MICROSTEAM® POWER SYSTEM

Opening a New Market for Energy Recovery and On-Site Power Generation

Carrier

Turn to the Experts.

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INTRODUCTION
Opening a New Market for Energy Recovery and On-Site Power Generation

In today’s unpredictable and sometimes volatile world energy market, district energy operators are continually challenged to find new ways to contain their costs and maximize their resources in order to deliver reliable, economical, efficient and environmentally sound energy services. Forward-thinking facility operators of healthcare and educational campuses that have steam boilers or steam services with pressure reducing valves (PRVs) are now realizing that they have a significant opportunity to generate their own electricity through the use of the new generation of the Microsteam power system. By doing so, they will take advantage of an available but often under-utilized resource, contribute to their electric power peak shaving efforts, improve their energy security, and implement a strategy that will help them meet their long-term energy needs.

THE UNIQUE MICROSTEAM POWER SYSTEM

The unique vertical Microsteam power system design (Fig. 1) targets applications up to 275 kW per unit of electrical production with a 4,000 to 20,000 lb/hr steam load. Multiple Microsteam power systems can be combined in parallel to deliver megawatts (mW) of electrical energy to satisfy the largest of commercial power needs. The physical arrangement of the Microsteam power system consists of a top mounted, high-speed, high efficiency Euler dual-pressure turbine connected to a planetary gear, which in turn is connected to an induction generator. This package design addresses the space limitations and reliability requirements of commercial applications; provides operational simplicity with single button start-up and shutdown; meets the sound criteria of equipment rooms; and delivers the performance requirements for a 2 to 5 year payback investment.

Fig. 1. Microsteam® Power System
The 34-in. wide by 42-in. deep by 78-in. high packaged arrangement accepts inlet steam pressures up to and including 250 psig. At a supplied pressure of 150 psig and a flow rate of 12,000 lb/hr, the package reduces the steam pressure to the load to 15 psig, and delivers 275 kWe electrical output in parallel operation with the utility grid, while operating at 85 dBA with less than 1 mil of vibration. This performance translates to an estimated 2 to 5 year payback depending on hours of operation and cost of electricity. The first commercial application is installed in the 7 World Trade Center building in New York City.

The Logic Behind Implementing a Microsteam® Power System Strategy

There are a many factors that prove why Microsteam power systems make sound fiscal and operational sense in today’s district energy environments.

First and foremost, the unstable and fluctuating (often rising) purchase cost of electricity continues to plague district energy operators. Today, electricity generation is one of the largest and most capital-intensive sectors of our economy. Total asset value is estimated to exceed $800 billion, with approximately 60% invested in power plants, 30% in distribution facilities, and 10% in transmission facilities [1]. By augmenting your ability to deliver electricity within your own facilities using existing steam pressure, the Microsteam power system can help combat rising electricity costs.

For those whose organizations are realizing the many benefits of certifying your building projects through the U.S. Green Building Council’s LEED® (Leadership in Energy and Environmental Design) Green Building rating system, the application of power generation from steam may contribute to LEED credits based on energy recovery, energy cost reduction, and innovation potential. As an example, the 7 World Trade Center project collected one LEED-NC IDc1 point under the Innovation in Design category for its use of the Microsteam power system.

Another contributing factor to the viability of using the Microsteam power system is the abundance of steam within many private district energy facilities. Without steam turbine generators, this valuable resource is currently being lost through PRVs.

Clearly, utilizing existing steam sources to generate electricity makes perfect fiscal, operational and environmental sense.

Speaking of the environment, the potential for this new Microsteam power system to be used on a wider base of installations represents an important step towards a world that views energy recovery as an integral and essential part of creating sustainable working and living environments for generations to come.

Buildings that use district steam now have many distinct advantages over traditional generating units such as diesel backup generators, microturbines or fuel cells. Using existing steam means there is no on-site combustion, so there are no requirements for emission permits, exhaust stacks, fuel delivery or storage, or extra fire safety systems. Additionally, new technologies are now making this option much more economically viable, creating an opportunity for energy cost cutting through steam-driven on-site power generation.

