



BSI Standards Publication

Distributed energy resources connection with the grid

Part 102: CAES connection to the grid

National foreword

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TECHNICAL REPORT

**Distributed energy resources connection with the grid -
Part 102: CAES connection to the grid**



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**Distributed energy resources connection with the grid -
Part 102: CAES connection to the grid**

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Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62786 series, published under the general title *Distributed energy resources connection with the grid*, can be found on the IEC website.

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1 Scope

This part of IEC 62786, which is a technical report, provides principles and technical needs for the interconnection of the compressed air energy storage (CAES) system to the distribution network. It is suitable for the planning, design, operation and testing of CAES system interconnection to distribution networks. It includes the additional needs for the CAES system, such as connection scheme, grid-connected process and needs, response characteristics of active power to frequency, response characteristics of active power to current, response characteristics of active power to injecting mass flow, response characteristics of active power to pressure, selection of the point of connection (POC), electromagnetic compatibility (EMC) and power quality, communication and automation, monitoring and protection, immunity to disturbances, grid-connected testing needs, etc.

The CAES systems considered within the scope of this document include supplementary combustion CAES system and non-supplementary combustion CAES system, interconnected to medium voltage (MV) or low voltage (LV) distribution networks in the form of electric motors and generators. This document will report response of active power to frequency, response of active power to current, response of active power to injecting mass flow, response of active power to pressure, response of reactive power to voltage, and grid-connected testing for distributed CAES system, as a supplement for IEC TS 62786-1:2023 [1]¹.

This document reports the interface needs for connecting CAES system to distribution network operating at a nominal frequency of 50 Hz or 60 Hz.

2 Normative references

There are no normative references in this document.

3 Terms and definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1

CAES system

system using compressed air as an energy storage carrier to achieve charging, discharging, and utilization of energy, generally including compressors, air storage devices, heat storage and exchange devices, turbines, generators, etc

3.1.2

compressor

device used to increase air pressure and temperature by compressing air

¹ Numbers in square brackets refer to the Bibliography.

3.1.3**turbine**

device that uses compressed air expansion to convert air internal energy and potential energy into mechanical energy

3.1.4**heat exchanger**

device that transfers part of heat from hot fluid to cold fluid

3.1.5**air storage device**

device for the injection, storage and extraction of compressed air using artificial pressure vessels or geological space

3.1.6**thermal storage device**

device that uses media such as water, thermal oil, and molten salt to absorb, store, and release heat

3.1.7**charging process**

process in which the motor drives the compressor to compress the air to a high-temperature and high-pressure state, which converts the electrical energy into the internal energy and potential energy of the compressed air

3.1.8**discharging process**

process in which the high-pressure air is released from the air storage device into the turbine to expand and work, driving the generator to produce electricity, which converts the internal energy and potential energy contained in the compressed air back into electrical energy

3.1.9**point of connection****POC**

reference point on the electric power system where the user's electrical device is connected

[SOURCE: IEC 60050-617:2009, 617-04-01]

3.1.10**surging state**

vibration state of a compressor under abnormal working conditions when the mass flow decreases to a certain extent

3.1.11**choking state**

working state in which the compressor is unable to operate normally due to internal blockage

3.2 Abbreviated terms

CAES	compressed air energy storage
EMC	electromagnetic compatibility
PMU	power management unit
POC	point of connection
MV	medium voltage
LV	low voltage
AVC	automatic voltage control

4 Introduction to CAES system

4.1 Basic principle of CAES system

According to whether the CAES system is heated during the expansion process, it is generally divided into a supplementary combustion CAES system and a non-supplementary combustion CAES system (see Annex A).

The schematic diagram of the supplementary combustion CAES system is shown in Figure 1, while the schematic diagram of the non-supplementary combustion CAES system is shown in Figure 2. When storing energy, off-peak electricity and green electricity generated by wind farms, photovoltaic power stations, etc., are used to drive the compressor, compressing the air to a high-temperature and high-pressure state. After cooling, the high-pressure air approaches the normal temperature state and is stored in the air storage device. When releasing energy, high-pressure air is released from the air storage device to drive the turbines and generators to produce electricity.

The supplementary combustion CAES system uses natural gas, fossil fuels, and other supplementary heat sources to heat the compressed air during power generation. The non-supplementary combustion CAES system does not require supplementary heat sources during power generation. Heat produced through the compression process is collected and released in the expansion process to meet the heating needs.

