American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-10, Issue-7, pp: 72-78
www.ajer.org
Research Paper Open Access

Compressed Air Energy Storage System

Ankit Aloni, Yashashwi Raj, Prof Vishal Mehtre

ABSTRACT*: Energy storage provides a spread of socio-economic benefits and environmental protection benefits. Energy storage are often performed during a sort of ways. Examples are: pumped hydro storage, superconducting magnetic energy storage and capacitors are often wont to store energy. Each technology has its advantages and drawbacks. One essential differentiating characteristic of the various technologies is that the amount of energy the technology can store and another is how briskly this energy are often released. This technology description focuses on compressed gas Energy Storage (CAES).*

INDEX TERMS*: Gas, Energy Storage, CAES*

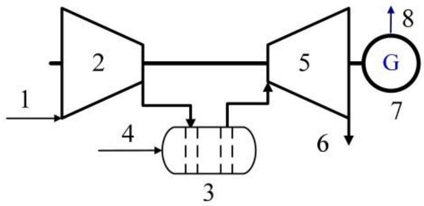
Date of Submission: 26-06-2021 Date of acceptance: 08-07-2021

I. INTRODUCTION:

Electrical Energy Storage (EES) refers to a process of converting electricity from an influence network into a form which will be stored for converting back to electricity when needed. Such a process enables electricity to be produced sometimes of either low demand, low generation cost or from intermittent energy sources and to be used sometimes of high demand, high generation cost or when no other generation is out there. The history of EES dates back to the turn of 20th century, when power stations often pack up for overnight, with lead-acid accumulators supplying the residual loads on the then DC (DC) networks. Utility companies eventually recognised the importance of the pliability that energy storage provides in networks and therefore the first central station energy storage, a Pumped Hydroelectric Storage (PHS), was in use in 1929. Up to 2011, a complete of quite 128 GW of EES has been installed everywhere the planet. EES systems is currently enjoying somewhat of a renaissance, for a spread of reasons including changes within the worldwide utility regulatory environment, an ever-increasing reliance on electricity in industry, commerce and therefore the home, power quality/quality-of-supply issues, the expansion of renewable energy as a serious new source of electricity supply, and every one combined with ever more stringent environmental requirements. These factors, combined with the rapidly accelerating rate of technological development in many of the emerging electricity storage systems, with anticipated cost reductions, now make their practical applications look very attractive on future timescales of only years. The anticipated storage level will boost to 10~15% of delivered inventory for USA and European countries, and even higher for Japan within the near future. There are numerous EES technologies including Pumped Hydroelectric Storage (PHS), Compressed Air Energy Storage system (CAES), Battery, Flow Battery, Fuel Cell, Solar Fuel, Superconducting Magnetic Energy Storage system (SMES), Flywheel and Capacitor and Supercapacitor. However, only two sorts of EES technologies are credible for energy storage in large scale above 100MW in single unit i.e. PHS and CAES. PHS is that the most generally implemented large-scale sort of EES. Its principle is to store hydraulic P.E. by transporting water from a lower reservoir to an elevated reservoir. PHS may be a mature technology with large volume, long storage period, high efficiency and comparatively low cost of capital per unit energy. However, it's a serious drawback of the scarcity of obtainable sites for 2 large reservoirs and one or two dams. A long-time interval of 10 years and an outsized amount of cost of hundreds to thousands million US dollars for construction and environmental issues for example removing trees and vegetation from the massive amounts of land before the reservoir being flooded are the opposite three major constrains within the deployment of PHS. These drawbacks or constrains of PHS make CAES an attracting alternative for giant scale energy storage. CAES is that the only other commercially available technology ready to provide the very-large system energy storage deliverability of about 100MW in single unit to use for commodity storage or other large-scale storage.

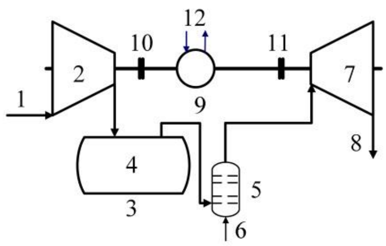
II. PRINCIPLE:

The concept of CAES often dated back to 1949 when Stal Laval filed the primary patent of CAES which used an underground cavern to store the compressed gas. Its principle is on the thought of conventional turbine generation.



