



# Compressed Air Energy Storage

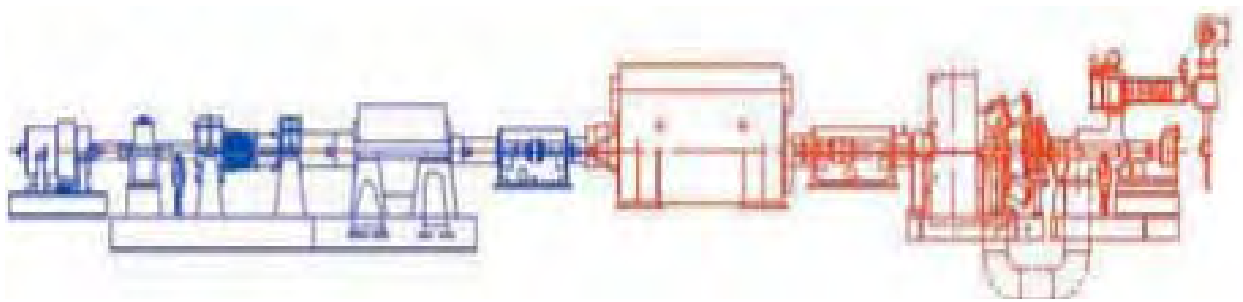
An Online Continuing Education Course for Engineers

**Course Number: M-3051**

**Credit: 3 Hours / 3 PDH / 3 CPD**

# Compressed Air Energy Storage

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### Credits

The line drawing on the cover page is courtesy of the Dresser-Rand Corporation. Some of the material in this course is based on a DOE report, [Handbook of Energy Storage for Transmission & Distribution Applications, 2003.](#)

## Introduction

Large quantities of electrical energy cannot be stored. Since the advent of the electric power industry, engineers have looked for ways to store energy for consumption at a later time. At the present, we really have only practical two choices to store energy; Pumped Storage Hydro-electric power or Compressed Air Energy Storage (CAES). The Electric Power Research Institute (EPRI) says that lithium-ion batteries are okay for electric vehicles and flywheels can store energy in short bursts. New technologies like flow batteries are emerging but they're still years away from utility-scale cost requirements. Pumped hydro is very site-specific and very little new pumped hydro sources have come on line in the last decade. Compressed Air Energy Storage, or CAES, is one of the few practical methods to store energy.

Compressed Air Energy Storage (CAES) is the term given to the technique of storing energy as the potential energy of a compressed gas. Usually it refers to air pumped into large storage tanks or naturally occurring underground formations.

While the technique has historically been used to provide the grid with a variety of ancillary services, it is also gaining attention as a means of addressing the intermittency problems associated with wind turbine electrical generators. When energy is available, it is used to run air compressors which pump air into the storage cavern. When electricity is needed, it is expanded through conventional gas turbine expanders. Note that some additional energy (typically natural gas) is used during the expansion process to ensure that maximum energy is obtained from the compressed air (albeit as much as 67% less gas than would be used for an equivalent amount of electricity using gas turbine generators without CAES).

With Compressed-Air Energy Storage (CAES), energy generated during periods of low energy demand can be released to meet higher demand periods. Off-peak electrical power compresses air into an underground air-storage “vessel”, and later the air feeds a gas-fired turbine generator complex to generate electricity during on-peak times.

Figure 1, shown on the following page, is a conceptual representation of a compressed-air energy storage system.