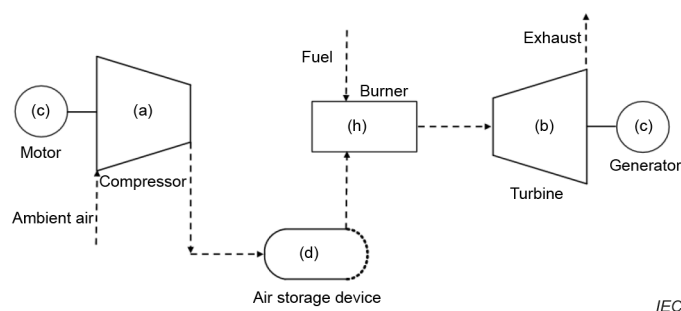


Figure 1 – Schematic diagram of supplementary combustion CAES system

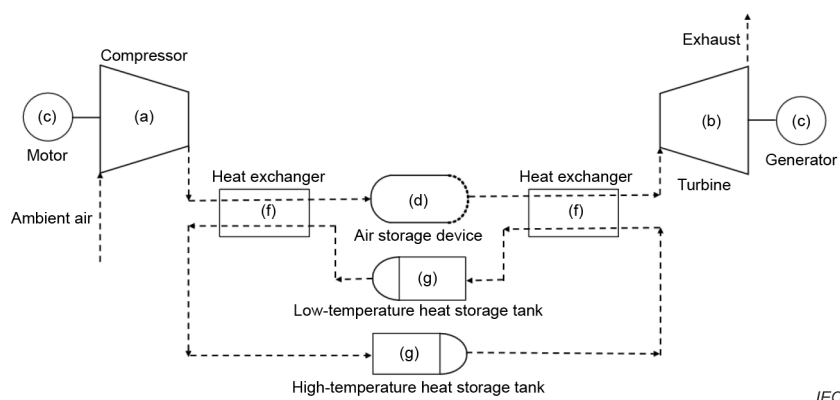


Figure 2 – Schematic diagram of non-supplementary combustion CAES system

The CAES system generally includes the main components below (see Annex C):

- a) compressor, which is generally a multi-stage compressor with inter-stage cooling device.
- b) turbine, generally multi-stage turbine with inter-stage reheat equipment.
- c) motor/generator, connecting with the compressor and turbine through the clutch respectively.

- d) air storage device, such as underground caves or above-ground pressure vessels.
- e) control systems and auxiliary equipment, including control systems, fuel devices, mechanical transmission systems, pipelines and accessories.
- f) heat exchanger, used for the recovery of waste heat.
- g) heat storage system, used to absorb and store the heat of compressed air, heating the compressed air during power generation process.
- h) burner, a device in which fuel is burned to heat the compressed air.

4.2 The energy conversion process of CAES system

4.2.1 General

Although the supplementary combustion CAES system needs external heat sources, its operation mode is relatively flexible, and the comprehensive economic benefits of this type are generally higher in areas close to heat sources or natural gas pipeline coverage. The compact and simple structure of the non-supplementary CAES system eliminates the dependence on external heat sources and fossil fuels and can achieve zero greenhouse gas emission. However, the unit-price investment of the non-supplementary CAES system is usually higher, and the further improvement of the capacity of the power station is limited by the development of the compressor, storage device and heat exchange system. From the perspective of comprehensive energy supply, both types of CAES systems have the capability of providing electricity, heating and cooling at the same time, so as to have higher comprehensive efficiency (see Annex B).

4.2.2 The energy conversion process during charging state

The CAES system generally divides the entire charging and compressing stage into two parts: steady-state compression of level 1 to $(N-1)$ and non-steady-state compression of the final stage. The expressions for the power consumption of steady-state compression at levels 1 to $(N-1)$ and non-steady-state compression at level N are as follows:

$$W_i^c(\Omega_s) = \frac{k_i \cdot T_{in,i}^c V_s (\Omega_s - \Omega_s^0)}{\eta_c (k_i - 1) T_s} \left(\frac{\Omega_s^{\frac{k_i-1}{k_i}}}{\Omega_s^0} - 1 \right) \quad (1)$$

$$W_N^c(\Omega_s) = H_1 \left[\left(\frac{\Omega_s}{\Omega_{in,N}^c} \right)^{\frac{2k_N-1}{k_N}} - \left(\frac{\Omega_s^0}{\Omega_{in,N}^c} \right)^{\frac{2k_N-1}{k_N}} \right] - H_2 (\Omega_s - \Omega_s^0) \quad (2)$$

where

$$H_1 = \frac{T_{in,N}^c V_s k_N^2 \Omega_{in,N}^c}{T_s (2k_N - 1) (k_N - 1)} \quad (3)$$

$$H_2 = \frac{T_{in,N}^c V_s k_N}{T_s (k_N - 1)} \quad (4)$$

where

$W_i^c(\Omega_s)$	is the power consumption for steady-state compression of level 1 to $(N-1)$,
$W_N^c(\Omega_s)$	is the power consumption for N -level non-steady-state compression,
Ω_s	is the pressure of the air storage device,
Ω_s^0	is the initial working pressure of the air storage device,
i	is the number of compressor levels, taken as $1 \sim (N-1)$,
a_i	is the pressure ratio of the i -stage compressor,
T_s	is the temperature of the air storage device,
$T_{in,i}^c$	is the inlet temperature of the i -level compressor,
k_i	is the polytropic index of the i -level compressor,
k_N	is the polytropic index of the N th level compressor,
η_c	is the compressor efficiency,
V_s	is the ideal gas constant,
$\Omega_{in,N}^c$	is the inlet pressure of the N th level compressor,
$T_{in,N}^c$	is the inlet temperature of the N th level compressor.

During the compressing process, the relationship between the energy absorbed from the grid and the pressure of the air storage device $E_c(\Omega_s)$ can be expressed as:

$$E_c(\Omega_s) = \sum_{i=1}^{N-1} W_i^c(\Omega_s) + W_N^c(\Omega_s) \quad (5)$$

The total energy $E_c(\Omega_s^1)$ absorbed from the grid in the entire compressing process is:

$$E_c(\Omega_s^1) = \sum_{i=1}^{N-1} W_i^c(\Omega_s^1) + W_N^c(\Omega_s^1) \quad (6)$$

where

Ω_s^1 is the maximum working pressure of the air storage device.