*SMART*CAES™

EQUIPMENT MAKES THE GRADE

IN TODAY'S ELECTRICITY MARKET, where a rapidly expanding portion of power is expected from renewable sources such as wind and solar, operating flexibility – rapid start-up, high turn-down ratios, short transition times between modes, and high ramping rates – has become a critical factor for successful integration of Compressed Air Energy Storage (CAES) into the renewable energy mix. To address these needs, Dresser-Rand has incorporated significant new elements and design enhancements into its CAES products and services. The result provides excellent load management capability and allows existing power generation assets to be utilized more efficiently.

Dubbed ***SMART***CAES™ equipment and services, this enhanced offering is more than a name; it's a reflection of Dresser-Rand's unique qualification to deliver the total integrated rotating equipment system – a "one-stop" CAES solution. This solution includes not only the rotating equipment, but all ancillary services as well – the heat exchange equipment, pollution abatement system, and the plant controls – complete with performance guarantees (both compression and power generation modes).

Constant research and developments in technology have driven the evolution of CAES, from a simple alternative to conventional combustion turbine peaking generators into a flexible, powerful, efficient, and emission-compliant system with several possibilities for renewable energy applications.

Understanding why Dresser-Rand is literally the smart choice for CAES solutions begins with a history lesson.

CAES was originally meant to store low-cost off-peak energy, which could then generate power during on-peak periods. In a CAES facility, off-peak electricity powers a motor/generator that drives compressors to force air into an underground storage reservoir at high pressures. During periods of intermediate to peak electrical demand the air is withdrawn from the reservoir, heated in gas- or oil-fired combustors, and expanded through turbo expanders that drive the same motor/generator to produce electrical power.

Using off-peak power to meet intermediate and peak demand is less expensive than using units completely powered by fuel or purchasing power from neighboring utilities, because the federal and state governments are facilitating the installation of green renewable energy such as wind power. (The peak power generation curve for wind power is generally 180 degrees out of phase with the traditional power demand curve.) In essence, the wind blows at higher velocities at night when power is not normally needed. CAES provides a means to utilize that off-peak renewable power when it's really needed, and makes it more dependable and more manageable from a grid load management perspective.

Nearly 20 years ago, Dresser-Rand designed and built the entire turbomachinery train for Alabama Electric Cooperative's (now Power South) McIntosh facility (the first benchmark CAES plant in the U.S.), and today it continues to perform exceptionally well. It has an impressive track record of availability and starting reliability, and continues to satisfy the intermediate and peak electrical production needs of this major utility.

Over the years, related research and development from other Dresser-Rand products have been incorporated into our CAES offering (*e.g.,* DATUM® compressor technology enhancements). These ever-improving technologies have put CAES at the "head of its class" on every relevant subject.

SMART on Technology

Technological advancements achieved since first introducing the CAES design for the Macintosh facility bring a range of benefits to Dresser-Rand's ***SMART***CAES equipment, including operating flexibility, increased power output, reduced fuel and air consumption, improved compressor efficiency, noise reduction, and improved recuperator design.

Operating flexibility – ***SMART***CAES equipment offers shorter start-up times to achieve rated output in power generation mode, higher load ramping rates in power generation mode, faster compression start-up times, and faster transition between compression and power generation modes.

In power generation mode, the system is designed to start-up in less than 10 minutes to ramp output up to the rated 135 MW. Once synchronized, any output from 15 to 100 percent of rated load can be sustained indefinitely. Within this range, output may be ramped up or down at 20 percent of rated load per minute, or 27 MW per minute.

A variable speed drive system provides for rapid compression starts requiring less than 3.5 minutes. Once air is flowing to storage, the compressors may be turned down to any load between 65 and 100 percent of rated power, using variable inlet guide vanes, at a rate of 35 percent per minute (see figures 1 and 2).

For single train systems using a combination motor-generator, the variable frequency drive (VFD) system can be used to speed up the transitions between power generation and compression modes. Transitioning from power generation to compression can be achieved in five minutes, while adjusting from compres-