## Compressed Air Energy Storage Schematic Diagram

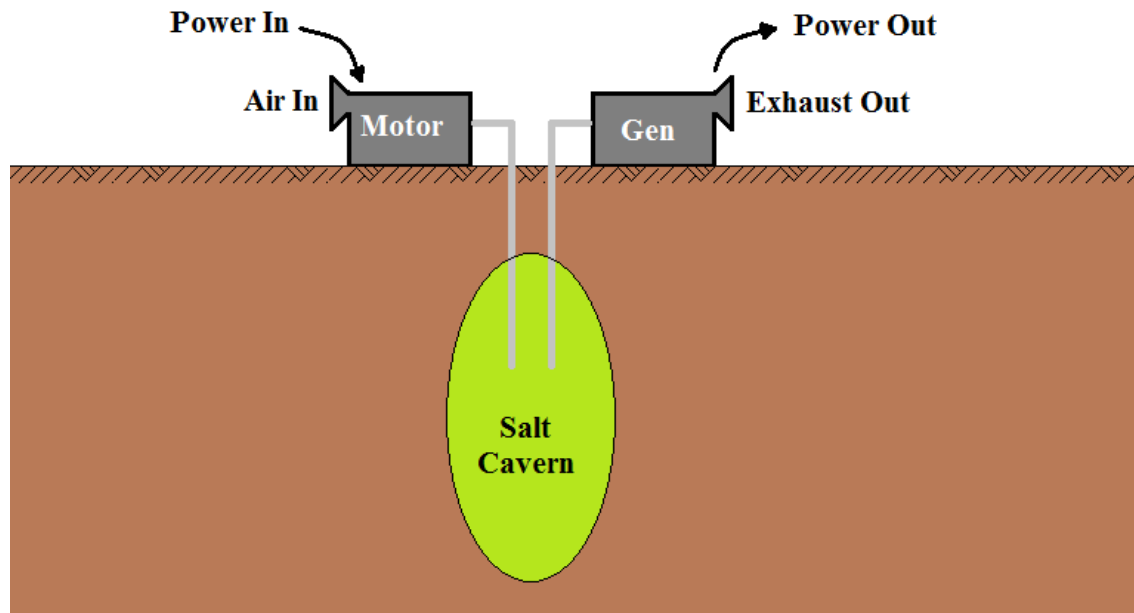


Figure 1

CAES technology uses low cost, off-peak energy to run a compressor train to create compressed air, which it stores, usually in an underground cavern, the air is then released during peak load hours and heated with the exhaust heat of a standard combustion turbine in an air bottoming cycle. This heated air is converted to energy through expansion turbines to produce electricity. Various power augmentation procedures can be added at this point (including air injection and inlet chilling), taking advantage of the cooled air, creating “free” megawatts.

### History

City-wide compressed air energy systems began operation in the 1870's to power machinery in cities such as Paris, France, Birmingham, England, and Dresden, Germany. These systems quickly evolved to deliver power to homes and industry. By 1896, the Paris system had 2.2 MW of generation distributed at 80 psi in 30 miles of air pipes for motors in light and heavy industry. Usage was measured by meters. The systems were the main source of house-delivered energy and also powered the machines of dentists, seamstresses, printing facilities and bakeries.

The technological concept of compressed air energy storage for electric power generation is more than 40 years old. CAES was seriously investigated in the 1970's as a means to provide load following and to meet peak demand while maintaining constant capacity factor in the nuclear power industry.

In 1978, the first utility-scale compressed air energy storage project, the 290 megawatt Huntorf plant, began operation in Germany. The 290 MW Huntorf plant, located in Bremen, Germany, is used to provide peak shaving, spinning reserves and VAR support. A volume of 11 million cubic feet is stored at pressures up to 1,000 psi. The plant is situated 2,100-2,600 feet below the surface. The plant uses a diaphragm to separate the compressed air from the water. The plant is capable of generating 290 MW of power to fully recharge the cavern. The plant can generate some additional power.

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The M  
reserv  
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recover  
Huntorf

### Key Features

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For power  
storage, the  
caverns, or  
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however som  
attractive depending on plant design and site conditions.

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pipes or pressure  
less than about 5 hours of capacity,

up to about 10 hours of storage may be economically

The project lead times for CAES plants are typically not more than three years, including development, design, construction, and startup. For example, the contract for the 110 MW