Erie - 345 megawatts - 3 units retired in 2016
- Holland Board of Public Works' DeYoung plant - 63 megawatts - 3 units retiring in 2017
- Lansing Board of Water and Light's Eckert plant - 335 megawatts - 6 units retiring in 2018
- Wisconsin Electric's Presque Isle plant - 450 megawatts - 5 units retiring in 2020.

= 2,233 MW of base load power generation
Why Recips & Turbines?

U.S. electricity generation by fuel, all sectors

thousand megawatthours per day

Source: Short-Term Energy Outlook, September 2017
Why Recips & Turbines?

U.S. residential electricity price

Source: Short-Term Energy Outlook, September 2017
Why Recips & Turbines?

Custom chart, monthly

cents per kilowatthour

Data source: U.S. Energy Information Administration
Why Recips & Turbines?

Monthly Natural Gas Prices, 2006 – Present ($/Million Btu)

Source: EIA
Why Recips & Turbines?

Grid Diversification

“The electric grid is currently undergoing a significant transformation – changing fuel mixes, advances in energy technologies, and evolving consumer demands. These changes present opportunities for consumers to become active market participants and to have greater control over their energy usage.”

Rep. Fred Upton (R-MI), Chairman of House Energy & Commerce Committee
CONSUMERS BENEFIT FROM RESOURCE DIVERSITY

• Grid Operators Are Successfully Managing More Gas and Renewables
• Grid Operators Increasingly Value Flexibility Over “Always On” Power
• Low-cost, flexible resources are the future of the electric grid.
Why Recips & Turbines?

Your customers are already thinking about peak shaving, load shifting, CHP, energy storage, etc…projects to help control their cost of energy.
The Case for Recips

• Attributes of diesel and gas engines
  • What’s Similar, What’s Different
  • Application Considerations (Demand Response/Peaking)

• Considerations if applying gas engines

• Technology selection for peaking applications

• Technology selection for CHP applications
Similarities between Gas and Diesel

- Electrical
- 4 Stroke Cycle
- Air Intake Systems
- Exhaust Systems
- Cooling Systems

3516C-HD 2/2.25/2.5MW

G3516H 2MW, Continuous
Differences Between Gas and Diesel

**Fuel System**
- Direct Injection
- Vs
- Carbureted

**Ignition System**
- Compression
- Vs
- Spark Ignited

3516C-HD 2/2.25/2.5MW

G3516H 2MW, Continuous

Cat® Electric Power
Diesel vs Natural Gas Fuel

• Diesel is standardized
  – #1, #2, ULSD, etc…

• Natural Gas is not
  – Typical 70-90MN
  – Variations across country
  – Variations at a given site
  – Always request gas analysis
  – Understand gas fluctuations
What’s Methane Number (MN)?

- Engine manufacturer calculation of fuel's resistance to uncontrolled combustion

Detonation Resistance

- LOW
  - Hydrogen
  - $\text{H}_2$
  - MN = 0

- HIGH
  - Methane
  - $\text{CH}_4$
  - MN = 100
Diesel vs Gas Ratings

- Diesel engine ratings
  - Rating limits structural
  - Increased rating, increased engine wear
  - Standby, Prime, and Continuous ratings
    - Ex: 3516C-HD 2500 / 2250 / 2050

- Gas engine ratings
  - Rating limits are thermal
  - Same rating for standby, prime, and continuous
  - No overload capability
## Diesel vs Gas Emissions

### NSPS EPA Comparison

<table>
<thead>
<tr>
<th></th>
<th>Emergency Use</th>
<th>Non-Emergency Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diesel</strong></td>
<td>NOx 6.4 g/bhp-hr</td>
<td>0.67 g/bhp-hr</td>
</tr>
<tr>
<td></td>
<td>CO 3.5 g/bhp-hr</td>
<td>3.5 g/bhp-hr</td>
</tr>
<tr>
<td><strong>Gas</strong></td>
<td>NOx 2 g/bhp-hr</td>
<td>1 g/bhp-hr</td>
</tr>
<tr>
<td></td>
<td>CO 4 g/bhp-hr</td>
<td>2 g/bhp-hr</td>
</tr>
</tbody>
</table>

>560 bkW example

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Diesel vs Gas Load Acceptance

- Diesel accepts transient load better than gas
- Diesel start faster than gas
- Steady state stability is better with diesel
- Some gas engines accept load better than others
  - Less efficient engines accept load better than high efficiency engines
  - Other contributing factors
    - Gas pressure, temperature, air restrictions
Diesel vs Gas CAPEX

- Gas CAPEX is typically 1.5 – 2X of emergency diesel
- Gas CAPEX on par with non-emergency use diesel
Applications for Gas and Diesel

• Standby

• Demand Response / Peak Shaving

• Continuous / CHP
DWSD – Y2K

• 55 x 2000kW Generators
• + Custom Enclosures
• + Ballistic Proof Fuel Tanks
• + Automatic Transfer Switches
• + Paralleling Switchgear
DC Cook Nuclear

- 2 x 2250 kW
- + Custom Enclosure
- + Dual Wall Fuel Tanks
- + Paralleling Switchgear
Peaking with Diesel

- Asset also used as standby
- Required to utilize non emergency diesel
- Regional demand response program
- Typically low hour 0-150 hours per year
Customer: CMS Energy
Location: Dearborn, Michigan