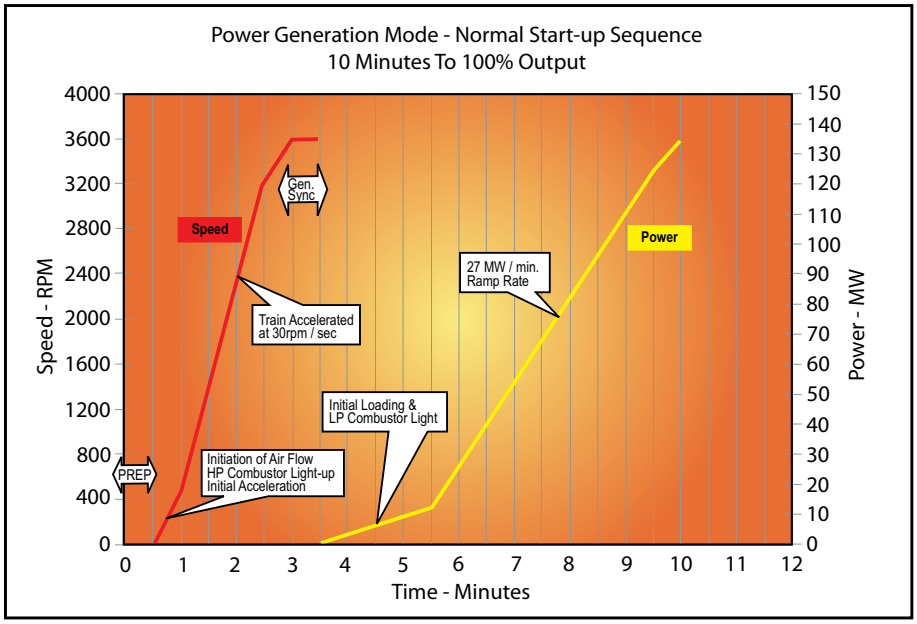

Figure 1: Power gen mode – normal start-up sequence.

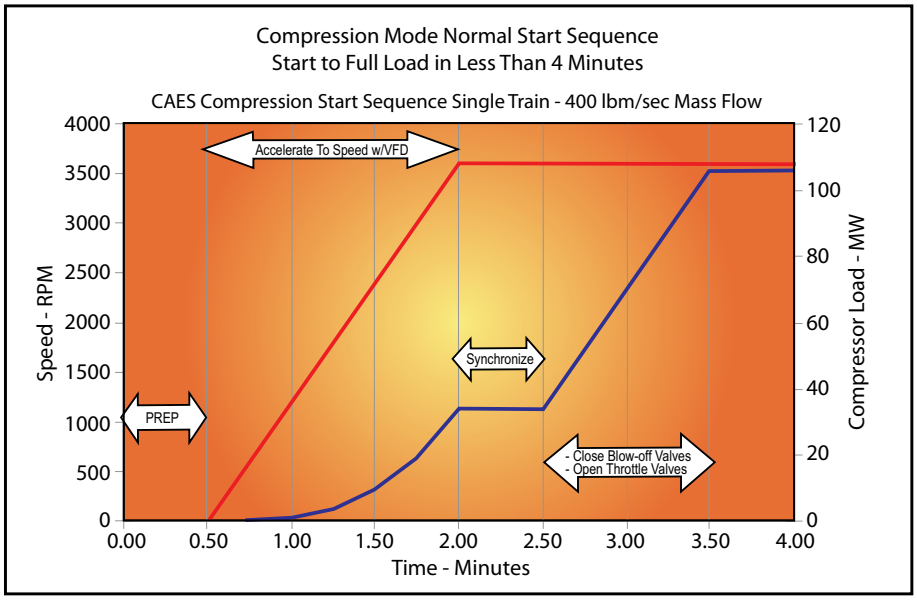

Figure 2: Compression mode normal start sequence.

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sion to power generation requires about 13 minutes. Multiple train systems, with separate motors for compression and generators for power production, eliminate mode transition time. The maximum transition time equals start-up time in the desired mode.

Power output – The output of ***SMART***CAES turbo expanders was increased from 110 MW to 135 MW. Combining modern analytical techniques and upgraded materials, the calculated safety factors for both the high-pressure and low-pressure turbines' flowpaths remain virtually unchanged, despite a total output increase exceeding 20 percent.

Fuel and air consumption – Turbine and system enhancements such as better recuperator effectiveness result in a two percent heat rate improvement, coupled with a 1.2 percent reduction in specific air consumption (SAC), across the design operating range from 20 MW to 135 MW. The heat rate of the Dresser-Rand ***SMART***CAES expanders is low and flat over a wide range of turndown from 100 percent load to 25 percent load because the expanders operate independent of the air compressors (see figure 3).