1.Air, 2.Compressor, 3.Combustor, 4.Fuel, 5.Turbine, 6.Exhaust, 7.Generator, 8.Electricity

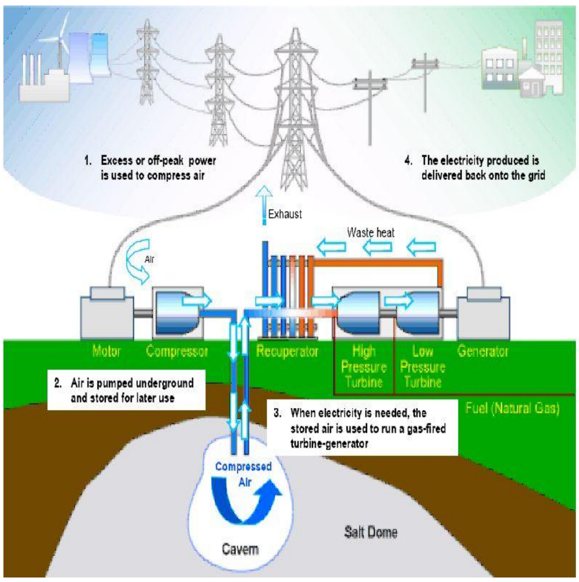
(a) Schematic diagram of GT system

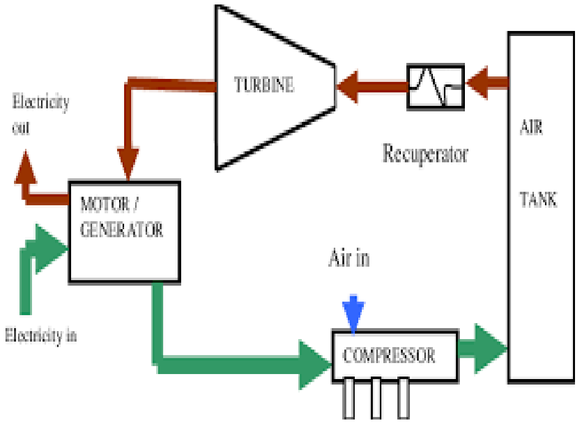


1.Air, 2.Compressor, 3.Reservoir, 4.Compressed air, 5.Combustor, 6.Fuel, 7.Turbine, 8.Exhaust, 9.Motor/Generator, 10 and 11.Clutch, 12.Electricity

(b) Schematic diagram of GT system

As shown in Figure, CAES decouples the compression and expansion cycle of a typical turbine into two separated processes and stores the energy within the sort of the elastic P.E. of gas. The energy is stored by compressing the air in an air tight chamber of 4 to 8 MPA example like an underground storage cave. To extract the stored energy, gas is drawn from the storage vessel, mixed with fuel and combusted, then expanded through a turbine. and thus, the turbine is connected to a generator to provide electricity. The waste heat of the exhaust are often captured through a recuperator before being released to the atmosphere.





As shown in Figure, a CAES system is formed of above-ground and below-ground components that combine man-made technology and natural geological formations to simply accept, store, and dispatch energy. There are six major components during a basic CAES installation including five above-ground and one under-ground components:

The motor or generator that employs clutches to supply for alternate engagement to the compressor or turbine trains.

There are two more stages in the compressor which are intercoolers and aftercoolers which are used to know the proportion of compression and reduce the moist in the gas.

The turbine train, containing both high- and low turbines.

Equipment controls for operating the combustion turbine, compressor, and auxiliaries and to manage and control changeover from generation mode to storage mode.

Auxiliary equipment consisting of fuel storage and handling, and mechanical and electrical systems for various heat exchangers required to support the operation of the power.

The under-ground component is especially the cavity used for the storage of the gas .

The underground Storage can be developed into different three categories of geological formations

1.Underground rock caverns formed by excavation of hard and impervious rock formation.

2. Salt caverns are created by dry mining of salt formations.

3.Porous media reservoirs are made by depleted gas or oil fields. Aquifers especially are often very attractive as storage media because the gas will displace water, fixing a unbroken pressure storage system while the pressure within the selection systems will vary when adding or releasing air.

