DISTRIBUTED ENERGY RESOURCES

ADVANCED RECIPROCATING ENGINES SYSTEMS (ARES) PROGRAM

TECHNOLOGY OVERVIEW

The reciprocating, or piston-driven, engine is a widespread and well-known technology. Also called the internal combustion (IC) engine, reciprocating engines require fuel, air, compression and a combustion source to function. Depending upon the ignition source, they generally fall into two categories: 1) spark-ignited engines, typically fueled by gasoline or natural gas, or 2) compression-ignited engines, typically fueled by diesel oil fuel.

The four-stroke, spark-ignited reciprocating engine has an intake, compression, power and exhaust cycle. In the intake phase, as the piston moves downward in its cylinder, the intake valve opens and the upper portion of the cylinder fills with fuel and air. When the piston returns upward in the compression cycle, the spark plug emits a spark to ignite the fuel/air mixture. This controlled reaction, or "burn", forces the piston down thereby turning the crank shaft and producing power.

The compression-ignition engine operates in the same manner, except the introduction of diesel fuel at an exact instant ignites in an area of highly compressed air/fuel mixture at the top of piston.

In the exhaust phase, the piston moves back up to its original position and the spent mixture is expelled through the open exhaust valve.

Commercially available reciprocating engines for power generation range from 0.5 kW to 6.5 MW. The wide power range and operating flexibility make reciprocating engines suitable for substations and small municipalities plus commercial, industrial, institutional, and even residential applications.

MARKET POTENTIAL

Reciprocating engines are the fastest-selling, lowest-cost distributed generation technology in the world today. Reciprocating engines can be used in a variety of applications due to their small size, low unit costs, and useful thermal output. They offer low capital cost, easy start-up, proven reliability, good load-following characteristics and heat recovery potential. Possible applications for reciprocating engines in power generation include continuous or prime power generation, peak shaving, back-up power, premium power, remote power, standby power and mechanical drive use. When properly treated, the engines can run on fuel generated by waste treatment (methane) and other bio-fuels. Reciprocating engines also make up a large portion of the combined heat and power (CHP), or cogeneration, market. Currently cogeneration accounts for seven percent of the electricity produced in the U.S. and approximately six percent (200MW) of worldwide capacity annually.

OVERVIEW OF ADVANCED RECIPROCATING GAS ENGINES

Installed Costs	\$400 - \$450/EkW
Maximum Efficiency	50% Thermal, 80+ % with CHP
NOx Emissions	0.1 grams/bhp-hr
Maintenance Costs	\$0.01/EkW-hr
Major Service Interval	Annually
Operator Training	100 hours

Why ARES?

The new millennium needs a higher standard of engine technology to meet ever increasing demands for more energy and stricter environmental regulations.

Established U.S. engine manufacturers are entering a into cooperative program, which over the next several years, will bring forth a new generation of highly advanced, natural-gas fired engines to meet future needs.

Through competitively funded, multiple-participant R&D programs, manufacturers and supplier teams will research advanced materials, unique fuel handling and processing systems, advanced ignition and combustion systems including catalysts, and technology that's compatible with existing transmission and distribution systems.

ARES program goals include:
- improved fuel efficiency and flexibility
- lessened dependence on foreign sources of fuel,
- ultra-low emissions,
- lower cost power technologies,
- improved power system and grid reliability.

DISTRIBUTED ENERGY RESOURCES

IC Engines Provide Proven Power

Internal Combustion engines have been produced for well over a century, and currently have an established base of sales and service outlets worldwide to efficiently support this technology. Manufacturers have continually invested in efficiency and reliability gains over this time, and more recently focused on reducing emissions in response to customer demands for a cleaner environment.

Natural gas versions of the internal combustion engines currently have thermal efficiencies between 37 and 40 percent, and can operate down to NOx levels of 1 gram per bhp-hr. These engines are commercially available, with demonstrated abilities to support local power grid requirements, combined heat and power applications, fuel supplies from wellhead to landfill gasses, and most recently prime power for the regional power shortage on the West Coast.

Internal Combustion engines have a well understood business model for the investment community, and provide consistent financial results for investors and operators alike.

Internal combustion engines providing combined heat and power.

U.S. DEPARTMENT OF ENERGY PROGRAM

The U.S. Department of Energy (DOE) is currently developing advanced natural gas-fired reciprocating engine systems for distributed energy resource (DER) applications in industry, commercial buildings, and utility settings. DER refers to local energy systems that generate electric, thermal or mechanical energy on or near the customers' site. In addition to power generation systems, DER includes energy storage, grid interconnection and demand management systems, which are important components in power quality and availability. The mission of this program is to lead a national effort to design, develop, test and demonstrate a new generation of reciprocating engine systems for DER applications that are cleaner, more affordable, reliable and efficient than products that are commercially available today.

Planned activities for this program focus on the following performance targets for the next generation of reciprocating engines:

High Efficiency - The target for fuel-to-electricity conversion efficiency (low heating value) is 50 percent by 2010, a 30 percent increase from today's average efficiency.

Environment - Engine improvements in efficiency, combustion strategy and emissions reduction will substantially reduce overall emission to the environment. The NOx target for the Advanced Natural Gas Reciprocating Engine is 0.1g/hp-hr, a 95 percent decrease from today's NOx emissions rate with no deterioration of other criteria or HAPS emission.

Fuel Flexibility - Natural gas-fired engines are to be adaptable to future firing with dual fuel capabilities. Dual fuel options may be considered in the design.

Cost of Power - The target for busbar energy costs, including operating and maintenance costs, is 10 percent less than current state-of-the-art engine systems while meeting new projected environmental requirements.

Availability, Reliability, and Maintainability - The goal is to maintain levels equivalent to current state-of-the-art systems.

ARES Program Activities

Program Initiation in 1998
ARES Consortium Formed in 1998
Team Goals Defined
Baseline Engine Development through 2001
Breakthrough Technologies Defined
ARES Concept Tests 2002

ARES Team Members
Caterpillar
Cummins
Waukesha Engine
Dept. of Energy

Supporting Activities
National Lab Activities
University Support Organization
Research Institutes

Supporting Technologies
Combustion Development
Air Systems Development
Aftertreatment Development
Control System Integration
Friction Reduction
Lube System Development

For More Information:

DOE Advanced Reciprocating
Engines Program
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