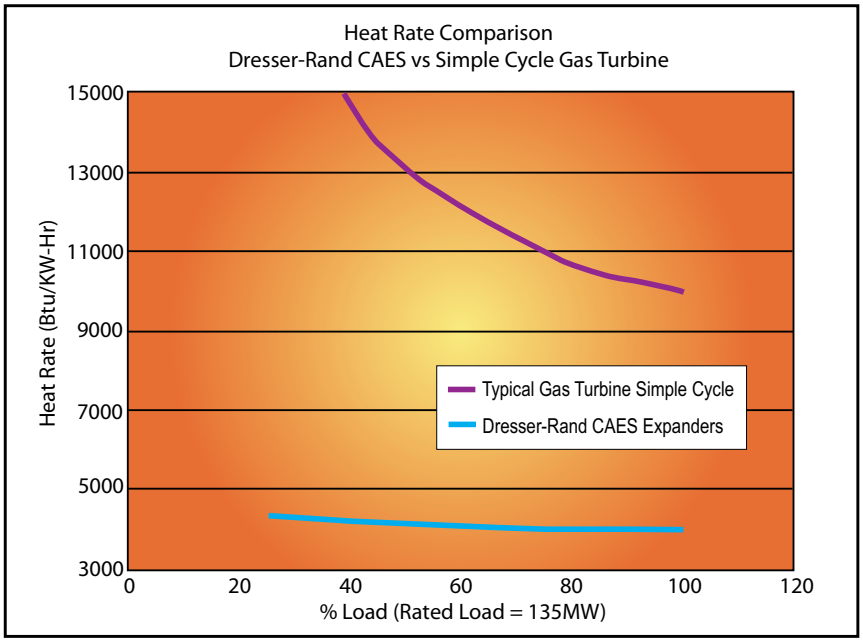

Figure 3: Heat rate comparison.

Compressor efficiency – Dresser-Rand's DATUM centrifugal compressor technology, more advanced axial compressor flowpath aerodynamics and careful design of the intercooled compression cycle all provide significant improvements in overall efficiency. Depending on final parameters, overall compression train flange-to-flange polytropic efficiency is in the mid-80 percent range in terms of energy consumption. The efficiency of the Power South CAES compressor train installed and operating in McIntosh is in the low 80 percent range (approximately three percent lower than Dresser-Rand's current CAES offering).

Noise reduction – Our patented noise reduction technology (D-R® duct resonator array) can achieve up to a 10 dB reduction in noise levels compared to centrifugal compressors that do not utilize this acoustic technology.

Recuperator design – The exhaust recuperator is a simpler design, with 85 percent heat transfer effectiveness compared to 75 percent in the earlier design. Strategically placed rows of stainless steel tubes minimize corrosion and exfoliation problems, and the entire recuperator is designed to operate at maximum air storage pressure, eliminating the cost and maintenance of pressure reducing valves. This change also makes sliding pressure cycles feasible where advantageous.

SMART on the Environment

The technological improvements to ***SMART***CAES equipment and services offer emission control options capable of meeting all current regulatory requirements for NOx and CO limits. With features that can meet current emissions requirements, ***SMART***CAES equipment can do its part to reduce the build-up of greenhouse gases in the atmosphere.

A simple diffusion flame combustor with H_2O injection for primary NOx control, coupled with an exhaust selective catalytic reduction system for final NOx control, provides stable operation at high turn-down ratios. It's possible to achieve final exhaust emission levels of 2 ppm NOx and 2 ppm CO, corrected to 15 percent O_2. This means, depending on the operating profile, many potential CAES sites would fall under small-source emission limit rules. In addition, the VFD system reduces the compression start

time, eliminating expander emissions from compression starts.

When used in conjunction with renewable energy such as wind or solar, ***SMART***CAES equipment has one-third the emissions of a conventional gas turbine.

SMART on Business

The world's increasing focus on cleaner, greener energy use presents Dresser-Rand with an ideal opportunity to successfully integrate our CAES technology into new markets.

We recently secured a patent for a concept to combine a conventional CAES facility with a sub-sea piping and compressed air storage system. Such a structure could bring CAES technology to a range of coastal locations that represent nearly 80 percent of the world's demand for electricity.

The growing popularity of wind and solar energy could also spur interest in ***SMART***CAES solutions. Wind farms typically generate more electricity at night, when there's already a surplus, and the ability to "bottle" electric energy for daytime use is an attractive option. Within the solar market, electricity from photo-voltaic farms in sunny regions could be transmitted to facilities that use ***SMART***CAES equipment in other areas, where turbines would generate electricity year-round.

The world would benefit from increased use of renewable energy sources, such as wind and solar, however, a common reality is that they are inherently intermittent and to some degree unreliable. ***SMART***CAES equipment provides an excellent tool for "smart grid" management by having excellent load following capability, helping base load assets to be more efficiently utilized during off-peak times, and by being able to provide ancillary services such as VAR support, regulation and reserve.

The dynamics of the worldwide energy market are changing, and ***SMART***CAES solutions are one example of how Dresser-Rand is repositioning its offerings to address global needs. Renewable energy sources can benefit from the bulk energy storage capabilities that ***SMART***CAES equipment offers. ***SMART***CAES equipment is also complementary to energy conservation and development efforts associated with the "smart grid," giving utility operators the means to run their base load plants more efficiently.

Considering the careful research, advancements and efficiencies surrounding ***SMART***CAES equipment and services, its potential benefits are an obvious choice for creating an efficient power generation system. ■