The basic functioning of gas Energy Storage (CAES) is explained in figure, while the introduction image above shows an artist's rendering of a CAES plant integrated with a wind turbine farm. Essentially, the term compressed gas energy storage outlines the essential functioning of the technology. In times of excess electricity on the grid (for instance because of the high-power delivery sometimes when demand is low), a gas energy storage plant can compress air and store the compressed gas during a cavern underground. Sometimes when demand is high, the stored air are often released and the energy are often recuperated. Because low-cost electricity is stored at low demand times, and electricity is formed, through releasing the stored energy, at high demand times at high prices, storing energy isn't only motivated by environmental protection benefits, but is additionally strongly motivated by economic benefits the technology provides. Additionally, the technology provides energy market support and socio-economic benefits. The essential components of a gas energy storage plant are illustrated also in Figure

The gas is typically stored in appropriate underground mines or caverns created inside salt rocks. rock bottom surrounding the cavern must be as air-tight as possible, which prevents the loss of energy through leakage. Storage in mined caverns is used for large scale CAES applications and it takes about 1.5 to 2 years to form such a cavern by dissolving salt. However, additionally to large scale facilities, gas energy storage can also be adapted to be utilized in distributed, small scale operations through the use of high-pressure tanks or pipes (APS, 2007)

In addition to large scale facilities, gas energy storage can also be adapted to be utilized in distributed, small scale operations through the use of high-pressure tanks or pipes.

Above Figure illustrates a small-scale application of gas energy storage. the tactic is really the same as for large scale gas energy storage technology, it's just that the reservoir is smaller and above ground. The smaller reservoir limits the number of electricity which can be stored with small scale technology.

When the plant discharges, it uses the gas to figure the combustion turbine generator. gas is burned during plant discharge, within an equivalent fashion as a typical turbine plant. However, during discharge, the combustion turbine during a CAES plant uses all of its energy to urge electricity thus the system is more efficient.

III. FEASIBILITY OF COMPRESSED AIR ENERGY STORAGE (CAES) AND OPERATIONAL NECESSITIES:

As mentioned, the CAES technology concept is sort of forty years old. the first and longest operating CAES facility within the planet is near Huntorf, Germany, the 290- MWe Huntorf plant has operated since 1978, functioning primarily for cyclic duty, ramping duty, and as a hot spinning reserve for the economic customers in northwest Germany. Recently this plant has been successfully leveling the variable power from numerous turbine generators in Germany.

The second commercial CAES plant, owned by the Alabama Energy Cooperative (AEC) in McIntosh, Alabama, has been operational for quite 15 years since 1991. The CAES system stores gas with a pressure of up to 7.5 MPa during a n underground cavern located during a solution mined salt dome 450m below the surface. It can store the air about 500,000 m3 with a generating capacity of 110 MW. The gas heats the air released from the cavern, which is then expanded through a turbine to urge electricity. It can provide 26 hours of generation. The CAES system utilizes a recuperator to reuse heat from the turbine, which reduces fuel consumption by 25% compared with the Huntorf CAES plant.

The third commercial CAES could even be a 2700 MW plant that's planned for construction within the us at Norton, Ohio developed by Haddington Ventures Inc. This Nine-unit plant will able to store compress air to 10 MPa in an existing limestone mine dome of 670m under-ground. the quantity of storage cavern is about 120,000,000 m3.

There are several planned or under development CAES projects:

Project Markham, Texas: This 540 MW project developed jointly by Ridege Energy Services and EI Paso Energy will contains four 135 MW CAES units with separate low and high motor driven compression trains. A salt dome is used because the storage vessel.

Iowa energy project is under construction by Iowa Association of Municipal Utilities, promises to be exciting and innovative. The gas is getting stored in an underground storage by using wind power for additionally to be available off-peak power. The plant is of 200MW of CAES capacity, with 100MW of wind energy. CAES will expand the role of wind energy within the region generation mix, and will operate to follow loads and provide capacity when other generation is unavailable or non-economic. The underground aquifer near Fort Dodge has the right dome structure allowing large volumes of air storage at 3.6 MPa pressure.

The Chubu Electric of Japan is looking for territory for appropriate CAES sites. Chubu is Japan’s third largest electric utility with 14 thermal and two atomic power plants that generate 21,380 MWh of electicity annually. Japanese utilities recognize the price of storing off-peak power during a nation where peak electricity costs can reach $0.53/kWh.