Figure 2 shows a typical installation of a Microsteam power system that generates electricity from an existing steam system utilizing a PRV. Connected in parallel with a PRV, a high-pressure steam source feeds both the PRV and the Microsteam power system. Prior to the installation of a Microsteam power system, the high-pressure steam was reduced in pressure (with a percentage being wasted) and used to power a single-effect absorption chiller and/or another low-pressure load. The addition of a Microsteam power system makes it possible to generate electricity, which can be fed back into the primary building grid.

![Fig. 2. Typical Installation of a Microsteam® Power System](image-url)
Zero-Emissions Distributed Generation as Certified by California’s Air Resources Board

On November 15, 2001, the Air Resources Board of California adopted a regulation that established a distributed generation (DG) certification program in support of their mission to promote and protect the public health, welfare and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state. In following this mission, the DG certification program requires manufacturers of electrical generation technologies, such as the Microsteam® power system, to certify their technologies to specific emission standards before they can be sold in California. The 275 kWe Microsteam power system has the distinction of being accepted under DG Certification, Executive Order DG-017 as a zero emission DG system granted on July 2, 2007. This certification is testimony to the zero emissions distinction of the Microsteam power system.

500 kW Applications: Challenges of the Past

As one of the oldest prime mover technologies still in production, traditional steam turbines have been generating most of the electricity in the U.S. for well over a century. Although steam turbine capacities can range from 50 kW to several thousand mW [2], the new generation of Microsteam power systems have been designed to meet the electrical needs of the commercial segment typically not serviced by steam turbine generation — the 500 kW and under market.

Until recently, choosing a steam turbine generator for electrical applications of 500 kW and under had significant drawbacks. Although the earlier generator “sets,” as they were called, represented the latest steam turbine generation technology of the day, the primary barriers to their application was a marginal payback. Commercially available steam turbines for these applications had efficiencies in the 35 to 50% range. This low efficiency resulted in low power production for a given steam load, which resulted in a high installed cost per kilowatt produced and low electricity cost savings.

Next, these units required architects and engineers to design large areas for their physical location as well as solve rigging and routing aspects, steam piping and electrical connection challenges. Finding enough space in a mechanical equipment room to engineer an extremely heavy and large-footprint unit into a permanent position often proved difficult.

Installing and calibrating these cumbersome horizontally configured units required extensive field wiring and installation labor and specialized mounting equipment and materials. As a result of their design complexity, the operational characteristics of these units required constant daily attention, in addition to costly annual shutdown and overhaul procedures.

In many cases, these devices were located close to the load and away from the central steam production plant, so there was a concern that the level of expertise required to run them was beyond the capabilities of a local operator.

While running, these machines were also prone to maintenance events as the result of excessive vibration, which also generated high decibels of ambient noise, requiring additional sound attenuation strategies to be employed.

The quality of the steam used to drive steam turbines often proved to have a damaging effect on many of the components, requiring costly downtime and maintenance. The susceptibility of these machines to corrosion, corrosion fatigue, minerals and non-ionic deposits is well documented.

The combination of these drawbacks led many within the industry to think that the 500 kW and under market could not be serviced efficiently with steam turbine generating technology.

Until now.

The New Generation of Microsteam Power System: A Perfect Fit

The revolutionary and innovative technologies found within the leading edge Microsteam power system are a direct response to the ever-increasing power demands of today’s energy climate and illustrate why these systems should become an integral part of your overall energy delivery strategy.

As shown in Fig. 2, the Microsteam power system is installed in parallel to an existing PRV. When started, the turbine automatically takes over the steam flow control from the PRV.

Whenever the turbine is shut down, the PRV automatically resumes steam control. Electricity generated from the turbine is fed directly to the building’s power panel with utility-approved protective relays, thus reducing purchased power and saving energy costs for building owners.

The Microsteam power system, an advanced, compact power system engineered to meet all the electricity generation needs of the 500 kW and under market, is the culmination of over 7 years of research, development, and testing. This fully packaged, vertically configured steam turbine generator meets all
of the criteria necessary to seamlessly and efficiently integrate into any existing system to provide steam-driven on-site power generation.

The beta test site for the initial prototype was the 11-story 130,000-sq ft Rolex building in New York City. This installation resolved a majority of the issues raised by the facility managers. Following an easy installation, its operation was automatic. Start-up and shutdown were implemented daily with a single push button and the unit operated unattended. Since the fall of 2003, this Microsteam® power system has demonstrated a maximum turbine efficiency of 74% and a power generation of 120 kWe at the maximum steam flow rate of 7,500 lb/hr.

