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Wind Power Generation by Compressed Air Energy Storage (CAES) Technology

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Abstract- Wind energy is clean, ecofriendly, safe non conventional energy resource. Energy storage systems are increasingly gaining importance with regard to their role in achieving load leveling, especially for matching intermittent sources of renewable energy with customer demand, as well as for storing excess nuclear or thermal power during the daily cycle. Compressed air energy storage (CAES), with its high reliability, economic feasibility, and low environmental impact, is a promising method for large-scale energy storage. Although there are only two large-scale CAES plants in existence, recently, a number of CAES projects have been initiated around the world, and some innovative concepts of CAES have been proposed. Existing CAES plants have some disadvantages such as energy loss due to dissipation of heat of compression, use of fossil fuels, and dependence on geological formations. This paper reviews the main drawbacks of the existing CAES systems and presents some innovative concepts of CAES. The scope of this paper is to simply create a methodology for wind power generation using the compressed air energy storage system.

Keywords- Compressed air energy storage (CAES), Carbon dioxide (CO2), Wind Energy.

I. INTRODUCTION

Interest in energy storage is currently on the rise, especially for storage that matches intermittent renewable energy with customer demand. Coal, oil, natural gas and other fossil fuels will eventually dried up, coupled with the needs of environmental protection, so that large-scale application of renewable energy is imperative. The renewable energy such as wind power and solar energy have the properties as randomness and volatility. The combination of Energy storage technologies and renewable energy generation technology not only can improve the stability of the system and improve power quality, but also improve resource utilization. Therefore, the large scale uses of renewable energy nee the support of distributed energy storage technology. In the case of pumped hydro storage, its dependence on specific geological formations. And environmental concerns associated with it make new development difficult. As an alternative to pumped hydro storage, compressed air energy storage (CAES), with its high reliability, economic feasibility, and low environmental impact, is a promising method of energy storage. In 1978, first CAES plant of 290MW capacity was built at Huntorf in Germany. In 1991, another 110MW plant was built in Mcintosh, USA. However, the existing CAES plants have some disadvantages such as their energy loss due to dissipation of heat of compression, use of fossil fuels, and dependence on geological formations. Therefore, some innovative concepts of CAES have been recently proposed. These analyses greatly help us to understand the characteristics of each CAES system and to compare different CAES systems

II. UNDERSTANDING THE CONCEPTS OF CAES SYSTEM

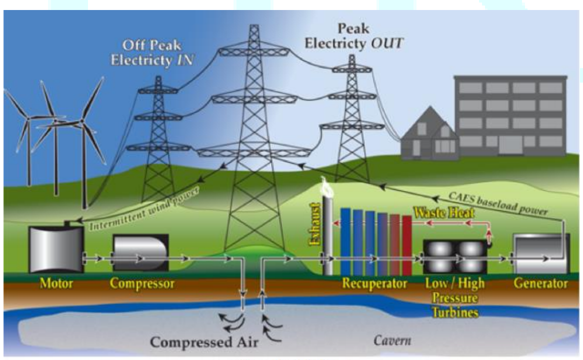
CAES is not a simple energy storage system, like other batteries. It can be viewed as a hybrid of energy storage and a gas turbine power plant. But it is different like conventional gas turbines, which consume about two-thirds of their input fuel to compress the air at the time of power generation; CAES compresses the air, using low-cost electricity form the power grid at off-peak time, and utilizes it with some gas fuel to generate electricity when required. The compressed air is stored in appropriate underground caverns or aboveground air vessels. Compressed air energy storage (CAES) is a unique way to store efficiently the energy on a large scale in order to provide low-cost energy and enhance grid reliability. A Compressed Air Energy Storage power generation uses electric motor-driven compressors to inject air into an underground storage cavern and later releases the compressed air to turn turbines and generate electricity back onto the grid. Storage media include underground salt dome caverns, underground hard rock mines. Compression normally occurs during off peak hours, when power prices are low. During hours of high electric demand, compressed air is withdrawn from the cavern, preheated, and introduced to one of several combustors. In the combustors, natural gas is fired to further heat the air, and the hot expanding gases are used to drive expansion turbines. These turbines are connected to a generator, which produces electricity for the grid.