South Africa has also expressed interest in exploring the economic benefits of CAES in the country.

In the U.S. a 110 MWe plant has been constructed near McIntosh, Alabama and has been operational since 1991.

In November 2009 the US Department of Energy awards $24.9 million in funds for phase one of a 300 MW, $356 million Pacific Gas and power service installation being developed near Bakersfield, California.

In 2012 General Compression completes construction of a 2 MW near-isothermal CAES project in Gaines, Texas. the world's third CAES project. The project uses no fuel.

In 2019 the first Underground CAES project was commissioned by Hydroster in Goderich, Ontario.

The European Union-funded RICAS 2020 (adiabatic) project in Austria uses a gravel to store heat from the compression process to reinforce efficiency. The system was expected to understand 70-80% efficiency.

Canadian company, Hydrostor plans to make four different Advance CAES plants in Toronto, Goderich, Angas, and Rosamond.

IV. RESEARCH AND DEVELOPMENT:

1. Improved conventional CAES system:

The principle of the improved conventional CAES system, is similar to normal CAES system instead of , there are intercoolers and aftercooler within the compression process; reheater is installed between turbine stages; and regenerator is employed to preheat the compressed gas by the exhausted gas. This Plants can reduce fuel consumption by 25% by using the methods. Other methods of the systems combined with a turbine shown in figure. When the electricity is in low-demand, the compressed gas is produced and stored in underground cavity or above ground reservoir. During the high-demand period, the CAES is charging the grid simultaneously with the GT power grid. The compressed gas is heated by the GT exhaustion and therefore the heated compression air expands within the high (HP) turbine then ejects to the GT turbine combustor to join GT working fluid. The CAES system shown above can recover almost 70% of energy.

2. Advanced Adiabatic CAES system:

The so-called Advanced Adiabatic CAES (AA-CAES) stores the potential and thermal energy of gas separately and recovers them during an expansion (as shown in figure 6). Although the price is about 20~30% above the traditional power station, this technique eliminates the combustor and maybe a fossil-free system. IAA-CAES could even be commercially viable thanks to the improvements of thermal energy storage (TES), compressor and turbine technologies. The project (AA-CAES) known as Advanced Adiabatic – gas Energy Storage are developing technology to satisfy the requirements.

3.Small-scale CAES system:

A man-made vessels is a more adaptable solution, without the need for caverns, especially for distributed generation that could be widely applicable to future power networks. The figure shows a small-scale CAES used for a standby power system. It can replace the battery with technical simplicity, low degradation of components, high reliability, low maintenance, and lower life cycle cost characteristics. The method can be alternative to the other method is which it replaces the battery with various parameter such as technical simplicity, components quality, high reliability, low maintenance. The CAES can work for 20 years, while acid batteries for 12 years for a 2KW power application. The duration for setting up the plant is 8 hours for CAES while for others it is 16 and 64 hours. As there is no heat recovery/storage component in this system, therefore its efficiency is lower than that of the other system.

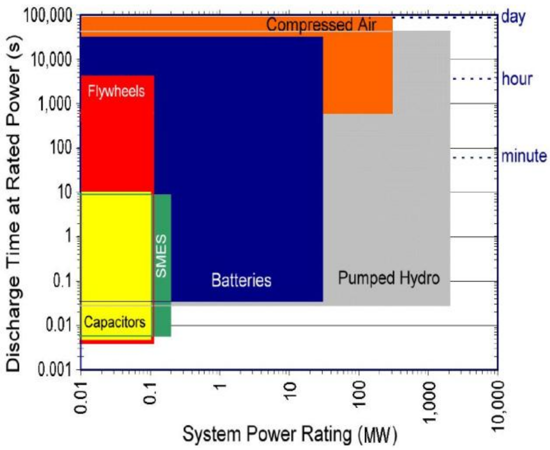
V. OPERATIONAL NECESSITIES OF COMPRESSED AIR ENERGY STORAGE (CAES):

A motor or generator with clutches on both ends to connect or disconnect it from the compressor train, the expander train, or both
Multi-stage air compressors with intercoolers to scale back the facility requirements needed during the compression cycle, and with an aftercooler to scale back the storage volume requirements.
An expander train consisting of high and low-pressure turbo expanders with combustors between stages
Control system to regulate and control the off-peak energy storage and peak power supply, to switch from the gas storage mode to the electric power generation mode, or to figure the plant as a synchronous condenser to manage VARS on the grid.
Auxiliary equipment consists of fuel storage and handling, cooling systems, mechanical systems, electrical systems, heat exchangers.
Underground or above-ground gas storage, including piping and fittings.
Underground storage is typically performed in aquifers or mined caverns, while aboveground air storage is executed within specially designed holding tanks.

VI. SEVERAL KEY FEATURES AND LIMITATIONS OF COMPRESSED AIR ENERGY STORAGE:

The CAES technology are often easily optimized for specific site conditions and economics.
CAES may be a proven technology and may be delivered on a competitive basis by a variety of suppliers.

CAES plants are capable of black start.



CAES technology is comparatively slow in discharging the stored power capacity, but has among the very best system power rating alongside batteries and pumped hydro storage technologies. Therefore, the quantity of energy this technology can store during a large-scale system is among the very best of the energy storage technologies currently available. Being relatively slow within the discharge of the stored energy, this technology can provide energy market support for up to several hours.
According to the 2002 EPRI study, the main reason for the small share of the market is likely to be the lack of awareness of this option by utility planners.
In addition, the underground geology is probably going perceived as a risk issue by utilities. However, very few engineers are aware of the fact that CAES sites are actually relatively common.
The 2002 EPRI study notes that approximately 80 you look after us contain suitable CAES sites. Due to these reasons, the market potential for CAES isn't won't to its full capacity

VII. CONCLUSION:

Research and application of compressed air energy storage system are discussed in this paper including principle, function, deployment, and R&D status.

Compressed Air Energy Storage is that the only other commercially available technology besides the PHS ready to provide the very-large system energy storage deliverability above 100MW during a single unit. It has an extended storage period, low capital costs but relatively low efficiency as compared with other energy storage technologies. CAES are often used for peak shaving, load leveling, energy management, renewable energy, and standby power. However, there are two major barriers to the implementation of CAES the reliance on favorable caverns and the reliance on fossil fuel. To alleviate the barriers, many improved CAES systems are under research and development like improved conventional CAES, AACAES, and little Scale CAES.

REFERENCES:

[1]. EPRI, 2002. Handbook for Energy Storage for Transmission or Distribution Applications. Report No. 1007189. Technical Update December 2002.

[2]. NETL, 2008. Market Analysis of Emerging Electric Energy Storage Systems. National energy technology laboratory and Department of Energy report with code DOE/NETL-2008/1330 of July 31, 2008.

[3]. Schoenung, 2001. Characteristics and technologies for long vs short-term energy storage. A study by the U.S. Department of Energy (DOE) Energy Storage Systems Program. A SANDIA report with code SAND2001-0765.

[4]. CPUC, 2010. Electric Energy Storage: An Assessment of Potential Barriers and Opportunities. A Policy and Planning Division white book of the California Public Utilities Commission.

[5]. Resources Group at UC Berkeley. November 2006.

[6]. APS, 2007. Challenges of electrical Energy Storage Technologies: A Report from the APS Panel on Public Affairs Committee on Energy and Environment.

Biographies:

Mr.Vishal.V.Mehtre

Has completed his master in electrical engineering (power systems) from bharati vidyapeeth (deemed to be university) college of engineering, pune. He is currently working as assistant professor in department of electrical engineering. He has an industrial experience of about 2 years in suzlon power infrastructure pvt. Ltd. As engineer in power evacuation department and has an teaching experience of more than 5 years. His area of interest is renewable sources of energy specially wind and solar with its analysis, optimization and power quality.

Mr. Ankit Aloni

Currently pursuing bachelor of technology degree in electrical engineering from Bharati Vidyapeeth (deemed to be university) college of engineering, pune. I have completed my diploma course in electrical stream from Shri Datta Meghe Institute of Polytechnic Nagpur

Mr. Yashashwi Raj

Currently pursuing bachelor of technology degree in electrical engineering from bharati vidyapeeth (deemed to be university) college of engineering, pune. I have completed my diploma course in electrical stream from bharati vidyapeeth jawaharlal nehru institute of technology, pune.

Ankit Aloni, et. al. "Compressed Air Energy Storage System."*American Journal of Engineering Research (AJER)*, vol. 10(7), 2021, pp. 72-78.