Based on a thorough analysis of the performance data from the beta site, the United Technologies Research Center was contracted to improve the prototype by developing a Design and Reliability (D&R) document that more closely answered the needs of a commercial facility. The D&R included lower noise criteria, smaller footprint, simplified operation, increased efficiency and a more robust component design.

The next Microsteam power system was installed in the cutting edge 7 World Trade Center building in New York City. This building contains 42 tenant floors with a rentable area of approximately 1,700,000 square feet [3] and is considered New York City's first "green" office tower for achieving gold status in the U.S. Green Building Council's LEED® certification program.[4]

The Microsteam power system serves many prestigious facilities, including:

**Rolex World Headquarters, New York, NY**
- 11-story, 130,000 sq ft office building
- Power generation from low-pressure absorption chiller steam pressure reduction
- Prototype installation
- 120 kWe output, 7500 lb/hr, 165 – 15 psig
- 208-v output with stepdown transformer
- Transported in 2500 lb passenger elevator
- Department of Energy (DOE) grant awarded
- Installed Fall 2003

**United Technologies Research Center, Hartford, CT**
- Research and development facility
- Power generation from waste steam source (high-pressure discharge from Pratt & Whitney’s Co-generation plant)
- Basis for United Technologies Corporation equipment qualification process
- 275 kWe output, 12,000 lb/hr, 125 – 15 psig
- Completed all necessary qualifications steps
- Reduced system size and increased output
- Verified reliability and corrosion resistant qualities
- Installed Spring 2004
Con Edison 74th Street Steam Plant, New York, NY

- Process steam utility building
- Power generation from steam deaerator system
- Low-pressure steam utilized for boiler feed water system
- 275 kWe output, 11,000 lb/hr, 200 – 7 psig, super heated system
- Electric output feeds building lighting and substation needs

Methodist Hospital, Brooklyn, NY

- 8-story, 1 million sq ft medical center
- Power generation from low-pressure absorption chiller steam pressure reduction
- Low-pressure steam also used for domestic hot water and patient room comfort
- 208 kWe output, 12,000 lb/hr, 100 – 15 psig
- Electrical output feeds mechanical equipment room pump stations and ancillary equipment
- Easy disassembly for small elevator transport
- NYSERDA (New York State Energy Research and Development Authority) incentives

Princeton University, Princeton, NJ

- Two units installed in parallel
- Sprawling 100-plus building campus
- Power generation from domestic hot water/heating steam pressure reduction
- 550 kWe output, 24,000 lb/hr, 100 – 15 psig
- Each Microsteam® power system provided with single skid design

7 World Trade Center, New York, NY

- 52-story, 1.7 million sq ft office building
- Power generation for heating and domestic hot water systems
- 200 kWe output, 125 – 15 psig
- Recognized by US Green Building Council for innovative use of technology
- Part of building’s LEED® Gold Certification – Microsteam® power system, sustainable building design innovation
MICROSTEAM® POWER SYSTEM: A CLOSER LOOK

To fully appreciate the long-term potential of today’s Microsteam® power system, we need to take a closer look at the unit’s specific components and the latest technologies employed in their creation.

Designed for optimal efficiency and performance on all levels, the unit’s basic parts are shown in Fig. 3.

The lightweight rotor enables a top-mounted unit with a vertical shaft. To facilitate easy connection to typical overhead steam lines, both the inlet and outlet ports are located at the top of the unit.

This patented turbine technology is based on the principles of an Euler turbine design [5]. In tests conducted at the United Technologies Research Laboratory, efficiency levels of greater than 80% were achieved.

**Gearbox**

To transfer the energy recovered by the turbine and reduce its high rotating speed, a planetary gearbox is utilized. This gearbox has single stage reduction for smooth reliable operation. The high-speed shaft supports the turbine and gear on rugged long-life bearings. The gearbox is directly mounted on a C-face flange of the generator with a rigid shaft connection. As a result, field alignment is never required.

The Microsteam power system gearbox ensures high efficiency, greater than 97%, and quiet operation of less than 85 dBA.