III. COMPONENTS OF CAES PLANT

A typical CAES unit consists of five basic components:

- Compressor train (compressor, inter-coolers and after cooler);
- Motor generator;
- Turbine expender train (including expanders and combustors);
- Recuperator
- Underground cavern

The CAES storage process in mainly formed by a compression stage, a storage stage and an expansion stage. During the compression stage, surplus electricity of the grid powers a compressor train to compress air to high pressure levels (between 60 bar to 100 bar). The storage stage involves the injection of the pressurized turbine is machine consisting of a compressor, a combustor and an expander, with extracts energy form a fuel. Electricity of the grid powers a compressor train to compress air to high pressure levels The storage stage involves the injection of the pressurized turbine is machine of a compressor, a combustor and an expender, which extracts energy form a fuel. In CAES plants the compressed air and combustion gas are channeled directly to the combustion chamber.



A Typical CAES Plant

IV Different Types of CAES System

A. Conventional Diabetic CAES system (with Fuel)

In the case of conventional CAES plants in order to increase the overall efficiency of the system, it is customary to perform multistage compression with intercooling and multistage expansion with reheating, and for the discharging process, the compressed air is generally heated using gas fuel for the production of 1-kWh output.

B.Adiabatic CAES system

Adiabatic CAES uses no fuel to heat the compressed air for the expansion process, representing an emission-free, pure storage technology with high storage efficiency. The basic idea of the adiabatic CAES concept is the use of heat storage as the central element of the plant. This implies that the heat needed to heat the compressed air for the expansion process is recovered from the compression and stored in thermal energy storage (TES) unit to eliminate the need for a combustor.

C. Isothermal CAES System

Isothermal CAES is an alternative CAES system which eliminates the need for fuel and high temperature thermal energy storage. Isothermal CAES can minimize the compression work and maximize the expansion work done through isothermal compression/expansion by means of effective heat transfer with the vessel's surroundings. This involves slow gas pressure change by liquid piston. During isothermal expansion, the gas is able to do more work by absorbing heat from its surroundings. The expanding air in the isothermal CAES system drives a hydraulic motor, which in turn drives an electric generator. The use of hydraulic pumps and motors enables procise compression and expansion of air, heat transfer with the surroundings, and a high level of thermal and overall system efficiency.

D. Trigenration Micro-CAES System

Large-scale CAES is very dependent on appropriate geological formations for air storage. Micro-CAES with subsurface or aboveground pressure vessels is a more adaptable solution, especially for distributed generation. Micro-CAES systems can be used as a multipurpose system, as a combination of energy storage and air cycle heating and cooling. The air cycle approach is one of the most promising long-term alternatives for refrigeration machines, air conditioners, and heat pumps. Because of the potential of highly efficient turbo machinery that is used. The micro-CAES system combined with air cycle heating and cooling could be a very good solution because it would then be possible to improve the energy efficiency and economics of the system as a multipurpose system. Transportable CAES was proposed as a solution. The micro-CAES system for energy storage and air cycle heating and cooling for HVAC of a building.

E.Constant-Pressure CAES System Combined with Pumped Hydro Storage

CAES systems are most commonly operated under constant volume conditions with a fixed, rigid reservoir operating over an appropriate pressure range. These varying pressure ratios can degrade the efficiencies of compression and expansion due to deviation from design points. Exiting CAES plants were designed to throttle the cavern air to a designed pressure despite the throttling loss. The energy loss of compressed air by throttling is about 5%-8% in existing CAES systems. It is possible to increase the storage volume to reduce the operating pressure range, doing so results in how energy density and high construction costs. So, in order to resolve such problems, a new constant-pressure CAES system combined with pumped hydro storage was proposed During the charging presses, the water in an air storage vessel (left) is transferred to a hydraulic accumulator (right) by a pump to maintain a constant pressure of air storage, consuming power. During the discharging process, the water in the hydraulic accumulator is returned to the air storage vessel through a water turbine to maintain a constant pressure of air storage, producing power.