Customer Requirement: Utility - Peak Shaving, 38 MW

Scope of Supply:
- Equipment:
  - 26 x Cat 3516 utility-grade power modules
  - 26 x 2500 kVA step-up transformers
  - Cable
- Services:
  - Installation and start-up
  - Maintenance
  - Monitoring
  - Decommissioning

Cat Rental Power Dealer: Michigan Cat, Novi, Michigan
Energy International, Miami, Florida
SOLAR® ENERGY STORAGE
Smart Solution for Energy Optimization

ENERGY STORAGE SYSTEM

1. BATTERIES
2. BATTERY PROTECTION UNIT
3. BATTERY RACK
4. INVERTERS
5. TRANSFORMER
6. FIRE SUPPRESSION
7. CONTROL PANEL
8. HEAT EXCHANGERS
9. AIR CONDITIONING UNITS

SMART INTEGRATED SOLUTION • ENERGY OPTIMIZATION • RENEWABLE INTEGRATION

Cat® Electric Power
Peaking with Gas

- Natural gas OPEX allows wider range for peaking
- Typically up to 3,000 hours per year
- Duel purpose gas standby/peaking creates larger revenue opportunity
- Minimal aftertreatment
Peaking with Gas
Peaking with Gas
Peaking/Solar Firming with Gas

- ISO Container Advantages:
  - Lower Capital Costs
  - Smaller Footprint
  - Greater Mobility

Switchgear

Radiator
Peaking with Land-Fill Gas
Peaking with Land-Fill Gas
Diesel vs Gas Summary

Installation: some minor differences

Load Acceptance

CAPEX (Emergency)

CAPEX (Non-Emergency)

OPEX
Recips vs. Turbines

• Diesel vs. Gas Engine
  – What’s Similar, What’s Different
  – Application Considerations
    – Demand Response / Peaking

• Gas Engine vs. Turbine
  • What’s Similar, What’s Different
  • Application Considerations
    • Peaking
    • Combined Heat & Power
The Case for Turbines

• Gas Engine vs. Gas Turbine
  • Advantages of each technology
  • Application Considerations
    • Peaking
    • Combined Heat & Power
Gas Engine and Turbine Similarities

• Low Emissions
• High Reliability
• High Availability
• Suited for High Hours
• Low Life Cycle Cost
Gas Engine Advantages

• Higher electrical efficiency
• Lower CAPEX
• Variable load applications
• High altitude/high ambient
• Lower fuel pressure
• Start and on-line time
Turbine Advantages

• Suited for CHP with large heat to ekW ratio
• Higher exhaust temps (900°F vs 750°F)
• 24/7 operations
• Footprint
• Less maintenance cost
• Lower emissions
Gas Engine vs. Turbine Technology Review

<table>
<thead>
<tr>
<th>Metric</th>
<th>Gas Engine</th>
<th>Turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Efficiency</td>
<td>100%</td>
<td>75%</td>
</tr>
<tr>
<td>75%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emissions (NOx g/bHP-hr)</td>
<td>0.5 - 1</td>
<td>0.075 - 0.125</td>
</tr>
<tr>
<td>Heat to Electricity Ratio</td>
<td>1:1</td>
<td>2:1</td>
</tr>
<tr>
<td>Type of Heat Available</td>
<td>Hot Water, Some Steam</td>
<td>Mostly Steam</td>
</tr>
<tr>
<td>Load</td>
<td>More Variable</td>
<td>More Constant</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>$0.01/kW-hr</td>
<td>$0.075/kW-hr</td>
</tr>
</tbody>
</table>

Cat® Electric Power
Application Considerations
Gas Engine vs. Turbine

- Peaking

- Combined Heat and Power
Peaking

Gas engines usually best option
  – Start time
  – Higher electrical efficiency
  – Frequent starts and stops
Combined Heat and Power (CHP)

- Gas engines make sense when...
  - Electricity generation is driving factor
  - Applications with hot water and some steam
  - Increased high altitude and high ambient capability
  - Better efficiency at part load
Combined Heat and Power (CHP)

- Turbines make sense when...
  - Heating / cooling driving factor
  - Applications with large steam demand
  - Extended run hours with consistent load
## Gas Engines vs. Turbine Summary

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<tr>
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<th>Turbines</th>
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<tr>
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</tr>
<tr>
<td>Electricity Cost Driver</td>
<td></td>
<td>![Electricity Cost Driver Logo]</td>
</tr>
<tr>
<td>Heat / Cooling Cost Driver</td>
<td>![Heat / Cooling Cost Driver Logo]</td>
<td>![Heat / Cooling Cost Driver Logo]</td>
</tr>
</tbody>
</table>
Oakland University

1 x 4.6 MW Combustion Turbine
+ Heat Recovery Water Boilers
MSU TB Simon Power Plant

- 15 MW Combustion Turbine
- + Heat Recovery Steam Turbine
Ford Motor Company

- 2 x Taurus 60
  - Portable combustion turbines
  - Each Rated at 5.2MW
  - Duel Fuel capable
  - Shipped to Venezuela
Combined Heat and Power (CHP)

Turbine or Gas Engine?

- 95% of cases there’s no contest
  - If NPV evaluation is made correctly the choice of the proper size and type of generator is easy

- Low temp, low pressure gas, high altitude…go engines

- Large heat/ekW ratio, high pressure steam…go turbines
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