**Generator**

The Microsteam power system utilizes a high efficiency induction generator, sometimes referred to as an asynchronous generator. This simply means a machine that is built as an induction motor and driven above synchronous speed, thus acting as an alternating-current generator. Below synchronism the machine takes in electrical energy and acts as an induction motor.

However, at synchronism, the power component of the current becomes zero and changes sign, so that above synchronism the machine (driven here by existing steam) outputs electrical energy as a generator. The generator is flange mounted directly to the base of the frame assembly for added rigidity. The generator frame, gearbox casing and turbine housing are bolted together, providing a self-supporting assembly. This generator operates at greater than 95% efficiency at 275 kWe.

The Microsteam Turbine

At the heart of the unit is a high-efficiency turbine rotor that is unique in several aspects. The operating principles of the turbine are simple — energy that is normally dissipated by reducing steam pressure in a PRV is now converted to power by reducing that same pressure through the turbine.

Steam flows radially outward from a single turbine rotor to allow the necessary pressure letdowns to efficiently turn the gear-connected generator that produces electricity. As a result, the turbine can efficiently perform the function of two PRVs in series while efficiently producing electrical power.

In addition to having a high efficiency, the rugged turbine rotor is constructed from corrosion and erosion resistant titanium alloy and uses centrifugal force to clear most of the particulates and contaminants often found in poor quality steam. This feature improves the reliability and durability of the Microsteam power system operating under many different steam conditions.
Controls

The programmable controls for the Microsteam® power system are Programmable Logic Controller (PLC) based, with a full color, easy-to-read display. The PLC was selected for its real-time programming capabilities and reliability within rugged industrial environments and is completely pre-tested at the factory.

Start-up is initiated by a single push button. The speed ramp is programmed into a Proportional-Integral-Derivative (PID) loop to provide a gradual opening of the inlet trip and throttle valve until near synchronous speed is reached. At that point, the breaker closes automatically and the generator produces power at the grid frequency. The PLC transfers control to another PID loop which is programmed to maintain the load steam pressure at a value that is slightly above the PRV settings. The valve opens until the required load pressure and steam flow are reached. At this point the PRV has closed and all of the steam flow is through the turbine. As the load requirements change, the valve is opened or closed and the output power follows the steam flow.

The control system has a digital multipoint protective relay and hardwired trips to protect the turbine and power system in the event of faults. If the unit is tripped, the inlet valve closes, the outlet pressure drops and the PRV automatically opens to maintain the original pressure setting. A touch screen displays all key operating parameters, alarms and trips. When the cause of a trip is determined and cleared, the unit can be started again with a single push button.

Atmospheric Lubrication System

The Microsteam power system atmospheric lubrication system consists of two separate oil pumps and an oil cooler. Delivering the lowest possible maintenance costs through ease of access and service, this forced-lube system also ensures that no contaminants enter the lubrication cycle.

The Microsteam power system robust frame supports the lubrication package and other ancillary items. An AC motor drives the primary lubrication pump. A DC motor fed by onboard batteries in the event of a power failure drives an auxiliary pump. The lubrication oil is cooled by plant water.

Compact Package — Size Matters

Although engineered by utilizing the most advanced steam turbine technologies available today, one of the most striking and universally appealing aspects of the Microsteam power system is its physical size. Vertically mounted and extremely compact, the standard 275-kWe power package measures a mere 34 in. wide by 42 in. long by 78 in. high, allowing it to easily fit through a standard door and maneuver through congested equipment rooms (see Fig. 4).

To keep installation time and costs at an absolute minimum, a plug-and-play strategy was implemented. All factory-assembled instrumentation and ancillary power connections are pre-wired and pre-tested. Once the package is in position, installation consists essentially of steam, power, safety, and plant utility connections.

Fig. 4. The Standard Microsteam® Power System Fits through a Standard Doorway
**Installation Flexibility with Factory Assembly**

The standard Microsteam® power system as shown in Fig. 4 is a factory-assembled package designed to meet the physical restrictions typical of many existing facilities. The assembly includes the essential system components (turbine, generator, control boxes and oil management system) while offering the contractor the convenience of moving the other compact system components into place separately. Quick-connect cables (Fig. 5) provide faster and easier connections between the system control and circuit breaker panels to further reduce installation time.