V.IS CAES TECHNOLOGY PROVES TO BE ENVIRONMENTAL FRIENDLY

The emissions responsible by CAES plant is observed to be less as compared to other plants which includes combined cycle, simple cycle and emissions through coal plant. Further it is found that the development of CAES plant has reduced cost requirement which evolves increased renewable penetration and Enhanced security of supply. It is producing less NOx, CO, CO_2, Sox and other toxic emission by design or by choice of fuel (e.g., bio fuels, waste products). It proves to be the Best Available Technology in term of low emissions and higher efficiencies, helps in controlling systems for better grid management. By using less water, perhaps with dry cooling. Preventing any direct environmental impact (e.g., using brine from depleted salt formations, instead of disposing it). Use pre-existing underground storage.

VI. IMPLEMENTATION OF CASE PLANT OVER OTHER STORAGES

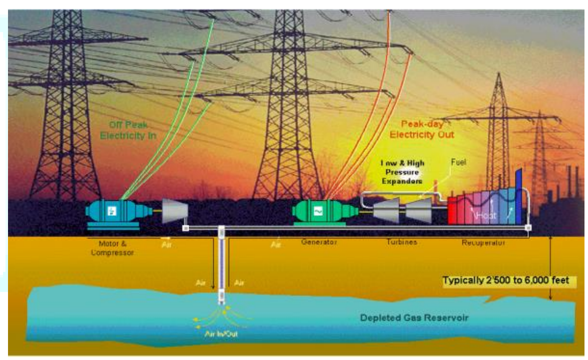
While batteries can also be used to store energy, they are expensive to make, use hazardous and toxic metals and compounds, and cannot hold energy for very long. CAES does not need any costly installations. Its losses are very small. A CAES system can be used to store energy for more than a year. Fast start-up is also an advantage of CAES. A CAES plant can provide a start-up time of about 9 minutes for an emergency start, and about 12 minutes under normal conditions.

Table Energy Storage Costs Per Cycle

Per cycle cost	US$ per MWh Low	US$ per MWh High
Pumped-hydro	1	15
CAES	20	50
Flywheel	30	220
NaS battery	80	250
Flow battery	50	800
Lithium-ion battery	150	1,000
Nickel-cadmium battery	200	1,000
Lead-acid battery	200	1,000
From Electricity Storage Association		

VII. CAES TECHNOLOGY MEETS WIND POWER GENERATION

One example is compressed-air wind turbine that is designed like a funnel, with no exposed blades, in order to cut down risks for birds. Fast start-up is also an advantage of CAES. A CAES plant can provide a start-up time of about 9 minutes for and emergency start, and about 12 minutes under normal conditions.



CAES Technology meets wind power generation

The wide availability of potentially suitable geology in wind-rich areas points to CAES as a technology well –suited for making base load power from wind-thereby making it feasible to provide wind power at electric grid penetrations far greater than 20%+ penetration rates that are feasible without storage. And, to the extent that wind-rich regions are remote from major electricity markets. Such base load power can often be delivered to distant markets via high voltage transmission lines at attractive costs. Aquifer CAES seems to be the most suitable storage geology for wind/CAES in the US due to the potential for low development costs and because regions with porous rock geologies are strongly correlated with the onshore wind-rich regions of the US the storage of energy through air compression offers the potential to enable wind to meet a large fraction of the world's electricity needs competitively in a carbon constrained world.

VIII. CONCLUSION

The result of this study was that the CAES technology has been used for grid operation support applications such as regulation control and load shifting. But a new major possibility that is especially relevant for a carbon constrained world is to enable exploitation at large intermittent wind resources that are often remote from major electricity demand centers. CAES appears to have many of the features necessary to integrate intermittent renewable energy generation. CAES has the potential to be a competitive solution among batteries, power to gas, pumped storage plants and others further it Enables electricity system to be operated more effectively, Reduction in peak demand, Potential to reduce CO2 emissions, Displacement of fossil fuel generation.

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