CAES For Today's Market

Septimus van der Linden[1]

Abstract

CAES Technology has been proven since 1978, with a first of a kind compressed air energy storage system of 290 MW in Germany, and a smaller 110Mw unit in the US since 10 years ago.

What has changed to meet the Market Requirements in Bulk Energy Storage?
Enhancements will be described since the first operational 290 Mw unit went into service and units, which were offered in the 80's for US projects. Considering today's requirement for low emissions with DLN combustors as well as SCR for single digit Nox , a 300 Mw nominally rated unit incorporating a rugged proven Gas Turbine design suitable for multiple starts/fast loading, will be presented.

A Modular CAES unit configuration will be described that potentially could be applied to utilize available underground caverns such as the limestone mine in Norton Ohio, with a total plant capacity up to 2700Mw(10.8 Million Megawatt hours). Also other existing or new salt dome caverns for single or multiple units providing 300 Mw to 1200 MW plant capacity can meet the Mid Range generation from 8/16hrs a day.

Introduction

The demand for electricity has considerable daily and seasonal variations and the maximum demand may last only for a few hours each year. As a result, some power stations are only required to operate for very short time periods each year - an inefficient use of expensive plants. In many plants, power stations run only for about 50% of the year, whereas they are capable of running 90% — such under-utilization of power plants is reflected in the price of electricity for consumers.

Storage allows energy production to be decoupled from its supply. By having large-scale electricity storage available over any time capacity, system planners would need to build only sufficient generating capacity to meet average electricity demand, rather than peak demands. In theory, a typical plant could operate with 40% less generating capacity than would otherwise be required. This represents considerable financial savings in peaking and intermediate plants. Additional reductions in emissions and capital investment can occur due to the generators operating more efficiently because they aren't changing their output.

CAES Proven Technology

The first CAES plant was not originally built to meet the needs of the Electricity Market, as outlined in the previous paragraphs, however what was learnt from the Huntorf modus operandi re-affirms, CAES as a Bulk Energy Storage System meets today's market requirements. The support role for nuclear plant black start etc. has evolved into a more dynamic role to the total generation resource system, including renewables such as Wind Energy, recently added to the site. Ref. [1]

As reported at the "Solution Mining Research Institute" Conference held in April 2001, a laser survey of the salt solution mined caverns in 2001 showed that after more than 20 years of operation, that there was practically no deviation in contour to the original sonar survey conducted in 1984. Furthermore even at high rates of withdrawal, salt contamination was very low (less their 1mg salt/kg/air) confirmed by no hot section corrosion of the turbine. (Ref. 2) Salt Dome or Salt Strata as used for Natural Gas Storage, are ideal for Bulk Energy Air Storage plants, and can be located in a large number of regions in the USA.

First CAES Plant

In Fig. 1, the Huntorf CAES plant main components are schematically illustrated, the motor/generator is connected via self-shifting-synchronous clutches, i.e. in the generation mode the compression train is disconnected, and during compression mode the turbine is disconnected by disengaging/engaging the appropriate clutches. Fig.2 , illustrates the 290MW Power Plant-Huntorf. While in an emergency both systems remain connected, the unit provided a lower output. Ref. (1). The single shaft

[1] ALSTOM Power Inc., Midlothian, Virginia. Email: sep.vanderlinden@power.alstome.com

compression/generation at the time, meant that compression selection was “fixed” by mission and rotational speed 3000 rpm, and limited the system to a short four (4) hour generation cycle, and long 16Hr x 60 MW of compression.

Huntorf CAES Plant – Main Components

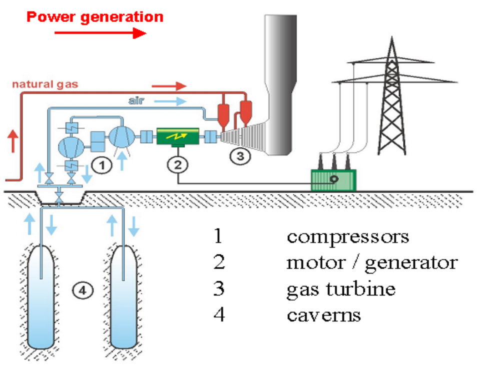

Fig. 1 - Huntorf CAES Plant – Main Components

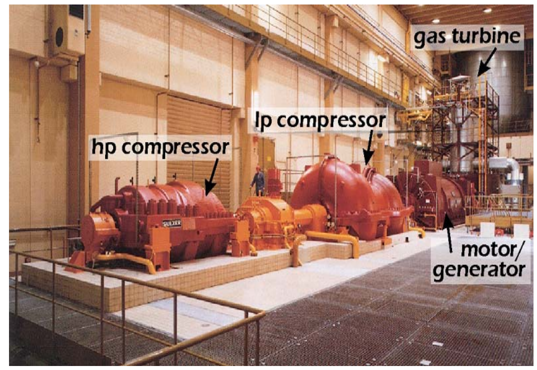

Fig. 2 – 290 MW Power Plant (Huntorf)

Fig. 3, represents the Utility E-On’s Typical Daily Grid Profile, Power Production vs. time. Fig. 4 is an example of the Utility 24 hour load profile & CAES operation, typically covering predictable winter peaking @ 11.30 AM, as well as 6:00 PM & heating, peaks at 10:00 PM.

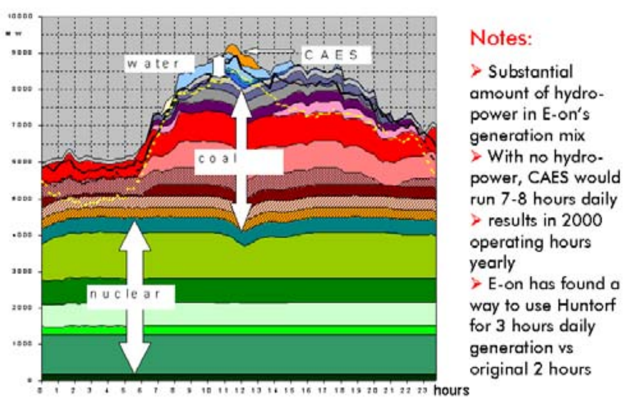

Fig. 3 – Power Production vs. Time

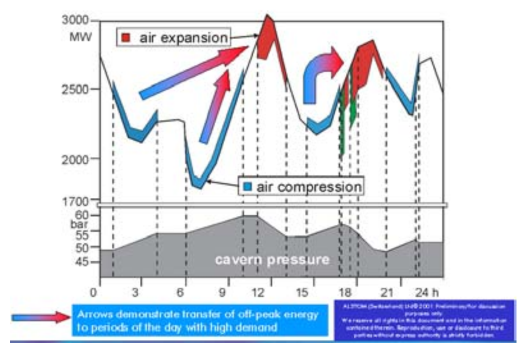

Fig. 4 Example of Utility 24 Hour Load Profile & CAES Operation

Today’s Market

The demand for electricity has considerable daily and seasonal variations and the maximum demand may last only for a few hours each year. As a result, some power stations are only required to operate for very short time periods each year - an inefficient use of expensive plants. In many plants, power stations run only for about 50% of the year, whereas they are capable of running 90% — such under-utilization of power plants is reflected in the price of electricity for consumers.

Storage allows energy production to be decoupled from its supply. By having large-scale electricity storage available over any time capacity, system planners would need to build only sufficient generating capacity to meet average electricity demand, rather than peak demands. In theory, a typical plant could operate with 40% less generating capacity than would otherwise be required. This represents considerable financial savings in peaking and intermediate plants. Additional reductions in emissions and capital investment can occur due to the generators operating more efficiently because they aren’t changing their output.

Concepts & Changes - changes in Machinery Arrangement

The changes in today's market requirements, where Energy Storage as a commodity (electricity as stored air energy) needs to be delivered when demand increases, offsets the volatility in electricity pricing, in the same way as Natural Gas Storage did.

To meet such requirements, some changes in the machinery arrangement, especially decoupling the compression from the main shaft, allows the flexibility of tailoring & operating the compression charging cycle or "power absorption" cycle independently of the generation cycle. Integrating advanced GT with Air Storage [Ref. 3] was proposed as one concept of decoupling compression & expansion, while retaining the GT for SC peaking or emergency use.

Fig. 5 illustrates the ALSTOM Multi-Shaft CAES Concept, where compression is decoupled from the generation (Power Island) and the compressors are separately motor driven. The compression can now be optimized for a) Standard available frame sizes to suit pressure and volume requirements of the storage facility b) LP & HP compression can be separated for matching motor drives using 4 pole motors up to 50MW+ in rating, currently in service for compressor drives. Increased daily generating of 8 hrs to 16 hrs can be accommodated by adding a duplicate compression train. Multiple smaller compression trains are envisaged as "variable" power absorption even during daily generation, to respond to load swings or sudden load rejection etc.

CAES ET11NM

The design philosophy is simple, use an available, reliable & proven Gas Turbine as the main LP expander with its combustion system. The GT11NM with latest performance improvements with more than 300,000 operating hours and 3,500 starts was selected, with an air expander (AT) turbine integrated on the same shaft, coupled to either an Air Cooled or Hydrogen cooled standard frame generator in the 300MW class. Fig. 6 & 6A illustrates this adaptation using the Huntorf experience however eliminating the HP Combustor. The addition of an 85% efficient exhaust heat recuperator with additional supplemental firing provides the heat to the air discharged from the cavern storage. Fig. 6A shows the removal of the standard compressor at the turbine housing and replacing it with the AT expander & casing. This insures that the current turbine operating parameters are maintained as illustrated in the ET11NM – T S diagram Fig. 7.

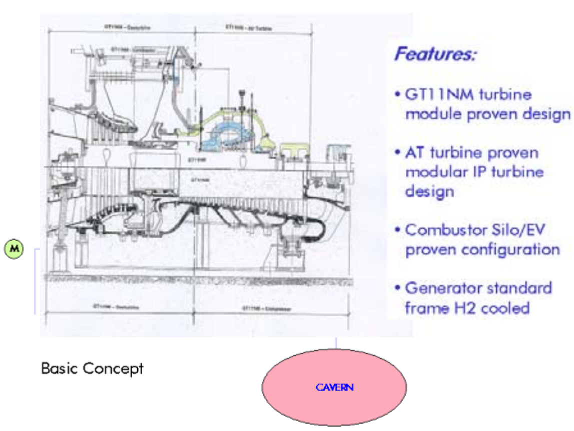

Fig. 6A- CAES: ET11NM vs. GT11NM

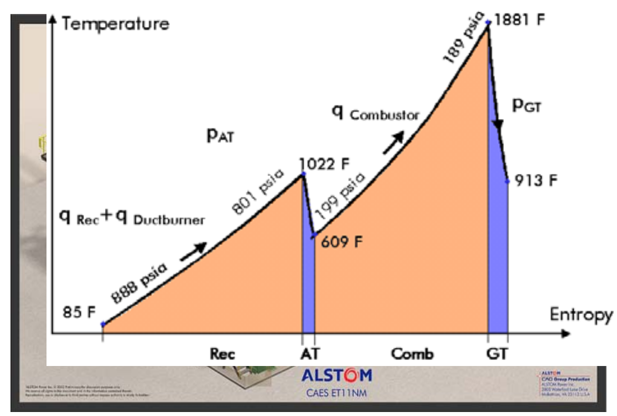

Fig. 7 – ET11NM Cycle

Norton Energy Storage Ohio

One of the first potential projects in the USA to benefit from the compression decoupling is a huge facility at Norton in Ohio which is permitted for 2700MW's of capacity, and as a commercial project, will be one of the largest Bulk Energy Storage facilities, including Pumped Hydro Systems to be built in the USA.

This Project called Norton Energy Storage, based on press information, will consist of 9x 300MW nominally rated CAES units, supported by an underground storage cavern volume of 338 million cubic feet 2,200 feet below the surface, originally mined in a limestone formation.

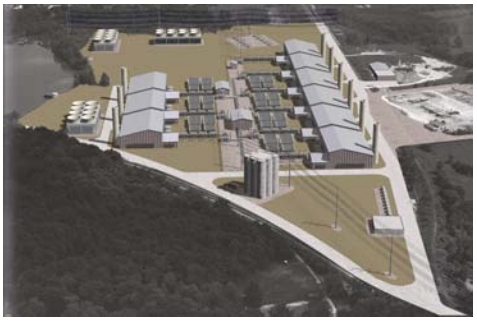

Fig. 8 - Norton 2700MW – Artist Rendering

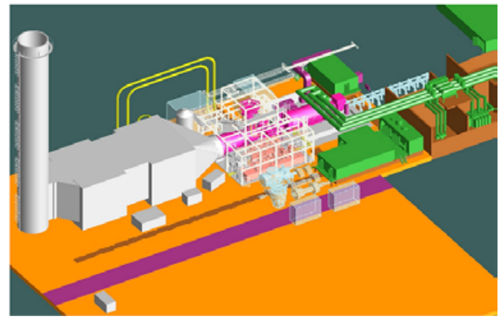

Fig. 9 - Nominal 300MW Power Island

The plant will be built modularly with continuous plant construction over a 5-year period, each power module will add $\pm$ 300MW of power to the electric grid. When complete the NES facility will provide at least 2,700 MW's of power to Ohio and East Central Area Reliability (ECAR) region, Fig. 8 and delivering enough energy to power more than one million households. More importantly, however is the ability of CAES technology to help provide reliable full electric power service for midrange & peak hours, extending the capabilities of large, low cost base load generation. Fig. 9 is a nominal 300MW Power Island with recuperator, with power delivery stepped up from 21.0 kV to a requirement of 138kV on 345kV to suit transmission line requirements.

Using substantially less natural gas fuel than an equivalent sized CC Plant the emissions such as No_x are much lower as well. With, (DLN) Dry Low No_x Combustors and post combustion catalytic treatment of exhaust gases, emission levels of 3.5 vppm for both types of plants can be achieved however CAES at the same level of emissions produces 1.73 MW for the equivalent of 1.0 MW of CC resulting in lower total emission per MWh generated

Generation & Compression Cycle

The limestone cavern is at a depth of 2200 ft. and can sustain a storage pressure of 1500 psig. The decoupling of compression trains allows for maximum flexibility of energy storage and up to 16 hrs of daily generation during the week. The generation compression cycle are illustrated in Fig. 10 where a single unit could provide 18 days of continuous generation.

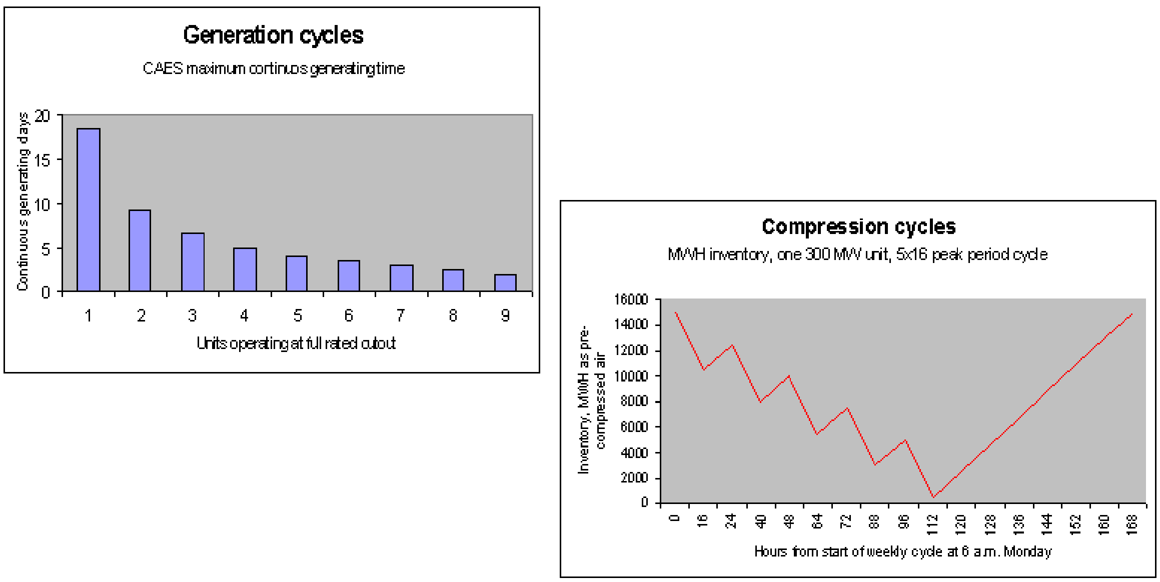

Fig. 10 - Generation & Compression Cycle

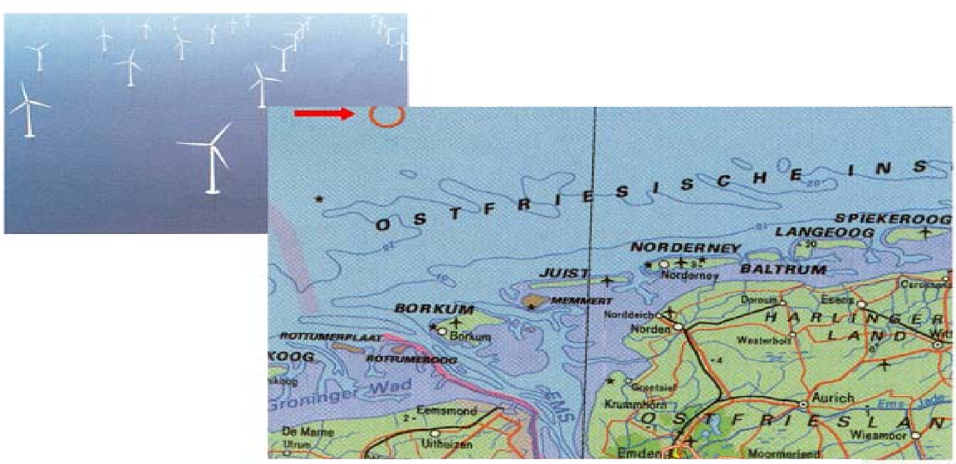

Fig. 11 – Global Wind Energy Storage Possibilities

CAES – Meeting Today's Market Need

Key potential application areas:

- Increase in system utilization, generation deferment, operating reserve and dynamic benefits
- Regulating output from stochastic renewables, such as wind
- Load leveling on island supplies & other electrical networks
- Network reliability and deferment of transmission network reinforcement
- Reducing network electrical losses & enhancing system stability
- Distribution network control - voltage & frequency control
- Supply reliability & meeting customer demand
- Electricity trading

Conclusions

Bulk Energy Storage as provided for by CAES in multi-MW rating of 150/300MW Modules, can meet Today's Market needs with plant sizes up to 2700 MW, or even larger.

The applications for CAES are varied & dynamic for the future of Power Generation Management and Conservation. One area of future and more detailed investigation will be renewables such as wind energy.

Europe is a leader in this renewable resource, accounting for 17,000 MW's or about 2% of total electric energy produced in 2001. The USA almost doubled the installed wind generation to 4,240 MW's in 2001 from year 2000. More large projects are planned in Texas, who alone added 900 MW in 2001, as well in New England and Northeastern, United States. Regulating the output from such large wind projects is one area that Bulk Energy Storage will benefit the industry.

References

[1] Stys, Stanley Z. & Naass, Peter. "Operation Experience with Huntorf 290 MW World's First Air Storage System Energy Transfer Plant" – American Power Conf. Chicago April 21-23 1980

[2] Crotogino, Fritz. Mohmeyer, K.V. Scharf, Roland. "Huntorf CAES: More Than 20 Years of Successful Operation" Spring 2001 Meeting – April-Orlando Mining Research Institute

[3] Nakhamkin, Michael. van der Linden, Septimus. "Integration of a Gas Turbine (GT) with Compressed Air Storage (CAES) Plant Provides Best Alternative For Mid-Range & Daily Cyclic Generation Needs" ASME IGTI Paper 200-GT-182 Munich Germany May 8/11 2000