For added convenience, the systems control and breaker panels can be skid-mounted along with the Microsteam power system assembly. This skid-mounted option ensures faster, lower cost installation of the Microsteam power system and associated electrical control and power protection panels.

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**RELIABILITY, PERFORMANCE, AND PAYBACK**

**Reliability**

To ensure that the Microsteam power system would meet strict safety and reliability standards to qualify it for commercial service, rigorous and exhaustive testing was conducted at the United Technologies Research Center (UTRC). The UTRC delivers the world's most advanced technologies, innovative thinking and disciplined research to the businesses of United Technologies — industry leaders in aerospace propulsion, building infrastructure and services, heating and air conditioning, fire and security systems and power generation. The Microsteam power system evaluated at the UTRC test laboratory was analyzed for safety, reliability and performance. The testing concluded that an 80% maximum efficiency can be achieved. Further laboratory test simulations demonstrated that a 15-year life cycle can be anticipated.

**Performance: On-Site Survey**

To determine the Microsteam power system performance for a specific application, a qualified engineer should conduct a thorough on-site survey of current steam usage and prevailing system conditions. Following a thorough review of a facility’s supplied electricity and steam bills, an estimate of expected annual savings should be submitted.

To understand the potential power generation of the Microsteam power system, Fig. 6 shows the relationship between Electric Power Generation and Steam Flow Rate for various steam pressure differentials. At these differentials, 275 kWe power generation can be reached for steam loads in excess of 10,000 lb/hr. Power output at lower steam loads is nearly linear making the Microsteam power system a reliable source of very predictable power generation.
Fig. 6. Power Generated vs Steam Load for Typical PRV Conditions
Payback

Given this information and design, let’s look at the savings performance of a typical Microsteam® power system installation as shown in Fig. 7. If the steam load is 11,740 lb/hr and the pressure is reduced from 125 psig to 15 psig, the chart (Fig. 6) shows a power generation of 275 kWe.

The amount of additional steam utilized to produce the power is 4 lb/kWe. For annual service operation of 8,000 hours per year, an average electricity cost of 10 cents/kWh, and a steam cost of $.011/lb ($11/thousand lb), the net savings can be determined as follows.

\[
\text{NET SAVINGS} = (275 \times .10) - (275 \times 4 \times .011) \times 8,000 = $123,200 \text{ per year.}
\]

![Fig. 7. Typical Microsteam® Power System Installation](image-url)
TIMELY TECHNOLOGY FOR ON-SITE ELECTRICITY GENERATION

Revolutionary. Innovative. Pioneering. All words that describe the technology behind the new generation of Microsteam® power system. Years of research, development and testing have culminated in a unit that is simple in its operation with a fail-safe design. The patented Microsteam power system is extremely efficient and highly resistant to the corrosion potential that is a factor of steam quality.

With a compact package configuration that occupies a footprint of only 34 in. wide x 42 in. long x 78 in. high, the standard Microsteam power system package fits through the typical 36-in. wide doorway. Once installed and running, the noise level for the unit is 85 dBA and the vibration characteristics are less than 1 mil. The 275 kWc maximum output can be achieved for a wide range of steam conditions. The unit is economic even for lower steam flows with a correspondingly lower power output. The application example shows a payback period of 3 years, which is well within range of most financial criteria for such a project.

Clearly, with the advent of the new generation of Microsteam power system, district energy operators no longer face physical restrictions, economic shortfalls and unacceptable performance associated with earlier versions of steam turbine technology. Now, the 500 kW and under market can benefit from an impressive list of advantages. Energy conversion with the new Microsteam power system can dramatically reduce the amount of electricity purchased, potentially saving thousands of dollars of energy costs. Now all buildings with high-pressure steam service and PRVs can be viewed as candidates to economically generate their own electric power from this dynamic technology.

In the final analysis, these units represent a significant opportunity for progressive-minded facility managers who want to reuse an existing energy resource, improve energy security, contain energy costs, and take an important step toward a sustainable future.

Energy conscious building owners seeking a means to minimize the CO₂ footprint of their new facility can now apply the Microsteam power system to contribute to LEED®-NC points with yet another environmentally responsible system from Carrier.
Bibliography


References:


